**Article:**

Kamali Tabrizi, Sina and Abdelmonem, Mohamed Gamal orcid.org/0000-0002-8271-0924 (2024) Contemporary construction in historical sites:The missing factors. Frontiers of Architectural Research. pp. 487-504. ISSN 2095-2643

https://doi.org/10.1016/j.foar.2024.01.002

Frontiers of Architectural Research 13 (2024) 487—504

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.keaipublishing.com/foar

RESEARCH ARTICLE

# Contemporary construction in historical sites: The missing factors

**Sina Kamali Tabrizi [a,*], Mohamed Gamal Abdelmonem [b]**

[a] *School of Architecture, Design and the Built Environment, Nottingham Trent University, Nottingham, UK*
[b] *Department of Architecture and the Built Environment, University of York, York, UK*

Received 29 November 2023; received in revised form 6 January 2024; accepted 19 January 2024

**KEYWORDS**
New building;
Contemporary construction;
Historical sites;
Sustainable development;
Architectural heritage

**Abstract** Historical sites (HSs) are akin to living entities, and their existence is perpetuated through the erection of new buildings or additions. Many HSs need sustainable development and new construction, as existing monuments fail to meet contemporary user requirements. Despite the urgent demand, many new buildings within HSs have been constructed without considering the influencing factors on contextual value, built, and natural environment. This oversight has led to irreversible damage to their historical value. Numerous studies have independently explored interventions, construction, and development within HSs. However, there is a conspicuous absence of comprehensive research that concurrently addresses these issues while preserving the intrinsic value of the HSs. This study aims to identify the variables and factors contributing to the successful design and construction of new buildings within HSs, satisfying user needs, conserving contextual values, and achieving sustainability with the natural and built environment. The research employs a mixed-method approach, gathering raw data through literature reviews, case studies, and expert interviews. The study population comprised 97 experts in architectural heritage conservation and sustainable development. Exploratory factor analysis was utilized for data analysis, leading to the identification of influential factors. The study highlights the significance of the location, function, scale, form, material, skyline, viewpoint, accessibility, reversibility, topography, sustainability, technology, structural system, lifespan, and interior design in constructing new buildings within a HS. Moreover, the design of new additions should adhere to five guiding principles: integrated design, volume design, green design, compatible design, and modern design. In this context, the new structures will fulfill user needs, preserve or enhance contextual values, and harmonize with the built and natural environment.


* Corresponding author.
*E-mail address:* sina_kamali@yahoo.com (S. Kamali Tabrizi).
Peer review under responsibility of Southeast University.

https://doi.org/10.1016/j.foar.2024.01.002

## 1. Introduction

A historical site is like a living organism whose life continues with the construction of new buildings. Today, many historical buildings (HBs) or historical sites (HSs) need spatial expansion, and the previously built spaces do not meet the needs of present users. Several factors play a crucial role in expanding the HSs, the most important of which is its reusability (Jones et al., 2022). In other words, with the passage of time and the emergence of new demands and expectations of users, for these sites to be responsive as they were in the past, there is a need to add new spaces to revitalize HSs (Fig. 1). Enhancing the visitor experience through constructing new buildings and implementing new technologies (Di Pietro et al., 2018) to maximize visitors' convenience can improve the memorability of the place and strengthen the visitors' sense of belonging to HSs and, finally, the site's popularity (Gholitabar et al., 2018). The more popularity a historical site gains, the more attention and conservation from government and non-government organizations it gets (Kostopoulou, 2022). Contemporary architecture introduced within the HS may have a similar effect as it does itself on popularizing a tourist site, mainly if it refers to the memory of the place (Węcławowicz-Gyurkovich, 2010).

Under charters and resolutions dedicated to the preservation of historical monuments, especially those issued by the International Council on Monuments and Sites (ICOMOS, 1964, 1994, 1999, 2010), it is imperative that the degree of intervention be kept to a minimum to avoid causing harm to the physical (tangible) and semantic (intangible) values of historical sites. A relatively latest approach in conservation and sustainable development is making HSs reusable by constructing new architectural spaces into the existing site (Wilczek, 2021).

A prominent example of this contemporary construction within historical sites is the project known as the Grand Louvre, which was designed by I.M. Pei in 1989. The initial

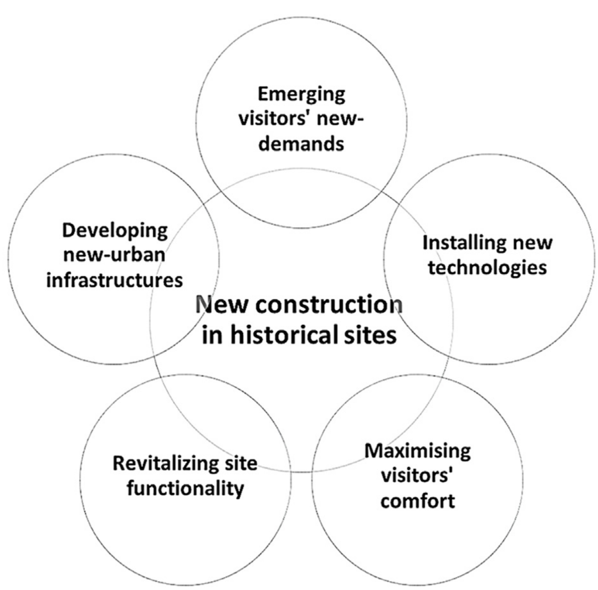



**Fig. 1** Why are new additions to the heritage context vital?

phase of this project, which resulted in the creation of the pyramid, saw Pei restructure the museum around the central courtyard, the Cour Napoléon, transforming it from a parking lot into one of the world's most renowned public spaces. Long-closed passageways through the palace were reopened, revitalizing the plaza and elevating it into a vibrant gathering space (Slavicek, 2009).

Most of the innovative structures added to the HSs have not been as successful as the Grand Louvre projects, and the new additions have caused irreparable damage to the physical and semantic values of the HSs. For instance, due to urban expansion projects exclusively in a historical context, many new additions have harmed the aesthetic and historical values of the HSs and reduced the authenticity of the place. This stems from the fact that no research has been conducted on contributing factors in designing a new building considering the historic site or context. Architectural contemporary interventions in historical contexts have different scales and vary from large-scale urban interventions in a city's historical site to small interventions in a historical building. This article seeks to find comprehensive guidelines for the design of new construction in the scale of buildings added to historical sites in such a way that while preserving and promoting the existing values in the historical context, they can also express the spirit of the contemporary era and meet the needs of users.

## 2. Methodology

The research method of this article is a mixed method (Fig. 2).

### 2.1. Variables identification

Upon thoroughly reviewing the existing literature, projects that have demonstrated success were meticulously analyzed. The objective of this analysis was to discern the variables that have had a positive influence on the design and construction of contemporary structures within historical sites. Through the application of content analysis, thirteen key variables were identified. These include location, function, scale, form, material, skyline, viewpoint, accessibility, reversibility, topography, sustainability, technology, and structural system. Content analysis is any method employed to systematically and objectively infer the specific characteristics of a given context (Tunison, 2023). When there is limited literature available and no existing theory on a research objective that aims to describe a phenomenon, conventional content analysis is utilized, also called inductive content analysis (Vears and Gillam, 2022). This approach's merits lie in acquiring direct information from the case studies without imposing preconceived categories or theoretical perspectives (Kuckartz and Rädiker, 2023).

### 2.2. Variables confirmation

A semi-structured questionnaire was designed to interview ten experts to identify the variables more comprehensively and verify the variables specified in the literature review and case studies. The semi-structured questionnaire is

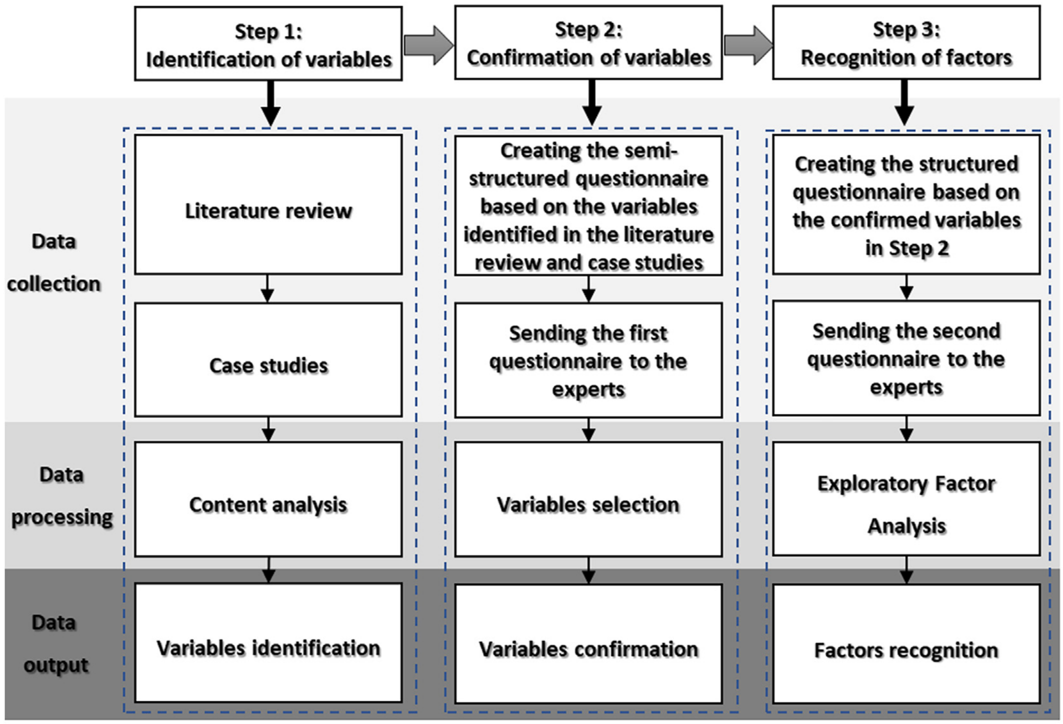



**Fig. 2** The methodology steps.

composed of open-ended (unstructured) and multiple-choice (structured) questions (Tusting, 2023). Open-ended questions allow new variables to be discovered by studying the experts' answers and act as a brainstorming strategy, aiming to reveal all the influential variables in this study (Piqueras-Fiszman, 2023). In order to carry out the interviews, the experts were requested to present and elucidate their proposed variables that are influential in the new construction of historical sites. Questions of a multiple-choice nature, predicated on the variables identified in the initial phase, were also employed to either confirm or refute the validity of the variables ascertained in the literature review and case studies, with responses categorized as "Effective" and "Not effective". For a variable to be verified, it necessitates that more than half of the experts select the "Effective" option, failing which, the variable will be excluded (Joffe, 1992). The initial variables have been confirmed after a meticulous analysis of the results from this stage. Additionally, two new variables, namely life span and interior design, have been identified. These have been subsequently included in the final comprehensive list of variables (Table 1).

**Table 1** Contributing variables in the construction of a new building in the historical context.

| No. | Factor | No. | Factor | No. | Factor |
|---|---|---|---|---|---|
| 1 | Location | 6 | Skyline | 11 | Sustainability |
| 2 | Function | 7 | Viewpoint | 12 | Technology |
| 3 | Scale | 8 | Accessibility | 13 | Structural system |
| 4 | Form | 9 | Reversibility | 14 | Life span |
| 5 | Material | 10 | Topography | 15 | Interior design |

## 2.3. Factor recognition

The statistical population of this study was comprised of expert architects who specialize in conserving architectural heritage and sustainable development. The selection criteria for these experts were based on four key attributes: a) an extensive understanding and experience in the field, b) a demonstrated willingness to participate in the study, c) the ability to dedicate sufficient time to engage in the study, and d) productive communication skills (Del et al., 2021). A purposive sampling technique was employed for the study, selecting experts based on their scientific competency, experience, or implementation (Walker, 2023).

The study encompasses a sample size of 97 participants. The adequacy of this sample was assessed utilizing the Kaiser-Meyer-Olkin (KMO) test, a measure that fluctuates between 0 and 1. A KMO value exceeding 0.6 indicates satisfactory sample adequacy (Shrestha, 2021). In the context of this study, the KMO value was determined to be 0.638, thereby affirming the adequacy of the sample size.

Utilizing a structured questionnaire, subject matter experts were solicited to assign rankings to variables, thereby rendering them quantifiable via a 5-point Likert scale (Alabi and Jelili, 2023). Within this scale, a score of 1 signifies strong disagreement, a score of 5 denotes strong agreement, and a score of 3 represents neutrality or hesitation toward the variable in question (Boone and Boone, 2012). The reliability of the data procured from the study was assessed using Cronbach's alpha test, which varies between 0 and 1. The data from the research is deemed reliable if the alpha coefficient exceeds 0.7 (Cheung et al., 2023). Given that the alpha coefficient was calculated to be 0.755, the reliability of the data procured from the research is thereby affirmed.

The acquired dataset from the questionnaire underwent analysis using an Exploratory Factor Analysis (EFA) method. This process organizes variables into distinctive factors based on the correlation's strength and proximity of correlation among them. This method involves a two-step sequence—extraction and rotation of factors—principally aimed at enhancing the interpretability of the results. In the initial phase, factors were extracted using the Principal Component Method. This step represents the groundwork of EFA (Del et al., 2022; Shrestha, 2021). The Varimax Rotation method was used to make the factors easily interpretable. After the rotation, the factors were named based on the constituent variables and considering the magnitude of their correlation coefficients (Acal et al., 2020). The meticulous execution of these steps provides meaningful insights from the data.

## 3. Contemporary intervention

Since historical buildings responded to the cultural, social, historical, political, and economic needs of their time (Del et al., 2020); similarly, new constructions in the HSs, in addition to understanding and respecting the historical place's characteristics, should respond to those needs with a contemporary approach (Zhang and Han, 2022). Therefore, what should be considered a critical principle in historical contexts is that new constructions should introduce and express the spirit of the present time, and at the same time, their design should consider and address the historical context where they are meant to be placed (Shahteimori and Mazaherian, 2012). The solutions and approaches related to the design of such construction will be different case by case based on the embedded material and immaterial values of the historical site's context (Feilden and Jokilehto, 1988).

In other words, after a detailed and profound context analysis, there will be unique solutions for designing new construction for each particular HS. It is almost impossible to provide the same techniques that can be used for all new additions in historical contexts (Forsyth, 2013). Therefore, the architectural elements that should be considered in the design and implementation phase are not fixed, but comprehensive guidelines and outlines can be provided to designers (Del and Tabrizi, 2020). For this purpose, there are three general steps: Digital documentation, Value recognition, and Contemporary construction to create new structures in the historical context, which, if paid attention to, in addition to meeting current needs, the physical and semantic values of the site are preserved along with accurate and scientific documentation (Fig. 3).

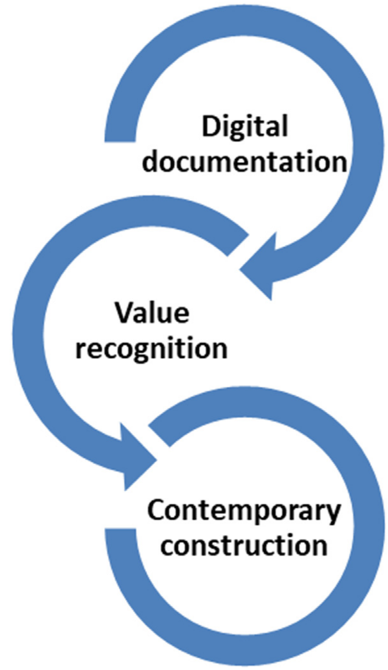



**Fig. 3** Main steps of contemporary construction in HSs.

### 3.1. Digital documentation

HSs are in great danger as they may be destroyed, lost, altered, or forgotten for several reasons. The primary sources of risk are natural hazards, violent actions, such as wars, terrorism, looting, illicit trafficking, vandalism, modern construction activities, globalization, modern way of life and indifference, urban population growth, and many more (Georgopoulos, 2018). Documentation of HSs is the first and foremost action that needs to be taken into account in conservation, maintenance, and contemporary sustainable development in the heritage site (Pirbazari and Kamali Tabrizi, 2022). Indeed, it was in the Venice Charter (1964) that the necessity of the Documentation of Architectural Heritage was firstly set as a prerequisite. In Article 16, it is stated "In all works of preservation, restoration or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs". These documents are the foundation of contemporary intervention in a historic place. The interest in the documentation of HSs has been rising rapidly over the last decades, especially due to the significant technological advances that can contribute to their promotion (Shabani et al., 2022). Many researchers now explore different methods for documentation, management, and sustainability of HSs, which have become an interdisciplinary approach (Tobiasz et al., 2019). Digital Technology is the most effective and cutting-edge means to document HSs (Khalid, 2022). Digital documentation (DD) methods are damage-free (Tejedor et al., 2022), easy-to-use for data integration (Masciotta et al., 2021), and have authenticity (Gros et al., 2023). These technologies can compensate for the shortcomings of traditional documentation methods by enabling non-destructive monitoring (Osman and Moropoulou, 2019), real-time monitoring (Li et al., 2023), data sharing (Pirbazari and Kamali Tabrizi, 2022), and virtual-real interaction with HSs (Debailleux et al., 2018). The key role of DD is to create a database through digital models of HSs and to systematically reconstruct HSs' components (Zhang et al., 2022). Several approaches have been proposed to achieve this goal. For example, Matini et al. (2019) used mixed data to build a post-earthquake 3D model of Bam city and applied VR and

AR technologies for visualizing the site; Koutsoudis et al. (2021) by using a multispectral camera installed under a commercial drone, they produced a 3D model of the urban area covering a multilayer texture map containing information from visible and near-infrared regions; Jia et al. (2022) used 3D laser scanning technology and point cloud information processing in combination with the characteristics of Chinese garden elements to reconstruct a 3D digital information model of the gardens; Bent et al. (2022) utilized Orsanmichele church as a case study and generated a 3D database of the interior and exterior of the building with a LiDAR scanner to develop a highly accurate virtual model for scholars and students; Saura-Gómez et al. (2021) used 3D reconstruction and LIDAR technology on the arches and vaults of a Renaissance factory to detect changes in architectural details and structural behavior.

The most breakthrough strategy for digital documentation and information management is the use of Building Information Modeling (BIM) and Digital Twin (DT) (Baghalzadeh et al., 2022). The terms "BIM" and "DT" are often used interchangeably. While a DT's key role is to simulate the real-world object's reflection in a virtual world, BIM's primary goal is to produce a 3D extension of a real-world item. The concept of HBIM (Historical Building Information Model) was introduced in 2009 (Murphy et al., 2009) and defined as the embedding of heritage building data in a 3D computer model of the entire conservation life cycle (Mol et al., 2020). Having only a digital model of a historical building like HBIM is insufficient to provide whole-life cycle asset management, especially in the maintenance and operation phase. The DT is a comprehensive concept that includes BIM, artificial intelligence (AI), and cloud computing (Jouan and Hallot, 2019). Therefore, there is ongoing research on the DT concept that integrates Artificial Intelligence, Machine Learning, and Big Data Analytics to create dynamic models that can learn and update the status of the physical counterpart from multiple heterogeneous data sources (Lu et al., 2020). DT enables us to monitor interior temperature and relative humidity, external climatic conditions, and spaces' occupancy considering the site's configuration and their interrelation. The joint analysis of such data can help identify issues and potential threats related to the initial design, spatial layout, and occupancy and understand the process behind it to suggest further possible solutions. Apart from the variables linked with climate control, others related to air quality, light radiation, acoustic performances, energy consumption, and structural behavior (crack monitoring, vibrations, etc.) can be observed (Mesas-Carrascosa et al., 2016).

## 3.2. Value recognition

Any intervention for sustainable development in the historical context first needs to analyze and evaluate its historical background to identify the essential values constituting a historical site's character. This process is called value-based recognition (Del et al., 2021).

The value-based recognition approaches in conservation procedures have become dominant in academic and professional discourses since the early 1990s (Clavir, 2012). From this point of view, this issue has been emphasized under various titles: "The meanings and values of HSs are the main reason for their conservation" (Pye, 2000), and "The reason for the conservation of HSs by societies is that these sites are valuable to people of those communities" (Richmond et al., 2009), and "are preserved because they have values" (Appelbaum, 2012). Nowadays, value recognition plays a leading role in HS conservation (Hagerman, 2023; Taher Tolou Del et al., 2022); as Fielden (2007) pointed out, recognizing and prioritizing HS values is the first step in the conservation process. Regarding recognition and prioritizing a historical site's values, two general scenarios can be faced: 1) HS has one or two values, and it is straightforward to prioritize them; 2) HS has multiple and latent values; prioritizing them will become necessary through a deep investigation (Del et al., 2021). Values related to a HS can be categorized into two main groups: tangible values (physical aspects) and intangible values (semantic aspects) (Taher Tolou Del et al., 2022).

Recognition of the physical aspects comes with visible and tangible values in HSs. According to Del and Tabrizi (2020), HSs' most critical physical aspects are building materials, geometry, construction techniques, facade design, structural systems, ornamentation, and color.

Recognition of the semantic aspects comes with invisible and intangible in HSs. According to the Nara Charter, recognition of the semantic aspects depends on the ability to identify, understand, and protect intangible values (ICOMOS, 1994). Also, according to the Burra Charter, semantic recognition is a set of measures enabling a person to achieve the values, meanings, messages, and concepts latent in heritage spaces (ICOMOS, 1999). Based on Del et al. (2020), HSs' most paramount semantic aspects are cultural, economic, identity, historical, integrity, authenticity, and aesthetic values.

Placing a new structure on the historical site, according to its location and design, can have either a harmful or beneficial effect on its surrounding environment, particularly on the historical building in its vicinity. The purpose of new creation in the historical context should be primarily to preserve the spatial qualities that have created the character of a historical site. In this regard, conserving the semantic-physical values of the place should be the main priority of any intervention (Del et al., 2020).

The new structures should be compatible with the character of the existing site while causing the least possible damage to the historical context. They also should not dominate the HS or significantly change the nature of the site. Meanwhile, if the new addition reflects the historical site's attributes and becomes compatible with them, it can strengthen the site's value (Shahteimori and Mazaherian, 2012). Reflecting semantic concepts like cultural and historical value into new architectural designs can be intricate, given the diversity in cultural interpretation and societal norms, along with the historical function of the site. For instance, churches often symbolize the historical significance and social connections of their era through elements like artwork, spatial hierarchy, sculptures, colors, and patterns (Cope, 2022). Conversely, mosques strive to communicate similar values, typically through geometric patterns and a restricted color palette, encompassing shades of blue, white, and brown, with minimal usage of statues or artwork (Erzen, 2011). In these instances, it is the function that alters the physical embodiment of semantic values. The design process should commence by recognizing the site's physical and semantic values associated with its function. This allows the architect to materialize these semantic values through tangible elements like shape, color, and pattern. In this context, architecture acts as a medium for transforming intangible elements into tangible ones.

## 3.3. Contemporary construction

After digital documentation and value recognition of HSs, the groundwork is ready to take the foremost step to contemporary construction in historical sites. Ginsberg summarised the most important aspects of contemporary construction within HSs, which are: the HSs should be addressed by contemporary life, not left them away; the intervention must not impose its forms and meanings on the HSs and should respect them; the HSs must be valued for their integrity. It is not to be restored, but it should be kept for what it is. HSs should speak their architectural language and function alongside modern architectural objects by creating a new whole (Ginsberg, 2021). Contributing items in contemporary construction as a new addition are as follows.

### 3.3.1. Location

Regarding the placement of a new addition, the substantial facades' view of the historic building should be preserved, not hidden or damaged (Silveira da Costa et al., 2022). A new addition's location should be considered so that it affects or conceal the least amount of the monument facades' view. The visual adverse effect of an addition on a historical building can be reduced by placing it on a side that occupies less of the monument facade's view. This is often accomplished by placing them near secondary and non-primary fronts or behind the monument (Grimmer and Weeks, 2010).

In general, placing an addition next to the main facade of the historical building or in front of it is inappropriate to cover the appearance of the historical building and its character, and it causes trouble in the design process. Although the new extension is highly recommended to connect to the secondary view, sometimes this is not possible. One of the proper solutions in such cases is the retreat of the new building's facade from the main facade of the historical building to preserve the characteristics and proportions of the historical building, and this technique helps visual separation (Fig. 4). Plus, placing a large part of the volume of the new structure underground to reduce its visual impact can be used (Fig. 5). Further preserving the main facade's view of historic buildings, the new structure's placement should respect the surrounding natural landscape and scenery (Orbasli, 2008).

### 3.3.2. Function

Another influential item on the character of a historical site is the existing dominant functions; therefore, the function of the new proposed structure should not weaken the current functions but also strengthen them while being compatible. In terms of functionality, it is crucial to examine the existing functions from a cultural, social, economic, and utility point of view in order to determine the coming structure's function (Ribera et al., 2020). The

**Fig. 4** The recess of the new building facade compared to the historical facade of Victoria Hall in Staffordshire, England. Source: The times.

purpose of the new building can serve to introduce HS and motivate individuals to explore them, particularly if the building possesses a conceptual significance related to the historical site. For example, consider a new museum constructed near a historic site, such as an ancient castle. The museum's architecture and design concept might be inspired by the castle's history and significance. In this case, the museum's purpose would not only be to showcase its own exhibits but also to introduce visitors to the nearby historic site (the castle) and encourage them to explore it. By establishing a connection between the new building and the HS, visitors are more likely to be interested in learning about and visiting the historic site.

In addition to being an introduction to historical sites, new buildings can incorporate additional functions that cater to the needs of today's users and create a dialogue between the old and the new (Barranha et al., 2017). These functions can include an exhibition space, a restaurant, a shop, a cinema, viewing platforms, and a visitor center (Wilczek, 2021). For example, an exhibition space within the new building can showcase artifacts and provide information about the historical site, while a restaurant can offer visitors a place to relax and enjoy a meal. By adding these new buildings and functions, the overall visitor experience can be enhanced, making the historical site more engaging.

### 3.3.3. Scale

The new addition's volume is considered to respect the historic building, so it should never surpass the scale and size of the historic building. It communes to the historical monument and always be subordinate to it. Therefore, an addition with the same height or shorter than the main historic building is always desired in order to reduce its

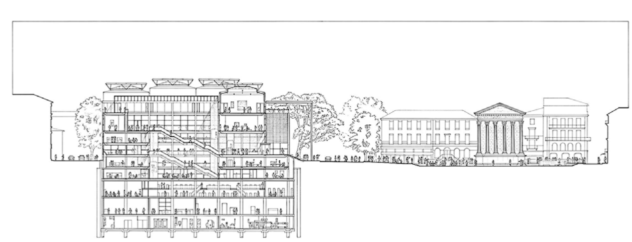


**Fig. 5** Placement of most of the Carre D'Art volume underground to not be dominant over the adjacent historical building. Source: Foster and partners.

visual impact (Li and Zhang, 2023). Suppose that the new building is going to be higher than the historic building. In that case, it is mandatory to place the addition behind important monument facades and create a mediator space to communicate with the main building. Putting the mediator or link space appropriate to the historical building can help to preserve the perceived proportions and scale of the historical part as well as visual separation of the addition from the historic building. Altogether, the appropriate scale for a new addition varies from one historical site to another. It depends on existing proportions, site location, site mass, site coverage, and the historical monuments' position (Siguencia Ávila and Rey Perez, 2016).

### 3.3.4. Form

The shape of a new structure is more sensitive when it comes to standing alongside a historical building. The form of new buildings in a historical context should be compatible with the dominant form of nearby buildings. The shape of the new building does not need to copy its neighboring building, but it should be in harmony with it in a proper way. In form finding, it is crucial to identify a connection between the new structure and the historical context (Ching, 2023). Incorporating cultural and architectural symbols, along with contextual values with contemporary expression, can facilitate establishing this relationship. If the new addition has a repetitive and unrecognizable shape from the historical part, it may not be possible to distinguish the old building from the new one. Although the new structure's form must be in harmony with the historic building and preserve its character, on the other hand, it should be effortlessly distinguishable from the historical one. So that the historical evolution on the site can be understood, and in this case, the visual identity of the historical building is not compromised by the new building. However, the new addition must not be that different, prominent, and noticeable in the eyes of the public to get the center of attention. One of the most suitable methods that meet global instructions is employing abstract forms. The abstraction approach tries to extract the essence and nature of historical buildings and convert them to a definite form. It represents latent meaning, sophisticated ideas, and classical concepts in an explicit way (Guzmán-Torres, 2009). It may also reflect historical architectural features in a simplified way. Still, at the same time, it does not copy them and seeks to recreate the character of the historic building by expressing them in a contemporary style (Sun et al., 2022).

In many cases, a modern style with an abstract form represents the new and contemporary building using a distinctive shape to reach clear exterior visibility (Penn, 2007; Semes, 2009). Also, the general form is designed so that it is subordinate to the historical context, not dominant to it.

### 3.3.5. Material

The proposed materials do not have to be precisely similar to the materials of the historical monument, but they should be harmonious with the monuments (Zhu and González Martínez, 2022). On the other hand, they should not be so distinct that they stand out from the historical monument and divert the view to itself (Grimmer and Weeks, 2010). For instance, using glass as a finishing material is a double edge sword. In some cases, the glass can draw attention too much due to its unwanted reflection in the historical context and takes its toll. In contrast, in other cases, it is employed to reflect the surrounding historical buildings' view and introduce the historical site. In this way, it neutralizes its presence (Fig. 6). Besides, the glass transparency features visual continuity and reduces the adverse visual impact on the site (Fig. 7). Using new materials that are compatible and homogeneous with ancient materials is an agreeable approach. For example, constructing a new building's facade with brutal concrete next to a historic stone building can create an interesting and visually appealing contrast. This approach allows for preserving the historic character of the old building while adding a modern touch to the new building.

Using new materials and colors for the exterior facade of new additions, in contrast with the historical sites, aids visitors in quickly identifying and locating new structures (Węcławowicz-Gyurkovich, 2010). When new additions, such as the Pombal Castle Visitor Center, are situated within the historical site, contrasting or different materials and colors are typically employed to ensure their visibility to visitors. However, when the new buildings are positioned on the outer layer of the historical site and impact its exterior, it is essential to harmonize the final material and color with the historical site. This approach minimizes any unfavorable and distinct visual impact that the new addition may have on the exterior of the historical site.

### 3.3.6. Skyline

If the new buildings are located within the historical site, efforts have been made to minimize their impact on the area's skyline. The height of the new addition is intentionally kept lower than that of the historical site components (Shahriar et al., 2023). However, if the new buildings are situated on the outer layer of the site, they inevitably affect the skyline visible from outside the site. In such cases, the volume and skyline of the new addition are designed to coordinate with the overall complex. For example, the Hambach Castle Restaurant is subordinated to the historical site in terms of its skyline.

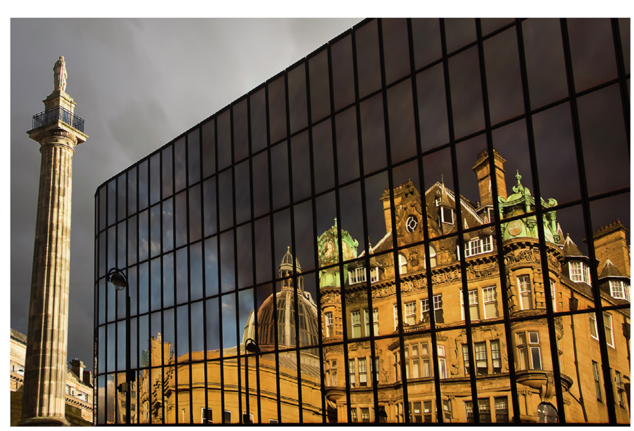


**Fig. 6** The reflection of Emerson Chambers in a glass-fronted building in Newcastle, England. Photograph by Alan Warriner.

**Fig. 7** Visual continuity in the Louvre Museum pyramid by using transparent materials. Photograph by Michael Mattox.

### 3.3.7. Viewpoint

In the context of historical sites, two distinct types of viewing experiences can be found in newly constructed buildings. The first of these is the observation deck, designed to provide a unique vantage point from which to appreciate the historical site. Observation decks are typically situated in the highest part of the structure, often without a roof, to offer a panoramic view and immerse visitors in the expansive scenery. The second type of viewing experience is an architectural feature that connects the interior of the building with the surrounding environment. This connection is frequently established through windows or other openings in the building's design (Sun, 2019). The positioning of these windows is crucial, as they should frame the exterior view in a manner akin to a work of art being framed. The aim is to present the landscape's aesthetic appeal, transforming it into an artwork in its own right. In essence, both types of viewing experiences—the observation decks and the carefully positioned windows—aim to offer visitors a unique perspective on the historical site and its surroundings. They provide an opportunity to appreciate the site from new perspectives. The design and implementation of these viewing experiences require careful consideration, as the way in which visitors view the site can significantly influence their overall experience and appreciation of the site's historical significance.

### 3.3.8. Accessibility

In many projects, such as Pombal Castle, the primary accesses to the historical site are either destroyed or do not meet the needs of today's tourists and visitors. Therefore, it is necessary to construct coherent and new paths that can facilitate access to the historical site while respecting its integrity. Since many historical sites, including castles, are situated at elevated locations, well-designed paths can offer direct views of the surrounding landscape and potentially serve as scenic routes. Moreover, incorporating recreational facilities such as cafes or restaurants along the way to the historical site can provide tourists with new experiences and create enjoyable moments (Bloomer et al., 2022).

### 3.3.9. Reversibility

The application of reversible processes during interventions at historical sites is always preferred. This approach ensures the potential for future remediation of unexpected issues without inflicting permanent damage to the architectural heritage or the historical site itself (DAHG, 2011). Reversibility serves as a tool to safeguard the authenticity of a historical site. Given that future generations may criticize the current interventions enacted on a site, considering reversibility criteria for future additions is strongly advised (ICOMOS, 2003). For instance, filling structural voids with concrete would constitute an irreversible action, whereas the use of loose fill could be easily removed later. It should be recognized that not all interventions can be reversible, and it would fall to the planning authority to make determinations in cases where irreversible interventions are proposed. As a rule, approved interventions that impact the character of a historical site should be reversible, implying a temporary alteration. Construction detachment of new additions with historical layers is one of the integral principles that should be employed to maintain the reversibility process.

### 3.3.10. Topography

Integrating new structures into historical sites necessitates a delicate balance between preservation and innovation. This process begins with an in-depth analysis of the natural and built environments, specifically focusing on the site's topography. The design of the new structure must then be meticulously undertaken to ensure that it not only complements the existing topography but also contributes to the sustainable development of the site. The ultimate goal is to achieve harmony between the new structure and its surroundings while maintaining the integrity of the historical site (Leatherbarrow, 2015). To illustrate, let's consider a scenario in which a new structure is added to a historical site in a mountainous region. The initial stage would involve conducting a thorough site contextual analysis. This would entail studying the site's topography, the existing built environment, and the natural elements present, such as the slope of the land, the type of soil, the vegetation, and the weather patterns (Grazuleviciute-Vileniske et al., 2020). Following this, the design of the new building would need to be responsive to these elements. For instance, it could be designed to adapt to the mountain's slope rather than altering it, thus preserving the natural topography.

### 3.3.11. Sustainability

Sustainability is a complex concept encompassing three key elements: societal, economic, and environmental. The primary objective of sustainable construction methods is to minimize ecological footprints (Peng et al., 2018). To achieve this goal, the following recommendations are proposed for constructing a new addition within a historical site.

*Enhancing community engagement*. It is crucial to involve the local community and consider their needs and preferences during the design phase. This approach fosters a sense of ownership and pride toward the new structure (Anthony, 2023).

*Use of local materials*. Utilizing locally sourced materials for construction can help reduce transportation emissions and ensure compatibility with existing monuments and the natural environment. Such materials include locally quarried stone, locally produced bricks, and locally harvested timber (Valentini et al., 2022).

*Adoption of recyclable materials*. Incorporating recyclable materials is essential for waste reduction and promoting a circular economy. These materials include recycled steel, reclaimed timber, and other eco-friendly alternatives (Delgado, 2020).

*Reducing energy consumption*. Integrating design elements such as effective insulation, energy-efficient lighting, and renewable energy sources can significantly decrease the building's energy usage and environmental impact (Das and Neithalath, 2018).

*Optimizing building orientation*. Strategically planning the orientation of the new building within historical sites can maximize the utilization of sunlight and wind patterns, thereby enhancing energy efficiency. This can be achieved by strategically placing windows, shading devices, and natural ventilation systems (Abanda and Byers, 2016).

#### 3.3.12. Technology

In designing a new building within HSs, it is imperative to incorporate the latest service technologies to maximize visitor welfare and safety. These technologies include internet access, the Internet of Things (IoT), virtual and augmented reality (VR/AR), 3D mapping (Guazzaroni and Pillai, 2019), and fire detection and extinguishment systems (Huang et al., 2022). These technologies enhance visitor interaction with museum exhibits (Pattakos et al., 2023), ensure visitor convenience, and promote maximum safety. Historical buildings were a testament to the technological advancements of their respective eras. Consequently, it is only fitting that contemporary constructions within historical sites mirror the technological progress of the present time.

#### 3.3.13. Structural system

The construction of any building necessitates a robust structural system to effectively distribute the forces originating from the weight of the building materials, imposed loads, and lateral forces (Del and Tabrizi, 2020). When constructing new buildings within areas of historical significance, it is imperative to use a structural system that provides strength, durability, and stability. This system should support the new building and preserve and protect the surrounding historical and natural environments. This process involves meticulous planning and skillful execution to ensure the safety of both the new building and the adjacent historical sites. Furthermore, understanding regional architecture and learning from traditional construction techniques can provide sustainable solutions for the new structure (Aguilar et al., 2018). This requires an interdisciplinary approach, the application of innovative technologies and materials, and learning from traditional construction techniques.

#### 3.3.14. Life span

Typically, the design and execution of architectural elements or new constructions at HSs are frequently treated with a lack of meticulousness, mainly due to their reversible and temporary functional nature. For instance, a temporary exhibition pavilion at a HS might be constructed with less attention to its aesthetic integration with the site, given its temporary status. However, it is not uncommon for these temporary structures to remain in place for extended periods, sometimes even becoming a part of the historical site's identity in the public's perception (Peng et al., 2021). A case in point is the Eiffel Tower, initially intended to be a temporary structure but has since become an iconic symbol of Paris (Chamberlain, 2022). However, it is essential to note that not all cases are as successful as the Eiffel Tower. There have been instances where temporary structures, despite their longevity, have not been well-received or have failed to integrate seamlessly with the historical site's identity. Therefore, the removal timeline or lifespan of such construction must be considered from the beginning.

#### 3.3.15. Interior design

The new construction's interior design, furniture, and decor should draw inspiration from the geometric pattern, motifs and decorations of the historical site rather than resorting to mere replication (Ranjazmay Azari et al., 2023). This approach, often overused in new buildings under the pretense of paying homage to the historical site, can lead to an oversaturation of imitations, thereby diminishing the site's value and authenticity due to a lack of innovation and new representation. For instance, if the historical site boasts a unique floral motif, the new building could implement a contemporary interpretation of this motif instead of directly duplicating the pattern. This approach ensures a respectful nod to the past while embracing the creativity and innovation of the present.

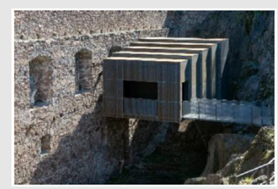
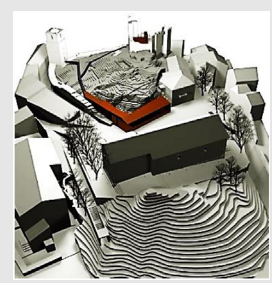
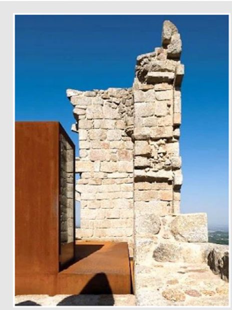
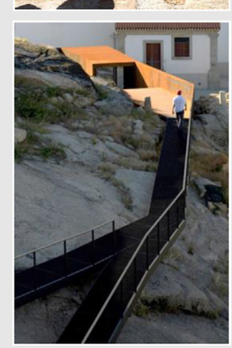
## 4. Case studies

The purpose of the case study investigation is to identify common contributing items used in the design and construction of new buildings in a historical context leading to the success of these projects (Table 2). In this regard, six successful projects have been scrutinized, all of which have won international awards. In Wilczek's research in (2021), the background, location, and interventions made in these historical sites are argued.

## 5. Result

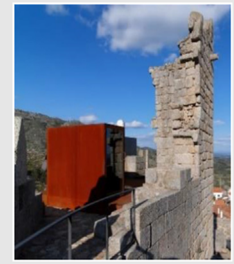
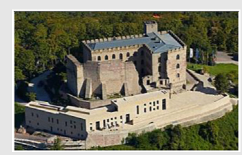
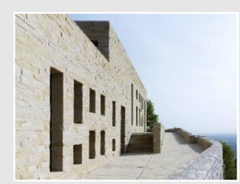
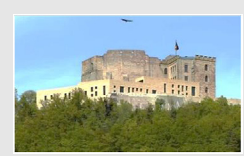
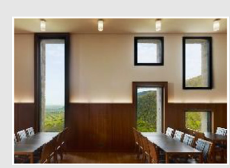
The results of R-factor analysis are presented in Table 3. The initial eigenvalues of five factors were significant and above one. The eigenvalues test shows all factors above one are meaningful (Kaiser, 1960; Yong and Pearce, 2013). Based on the Total Variance Explained, up to 67.12 % of effective factors in the contemporary construction in HSs are identified and can be interpreted with certainty according to interviews with architectural heritage experts.

**Table 2** Successful construction projects in historical sites. Source: Arch Daily and reconstructed by authors.

| Case studies | Architect | Measures | Variable | Feature of new additions | Photo |
|---|---|---|---|---|---|
| Firmiano Castle, Museum of Mountain, Bolzano, Italy | Werner Tscholl | All new objects were built below the level of the castle's perimeter walls and in the inner space of the towers. | Skyline | Below the level of monuments |  |
| | | New construction, the cinema building is suspended in the castle courtyard, emphasizing its functional separateness. | Reversibility<br>Material | Detached from historical layer<br>Contrast of finishing material with context |  |
| | | New footbridges and stairs create a new layer, clearly visible against the stone walls of the complex. | Form | Distinctive volume |  |
| Castelo Novo Visitor Center, Fundão, Portugal | Comoco Architects | The new complex is a series of structures forming a coherent whole, with its elements adapted to the place's character and topography. | Topography | In harmony with surrounding topography |  |
| | | The new construction is a single L-shaped floor with extended platforms and has a skyline below the ruin. | Skyline | Below the level of monuments |  |
| | | The new complex is constructed apart from the historical layer, which ensures the integrity of the historic walls and the ability to disassemble and restore the original state. | Reversibility | Detached from historical layer |  |

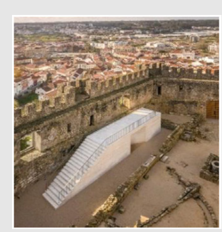
(*continued on next page*)

**Table 2** (*continued*)

| Case studies | Architect | Measures | Variable | Feature of new additions | Photo |
|---|---|---|---|---|---|
| | | The material selected for the completion of the new structures was Corten steel. This choice establishes a distinct and striking contrast with the deteriorating stone structure of the castle. The robust hue of the steel distinctly delineates the new spatial elements, thereby facilitating the visitors in identifying and accessing them. | Material | Contrast of finishing material with context |  |
| | | At the top of the tower is a glass pavilion offering spectacular views of the entire hill and the Serra da Gardunha massif. | Viewpoint | Created a viewpoint |  |
| Hambach Castle Restaurant and Entrance Building, Neustadt an der Weinstrasse, Germany | Max Dudler | The new building's light color and rectilinear form harmoniously nestle into the existing historical castle building, providing an optical continuation of the medieval ring wall and a logical evolution of the castle's structural layout. | Material | Harmony of finishing material with context |   |
| | | The new building volume and its shape derived from the basic archetype form giving it a subordinate role regarding the castle itself. | Skyline | Subordinating with the castle |  |
| | | From the inside of the restaurant, they frame views of the valley's panorama. | Viewpoint | Created a viewpoint |  |

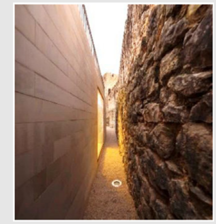
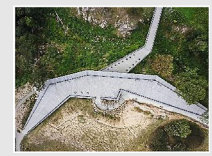
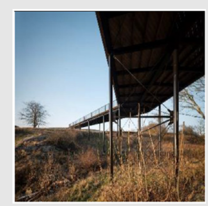
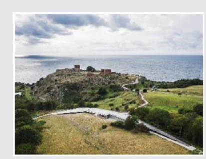
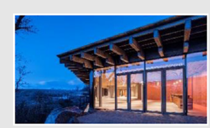
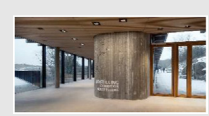
(*continued on next page*)

**Table 2** (*continued*)

| Case studies | Architect | Measures | Variable | Feature of new additions | Photo |
|---|---|---|---|---|---|
| Heidelberg Castle Visitor Center and Restaurant, Heidelberg, Germany | Max Dudler | The building is blended in with the surrounding historical fortifications through its re-interpretation of elements of the existing site's architecture. | Material | Harmony of finishing material with context |  |
| | | The dialogue between the new object and the monument is emphasized by chamfered, deep window recesses that direct visitors' eyes toward selected fragments of ruins. | Viewpoint | Created a viewpoint |  |
| Pombal Castle Visitor Center, Pombal, Portugal | Comoco Architects | A newly established, cohesive pathway system connects the hill with the city, thereby enhancing accessibility for both residents and tourists. | Accessibility | Created a new coherent path system |  |
| | | The pavilion, nestled within the remnants of the ancient walls, is a uniquely shaped monolith composed of limestone. It has been meticulously incorporated into the existing landscape, standing out distinctly against the backdrop of the natural environment and the pre-existing historical fabric. The newly introduced spatial elements possess their own distinct identity. | Form | Distinctive volume |  |
| | | The pavilion serves as an observation deck, facilitating access to the sixteenth-century windows situated in the castle's southwest wall. The architects aimed to "utilize the new construction to stimulate previously inactive spatial experiences." | Viewpoint | Created a viewpoint |  |

(*continued on next page*)

**Table 2** (*continued*)

| Case studies | Architect | Measures | Variable | Feature of new additions | Photo |
|---|---|---|---|---|---|
| | | The pavilion is constructed apart from the historical wall to preserve the reversibility rule. | Reversibility | Detached from historical layer |  |
| Hammershus Visitor Center, Bornholm, Denmark | Arkitema Architects and Christoffer Harlang | The Visitor Center building is built on a rocky slope opposite the castle. The new object blended into the landscape and did not compete with the ruins. The building's irregular shape is adapted to the hill line. | Topography | In harmony with surrounding topography |   |
| | | A light wooden footbridge over the ravine connects it to the medieval stone road. | Accessibility | Created a new coherent path system |  |
| | | The building is a frame for a panoramic view of the stronghold ruins and sea. | Viewpoint | Created a viewpoint |  |
| | | The materials employed in the construction, which include concrete poured in situ (incorporating local granite aggregate) and oak wood sourced from nearby forests utilized for ceilings, floors, and furniture, contribute significantly to the harmonious integration of the building with the surrounding coastal landscape. | Material | Harmony of finishing material with context |   |

The most important factor identified are the first two factor. This factor explains 32.54% of the total variance.

The Varimax rotation method, which is the widely used factor rotation method, was used to make factors more easily interpretable. The variables are classified into single factors based on the magnitude and proximity of their correlation coefficients. For example, the first factor includes three variables of viewpoint, interior design, and accessibility, and their correlation coefficients are the highest and close to each other. Then, the factors are labeled based on the constitutive variables and their correlation coefficients (Table 4). In a factor, that variable

**Table 3** Total Variance Explained.

| Component | Initial Eigenvalues | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | Percentage of Variance (%) | Cumulative (%) | Total | Percentage of Variance (%) | Cumulative (%) |
| 1 | 3.702 | 24.681 | 24.681 | 2.449 | 16.329 | 16.329 |
| 2 | 2.363 | 15.752 | 40.433 | 2.433 | 16.219 | 32.548 |
| 3 | 1.828 | 12.185 | 52.618 | 2.044 | 13.629 | 46.177 |
| 4 | 1.157 | 7.715 | 60.333 | 1.757 | 11.713 | 57.890 |
| 5 | 1.018 | 6.787 | 67.120 | 1.385 | 9.231 | 67.120 |
| 6 | .933 | 6.222 | 73.343 | | | |
| 7 | .851 | 5.675 | 79.018 | | | |
| 8 | .717 | 4.781 | 83.799 | | | |
| 9 | .590 | 3.935 | 87.734 | | | |
| 10 | .519 | 3.457 | 91.191 | | | |
| 11 | .482 | 3.212 | 94.403 | | | |
| 12 | .404 | 2.697 | 97.100 | | | |
| 13 | .327 | 2.181 | 99.281 | | | |
| 14 | .094 | .624 | 99.905 | | | |
| 15 | .014 | .095 | 100.000 | | | |

Extraction Method: Principal Component Analysis
Highlighted factors indicate significance of acceptable initial eigenvalues of factors (Total > 1)

with the greater correlation coefficient should be considered more in the labeling process (Shrestha, 2021).

## 6. Discussion

The findings reveal five key elements that significantly impact the success of contemporary construction within historical sites. These elements include integrated design, volume design, green design, compatible design, and modern design, which will be further elaborated upon in the following.

### 6.1. Integrated design

The principal element in the first factor relates to the concept of integrated design. This denotes that when devising a novel design, it is paramount to ensure its integration and congruity of the newly designed elements with elements of the HS, thereby culminating in a unified entity. This integration is accomplished by instituting perspectives and a visual continuity link that transitions from the new elements to those of the historical site. Considering the site's historical pattern is vital as it serves as a source of inspiration for interior design, fostering the creation of a unified, symbolically rich design. Moreover, if the construction of new pathways is deemed necessary, they should be designed in a manner that allows for their integration with the existing ones.

### 6.2. Volume design

The predominant characteristic within the second factor pertains to the volume of the new addition proposed to be

**Table 4** Rotated Component Matrix[a].

| Factor / Variable | Integrated design | Volume design | Green design | Compatible design | Modern design |
|---|---|---|---|---|---|
| Viewpoint | .948 | .140 | .103 | .014 | .097 |
| Interior design | .946 | .129 | .109 | -.001 | .105 |
| Accessibility | .671 | -.112 | -.010 | .309 | .148 |
| Scale | .052 | .819 | .082 | -.119 | .053 |
| Topography | .204 | .725 | .165 | .319 | .032 |
| Form | -.100 | .661 | -.188 | .145 | .136 |
| Skyline | .133 | .643 | .088 | -.099 | -.399 |
| Location | -.044 | .490 | -.134 | .259 | -.416 |
| Sustainability | .081 | .009 | .947 | .171 | .105 |
| Lifespan | .073 | .064 | .916 | .174 | .051 |
| Function | .032 | .107 | .063 | .719 | -.163 |
| Structural system | .137 | -.130 | .308 | .626 | .124 |
| Reversibility | .071 | .322 | .090 | .556 | .188 |
| Material | .257 | .165 | .037 | .023 | .807 |
| Technology | .169 | -.081 | .287 | .412 | .496 |

Extraction Method: Principal Component Analysis.
a. Rotation Method: Varimax with Kaiser Normalization
Rotation converged in 6 iterations
Highlighted variables indicate a high correlation coefficient in each factor

integrated into the HS. This addition, while maintaining respect for and subordination to the HS, should nonetheless possess a distinct identity, enabling easy recognition by visitors. The comprehension of this volume is inherently intuitive. It is contingent upon the existing scale of the HS, both natural and constructed topography, the form and skyline of the HS, and the positioning of the new structure concerning other historical buildings.

### 6.3. Green design

The third factor primarily focuses on the application of green design principles. These principles are developed to lessen the adverse effects of new constructions on the surrounding environment. Green design can be achieved by using either locally sourced or recyclable materials, reducing energy consumption, and harnessing renewable energy sources. Furthermore, it's essential to establish the expected lifespan of the new building. This allows for a reassessment of its efficiency, especially in terms of sustainability, and the implementation of necessary measures once it reaches the end of its useful life.

### 6.4. Compatible design

The central theme of the fourth factor is the notion of compatible design. This concept implies that any new construction should be designed in a way that harmoniously blends with the historical site, thereby enhancing its value. A critical aspect of this process is ensuring the reversibility of any alterations made, thus safeguarding the authenticity of the historical site for the long term. The function of any new construction should not undermine the existing uses of the historical site. Instead, it should complement and enhance them. This compatible design approach can also be viewed as a technical adaptation of the existing structures within the site, depicting them in novel ways. For instance, if the architectural style of the neighboring monuments features arches and load-bearing system transfers compression, a parametric design approach could be employed based on a structural model generated by Rhino Vault plug-in.

### 6.5. Modern design

The fifth principle underlines the importance of comprising modern design solutions in contemporary construction within historical sites, thereby symbolizing the essence of the present era. This involves using avant-garde technologies, including the Internet of Things, Virtual Reality, and Augmented Reality. These technologies amplify visitor engagement and interaction with historical artifacts through innovative representation methods. Furthermore, employing eco-friendly modified materials that mirror the current era and exhibit a unique identity is highly appropriate. This should be achieved while ensuring harmony with the surrounding environment is maintained.

## 7. Conclusion and future research

Through this research, it has been underscored that two pivotal steps must be undertaken to safeguard the HS before designing a new building on the site.

The first step involves digital documentation primarily through the digital twin method, which offers the advantages of non-destructive evaluation, real-time monitoring, data sharing, intelligent management, and forecasting the future state of the HS. These digital documents must record the existing condition of the HS both before and after any new construction or intervention, serving as the primary tools for the roadmap of maintenance and conservation of the HS.

The second step necessitates identifying the site's contextual value, which encompasses physical and semantic values, in order to preserve them. In the design and construction of the new building, these values act as the cornerstone, inspiration, and cautionary signals for any procedure, guiding what should or could be done for sustainable development. New constructions at HSs require meticulous consideration of the site's contextual value derived from the site's identity, local culture, and vernacular architecture. This approach ensures the new addition integrates with the existing historical context, preserving the site's authenticity and cultural relevance. HSs are more than mere physical spaces; they serve as repositories of a community's history, culture, and identity. Neglecting these elements in new constructions risks damaging the site's historical integrity and disconnecting it from the community it represents. However, designs that respect and preserve these elements can enhance the site's value, foster a sense of continuity with the past, and strengthen the bond between the site and the community.

The integrity of a HS can be compared to a symphony orchestra's performance, where every instrument contributes to the overall performance. In this analogy, if one instrument is out of tune, it can disrupt the entire performance. Similarly, any new building or changes made at a HS must harmonize with the rest of the site to maintain the overall integrity. The findings of this research emphasize the importance of location, function, scale, form, material, skyline, viewpoint, accessibility, reversibility, topography, sustainability, technology, structural system, life span, and interior design when constructing a new building at a HS. Furthermore, the design and implementation should follow five guiding principles: integrated design, volume design, green design, compatible design, and modern design. In this scenario, the new buildings will cater to the users' needs, preserve, or even enhance the contextual values, and harmonize with the built and natural environment.

The current research has comprehensively analyzed the variables and factors contributing to the successful design and construction of new buildings within historical sites. However, several areas could benefit from further exploration in future research.

1) **Impact of user feedback:** Future research could investigate how user feedback influences the design and

construction of new additions within historical sites. This could involve surveying visitors to historical sites, collecting feedback on the new additions, and then correlating this feedback with the design decisions made. Understanding how users interact with these new additions and their impact on the visitor experience could provide valuable insights for future design and construction projects in HSs.

2) **Influence of cultural context:** The current research did not explicitly consider the influence of cultural context on the design and construction of new additions. Future research could explore how cultural contexts shape the design of new additions and how different cultural groups receive these designs.
3) **Cost-benefit analysis:** Future research could perform a cost-benefit analysis of new additions within historical sites. This would involve comparing the costs of constructing new additions with their benefits, such as increased visitor satisfaction, improved site visibility, or enhanced educational opportunities.

## Declaration of competing interest

The authors declare they have no competing interests.

## Acknowledgments

We would like to thank all the participants who made the present study possible.

## References

Abanda, F.H., Byers, L., 2016. An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling). Energy 97, 517—527. https://doi.org/10.1016/j.energy.2015.12.135.

Acal, C., Aguilera, A.M., Escabias, M., 2020. New modeling approaches based on varimax rotation of functional principal components. Mathematics 8 (11), 2085. https://doi.org/10.3390/math8112085.

Aguilar, R., Torrealva, D., Moreira, S., Pando, M.A., Ramos, L.F. (Eds.), 2018. Structural Analysis of Historical Constructions: an Interdisciplinary Approach, vol. 18. Springer. https://doi.org/10.1007/978-3-319-99441-3.

Alabi, A.T., Jelili, M.O., 2023. Clarifying likert scale misconceptions for improved application in urban studies. Qual. Quantity 57 (2), 1337—1350. https://doi.org/10.1007/s11135-022-01415-8.

Anthony Jr., B., 2023. The role of community engagement in urban innovation towards the Co-creation of smart sustainable cities. J. Knowledge Economy 1—33. https://doi.org/10.1007/s13132-023-01176-1.

Appelbaum, B., 2012. Conservation Treatment Methodology. Routledge.

Baghalzadeh Shishehgarkhaneh, M., Keivani, A., Moehler, R.C., Jelodari, N., Roshdi Laleh, S., 2022. Internet of Things (IoT), building information modeling (BIM), and digital twin (DT) in construction industry: a review, bibliometric, and network analysis. Buildings 12 (10), 1503. https://doi.org/10.3390/buildings12101503.

Barranha, H., Caldas, J.V., Silva, R.N.N.D., 2017. Translating heritage into museums: two architectural strategies inside Lisbon Castle. J. Cult. Herit. Manag. Sustain Dev. 7 (1), 33—47. https://doi.org/10.1108/JCHMSD-05-2016-0033.

Bent, G.R., Pfaff, D., Brooks, M., Radpour, R., Delaney, J., 2022. A practical workflow for the 3D reconstruction of complex historic sites and their decorative interiors: florence as it Was and the church of Orsanmichele. Heritage Science 10 (1), 1—17. https://doi.org/10.1186/s40494-022-00750-1.

Bloomer, R., Cook, M., Kunynskyj, L., Wolter, S., 2022. Lincoln Home National Historic Site Accessibility Assessment. Eppley Institute for Parks and Public Lands, Indiana University.

Boone, H.N., Boone, D.A., 2012. Analyzing likert data. J. Ext. 50 (2), 1—5.

Chamberlain, P., 2022. Will temporary become permanent? Design for Health 6 (1), 1—3. https://doi.org/10.1080/24735132.2022.2072072.

Cheung, G.W., Cooper-Thomas, H.D., Lau, R.S., Wang, L.C., 2023. Reporting reliability, convergent and discriminant validity with structural equation modeling: a review and best-practice recommendations. Asia Pac. J. Manag. 1—39. https://doi.org/10.1007/s10490-023-09871-y.

Ching, F.D., 2023. Architecture: Form, Space, and Order. John Wiley & Sons.

Clavir, M., 2012. Preserving what is Valued. ubc Press. https://doi.org/10.59962/9780774850155.

Cope, G., 2022. Symbolism in the Bible and Church. Open Road Media.

DAHG (Department of Arts, Heritage and the Gaeltacht), 2011. Architectural Heritage Protection Guidelines for Planning Authorities.

Das, B.B., Neithalath, N. (Eds.), 2018. Sustainable Construction and Building Materials: Select Proceedings of ICSCBM 2018, vol. 25. Springer. https://doi.org/10.1007/978-981-13-3317-0.

Debailleux, L., Hismans, G., Duroisin, N., 2018. Exploring cultural heritage using virtual reality. In: Digital Cultural Heritage: Final Conference of the Marie Skłodowska-Curie Initial Training Network for Digital Cultural Heritage, ITN-DCH 2017, Olimje, Slovenia. Springer International Publishing, pp. 289—303. https://doi.org/10.1007/978-3-319-75826-8_24.

Del, M.S.T.T., Tabrizi, S.K., 2020. A methodological assessment of the importance of physical values in architectural conservation using Shannon entropy method. J. Cult. Herit. https://doi.org/10.1016/j.culher.2019.12.012.

Del, M.S.T.T., Sadooghi, Z., Tabrizi, S.K., 2022. Recognition of defensive factors in the architectural heritage of Iran's organic ancient shelters. Frontiers of Architectural Research 11 (4), 709—730. https://doi.org/10.1016/j.foar.2022.02.003.

Del, M.S.T.T., Sedghpour, B.S., Tabrizi, S.K., 2020. The semantic conservation of architectural heritage: the missing values. Heritage Science 8 (1), 1—13. https://doi.org/10.1186/s40494-020-00416-w.

Del, M.S.T.T., Sedghpour, B.S., Tabrizi, S.K., 2021. Factors affecting the value revitalization of Qajar religious schools in Tehran. Heritage Science 9 (1), 1—20. https://doi.org/10.1186/s40494-021-00526-z.

Delgado, J.M. (Ed.), 2020. Sustainable Materials in Building Construction, vol. 11. Springer Nature. https://doi.org/10.1007/978-3-030-46800-2.

Di Pietro, L., Guglielmetti Mugion, R., Renzi, M.F., 2018. Heritage and identity: technology, values and visitor experiences. J. Herit. Tourism 13 (2), 97—103. https://doi.org/10.1080/1743873X.2017.1384478.

Erzen, J.N., 2011. Reading mosques: meaning and architecture in islam. J. Aesthet. Art Critic. 69 (1), 125—131. https://doi.org/10.1111/j.1540-6245.2010.01453.x.

Feilden, B., 2007. Conservation of Historic Buildings. Routledge. https://doi.org/10.4324/9780080502915.

Feilden, B.M., Jokilehto, J., 1998. Management Guidelines for World Cultural Heritage Sites.

Forsyth, M. (Ed.), 2013. Understanding Historic Building Conservation. John Wiley & Sons.

Georgopoulos, A., 2018. CIPA's perspectives on cultural heritage. In: Digital Research and Education in Architectural Heritage: 5th Conference, DECH 2017, and First Workshop, UHDL 2017. Springer International Publishing, Dresden, Germany, pp. 215—245. https://doi.org/10.1007/978-3-319-76992-9_13.

Gholitabar, S., Alipour, H., Costa, C.M.M.D., 2018. An empirical investigation of architectural heritage management implications for tourism: the case of Portugal. Sustainability 10 (1), 93. https://doi.org/10.3390/su10010093.

Ginsberg, R., 2021. The Aesthetics of Ruins. Brill. https://doi.org/10.1163/9789004495937.

Grazuleviciute-Vileniske, I., Seduikyte, L., Daugelaite, A., Rudokas, K., 2020. Links between heritage building, historic urban landscape and sustainable development: systematic approach. Landsc. Archit. Art 17, 17. https://doi.org/10.22616/j.landarchart.2020.17.04.

Grimmer, A.E., Weeks, K.D., 2010. New Exterior Additions to Historic Buildings: Preservation Concerns. National Park Service, US Department of the Interior, Technical Preservation Services.

Gros, A., Guillem, A., De Luca, L., Baillieul, É., Duvocelle, B., Malavergne, O., Zimmer, T., 2023. Faceting the post-disaster built heritage reconstruction process within the digital twin framework for Notre-Dame de Paris. Sci. Rep. 13 (1), 5981. https://doi.org/10.1038/s41598-023-32504-9.

Guazzaroni, G., Pillai, A.S. (Eds.), 2019. Virtual and Augmented Reality in Education, Art, and Museums. IGI Global.

Guzmán-Torres, Z., 2009. Historic Buildings and Contemporary Additions: the Elements of a Cohesive Design Relationship.

Hagerman, M., 2023. An analysis of key cultural heritage resolutions, documents, charters, and legislation. In: Prioritizing People in Ethical Decision-Making and Caring for Cultural Heritage Collections. Routledge, pp. 3—14.

Huang, X., Wu, X., Usmani, A., 2022. Perspectives of using artificial intelligence in building fire safety. In: Handbook of Cognitive and Autonomous Systems for Fire Resilient Infrastructures. Springer International Publishing, Cham, pp. 139—159. https://doi.org/10.1007/978-3-030-98685-8_6.

ICOMOS, 1964. International Charter for the Conservation and Restoration of Monuments and Sites (The Venice Charter 1964). 2nd International Congress of Architects and Technicians of Historic Monuments, Venice, 1964.

ICOMOS, 1994. The Nara Document on Authenticity.

ICOMOS, 1999. The Burra Charter (The Australia ICOMOS Charter for Places of Cultural Significance).

ICOMOS, 2010. ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value. Revised 2010.

Icomos, C., 2003. Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage. Ratified by the ICOMOS 14th General Assembly Victoria Falls Livingstone-Zambia.

Jia, S., Liao, Y., Xiao, Y., Zhang, B., Meng, X., Qin, K., 2022. Conservation and management of Chinese classical royal garden heritages based on 3D digitalization-A case study of Jianxin courtyard in Jingyi garden in fragrant hills. J. Cult. Herit. 58, 102—111. https://doi.org/10.1016/j.culher.2022.09.020.

Joffe, M., 1992. Validity of exposure data derived from a structured questionnaire. Am. J. Epidemiol. 135 (5), 564—570. https://doi.org/10.1093/oxfordjournals.aje.a116323.

Jones, T.E., Bui, H.T., Ando, K., 2022. Zoning for world heritage sites: dual dilemmas in development and demographics. Tourism Geogr. 24 (1), 33—55. https://doi.org/10.1080/14616688.2020.1780631.

Jouan, P.A., Hallot, P., 2019. Digital Twin: a HBIM-based methodology to support preventive conservation of historic assets through heritage significance awareness, International Archives of the Photogrammetry. Remote Sensing and Spatial Information Sciences 42 (2019). https://doi.org/10.5194/isprs-archives-XLII-2-W15-609-2019.

Kaiser, H.F., 1960. The application of electronic computers to factor analysis. Educ. Psychol. Meas. 20 (1), 141—151. https://doi.org/10.1177/001316446002000116.

Khalid, A., 2022. Conservation challenges and emerging trends of digital preservation for UNESCO architectural heritage, Pakistan. Conservation 2 (1), 26—37. https://doi.org/10.3390/conservation2010003.

Kostopoulou, S., 2022. Architectural heritage and tourism development in urban neighborhoods: the case of upper city, thessaloniki, Greece. In: Conservation of Architectural Heritage. Springer International Publishing, Cham, pp. 139—152. https://doi.org/10.1007/978-3-030-74482-3_12.

Koutsoudis, A., Ioannakis, G., Pistofidis, P., Arnaoutoglou, F., Kazakis, N., Pavlidis, G., Tsirliganis, N., 2021. Multispectral aerial imagery-based 3D digitisation, segmentation and annotation of large scale urban areas of significant cultural value. J. Cult. Herit. 49, 1—9. https://doi.org/10.1016/j.culher.2021.04.004.

Kuckartz, U., Rädiker, S., 2023. Qualitative Content Analysis: Methods, Practice and Software. SAGE.

Leatherbarrow, D., 2015. Topographical Stories: Studies in Landscape and Architecture. University of Pennsylvania Press.

Li, X., Zhang, Y., 2023. Conserving and Managing Historical Urban Landscape: an Integrated Morphological Approach. https://doi.org/10.1007/978-981-19-4222-8.

Li, Y., Zhao, L., Chen, Y., Zhang, N., Fan, H., Zhang, Z., 2023. 3D LiDAR and multi-technology collaboration for preservation of built heritage in China: a review. Int. J. Appl. Earth Obs. Geoinf. 116, 103156. https://doi.org/10.1016/j.jag.2022.103156.

Lu, Q., Xie, X., Heaton, J., Parlikad, A.K., Schooling, J., 2020. From BIM towards digital twin: strategy and future development for smart asset management. Service Oriented, Holonic and Multiagent Manufacturing Systems for Industry of the Future: Proceedings of SOHOMA 2019 9, 392—404. https://doi.org/10.1007/978-3-030-27477-1_30.

Masciotta, M.G., Morais, M.J., Ramos, L.F., Oliveira, D.V., Sanchez-Aparicio, L.J., González-Aguilera, D., 2021. A digital-based integrated methodology for the preventive conservation of cultural heritage: the experience of HeritageCare project. Int. J. Architect. Herit. 15 (6), 844—863. https://doi.org/10.1080/15583058.2019.1668985.

Matini, M.R., Andaroodi, E., Ono, K., 2019. A 3D approach to reconstitution of the adobe citadel of Bam after earthquake: a complementary interpretation of architectural heritage knowledge, aerial photogrammetry, and heterogeneous data. Int. J. Architect. Herit. 13 (4), 600—618. https://doi.org/10.1080/15583058.2018.1450907.

Mesas-Carrascosa, F.J., Verdú Santano, D., Meroño de Larriva, J.E., Ortíz Cordero, R., Hidalgo Fernández, R.E., García-Ferrer, A., 2016. Monitoring heritage buildings with open source hardware sensors: a case study of the mosque-cathedral of Córdoba. Sensors 16 (10), 1620. https://doi.org/10.3390/s16101620.

Mol, A., Cabaleiro, M., Sousa, H.S., Branco, J.M., 2020. HBIM for storing life-cycle data regarding decay and damage in existing timber structures. Autom. ConStruct. 117, 103262. https://doi.org/10.1016/j.autcon.2020.103262.

Murphy, M., McGovern, E., Pavia, S., 2009. Historic building information modelling (HBIM). Struct. Surv. 27 (4), 311—327. https://doi.org/10.1108/02630800910985108.

Orbasli, A., 2008. Architectural Conservation: Principles and Practice.

Osman, A., Moropoulou, A. (Eds.), 2019. Nondestructive Evaluation and Monitoring Technologies, Documentation, Diagnosis and Preservation of Cultural Heritage. Springer. https://doi.org/10.1007/978-3-030-25763-7.

Pattakos, A., Zidianakis, E., Sifakis, M., Roulios, M., Partarakis, N., Stephanidis, C., 2023. Digital interaction with physical museum artifacts. Technologies 11 (3), 65. https://doi.org/10.3390/technologies11030065.

Peng, Y., Roders, A.R., Schröder, T.W.A., Colenbrander, B.J.F., 2018. Sustainable architecture in urban historic contexts: a systematic literature review. In: 2nd International Conference on Heritage of China (ICHC 2018).

Peng, Z., Zhao, S., Shen, L., Ma, Y., Zhang, Q., Deng, W., 2021. Retrofit or rebuild? The future of old residential buildings in urban areas of China based on the analysis of environmental benefits. Int. J. Low Carbon Technol. 16 (4), 1422–1434. https://doi.org/10.1093/ijlct/ctab070.

Penn, W., 2007. Sense of Place: Design Guidelines for New Construction in Historic Districts. A Publication of the Preservation Alliance for Greater, Philadelphia.

Piqueras-Fiszman, B., 2023. Open-ended questions in sensory testing practice. In: Rapid Sensory Profiling Techniques. Woodhead Publishing, pp. 349–370. https://doi.org/10.1016/B978-0-12-821936-2.00015-7.

Pirbazari, A.G., Tabrizi, S.K., 2022. RecorDIM of Iran's cultural heritage using an online virtual museum, considering the coronavirus pandemic. ACM Journal on Computing and Cultural Heritage (JOCCH) 15 (2), 1–14. https://doi.org/10.1145/3500925.

Pye, E., 2000. Caring for the Past: Issues in Conservation for Archaeology and Museums.

Ranjazmay Azari, M., Bemanian, M., Mahdavinejad, M., Körner, A., Knippers, J., 2023. Application-based principles of islamic geometric patterns; state-of-the-art, and future trends in computer science/technologies: a review. Heritage Science 11 (1), 22. https://doi.org/10.1186/s40494-022-00852-w.

Ribera, F., Nesticò, A., Cucco, P., Maselli, G., 2020. A multicriteria approach to identify the Highest and Best Use for historical buildings. J. Cult. Herit. 41, 166–177. https://doi.org/10.1016/j.culher.2019.06.004.

Richmond, A., Bracker, A., Bracker, A.L. (Eds.), 2009. Conservation: Principles, Dilemmas and Uncomfortable Truths. Routledge.

Saura-Gómez, P., Spairani-Berrio, Y., Huesca-Tortosa, J.A., Rizo-Maestre, C., Mesas-Carrascosa, F.J., 2021. Advances in the restoration of buildings with lidar technology and 3d reconstruction: forged and vaults of the refectory of santo domingo de orihuela (16th century). Appl. Sci. 11 (18), 8541. https://doi.org/10.3390/app11188541.

Semes, S.W., 2009. The Future of the Past: A Conservation Ethic for Architecture, Urbanism, and Historic Preservation.

Shabani, A., Skamantzari, M., Tapinaki, S., Georgopoulos, A., Plevris, V., Kioumarsi, M., 2022. 3D simulation models for developing digital twins of heritage structures: challenges and strategies. Procedia Struct. Integr. 37, 314–320. https://doi.org/10.1016/j.prostr.2022.01.090.

Shahriar, A.T.M., Mithun, S.N.H., Saha, D., Ahmed, S., 2023. Designing architectural continuity in a historic urban quarter of Dinajpur, Bangladesh. Frontiers of Architectural Research. https://doi.org/10.1016/j.foar.2023.05.001.

Shahteimori, Y., Mazaherian, H., 2012. Design guidelines for new constructions in historic context. Honar-ha-ye Ziba: Memary Va Shahrsazi 17 (4), 1–15. https://doi.org/10.22059/jfaup.2012.36363.

Shrestha, N., 2021. Factor analysis as a tool for survey analysis. Am. J. Appl. Math. Stat. 9 (1), 4–11.

Siguencia Ávila, M.E., Rey Perez, J., 2016. Heritage values protection, from the monument to the urban dimension. Case study: the historic centre of Santa Ana de los Ríos de Cuenca, Ecuador, The Historic Environment: Policy & Practice 7 (2–3), 164–176. https://doi.org/10.1080/17567505.2016.1172785.

Silveira da Costa, V., Montagna da Silveira, A., da Silva Torres, A., 2022. Evaluation of degradation state of historic building facades through qualitative and quantitative indicators: case study in Pelotas, Brazil. Int. J. Architect. Herit. 16 (11), 1642–1665. https://doi.org/10.1080/15583058.2021.1901161.

Slavicek, L.C., Pei, I.M., 2009. IM Pei. Infobase Publishing.

Sun, C., Zhou, Y., Han, Y., 2022. Automatic generation of architecture facade for historical urban renovation using generative adversarial network. Build. Environ. 212, 108781. https://doi.org/10.1016/j.buildenv.2022.108781.

Sun, Y., 2019. Between Architecture and Landscape-Site Revitalization in Magnuson Park by an Integration of Landscape and Building Reuse, Doctoral Dissertation. University of Washington.

Taher Tolou Del, M.S., Saleh Sedghpour, B., Kamali Tabrizi, S., 2022. The value revitalization model of Qajar religious schools in Tehran. Heritage Science 10 (1), 26. https://doi.org/10.1186/s40494-022-00658-w.

Tejedor, B., Lucchi, E., Bienvenido-Huertas, D., Nardi, I., 2022. Non-destructive techniques (NDT) for the diagnosis of heritage buildings: traditional procedures and futures perspectives. Energy Build., 112029 https://doi.org/10.1016/j.enbuild.2022.112029.

Tobiasz, A., Markiewicz, J., Łapiński, S., Nikel, J., Kot, P., Muradov, M., 2019. Review of methods for documentation, management, and sustainability of cultural heritage. case study: museum of King Jan III's Palace at Wilanów. Sustainability 11 (24), 7046. https://doi.org/10.3390/su11247046.

Tunison, S., 2023. Content analysis. In: Varieties of Qualitative Research Methods: Selected Contextual Perspectives. Springer International Publishing, Cham, pp. 85–90. https://doi.org/10.1007/978-3-031-04394-9_14.

Tusting, K., 2023. Surveys, questionnaires, interviews and focus groups. In: Introducing Linguistics. Routledge, pp. 413–425.

Valentini, L., Moore, K.R., Bediako, M., 2022. Sustainable sourcing of raw materials for construction: from the Earth to the Moon and beyond. Elements: An International Magazine of Mineralogy, Geochemistry, and Petrology 18 (5), 327–332. https://doi.org/10.2138/gselements.18.5.327.

Vears, D.F., Gillam, L., 2022. Inductive content analysis: a guide for beginning qualitative researchers. Focus on Health Professional Education: A Multidiscip. J. 23 (1), 111–127.

Walker, K.D., 2023. Interpretation and expert panels. In: Varieties of Qualitative Research Methods: Selected Contextual Perspectives. Springer International Publishing, Cham, pp. 243–248. https://doi.org/10.1007/978-3-031-04394-9_39.

Węcławowicz-Gyurkovich, E., 2010. Nowe Formy Zderzone Z Historycznymi, Politechnika Krakowska. Czasopismo Techniczne.

Wilczek, I., 2021. The layers of history: new architecture interventions in castle ruins. Frontiers of Architectural Research 10 (2), 351–368. https://doi.org/10.1016/j.foar.2020.12.001.

Yong, A.G., Pearce, S., 2013. A beginner's guide to factor analysis: focusing on exploratory factor analysis. Tutorials in quantitative methods for psychology 9 (2), 79–94. https://doi.org/10.20982/tqmp.09.2.p079.

Zhang, X., Zhi, Y., Xu, J., Han, L., 2022. Digital protection and utilization of architectural heritage using knowledge visualization. Buildings 12 (10), 1604. https://doi.org/10.3390/buildings12101604.

Zhang, Y., Han, Y., 2022. Vitality evaluation of historical and cultural districts based on the values dimension: districts in Beijing City, China. Heritage Science 10 (1), 137. https://doi.org/10.1186/s40494-022-00776-5.

Zhu, Y., González Martínez, P., 2022. Heritage, values and gentrification: the redevelopment of historic areas in China. Int. J. Herit. Stud. 28 (4), 476–494. https://doi.org/10.1080/13527258.2021.2010791.