ITU A|Z • Vol 23 No 1 • March 2026 • 161-192

Intervention to the building – Exploring the interrelations by systematic literature review

Hatice Yasemin ÇAKIR UZELLİ[1*], Ömer Şükrü DENİZ[2], Ecem EDİS[3]
[1] yasemin.cakir@msgsu.edu.tr • Department of Architecture, Graduate School, Mimar Sinan Fine Arts University, Istanbul, Türkiye
ORCID: 0000-0001-8354-1459
[2] omer.sukru.deniz@msgsu.edu.tr • Department of Architecture, Faculty of Architecture, Mimar Sinan Fine Arts University, Istanbul, Türkiye
ORCID: 0000-0002-2721-774X
[3] ecem@itu.edu.tr • Department of Architecture, Faculty of Architecture, Istanbul Technical University, Istanbul, Türkiye
ORCID: 0000-0002-9647-2090

** Corresponding author*
Received: February 2025 • Final Acceptance: August 2025

Abstract
Various factors contribute to the obsolescence of a building or its part(s), and these are addressed through interventions resulting in physical alterations. In other words, intervention is a complex process involving the following components: building or its part(s), factors, obsolescence, and intervention approach (i.e. intervention type and criteria). Additionally, there are numerous intervention types, such as adaptation, conservation, maintenance, remodelling, renewal, replacement, restoration, strengthening, etc., whose contexts may sometimes partially overlap. Therefore, this study aimed to gain insight into the boundaries, interrelations, and differences within the scope of the intervention process through a systematic literature review of 170 articles. Firstly, the components of the intervention were examined and classified from key references. Subsequently, 170 articles to be analysed were determined through a literature scan. While reviewing these articles, the preliminary classification was refined, and the articles were systematically categorized accordingly. Finally, analyses were performed on the categorized data to understand the scope and focal points of each intervention component, the relationship between them, and the physical output of the intervention, namely the planned/executed application. In conclusion, it is observed through this review that parts of the envelope, which constitute the boundary between the external and internal environment, are generally the primary targets of intervention to remove the marks of physical and environmental obsolescence. Retrofit is the most common intervention type, typically applied to fulfil sustainability criteria, regardless of heritage value. Additionally, rehabilitation and restoration are frequently applied in heritage buildings, while refurbishment and renovation are more prevalent in non-heritage ones.

Keywords
Building envelope, Degradation, Retrofit, Refurbishment, Renovation.

doi: 10.58278/0.2026.120

1. Introduction

The building life cycle, which is related to the assessment of the environmental performance of buildings, comprises a series of interconnected stages: product, construction, use, and end-of-life (British Standards Institution [BSI], 2011a, 2021). The use stage encompasses maintenance, repair, replacement, and refurbishment with the objective of extending the useful life of the building and preventing it from becoming partially/fully obsolete (BSI, 2011a; Douglas, 2006). In other words, interventions on different scales are applied to the building for this purpose, resulting in physical changes (BSI, 2013, 2017a, 2019; International Council on Monuments and Sites [ICOMOS] International Committee on Twentieth Century Heritage, 2017). These changes in buildings were classified by Markus et al. (1972) as: improvision – easily reversible and low-cost small physical changes, change – not easily reversible adaptation of the building system, and extension – addition of spaces. Similarly, Broadbent (1980) defined four categories as changes in furniture, fittings/finishes, services, and structure. Brand (1994) further developed this classification by considering the change period and changing layers and classified them from the most permanent to the most temporary as changes in site, structure, skin, services, space plan, and stuff. Within these classifications, interventions that cause changes appear in diverse dimensions.

The intervention process can be explained by examining its components, which can be identified through the questions "WHEREAT", "WHY", and "HOW". The response to the "WHEREAT?" question describes the subject of the process, that is, the building or its parts(s). Factors and obsolescence that address the "WHY?" question serve as the rationale for intervention. The response to the "HOW?" question represents the intervention approach, which defines the selected intervention type, and the associated criteria. In summary, these answers constitute the components of the intervention process as presented in Figure 1, which was developed by the authors as a conceptual framework based on the synthesis of the reviewed literature.

Regarding intervention types as one of these components, various classifications were usually done considering their main objective and the magnitude of physical changes that they cause. For example, Douglas (2006) listed them as preservation, conservation, refurbishment, rehabilitation, renovation, remodelling, restoration, and demolition. Similarly, Vos and Storgaard (2018) proposed a hierarchical classification ranging from the least to the most extensive as preservation, conservation, restoration, refurbishment, rehabilitation, renovation, conversion, and retrofit. Pereira Roders (2007), considered deprivation and demolition as initial and ultimate levels respectively, and listed among them preservation, conservation, restoration, rehabilitation, and reconstruction. Regarding conservation, Zhang and Dong (2021) defined intervention levels from low to high as maintenance, repair, renewal, reuse, and new design. Furthermore, interventions were classified according to their application time during the building life cycle such as in the report of the International Council for Research and Innovation in Building and Construction [CIB] Working Commission W60 (1982) where restoration was considered to be a more complex intervention following maintenance. Likewise, priority was another perspective in the classification as in BS ISO 15686-7:2017 (2017b) where interventions applied during the use phase of building life cycle were outlined to be maintenance, refurbishment and repair, replacement, and renewal respectively.

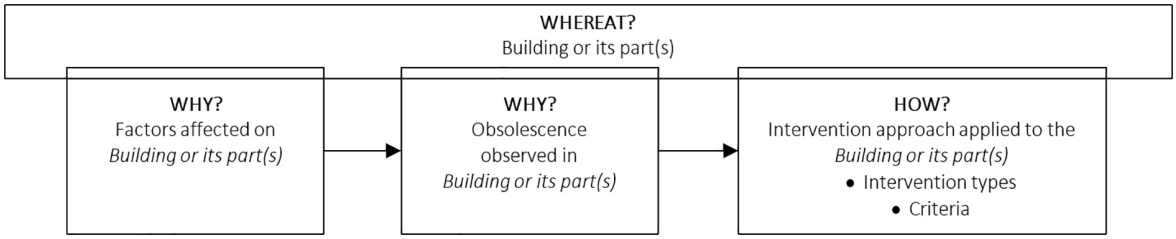


Figure 1. *Intervention process and its components.*

Most of these intervention types were explored usually individually in various literature review papers, delving into their implementation scales, factors considered, and obsolescences causing them to consider a particular focus. Sustainable development was a common focus in this respect, where, for instance, life cycle assessment of building refurbishment (Vilches et al., 2017), retrofit interventions to reduce energy consumption (Sarihi et al., 2021), correlation between energy consumption and maintenance strategies (Alghanmi et al., 2022), and thermal renovations on opaque façade consisting auto-responsive technologies (Andrade Santos et al., 2020) were studied. Sustainability of residential buildings was a common consideration too, where residential building renovations in temperate climates (Abdul Hamid et al., 2018), low-energy retrofit interventions (Hurst & O'Donovan, 2019), deep energy retrofit interventions (Ibañez Iralde et al., 2021), passive thermal retrofit interventions (Carratt et al., 2020), data-centric retrofit actions (Simpson et al., 2020), etc. were explored. Sustainability and energy efficiency of heritage buildings gained importance as well, where for instance, the embodied energies of demolishing and rebuilding and of adaptive reuse were comparatively reviewed to support deciding between those (Guidetti & Ferrara, 2023), the criteria used for sustainable conservation (Gonçalves et al., 2022), zero-emission refurbishment applications (Loli & Bertolin, 2018), or the sustainability of historic buildings' envelopes (Posani et al., 2021) were investigated. Regarding buildings with heritage value, in addition to the review studies, studies on interventions for employing non-destructive monitoring methods to identify defects and to determine preservation methods (Zendri et al., 2017), use of as-built parametric models to support refurbishment and conservation interventions (S. Bruno et al., 2018), and multi-criteria decision-making methods for intervention approaches (Nadkarni & Puthuvayi, 2020) were of particular significance.

Apart from the aforementioned literature review papers, there are papers that present methodological approaches to intervention types and their components. One current issue is the assessment of building conditions, which was considered a key step in planning rehabilitation and maintenance activities (Ferraz et al., 2016). The type and severity of the defects were used to determine the extent of upgrading works (Brandt & Rasmussen, 2002), and the repairs, which also influence the rental prices (Pedro et al., 2008). There are also papers focusing on the degradation of the specific part of the building and the relation of the degradation level to the repair, such as the building envelope (Ferreira, Silva, et al., 2021b) and roof (Gocer, 2024). Some other papers discuss existing preservation approaches, such as the vernacular preservation of the post-industrial landscape (Arnold & Lafreniere, 2017) and modern architecture (Prudon, 2017). As in the literature review studies, sustainability is of great importance in terms of retrofitting (Filippi, 2015) and green maintenance (Forster et al., 2011) of historic buildings, as well as cost-effective energy efficiency and carbon emission optimization (Almeida & Ferreira, 2018) and bottom-up energy efficiency in the residential sector (McKenna et al., 2013).

On the other hand, papers present literature review and methodological approach generally address on specific intervention types rather than multiple types. Notably, there were no studies in which all intervention types were considered together, where their boundaries, interrelations and differences were discussed. To address this gap, the present study aimed to conduct a systematic literature review on all intervention types with the objective of examining their relations, distinctions and hierarchy. To this end, the intervention process was examined in a broader term to understand the relations between the components given in Figure 1. Following in-depth examinations, the scope of each intervention type within the context of the intervention process was delineated.

In this context, the methodology employed in the literature review was first explained, and the findings of analyses were then presented. Subsequently, important points regarding each type of intervention were summarized and discussed. Finally, the relation between intervention types was attempted to be explained in consideration of the components of the intervention process.

2. Method

The study was comprised of four stages: (i) formulation of the intervention process and its components from key references, (ii) determination of the analysis dataset, i.e. research studies through a systematic database search, screening and elimination, (iii) systematic categorization of the data in these studies, and (iv) analysis of the articles through categorized data considering all the intervention components up to the planned/executed applications to understand the scope of each main intervention type (Figure 2).

2.1. Formulation of the intervention process and its components

Initially, the definitions of different intervention types were gathered from key references (i.e. standards, regulations, and main references) to be a base for the analyses (Table 1). Different classifications and definitions were then searched for the remaining components of the intervention process using similar references, i.e. for factors, obsolescences, and criteria. Consequently, a preliminary classification of intervention components

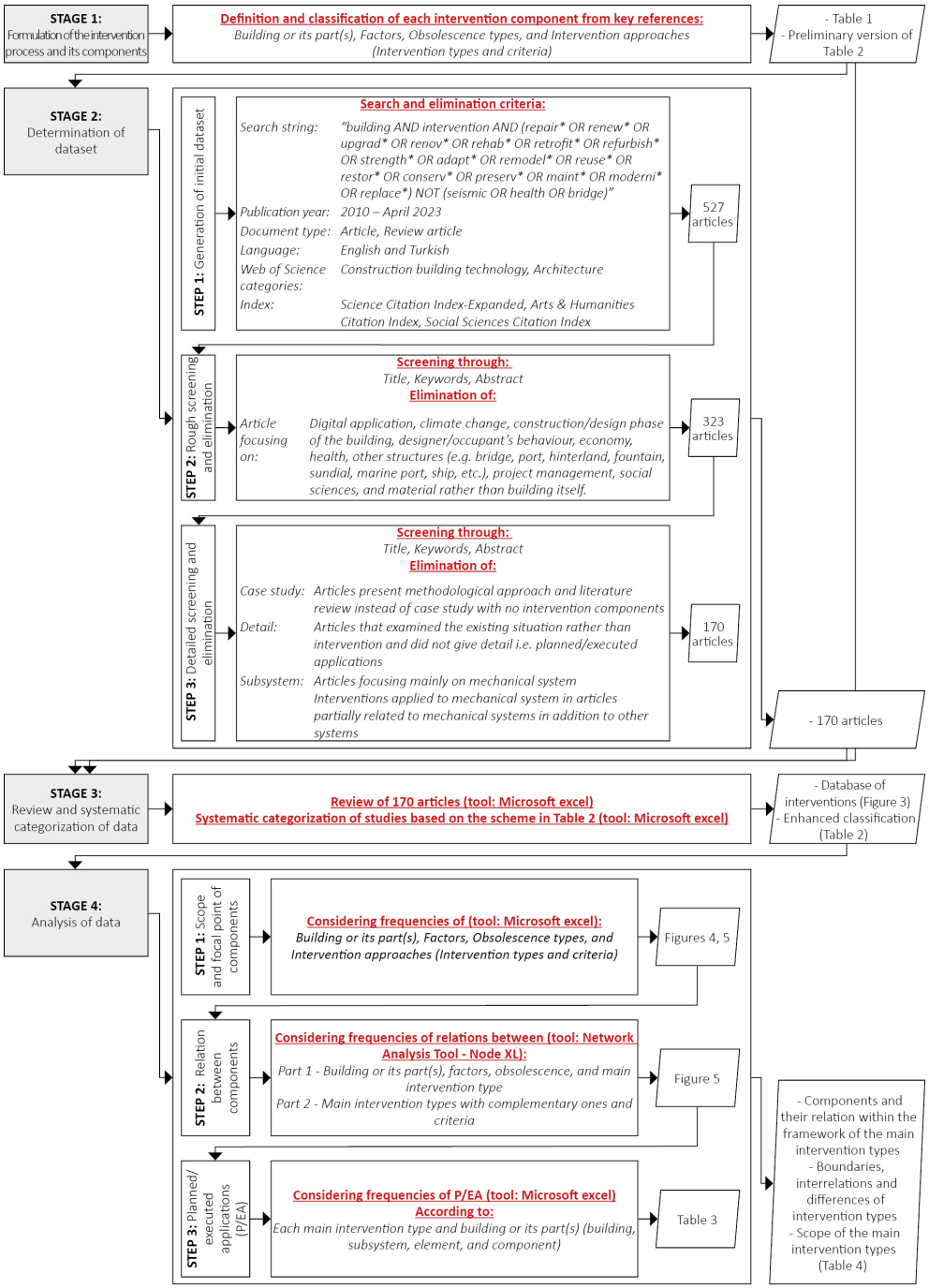


Figure 2. *The literature review method.*

was formed and later enhanced during the third stage, which was also utilized for the systematic categorization of the articles.

Hierarchically, a man-made system is composed of subsystems, elements, components, general products, and materials (CIB Working Commission W60, 1982; Rush, 1986). A hierarchical building classification was observed to be necessary since interventions are not only applied to the whole building but its parts. In this regard, Broadbent (1980) divided the building system into two parts: internal ambience, and building technology which included structural, space separating, services system, and fitting system. Rush (1986) examined building under four subsystems: structure, envelope, mechanical, and interior. CIB Working Commission W60 (1982) and International Standard of Organization [ISO] 19208:2016 (2016) evaluated building under five subsystems: structure, external envelope, spatial dividers outside the envelope, spatial dividers within the envelope, and services. Following the classifications in (CIB Working Commission W60, 1982; ISO, 2016; Rush, 1986) and the subgroups within, the subsystems of the building and their elements are specified for the study as (i) structural system – load-bearing structural wall, skeletal structural members, foundation/floor; (ii) envelope – non-structural external wall, wall opening, roof; (iii) spatial dividers – non-structural internal wall, circulation element; and (iv) services – water supply and disposal, heating and ventilation, gas/electricity supply, etc. This classification was then enhanced through the literature review and presented in Table 2 under the heading "Scale".

Regarding factors, as a component of intervention, the service life of a building or its parts is influenced by three major groups of factors: inherent quality characteristics, environment, and operation conditions (BSI, 2008, 2017b). Inherent quality characteristics encompass the inherent performance level – its features when it is first sup-

Table 1. *Intervention types and their brief definitions.*

Intervention Types	Definition
Adaptation	Interventions leading to change in the use, size, or performance of a building or its part(s) (Australia IC 2006).
Conservation	Interventions aiming to preserve a culturally significant building or its part(s) (Australia ICOMOS, 201
Maintenance	Periodic conservation/protective care actions to sustain the required performance level of a building ICOMOS, 2013; BSI, 2011b, 2013, 2019; ICOMOS International Committee on Twentieth Centu distinction was expressed for repair by Australia ICOMOS (2013).
Modernization	Improving a building or its part(s) to bring it to an acceptable standard (BSI, 2020; Douglas, 2006).
Preservation	Maintenance/repair of building or its part(s) to prevent demolition/decay in its existing form (Austral 2013, 2020; Douglas, 2006).
Refurbishment	Large-scale interventions to sustain current function and to improve the building or its part(s)s par such as technical modernization, change of plan or function, etc. (BSI, 2017a, 2020). It was limi interventions by Douglas (2006). In BS EN 15643:2021 (2021), it was taken similarly with deep renova
Rehabilitation	Interventions aiming to meet existing/new function's requirements (BSI, 2020; Douglas, 2006; Eur Standardization [CEN], 2020). In BS EN 15898:2019 (2019), the possibility of containing conservation a although not considered as a conservation activity.
Remodelling	Making new or restoring a building or its part(s) to the former situation. Its similarities to the adapta by Douglas (2006).
Renewal	Increasing the performance of a building or its part(s) by demolishing or rebuilding it at a level equal t to that of during its initial construction (BSI, 2017b; Douglas, 2006).
Renovation	Upgrading/repairing/changing/renewing an old building or its part(s) to the current expectations (BSI, Respecting the original material or significance is not a must, and therefore, it was not considered as a in BS EN 15898:2019 (2019).
Repair	Restoration/reconstruction/renewal/replacement of damaged or degraded part(s) of building or its state (BSI, 2020; ICOMOS International Committee on Twentieth Century Heritage, 2017). In BS EN was counted as a conservation action if heritage significance was taken into consideration.
Replacement	Changing parts to meet functional requirements (BSI, 2017b).
Restoration	Returning a building or its part(s) to a known previous state by removing/reassembling (Australia ICO CEN, 2020; ICOMOS International Committee on Twentieth Century Heritage, 2017).
Retrofit	Increasing the performance of a subsystem considering the current requirements by replacing the e ones that were not originally present (Douglas, 2006).
Reuse	Using a building or its part(s) with a function different from its original (Australia ICOMOS, 2013).
Strengthening	Restoring deteriorated structural system or its part(s) to its original situation or improvement of me 2019; ISO, 2013).

plied, decided design level – features determined at the design stage, and work execution level – skill and control at the construction site (BSI, 2008). The environment includes indoor and outdoor environmental agents that affect the building or its parts (BSI, 2008). The operation conditions are mainly related to the building use phase i.e. usage and maintenance conditions (BSI, 2008). This classification was further enhanced again in the third stage, as provided in Table 2, under the heading "Factors".

Obsolescence is the "loss of ability of an item to perform satisfactorily due to changes in performance requirements (BSI, 2011b), and as a component, it is the reason for the intervention. BS ISO 15686-1:2011 (2011b) examined obsolescence under three categories: functional where the initial function is no longer required; technological where better/modern alternatives exist or usage way changes; and economic where efficient/cheaper alternatives exist. Replacement due to changing fashion or style, as a common issue, was evaluated under economic obsolescence (BSI, 2011b). In BS 7913:2013 (2013), although obsolescence was not specifically mentioned, similar parameters were addressed for the conservation process as "drivers for change", which were economic (i.e. economic regeneration, change of use), social (i.e. changes of owner/tenant, planning policy, legislations) and environmental changes, and building's vulnerability (i.e. condition, external pressure). Pourebrahimi et al. (2020) offered a classification for obsolescence that covers and elaborates on the aforementioned ones, which were aesthetic, economic, environmental, functional, legal, locational, physical, social, technological, and tenure. Since this classification encompasses others, it was used as exactly in Table 2 for "Obsolescence" classes.

The intervention approach to be applied to a particular building was developed within a broader context which may include different intervention types as mentioned by ICOMOS Türkiye (2013), which were shaped with various criteria to judge or decide something. The intervention types given in Table 1 were used in Table 2 with an additional categorization of main and complementary.

In a building, the criteria both for design and intervention approach are parallel to the user's requirements. Broadbent (1980) defined internal ambiance as physical conditions for performance of activities in terms of structural mass – visible surfaces and enclosed space, and sensory environment – lighting, sound control, and heating/ventilation. Markus et. al. (1972) named the criteria as the boundaries of physical performance, which were cost, durability, fire, flexibility, maintenance, optical, sound, strength, thermal conductance, etc. ISO 19208:2016 (2016) associated objectives directly with user requirements/social expectations and listed them as accessibility, acoustical, air purity, contributions to sustainable development, durability, dynamic, economic, fire safety, hygiene, hygrothermal, safety in use, stability, suitability of spaces for specific uses, tactile, tightness, and visual. Similarly, BS EN 16883:2017 (2017a) specified targets for improving the energy efficiency of heritage buildings as technical compatibility with the existing systems, heritage significance of the building and its settings, economic viability, energy performance-sustainability, indoor environmental quality, impact on the outdoor environment, and aspects of use. Considering the criteria in (BSI, 2017a; ISO, 2016; Markus et al., 1972), an intervention criteria list presented in Table 2 under the heading of "Criteria" was formed and further developed in the third stage.

2.2. Determination of dataset

The systematic literature review comprised of three steps: (i) determination of the initial dataset, (ii) rough screening and elimination, and (iii) detailed screening and elimination (Stage 2 in Figure 2).

In the first step, a search was performed on "Web of Science" database until April 2023 using the search terms "building", "intervention" and intervention types outlined in Table 1. The formulated search string and further limitations retrieved 527 articles. In the second step, a rough screening was conducted on the article title, keywords, and abstract, and 204 articles were eliminated as their focus did not align

with the research objectives. During the third step, the remaining 323 articles underwent screening and elimination process through full-text reading. The elimination criteria in this step were mainly concerning the method of work, the details given about the intervention and the presence of mechanical systems from the building subsystems. Finally, 170 articles were selected for systematic categorization and analysis.

2.3. Review and systematic categorization of data

While reviewing selected articles, the classifications developed in Stage 1 (see Section 2.1) were enhanced simultaneously, and using the enhanced version, the articles were categorized in a database (Figure 3). The major revisions made in this respect in Table 2 were as follows;

- Regarding building or its part(s), the examined building's function, construction period, and heritage value were decided to be noted as identity information. To specify the function, the OmniClass classification of "Construction Entities by Function" (Construction Specifications Institute [CSI], 2013) was used. Additionally, concerning the intervention scale, elements can be a part of more than one subsystem (e.g. loadbearing masonry external wall is part of both structural system and envelope), and sometimes, more than one element/subsystem was presented together in the articles (e.g. external wall, window, and roof mean envelope above ground). Therefore, the classification of subsystems and elements was enhanced by including the combination of them. Likewise, some of the articles presented the intervention process considering all elements, or an addition to the building was subjected. To cover such instances, the intervention scale "Building" was included. Moreover, elements were further divided into their components to use in the detailed investigation. In the case that the article presents a detailed intervention type description, the related components were also noted, otherwise it was noted as general.
- Regarding the intervention approach, it was seen that ascertaining a clear distinction between intervention approach and type was not possible. For example, retrofit can either be an approach encompassing conservation, preservation, and renovation as intervention types or be a type under renovation approach. Consequently, instead of naming them as intervention approach and type, they were called as the main and complementary intervention types (M-, C-). The intervention type mentioned in the article title or keywords was considered as the main intervention type while the others were complementary. Furthermore, a list of planned/executed applications containing six types was generated while reviewing the full texts to note the physical output of the decision process. This list was included in Table 2.

2.4. Analysis of data

The analysis of the articles consisted of three steps; analysis of (i) the scope and focal points of each intervention component, (ii) the relation between the components, and (iii) the physical output of the intervention process i.e. planned/executed application. In the analysis, the categorized data shown

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		BUILDING OR ITS PART(S)				FACTOR (F)	OBSOLESCENCE (O)	INTERVENTION APPROACH						
2											PLANNED/EXECUTED APPLICATIONS (PEA)			
3	ARTICLE CODE	FUNCTION	CONS. PERIOD	HERITAGE VALUE	SCALE (S)			MAIN INTERVENTION TYPE	COMPLEMENTARY INTERVENTION TYPE	CRITERIA	DETAIL	PEA CODE	ELEMENT	COMPONENT
4	10	Housing facility	19	1	(S4) - Structural system and Envelope* (without roof)	F8 - Degradation type/level	O3 - Environmental	M-Renovation	C-Preservation	C5 - Durability	Application of internal thermal insulation and vapor barrier	PEA1	S10	c
5							O4 - Functional			C7 - Economic	Usage of insulated lining with plaster on the window	PEA1	S15	c
6						F10 - Intervention character/level	O5 - Legal			C17 - Heritage value		PEA1	S15	d
7							O7 - Physical			C10 - Hygrothermal	Replacing existing glazing with double or triple glazing	PEA2	S15	e
8	14	Production facility	19	1	(S1) - Building	F8 - Degradation type/level	O4 - Functional	M-Reuse	C-Restoration	C5 - Durability	Addition of new reinforced concrete strip foundation inside the	PEA5	S12	b
9							O5 - Legal		C-Conservation	C17 - Heritage value	Strengthening the load bearing wall with steel mesh polymer	PEA5	S10	b
10							O7 - Physical		C-Adaptation	C12 - Stability	Strengthening the timber truss and string beam with steel plates	PEA5	S14	b
11										C13 - Suitability of spaces	Some bricks of the façade were replaced with the new ones, and	PEA2	S10	b
12											Doors and windows were repaired and replaced	PEA2	S15	a
13											Doors and windows were repaired and replaced	PEA4	S15	a
14											Addition of insulation and waterproofing	PEA1	S10	c
15											Interior staircase was reconstructed and steel staircase was added	PEA1	S17	a
16											Addition of internal walls to create new alyout	PEA1	S16	a

Figure 3. *A screenshot of the database for systematic categorization.*

Table 2. *Components of intervention process and their codes.*

Building or its part(s)		
Examined building's		
Function is adapted from (CSI, 2013) (assembly, cultural, educational, health care, housing, lodging, office, production, and public service, retail, storage, and transportation facilities, other, no information), Construction period, Heritage value		
Scale (S) (Adapted from (CIB Working Commission W60, 1982; ISO, 2016; Rush, 1986)		
Building	**(S1)** Building	
Subsystems (Combination of Subsystems/ Elements)	***(S2)*** *Structural system and Envelope**	***(S7)*** *Envelope (without wall opening)*
	(S3) *Structural system and Envelope* (without window/door)*	***(S8)*** *Envelope (without roof)*
	(S4) *Structural system and Envelope* (without roof)*	***(S9)*** *Spatial dividers***
	(S5) *Structural system*	***(S10)*** *Other*
	(S6) *Envelope*	
Elements	**(S11)** Masonry structural wall, **(S12)** Skeletal structural members, **(S13)** Foundation/Floor, **(S14)** External wall (non-structural), **(S15)** Roof, **(S16)** Window/door, **(S17)** Internal wall (non-structural), **(S18)** Circulation element**	
Components	**(a)** General, **(b)** Core/structural component, **(c)** Protective layer, **(d)** Finishing layer, **(e)** Complementary component	
Factors (F) (Classification is adapted from (BSI, 2008, 2017b), and examples are collected from articles)		
(F1) Inherent performance level	Envelope performance, thermo-physical characteristics, performance level	
(F2) Design level	Selected materials, façade characteristics, presence of window, structural system	
(F3) Work execution level	Vulnerable original structure, material incompatibilities	
(F4) Outdoor environment	Climate condition, earthquake, closeness to the sea, location, vegetation, humidity	
(F5) Indoor environment	Internal condition, relative humidity, solar and internal gains, heat capacity	
(F6) Usage condition	Vandalism, building uses, addition of high live loads	
(F7) Maintenance condition	Preservation status, maintenance plan, maintenance/preservation condition	
(F8) *Degradation type/level*	Damage/degradation/deterioration pattern/level, risk condition, severity	
(F9) *Descriptive properties*	Construction period, typology, heritage value, geometry, building type/size	
(F10) *Intervention character/level*	Location/thickness of the material, intervention level/scenario/time/frequency	
(F11) *Other*	Occupancy, stakeholder, users	
Obsolescence (O) (Classification and definitions are adapted from (BSI, 2011b, 2013; Pourebrahimi et al., 2020)		
(O1) Aesthetic	Fashion or architectural style may be changed.	
(O2) Economic	Higher operation and maintenance cost than a new building/part of it	
(O3) Environmental	Building is not enough to fulfil or detrimental concerning environmental expectations	
(O4) Functional	Building is not enough to fulfil functional requirements or function is not required	
(O5) Legal	Building is no longer in compliance with the regulations	
(O6) Locational**	Function of area changes or its value decreases	
(O7) Physical	Deterioration occurs due to environmental, design or construction-related factors	
(O8) Social **	Society's request or expectations changes over time	
(O9) Technological	Building technology/service is no longer enough due to the existence of better alternatives	
(O10) Tenure **	Existing situation may be changed/enhanced parallel to occupants and host relation	
Intervention Approach		
Main (M-) and Complementary (C-) Intervention Types		
Adaptation, Conservation, Maintenance, Modernization, Preservation, Refurbishment, Rehabilitation, Remodelling, Renewal, Renovation, Repair, Replacement, Restoration, Retrofit, Reuse, Strengthening, Upgrading		
Criteria (C) (Classification is adapted from (BSI, 2017a; ISO, 2016; Markus et al., 1972), and examples are collected from articles)		
(C1) Accessibility	Accessibility	
(C2) Acoustical	Acoustic comfort/performance/condition/properties	
(C3) Air purity	Indoor air quality, air change rate, ventilation	
(C4) Sustainability	Energy efficiency/consumption, reducing environmental impact, net-zero energy	
(C5) Durability	Severity of the anomaly, ensuring durability, deformation, service life	
(C6) Dynamic **		
(C7) Economic	Cost, feasibility, minimum economic impact, operation/maintenance cost	
(C8) Fire safety	Fire resistance/protection, fireproofing	
(C9) Hygiene	Hygric properties	
(C10) Hygrothermal	Thermal transmittance/comfort/behaviour/conductivity, heat loss/gain, water vapor	
(C11) Safety in use	Security, habitability, comfort	
(C12) Stability	Mechanical properties, load capacity, structural stability/safety, compressive strength	
(C13) Suitability for specific uses	New functions requirement, dimensional standard, spatial layout	
(C14) Tactile	Physical properties, shape and texture, aesthetic aspect, density	
(C15) Tightness	Airflow, water permeability, airtightness, hydraulic resistance	
(C16) Visual	Visual comfort, aesthetic appearance, glare, light and shadow	
(C17) Heritage value	Minimum intervention, preserving authenticity, integrity, compatibility, reversibility	
(C18) *Constructability*	Time, easy installation, ease of use, feasibility, workability on-site, affordability	
(C19) *Other*	Social context/benefit, socio-economic	
Planned/Executed Applications (P/EA) (Definitions are developed through articles are given)		
(P/EA1) *Addition/removal*	The addition of a new or removal of an old element/component, and even the building.	
(P/EA2) *Changing*	Replacement of deteriorated or insufficient element/component totally/partially.	
(P/EA3) *Cleaning*	Effacement of deteriorated parts on surface, generally.	
(P/EA4) *Mending*	Repairing the deteriorated element/component to turn it into original/better condition.	
(P/EA5) *Structural reinforcement*	Applications on structural parts to retrieve or improve original performance.	
(P/EA6) *Other*	Any application whose details were not given.	

*: Floors and foundations are not included in this grouping, since in some of the articles they had been studied as a part of the structural system, while omitted in some others. **: Not detected in the investigated articles.
Factors and Criteria written in italic are added to the classifications through the systematic literature review.

in Figure 3 was used, based on the frequencies of components discussed in the articles. In the first step, each component was examined, separately. In some articles, several buildings with different construction years or functions may be presented, or several types of intervention components may be considered. As a result, the total number of construction periods, functions, factors, obsolescence types, complementary intervention types, and criteria exceeds the number of reviewed articles (i.e. 170). In the second step, the frequency of the connections between the components was examined rather than the relations of most common components. Finally, planned/executed applications to the element/component under the main intervention type were discussed. Among components, heritage value was regarded as a distinctive and significant characteristic of a building and therefore, examinations were conducted considering it. The scope of these analyses, the tools used in them and the figures/tables that were the output of each were detailed in Figure 2.

3. Results

Analysis results of 170 articles done to understand the scope and focal points of each intervention component, the relations between them, and planned/executed applications for intervention types were given in the following subsections. The heritage value was highlighted with colours (i.e., blue and red) in the figures or symbols (i.e., + and -) in the tables, and the number of instances was presented in parenthesis as total, with and without heritage value, respectively.

3.1. The scope and focal points of each intervention component

The scope and focal points of each component were evaluated separately. The frequencies of the functions and construction years are shown in Figure 4 and observations on them were given below.

- Regarding the functions, the housing, education, and cultural facility buildings were the most incident (37%, 12%, and 10%, respectively). It should be noted that all cultural facilities possess heritage value. Consequently, office facilities assume greater importance in buildings without heritage value.
- 20th and 19th century buildings were the most frequently discussed ones (38% and 14%, respectively), when those with insufficient information were excluded. In association with their heritage value, all buildings were constructed in the 19th century and before, and one-third of the 20th-century buildings had heritage value.

The frequencies of the other components (i.e., intervention scales, factors, obsolescences, main/complementary intervention types and criteria) were shown in Figure 5, which also shows the relationship between the components and will be discussed in the next section.

- 9% of the articles discussed interventions throughout the entirety of the building (i.e. S1), especially in the case of heritage buildings. Of the subsystems, "structural system and envelope (S2)", "envelope (S6)", and "structural system and envelope – without window/roof

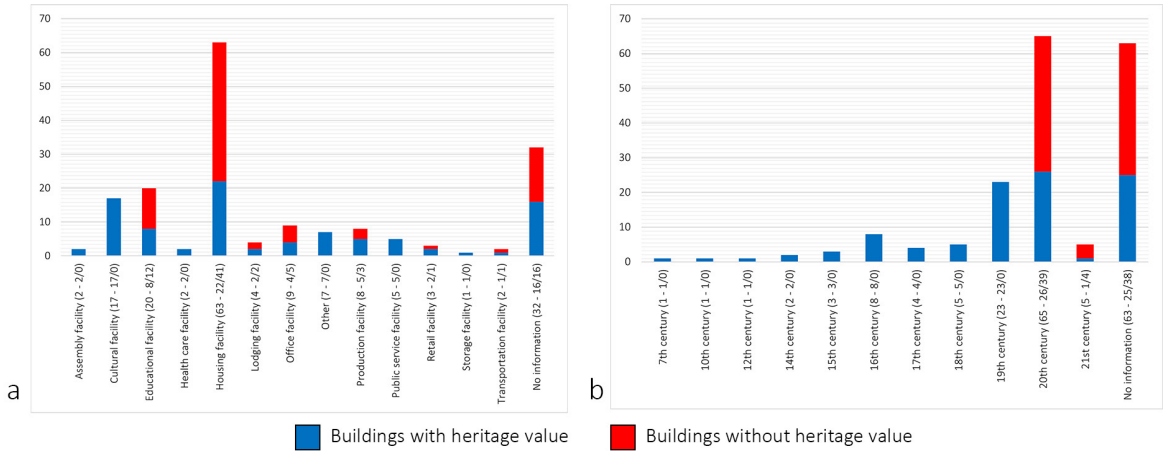
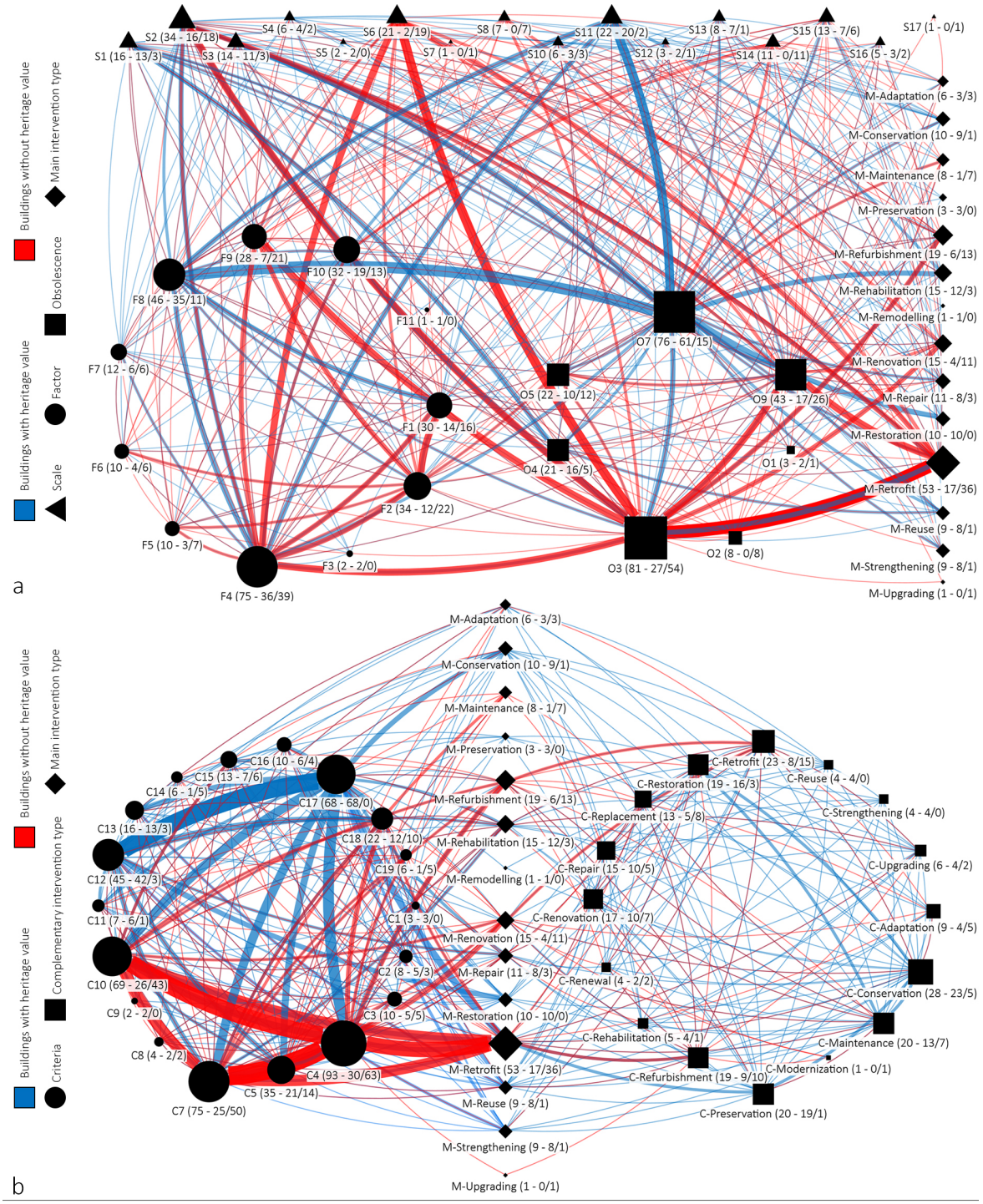


Figure 4. *Frequency of a) Construction years, b) Function.*



(F1) Inherent performance level
(F2) Design level
(F3) Work execution level
(F4) Outdoor environment
(F5) Indoor environment
(F6) Usage condition
(F7) Maintenance condition
(F8) Degradation type/level
(F9) Descriptive properties
(F10) Intervention character/level
(F11) Other

(O1) Aesthetic
(O2) Economic
(O3) Environmental
(O4) Functional
(O5) Legal
(O7) Physical
(O9) Technological

(C1) Accessibility
(C2) Acoustical
(C3) Air purity
(C4) Sustainability
(C5) Durability
(C7) Economic
(C8) Fire safety
(C9) Hygiene
(C10) Hygrothermal
(C11) Safety in use
(C12) Stability
(C13) Suitability for specific uses
(C14) Tactile
(C15) Tightness
(C16) Visual
(C17) Heritage value
(C18) Constructability
(C19) Other

(S1) Building
(S2) Structural system and envelope
(S3) Structural system and envelope (without window/door)
(S4) Structural system and envelope (without roof)
(S5) Structural system
(S6) Envelope
(S7) Envelope (without wall opening)
(S8) Envelope (without roof)
(S10) Other
(S11) Masonry structural wall
(S12) Skeletal structural member
(S13) Foundation/floor
(S14) External wall (non-structural)
(S15) Roof
(S16) Window/door
(S17) Internal wall (non-structural)
(S18) Circulation element

Figure 5. *Relations among a) Building or its part(s), factors, obsolescence, and main intervention types, b) Criteria and main/complementary intervention types (Note: The width/opacity of the lines, and the size of the symbols represent frequency.).*

(S3)" were the three most frequently intervened parts (19%, 12%, and 8%, respectively). In the case of elements, "masonry structural wall (S11)", "roof (S15)", and "external wall (S14)" were the three mostly intervened elements (13%, 8%, and 6%, respectively). The envelope-related subsystems/elements were the most frequently intervened parts, regardless of heritage value, while subsystems/elements including load-bearing parts were mostly associated with heritage buildings (i.e. S3 and S11). The reason for this could be attributed to technological advancements in the structural system, i.e. the increased use of skeletal structural system and non-structural external wall instead of a masonry structural wall.

- Analysis of the factors showed that "outdoor environment (F4)", "degradation type/level (F8)", and "design level (F2)" were the three most effective ones (44%, 27%, and 20%, respectively). The high incidence of F4, regardless of heritage value, could be attributed to its relation to the envelope. It is notable that F2 was predominantly associated with buildings without heritage value, while F8, observed in heritage buildings due to their relatively long-life span. Long-life span, where a detailed analysis on the severity levels of these degradations could be a future research focus.
- The most frequently observed obsolescence types were "environmental (O3)", "physical (O7)", and "technological (O9)" (48%, 45%, and 25%, respectively). The results were similar in buildings with/without heritage value, although in a different order. In the heritage buildings, O7 emerged as a significant consideration among the three, while O3 assumed greater significance for the others. This may be attributed to the long service life of heritage buildings where the damage that occurs during this period may cause sustainability to become less prominent.
- Analyses concerning the intervention approach presented that the most prevalent main intervention type was M-Retrofit (31%), followed, with a considerable decrease, by M-Refurbishment (11%), and M-Rehabilitation and M-Renovation both with the same frequency (9%). Among them, M-Rehabilitation was generally preferred for those with heritage value alongside M-Restoration and M-Conservation. On the other hand, M-Retrofit was mostly applied to other buildings.
- Concerning the complementary intervention types, C-Conservation was the most prevalent (16%), followed by C-Retrofit (14%), and then C-Maintenance and C-Preservation with the same incidences (12%). In heritage buildings, the significance of C-Restoration increased, while C-Refurbishment and C-Replacement came into prominence in the other buildings.
- It was observed that "sustainability (C4)", "economic (C7)", and "hygrothermal (C10)" were three of the most used criteria (55%, 44%, and 41%). High incidence of the C4 was expected since energy-related issues are a global concern. Likewise, as each intervention project has a certain budget, C7 was another crucial criterion, and C10 pertains to the thermal and water resistance performance of mostly the envelope. Among them, "heritage value (C17)" emerged as the most important in heritage buildings, as would be expected, while C7 related to other buildings.

3.2. Relation between the components

The relations observed between the intervention components were illustrated in Figure 5 in two parts to facilitate comprehension, where the link is the main intervention type.

Regarding buildings with heritage value (90/170), in the relation between intervention scales and influencing factors, the "masonry structural wall (S11)", as the most intervened element, and its relations with the factors of "degradation type/level (F8)", "outdoor environment (F4)", and "intervention character/level (F10)" came front. The reason for this situation may be that

F4 causes degradation (i.e. F8) on S11, and F10 becomes important in deciding how to overcome the degradation. The intense connection of "structural system and envelope (S2)", as the most intervened subsystem, with F4 might be due to the same reason. Concerning the interconnections of the factors, in addition to the relation between "inherent performance level (F1)" and "design level (F2)", those between F4, F8, and F10 came to the fore. Regarding the obsolescence types observed on building parts, "physical (O7)" obsolescence on S11 was the most common. Looking at the causes (i.e. the factors) F4 and F8 stand out. Although not as strong as previous, there were considerable relationships between "environmental (O3)" obsolescence and S2, "functional (O4)" obsolescence and "building (S1), and O7 and "structural system and envelope – without window/door (S3)" as well. As expected, O4 was related to the whole building, while the others were related to its envelope, mostly. Concerning the interrelations within obsolescence types, O7 was frequently accompanied by "technological (O9)" obsolescence, while it had less strong associations with O3, O4, and "legal (O5)" obsolescences. Looking at the main intervention types applied at different scales, the relationships between M-Reuse and S1, M-Retrofit and S2, and M-Rehabilitation and S11 appeared dominant. Given that, loss of function (O4) was observed to be the main reason for M-Reuse, and thus it was mainly related to the building. In M-Retrofit, interventions on the envelope to meet environmental expectations were one of the main concerns, and although less dominant, it was also applied to remove traces of degradation (i.e. O3, and O7, respectively). On the other hand, M-Rehabilitation was mainly related to the removal of degradation (i.e. O7), rather than the fulfilment of environmental expectations. The two main intervention types aforementioned (i.e. M-Retrofit and M-Rehabilitation) came forward also, when examining their relationships with the complementary interventions, and criteria. In the case of M-Retrofit, C-Refurbishment and C-Preservation were used as complementary with the criteria of "sustainability (C4)" and "heritage value (C17)" mainly. On the other hand, M-Rehabilitation was used accompanied by C-Conservation and C-Maintenance with the criteria of "stability (C12)" and C17. These results support the findings on the relation of these two main intervention types with obsolescence types. Besides, the relationship between M-Restoration and C-Conservation, and M-Repair and C-Conservation also attracted attention. In both cases, C12 and C17 were the criteria mainly used.

Concerning buildings without heritage value (80/170), in the relation between the intervention scale and factors, the connection between "envelope (S6)" and "outdoor environment (F4)" was notable. Although less dominant, "inherent performance level (F1)" and "design level (F2)" were also affected on S6. Similarly, F4 was affected on "structural system and envelope (S2)" as well. Therefore, it can be said that the outdoor environment is an important factor for the parts of the building envelope, as in the case of heritage buildings. F1 and F2 were of great importance for the multilayer walls, in contrast to masonry walls, which were mostly seen in heritage buildings, with simpler details and one/fewer layers. Regarding the relations between factors, these three factors (i.e. F1, F2, and F4) were observed to have strong interconnection too, and also related to "descriptive properties (F9)". Considering the obsolescence types and intervention scales, "environmental (O3)" obsolescence was detected on S2 and S6. Although less prominent, "envelope – without roof (S8)" was also under the effect of the same type of obsolescence. Additionally, interventions on S6 were also related to "technological (O9)" obsolescence. The reasons for O3 on parts of the envelope were being exposed to outdoor environment and being behind the current technology in terms of construction year and typology (i.e. factors of F4 and F9, respectively), as also observed in heritage buildings. Looking at the interconnections between obsolescence, that of "legal (O5)" obsolescence with O3 and O9 also stands out. This inference confirms that environmental and techno-

logical development is reflected in regulations. Analysis of the relationships between the intervention scale and the main intervention types showed that M-Retrofit was associated with S2, S6 and S8. Similarly, there was a notable association between M-Renovation and S6. Therefore, it can be said that the focus of the interventions on buildings without heritage value was mainly the envelope. Looking at the obsolescence that led to intervention, the main reason for the M-Retrofit was O3, and O9 with a considerable frequency decrease. O3 was also effective for the M-Renovation and M-Refurbishment. The aforementioned three main intervention types came into prominence too, regarding their relation to the complementary intervention types and criteria. C-Retrofit was used as a complementary intervention type in the M-Renovation and M-Refurbishment, while C-Refurbishment and C-Renovation were accompanying M-Retrofit. "Sustainability (C4)", "economic (C7)", and "hygrothermal (C10)" criteria were dominant for all of them, and their interconnections appeared to be quite strong. As a result, all three types of main interventions were applied to fulfil environmental expectations.

3.3. Planned/executed applications for main intervention types

The relations between each planned/executed application (P/EA) and the main intervention types were given in Table 3, through the intervened parts of the building. The observations for each of them were mentioned in the following.

- Addition/removal (P/EA1) was the most preferred application (71%) seen in more than half of the buildings with heritage value and in almost all the others. It was applied from the scale of the "building (S1)" to the elements (S11, S12, S13, S14, S15, S16, S17, S18). Among them, the addition of a protective layer (thermal insulation in most cases) to the roof (S15c, 52%), external wall (S14c, 45%), masonry structural wall (S11c, 28%), and foundation/floor (S13c, 27%), and addition of sun shading/shutter to the window/door (S16e, 20%) were the most prevalent. It was involved in almost all the main intervention types, except M-Strengthening, and most preferred within the scope of the M-Refurbishment (100%), M-Retrofit (91%), M-Reuse (89%), M-Renovation (87%), M-Adaptation (83%), M-Rehabilitation (73%), and M-Preservation (67%). Although the preference rate for P/EA1 in M-Remodelling and M-Upgrading was 100%, it was not accounted for since these main interventions were only considered in one article.
- Changing (P/EA2) was the second most common intervention (55%), particularly in more than half of the buildings without heritage value and almost half of the heritage buildings. It was applied to almost all elements, except the internal wall and not used in the building scale (S11, S12, S13, S14, S15, S16, S18). Among them, changing a component of window/door i.e. glazing (S16e, 55%), whole window/door (S16a, 22%), and frame (S16b, 113%) to improve thermal performance were by far the most preferred. Although with a lower incidence, changing either the whole or finishing layer of the external wall both to ensure performance or eliminate deterioration (S14d, 6%, S14a, 5%), and changing the deteriorated parts of the masonry structural wall and roof (S11b, S15b, 5% for both) were also detected. It was involved in almost all main intervention types, except M-Remodelling and M-Upgrading, and mostly preferred as part of M-Maintenance (75%), M-Refurbishment (68%), M-Preservation (67%), M-Repair (64%), and M-Conservation (%60).
- Cleaning (P/EA3) was one of the least preferred interventions, regardless of the heritage value of the building (9%). It was applied to the core of the masonry structural wall in most cases (S11b, 33%), followed by the whole/core of other elements such as skeletal structural member, foundation/floor, external wall, and roof (S12, S13, S14, S15). It constituted the largest proportion for M-Maintenance (75%) and M-Preservation (67%).

Table 3. *Incidence of P/EA according to main intervention type and intervention scale.*

Addition/Removal (P/EA1)	Changing (P/EA2)	Cleaning (P/EA3)	Mending (P/EA4)	Structural Reinforcement (P/EA5)	Other (P/EA6)
M-Adaptation (T¹: 6-3/3) (Buxadé, 2014; Domínguez-Amarillo et al., 2019; Marinic, 2016; Philokyprou, 2014; S. Porritt et al., 2011; Tian & de Wilde, 2011)					
S1; S11c, d; S12a; S14c; S15c, d; S16a, e; S17a, d; S18a	S16a, e			S13b	
T³: 83% (5-2/3)	50% (3-2/1)	-	-	17% (1-1/0)	-
M-Conservation (T¹: 10-9/1) (Arrieta et al., 2018; Conde et al., 2014; Efthymiopoulos et al., 2021; García-Esparza, 2011; Iyer-Raniga & Wong, 2012; Marcus et al., 2019; Muñoz-González et al., 2016; Musso & Franco, 2015; Pankhurst & Harris, 2013; Salman et al., 2018)					
S11c; S13c; S14c; S15c; S16e	S12b; 15a; S16a, e	S11b	S11b; 12b; S14c; S16a	S11b; S13b; S15b	S17a
T³: 50% (5-4/1)	60% (6-6/0)	10% (1-1/0)	50% (5-4/1)	40% (4-4/0)	10% (1-1/0)
M-Maintenance (T¹: 8-1/7) (Dias et al., 2022; Ferreira, Dias, et al., 2021; Ferreira, Silva, et al., 2021; Flores-Colen & de Brito, 2010; Morgado et al., 2017; Pallis et al., 2019, 2021; Perez-Monserrat et al., 2018)					
S13c; S14c; S15c; 16e	S14a, d; S16a, e	S11b; 14a, d; S15a	S14d		S14a, d; S15a
T³: 25% (2-0/2)	75% (6-0/6)	75% (6-1/5)	13% (1-0/1)	-	63% (5-0/5)
M-Preservation (T¹: 3-3/0) (Guizzardi et al., 2015; Kou et al., 2020; Resende et al., 2022)					
S11c, d	S11d; S14a	S11a, b; S12b	S11a	S12b; S13b	
T³: 67% (2-2/0)	67% (2-2/0)	67% (2-2/0)	34% (1-1/0)	34% (1-1/0)	-
M-Refurbishment (T¹: 19-6/13) (Ascione et al., 2017; Badea & George-Vlad, 2015; Barbosa et al., 2020; Bellia et al., 2018; Berto et al., 2018; Bruno et al., 2021; Carpino et al., 2018, 2020; D'Agostino et al., 2022; De Fino et al., 2017; Dukanovic et al., 2016; Gaspar & Santos, 2015; Hawkins & Mumovic, 2017b, 2017a; Milone et al., 2015; Pierangioli et al., 2017; Pomponi et al., 2015; Rodrigues et al., 2018; Watson, 2022)					
S1; S11c, d; S13c; S14a, c; S15a, c, e; S16a, e; S17a; S18a	S13d; S14a, d; S15c, e; S16a, b, e		S16a		
T³: 100% (19-6/13)	68% (13-5/8)	-	5% (1-1/0)	-	-
M-Rehabilitation (T¹: 15-12/3) (Alexakis et al., 2018; Boffill et al., 2020; Brás & Gomes, 2015; Cunha et al., 2015; De Berardinis et al., 2014; Garavaglia et al., 2018; Ignjatovic et al., 2016; Lstiburek, 2018; Moropoulou et al., 2021; Prieto et al., 2022; Ruiz et al., 2023; Serrrano-Lanzarote et al., 2020; Stastny et al., 2021; Stellacci et al., 2018; Vilhena et al., 2017)					
S11c, d; S11e; S13c; S14c, d; S15c	S13b; S15a; S16b, e	S11b	S11b; S13b	S11b, d; S13b; S15b	S15a
T³: 73% (11-8/3)	33% (5-4/1)	7% (1-1/0)	13% (2-2/0)	40% (6-6/0)	7% (1-1/0)
M-Remodelling (T¹: 1-1/0) (Ultav & Savasir, 2012)					
S17a; S18a					
T³: 100% (1-1/0)	-	-	-	-	-
M-Renovation (T¹: 15-4/11) (Borras et al., 2022; Kroftová & Zigler, 2023; Maria Calama-Gonzalez et al., 2022; Martinez-Millana & Alcaraz, 2020; Österbring et al., 2019; Palma et al., 2022; Patiño-Cambeiro et al., 2019; Salvalai et al., 2017; Semprini et al., 2016; Serrano-Jimenez et al., 2017; Serrano-Jiménez et al., 2018; Serrano-Lanzarote et al., 2016; Tovarovic et al., 2017; Unuk et al., 2021; van der Bent et al., 2021)					
S1; S11c; S13c; S14a, c; S15a, c; S16a, c, d, e; S18a, e	S13d; S14a, d; S16a, b, e		S16a, b	S13b	
T³: 87% (13-2/11)	73% (11-2/9)	-	13% (2-1/1)	7% (1-1/0)	-
M-Repair (T¹: 11-8/3) (Alba-Rodriguez et al., 2022; Corradi et al., 2018; Fodde & Cooke, 2013; Illampas et al., 2017; Kloiber et al., 2023; Marin-Garcia et al., 2023; Ray, 2014; Sahin Güçhan & Kuleli, 2018; Salmeron et al., 2022; Theodossopoulos, 2016; Wittocx et al., 2022)					
S11c; S13c, d; S15b, c, e; S16a, e	S11b; S13b; S15a; S16b, e; S18a	S11b, d; S13b	S11b; S13b; S15b	S11b	
T³: 36% (4-3/1)	64% (7-5/2)	27% (3-2/1)	64% (7-5/2)	27% (3-3/0)	-
M-Restoration (T¹: 10-10/0) (Bertolini-Cestari et al., 2019; Brandonisio et al., 2013; Candelas-Gutiérrez & Borrallo-Jimenez, 2020; Coronelli et al., 2015; Galli & Conserva, 2016; Gunaydin et al., 2023; Shimoda et al., 2022; Soler-Estrela & Soler-Verdú, 2016; Valença et al., 2015; Vissilia & Villi, 2010)					
S13a, c; S18a	S11b, d; S13b; S15a, d; S16a	S13a	S11a, b; S12b; S13b; S15a, b, d; S16a	S11b; S13a, b; S15a, b	S1; S15a
T³: 18% (2-2/0)	36% (4-4/0)	9% (1-1/0)	45% (5-5/0)	64% (7-7/0)	18% (2-2/0)
M-Retrofit (T¹: 53-17/36) (Aghamolaei & Ghaani, 2020; Alonso et al., 2021; Alves et al., 2018; Asadi et al., 2012; Asdrubali et al., 2019, 2021; Aste et al., 2012, 2016; Barbaresi et al., 2017; Belpoliti & Bizzarri, 2015; Coady & Duquette, 2021; Cornaro et al., 2016; D'Agostino et al., 2023; Dall'O' et al., 2012; Dall'O et al., 2020; Daniotti et al., 2022; de Santoli et al., 2014; Di Giuseppe et al., 2017; Duran & Lomas, 2021; Eliopoulou & Mantziou, 2017; Famuyibo et al., 2013; Fantucci & Serra, 2019; Fenoglio et al., 2018; Ferrarini et al., 2016; Galbiati et al., 2021; Ginks & Painter, 2017; Hacene & Sari, 2020; Hall et al., 2013; Hamilton et al., 2014; Heo et al., 2012; Juliá et al., 2024; Litti et al., 2018; Macchi & Macchi, 2015; Martín-Garín et al., 2021; Menconi & Grohmann, 2014; Montoliu-Hernández & Rodríguez-Alvarez, 2017; Ohene et al., 2022; O'Riain & Harrison, 2016; Parker et al., 2019; Pellegrino et al., 2016; S. M. Porritt et al., 2012; Ruggeri et al., 2020; Stazi et al., 2014, 2015; Suárez & Fernández-Agüera, 2015; Sugár et al., 2020; Tagliabue et al., 2018; Taylor et al., 2010; Timur et al., 2022; Tokede et al., 2018; Varriale, 2016; Verbist et al., 2018; Zhou et al., 2017)					
S1; S11c, d, e; S13c; S14a, c, d; S15a, c, d; S16a, e; S17a	S14d; S15d; S16a, b, e		S11b; S14a; S15a; S16a, b, e	S11b; S13b; S15b	
T³: 91% (48-13/35)	66% (35-8/27)	-	19% (10-4/6)	4% (2-2/0)	-
M-Reuse (T¹: 9-8/1) (Cascone & Sciuto, 2018; Elvarsson et al., 2021; Ferriss, 2021; Iglesias & Bernardo, 2022; Marzouk et al., 2020; Pieczka & Wowrzeczka, 2021; Ramos et al., 2016; Wilczek, 2021; Xiong et al., 2023)					
S1; S11c; S13a, c; S14c; S15a, c; S16a; S17a; S18a	S11b; S16a, b, e		S12b; S16a	S11b; S13b; S15b	S1
T³: 89% (8-7/1)	33% (3-3/0)	-	22% (2-2/0)	44% (4-4/0)	22% (2-1/1)
M-Strengthening (T¹: 9-8/1) (Cassese et al., 2021; Cescatti et al., 2018; Corredor et al., 2016; Hamdy et al., 2018; Liberotti et al., 2022; Lignola & Manfredi, 2011; Sandoval et al., 2021; Shrestha et al., 2020; Valluzzi et al., 2014)					
	S11b	S11a; S12a; S13a	S11b; S13b; S15d; S18e	S11b; S12b; S13b; S15b	
T³: -	11% (1-1/0)	11% (1-1/0)	33% (3-3/0)	89% (8-7/1)	-
M-Upgrading (T¹: 1-0/1) (Pomponi & D'Amico, 2017)					
S14a; S16a					
T³: %100 (1-0/1)	-	-	-	-	-
Total (T: 170-90/80)					
S1 (7); S11c, d, e (34, 6, 2)	S11b, d (5, 2); S12b (2)	S11a, b, d (2, 5, 1)	S11a, b (2, 11); S12b (3)	S11b, d (25, 1)	S1 (2)
S12a (1); S13a, c, d (2, 32, 1)	S13b, d (4, 2)	S12a, b (1, 1)	S13a, b (1, 6)	S12b (2)	S14a, d (3, 1)
S14a, c, d (4, 54, 2)	S14a, d (5, 6)	S13a, b (2, 1)	S14a, c, d (1, 1, 1)	S13a, b (1, 21)	S15a (3)
S15a, b, c, e (8, 1, 62, 3, 2)	S15a, b, c, d, e (5, 1, 1, 4, 1)	S14a, d (3, 2)	S15a, b, d (3, 4, 2)	S15a, b (1, 11)	S17a (1)
S16a, c, d, e (9, 1, 1, 24)	S16a, b, e (21, 12, 52)	S15a (1)	S16a, b, e (11, 2, 2)		
S17a, d (12, 1); S18a, e (8, 1)	S18a (2)		S18e (1)		
T²: 71% (120-49/71)	55% (94-40/54)	9% (15-9/6)	23% (39-28/11)	22% (38-37/1)	6% (10-4/6)

Codes of the intervention scale are given in Table 2. Total number of articles (T). Total number of articles per; each main intervention type (T^1), each planned/executed application (T^2), each main intervention type and planned/executed application (T^3).

- Mending (P/EA4) was the third most frequently discussed intervention, particularly in heritage buildings. It was applied to almost all elements, except internal walls (23%), to repair the deteriorated parts. Most instances involved the core of the masonry structural wall (S11b, 48%), and the structural components of the foundation/floor (S13b, 26%) and roof (S14b, 17%), respectively. It was applied under almost all main intervention types, except M-Adaptation, M-Remodelling, and M-Upgrading. Yet, it was preferred only in the M-Retrofit in the first order (64%). In addition, it had also an important role in the scope of the M-Conservation (50%) and M-Restoration (45%).
- Structural reinforcement (P/EA5) had almost the same incidence as mending (22%) and was particularly preferred for the heritage buildings. It was applied to the structural elements (i.e. masonry structural wall, skeletal structural member, foundation/floor) and roof to retain or improve their structural capacity. Among them, those applied to the core of the masonry structural wall (S11b, 66%), foundation/floor (S13b, 55%), and roof (S15b, 29%) were of particular significance. It was the most significant aspect of the M-Strengthening (89%) and M-Restoration (64%), whereas it was not included in M-Maintenance, M-Refurbishment, M-Remodelling, and M-Upgrading.
- Others (P/EA6) encompassed major/minor/light/cyclic intervention, and it was the least preferred intervention, regardless of heritage value (6%). It was frequently preferred only for M-Maintenance (63%).

4. Summary and discussion

The main intervention types and their first three relations with other components which stood out in the analyses were summarized in Table 4. In the table, intervention components that were only discussed in one or no article were not mentioned, and marked with an asterisk (*), since it was not possible to provide accurate inference. Additionally, Modernization, Renewal, and Replacement were not included in the table as a main intervention type, since they were used as complementary intervention, rather than main. Aspects of each main intervention type that differed from the general (i.e. those seen in all the buildings with and without heritage value) were summarized and discussed as follows, regarding the definitions given in Table 1 and existing literature review studies.

- In the articles focusing on M-Adaptation, the "outdoor environment (F4)" and "addition/removal (P/EA1)" appear to be a significant factor and intervention type regardless of heritage value. Therefore, its main objective can be defined as the adaptation to the changing outdoor environment, which in turn the adaptation of the performance level. This inference is partially aligned with the definition provided in Table 1 by considering only the performance.
- M-Conservation was primarily discussed for heritage buildings. On the contrary to the general, "changing (P/EA2)" of deteriorated parts presented greater significance. This inference potentially reflects the objective of preserving the original as mentioned in Table 1, by opposing the addition of a new or removal of an original part.
- M-Maintenance was mainly related to buildings without heritage value. Among the planned/executed applications observed, "changing (P/EA2)", "cleaning (P/EA3)", and "others (P/EA6)" were far more frequent than "addition/removal (P/EA1). The absence of the "mending (P/EA4)" proves its difference from M-Repair, and the existences of the "physical (O7)" obsolescence and "economic (C7)" criterion reflects the objective of maintaining the required performance level as mentioned in Table 1.
- M-Preservation was preferred mainly for buildings with heritage value. The existence of C-Restoration as a complementary intervention type and "heritage value (C17)" as a criterion support the definition given in Table 1.
- M-Refurbishment was observed regardless of heritage value, although it was more dominant in buildings

Table 4. *The scope of the main intervention types.*

	Factors (F)	Obsolescence (O)	Intervention Scale (S)	Criteria (C)	Planned/Executed Application (P/EA)
M-Adaptation (6-3/3) without specific complementary intervention type in the buildings with/without heritage value					
(+)	F4 (2)	*	*	C12 (2)	P/EA1 (2); P/EA2 (2)
(-)	F4 (2)	*	*	C4 (2); C10 (2)	P/EA1 (3)
M-Conservation (10-9/1) with C-Renovation (3); C-Repair (3); C-Restoration (3); and C-Maintenance (2) in the buildings with heritage value					
(+)	F8 (7); F1 (3); F4 (3); F2 (2)	O7 (6); O3 (4); O5 (2); O9 (2)	S2 (2)	C17 (9); C4 (4); C5(3); C12 (3); C13 (3)	P/EA2 (6); P/EA1 (4); P/EA4 (4); P/EA5 (4)
M-Maintenance (8-1/7) with C-Repair (2); and C-Replacement (2) in the buildings without heritage value					
(-)	F8 (5); F2 (4); F4 (4); F9 (4); F1 (3); F7 (3)	O7 (5); O2 (3); O3 (3)	S2 (2)	C7 (6); C4 (3); C5 (3)	P/EA2 (6); P/EA3 (5); P/EA6 (5); P/EA1 (2)
M-Preservation (3-3/0) with C-Restoration (2) in the buildings with heritage value					
(+)	F4 (2)	O7 (3); O9 (2)	S11 (2)	C10 (2); C15 (2); C17 (2)	P/EA1 (2); P/EA2 (2); P/EA3 (2)
M-Refurbishment (19-6/13) with C-Retrofit (2) in the buildings with heritage value; with C-Retrofit (5); C-Maintenance (3); C-Renovation (2); C-Repair (2); and C-Replacement (2) in the others					
(+)	F1 (2); F4 (2); F9 (2)	O3 (5); O7 (2)	S2 (3)	C4 (5); C17 (4); C7 (3); C10 (3)	P/EA1 (6); P/EA2 (5)
(-)	F4 (7); F1 (4); F2 (4); F6 (3)	O3(10); O5 (3); O7 (2); O9 (2)	S6 (4); S2 (2); S15 (2)	C4 (11); C7 (7); C10 (7); C3 (2)	P/EA1 (13); P/EA2 (8)
M-Rehabilitation (15-12/3) with C-Conservation (4); C-Maintenance (4); C-Restoration (3); and C-Preservation (2) in the buildings with heritage value; without specific complementary intervention type in the others					
(+)	F4 (7); F8 (5); F2 (2)	O7 (10); O9 (4); O3 (3); O5 (3)	S11 (5); S3(3)	C17 (8); C12 (7); C7 (5)	P/EA1 (8); P/EA5 (6); P/EA2 (4)
(-)	*	O3 (3)	S14 (2)	C4 (3); C10(3); C5 (2)	P/EA1 (3)
M-Renovation (15-4/11) with C-Preservation (2) in the buildings with heritage value; with C-Retrofit (7); C-Adaptation (2); C-Conservation (2); and C-Refurbishment (2) in the others					
(+)	F10 (2)	O3 (3); O4 (2)	*	C17 (3); C4 (2); C5 (2)	P/EA1 (2); P/EA2 (2)
(-)	F4 (6); F9 (5); F2 (2)	O3 (9); O9 (7); O5 (3)	S6 (5); S2 (3)	C4 (11); C7 (8); C10 (8); C19 (3)	P/EA1 (11); P/EA2 (9)
M-Repair (11-8/3) with C-Conservation (4); C-Preservation (3); C-Renovation (2); and C-Restoration (2) in the buildings with heritage value; with C-Replacement (2) in the others					
(+)	F4 (3); F8 (3); F10 (2)	O7 (7); O9 (2)	S11 (2)	C12 (6); C17 (6); C7 (3); C5 (2)	P/EA2 (5); P/EA4 (5); P/EA1 (3); P/EA5 (3); P/EA3 (2)
(-)	F8 (2)	O7 (3)	*	C4 (2); C5 (2); C7 (2)	P/EA2 (2); P/EA4 (2)
M-Restoration (10-10/0) with C-Conservation (4); C-Repair (3); and C-Strengthening (2) in the buildings with heritage value					
(+)	F8 (8); F1 (3); F4 (3); F6 (3); F2 (2); F3 (2)	O7 (10)	S3 (3); S15 (3)	C12 (9); C17 (8); C5 (2); C7 (2); C10 (2)	P/EA5 (7); P/EA4 (5); P/EA2 (4)
M-Retrofit (53-17/36) with C-Refurbishment (6); C-Preservation (5); C-Conservation (3); and C-Renovation (3) in the buildings with heritage value; with C-Refurbishment (5); C-Renovation (4); C-Conservation (3); and C-Maintenance (3) in the others					
(+)	F4 (11); F10 (7); F9 (3)	O3 (10); O7 (8); O9 (3)	S2 (6); S11 (4); S6 (2); S16 (2)	C17 (13); C4 (12); C10 (9)	P/EA1 (13); P/EA2 (8); P/EA4 (4); P/EA5 (2)
(-)	F4 (17); F9 (10); F10 (7)	O3 (27); O9 (13); O2 (4); O5 (4)	S2 (10); S6 (9); S8 (5)	C4 (30); C7 (24); C10 (21)	P/EA1 (35); P/EA2 (27); P/EA4 (6)
M-Reuse (9-8/1) with C-Adaptation (2); C-Conservation (2); C-Maintenance (2); C-Preservation (2); C-Restoration (2); and C-Retrofit (2) in the buildings with heritage value					
(+)	F10 (3); F8 (2)	O4 (8); O7 (5); O5 (2)	S1 (6)	C17 (8); C13 (6); C16 (4)	P/EA1 (7); P/EA5 (4); P/EA2 (3)
M-Strengthening (9-8/1) with C-Restoration (3); and C-Conservation (2) in the buildings with heritage value					
(+)	F8 (4); F10 (3)	O7 (7)	S11 (4); S13 (2)	C12 (8); C17 (5); C18 (4)	P/EA5 (7); P/EA4 (3)

+: Buildings with heritage value; -: Buildings without heritage value (also related line is coloured with grey).
*: Intervention components that are discussed in one or no article. Codes are given in Table 2.

without heritage value. As mentioned in Section 3, it was one of the intervention types focusing on sustainability. It included "addition/removal (P/EA1)" and "changing (P/EA2)", but not "structural intervention (P/EA5)" in line with the explanations in Table 1. In a literature review discussing zero-emission refurbishment for heritage buildings, the intervention levels were classified as low (preservation and conservation), middle (refurbishment and rehabilitation), and high (renovation and restoration), and conservation, preservation, and restoration were the most preferred ones (Loli & Bertolin, 2018). When these levels were counted as complementary intervention types as used in this study, their findings were different, since retrofit was found here as a prominent complementary intervention for heritage buildings. A possible reason was the occurrence of the word "preserv*" in the search string, and in turns, all the reviewed articles related to preservation.

- M-Rehabilitation was applied mainly to heritage buildings, while less to others. It was related to "physical (O7)" obsolescence, and in relation

to that, "structural reinforcement (P/EA5)" was generally planned/executed, as described similarly in Table 1. However, the description highlighting that it is not a conservation activity is not in line with the findings considering that there were many articles focusing on heritage building.

- M-Renovation was mainly seen in buildings without heritage value to fulfil environmental expectations (i.e. O3), and applied less in the others. "Technological (O9)" obsolescence was also significant, which might reflect fulfilling current expectations as defined in Table 1. The small number of heritage buildings with this intervention type was also parallel to the definition. In a study on the renovation of multifamily buildings, energy efficiency measures were the most frequent compared to economic, environmental, user-related, and other measures and generally improvements of the wall/façade, roof/attic, and windows interventions were preferred (Abdul Hamid et al., 2018). Parallel to that, sustainability criterion (i.e. C4) was found here more important than others and "addition/removal (P/EA1)" of protective layer came to the fore.
- M-Repair was generally applied to buildings with heritage value rather than others. "Stability (C12)" criterion and "mending (P/EA4)" application appeared important as much as "heritage value (C17)" and "addition/removal (P/EA1)". In other words, concerning stability, the objective was related only to degraded parts similar to those defined in Table 1. The frequency of the heritage buildings, the heritage value criterion, and the presence of the complementary intervention types such as conservation, preservation, and restoration were in line with the definition, also.
- M-Restoration was totally concerned with heritage buildings. As in the case of M-Repair, "stability (C12)" had an importance, and even surpassed that of "heritage value (C17)". Besides, "structural reinforcement (P/EA5)" was preferred most for doing it, followed by "mending (P/EA4)". Therefore, it can be said that M-Restoration commonly includes structural interventions among others with the objective of returning it to its original condition, in line with the definition in Table 1.
- M-Retrofit was the most preferred intervention, regardless of heritage value with the objective of sustainability (i.e. in relation to "environmental (O3)" obsolescence and "contribution to sustainable development (C4)" criterion), which is consistent with the definition in Table 1. In parallel, in a bibliometric literature review on retrofit of dwelling across Northwestern Europe, energy efficiency was expressed as the leading trend in this field (Simpson et al., 2020). In another study on energy retrofitting of the residential buildings (Ibañez Iralde et al., 2021), the most preferred intervention category was identified as the passive strategy obtained by façade/roof/floor insulation and green/ventilated façade/roof, window/glass replacement, and providing airtightness and waterproofing, etc. Among these, façade insulation, window/glass replacement, and roof insulation were three of the most selected interventions in the current analysis. Similarly, another study evaluating passive thermal retrofit strategies expressed that wall insulation, glazing improvement, and roof insulation were three of the most preferred ones (Carratt et al., 2020), which are parallel to the "addition/removal (P/EA1)" and "changing (P/EA2)".
- M-Reuse was preferred mainly in heritage buildings, particularly in instances where alterations were made to accommodate a change in function, i.e. "functional (O4)" obsolescence. On the contrary of the other main intervention types, the criterion of "suitability of spaces for specific uses (C13)" attracted attention, which was an expected result of function change in parallel to the definition in Table 1.
- M-Strengthening, which was generally preferred for heritage buildings, is like M-Restoration considering

prominent type of obsolescence, criteria, and planned/executed applications. But, in specifically, it is related to restoration of degraded parts of structural system, as indicated in Table 1. Apart from these, the criterion "constructability (C18)" appeared to be important.

5. Conclusion

The study aimed to examine the intervention types starting from a broader framework of the intervention process to its components. The components of the intervention process (i.e. building or its part(s), factors, obsolescence types, and intervention approaches covering intervention types and criteria) were identified and classified in this respect. Throughout this classification, a systematic review of 170 articles was conducted to understand the frequencies and relation of the intervention components, and the scope of the intervention types (i.e. planned/executed applications). Key conclusions drawn from this review are briefly as follows;

- The elements and subsystems constituting the envelope are directly influenced by the outdoor environment and therefore have the greatest degree of intervention. Influenced parts of the envelope are changed according to the structural system of the building. In this case, it is notable that the construction year and technology of that period are important indicators. As a result of the long-life span, physical obsolescence is typically observed in heritage buildings, whereas environmental obsolescence becomes more prevalent in the others.
- The most prevalent intervention type is retrofit, aimed at addressing environmental obsolescence, regardless of heritage value. In this process, sustainability criterion is prioritized in buildings without heritage value, while in heritage buildings, preservation of heritage value supersedes sustainability concerns.

Concerning the intervention types the generalized remarks are as follows;

- Adaptation and reuse resemble each other since they are used to meet changing circumstances (i.e. performance and function).
- Conservation and preservation are predominantly associated with heritage buildings, with the objective of maintaining their cultural significance and preventing the formation of degradation. It can be argued that maintenance can be considered as a version of the aforementioned approaches applied to buildings without heritage value.
- Rehabilitation, repair and strengthening are preferred for the heritage buildings to remove the degradation, whereas the last one relates to structural reinforcement, specifically. In other words, these interventions represent a more comprehensive version of the conservation, preservation, and maintenance, which aim beyond keeping the parts in its existing situation.
- Restoration can be conceptualized as a comprehensive version of the aforementioned interventions related to heritage value, to turn the building into a specific period.
- Refurbishment, renovation, and retrofit are predominantly associated with the envelope and are intended to ensure sustainability. Although they are typically applied to buildings without heritage value, retrofit is also discussed for those with heritage value as well.

Consequently, the findings and information obtained in this review are largely aligned with those in the main references and existing literature reviews. Besides, as a further contribution to the associated field, the intervention process was elucidated in detail to ascertain the extent of each intervention type, and minor inferences were drawn to understand their boundaries and interrelations, and the differences between them. It is important to highlight that the frequencies presented in this study are derived from a systematic literature review, which includes simulations and experiments in addition to actual applications and therefore, may not directly reflect the real-world prevalence of interventions.

References

Abdulhamid, A., Farsäter, K., Wahlström, Å., & Wallentén, P. (2018). Literature review on renovation of multi-

family buildings in temperate climate conditions. *Energy and Buildings*, *172*, 414–431. https://doi.org/https://doi.org/10.1016/j.enbuild.2018.04.032

Aghamolaei, R., & Ghaani, M. R. (2020). Balancing the impacts of energy efficiency strategies on comfort quality of interior places: Application of optimization algorithms in domestic housing. *Journal of Building Engineering*, *29*. https://doi.org/10.1016/j.jobe.2020.101174

Alba-Rodriguez, M. D., Marrero, M., & Solis-Guzm, J. (2022). Evaluation model of the economic-environmental impact on housing recovery. Application in the city of Seville, Spain. *Sustainable Cities and Society*, *83*. https://doi.org/10.1016/j.scs.2022.103940

Alexakis, E., Delegou, E. T., Lampropoulos, K. C., Apostolopoulou, M., Ntoutsi, I., & Moropoulou, A. (2018). NDT as a monitoring tool of the works progress and the assessment of materials and rehabilitation interventions at the Holy Aedicule of the Holy Sepulchre. *Construction and Building Materials*, *189*, 512–526. https://doi.org/10.1016/j.conbuildmat.2018.09.007

Alghanmi, A., Yunusa-Kaltungo, A., & Edwards, R. E. (2022). Investigating the influence of maintenance strategies on building energy performance: A systematic literature review. *Energy Reports*, *8*, 14673–14698. https://doi.org/https://doi.org/10.1016/j.egyr.2022.10.441

Almeida, M., & Ferreira, M. (2018). Ten questions concerning cost-effective energy and carbon emissions optimization in building renovation. *Building and Environment*, *143*, 15–23. https://doi.org/https://doi.org/10.1016/j.buildenv.2018.06.036

Alonso, A., Suarez, R., Patricio, J., Escandon, R., & Sendra, J. J. (2021). Acoustic retrofit strategies of windows in facades of residential buildings: Requirements and recommendations to reduce exposure to environmental noise. *Journal of Building Engineering*, *41*. https://doi.org/10.1016/j.jobe.2021.102773

Alves, T., Machado, L., de Souza, R. G., & de Wilde, P. (2018). Assessing the energy saving potential of an existing high-rise office building stock. *Energy and Buildings*, *173*, 547–561. https://doi.org/10.1016/j.enbuild.2018.05.044

Andrade Santos, R., Flores-Colen, I., Simões, N., & Silvestre, J. D. (2020). Auto-responsive technologies for thermal renovation of opaque facades. *Energy and Buildings*, *217*, 109968. https://doi.org/https://doi.org/10.1016/j.enbuild.2020.109968

Arnold, J., & Lafreniere, D. (2017). The persistence of time: Vernacular preservation of the postindustrial landscape. *Change Over Time*, *7*, 114–133. https://doi.org/10.1353/cot.2017.0006

Arrieta, L. G., Rodríguez, I. M., Arlanzón, N. L., & Blanco, E. B. (2018). Damage assessment and conservation strategy for the largest covered market in Europe: the Ribera Market (Bilbao). *International Journal of Architectural Heritage*, *12*(6), 997–1018. https://doi.org/10.1080/15583058.2018.1431728

Asadi, E., Da Silva, M. G., Antunes, C. H., & Dias, L. (2012). Multi-objective optimization for building retrofit strategies: A model and an application. *Energy and Buildings*, *44*(1), 81–87. https://doi.org/10.1016/j.enbuild.2011.10.016

Ascione, F., De Masi, R. F., Mastrullo, R. M., Ruggiero, S., & Vanolide, G. P. (2017). Experimental investigation and numerical evaluation of adoption of multi-layered wall with vacuum insulation panel for typical Mediterranean climate. *Energy and Buildings*, *152*, 108–123. https://doi.org/10.1016/j.enbuild.2017.07.029

Asdrubali, F., Ballarini, I., Corrado, V., Evangelisti, L., Grazieschi, G., & Guattari, C. (2019). Energy and environmental payback times for an NZEB retrofit. *Building and Environment*, *147*, 461–472. https://doi.org/10.1016/j.buildenv.2018.10.047

Asdrubali, F., Venanzi, D., Evangelisti, L., Guattari, C., Grazieschi, G., Matteucci, P., & Roncone, M. (2021). An evaluation of the environmental payback times and economic convenience in an energy requalification of a school. *Buildings*, *11*(1). https://doi.org/10.3390/buildings11010012

Aste, N., Adhikari, R. S., & Buzzetti, M. (2012). Energy retrofit of historical buildings: An Italian case study. *Journal of Green Building*, *7*(4), 144–165. https://doi.org/10.3992/jgb.7.4.144

Aste, N., Caputo, P., Buzzetti, M., & Fattore, M. (2016). Energy efficiency in buildings: What drives the investments? The case of Lombardy Region. *Sustainable Cities and Society*, *20*, 27–37. https://doi.org/10.1016/j.scs.2015.09.003

Australia International Council on Monuments and Sites [ICOMOS]. (2013). *The Burra Charter*.

Badea, N., & George-Vlad, B. (2015). Life cycle analysis in refurbishment of the buildings as intervention practices in energy saving. *Energy and Buildings*, *86*, 74–85. https://doi.org/10.1016/j.enbuild.2014.10.021

Barbaresi, A., Dallacasa, F., Torreggiani, D., & Tassinari, P. (2017). Retrofit interventions in non-conditioned rooms: Calibration of an assessment method on a farm winery. *Journal of Building Performance Simulation*, *10*(1), 91–104. https://doi.org/10.1080/19401493.2016.1141994

Barbosa, F. C., de Freitas, V. P., & Almeida, M. (2020). School building experimental characterization in Mediterranean climate regarding comfort, indoor air quality and energy consumption. *Energy and Buildings*, *212*. https://doi.org/10.1016/j.enbuild.2020.109782

Bellia, L., Borrelli, M., De Masi, R. F., Ruggiero, S., & Vanoli, G. P. (2018). University building: Energy diagnosis and refurbishment design with cost-optimal approach. Discussion about the effect of numerical modelling assumptions. *Journal of Building Engineering*, *18*, 1–18. https://doi.org/10.1016/j.jobe.2018.02.017

Belpoliti, V., & Bizzarri, G. (2015). A parametric method to assess the energy performance of the social housing stock and simulate suitable retrofit scenarios: An Italian case study. *Energy and Buildings*, *96*, 261–271. https://doi.org/10.1016/j.enbuild.2015.03.017

Berto, R., Stival, C. A., & Rosato, P. (2018). Enhancing the environmental performance of industrial settlements: An economic evaluation of extensive green roof competitiveness. *Building and Environment*, *127*, 58–68. https://doi.org/10.1016/j.buildenv.2017.10.032

Bertolini-Cestari, C., Brino, G., Cestari, L., Crivellaro, A., Marzi, T., Pignatelli, O., Rolla, S., & Violante, A. (2019). The great timber roof of Porta Nuova railway station in Turin: The role of assessment and diagnosis for sustainable repair and conservation. *International Journal of Architectural Heritage*, *13*(3rd International Conference on Protection of Historical Constructions (Prohitech)), 172–191. https://doi.org/10.1080/15583058.2018.1497226

Boffill, Y., Blanco, H., Lombillo, I., & Villegas, L. (2020). Structural assessment of ancient masonries before and during a rehabilitation process. *International Journal of Architectural Heritage*, *14*(2), 299–312. https://doi.org/10.1080/15583058.2018.1539784

Borras, J. G., Lerma, C., Mas, A., Vercher, J., & Gil, E. (2022). Energy efficiency evaluation of green roofs as an intervention strategy in residential buildings in the field of Spanish climate. *Buildings*, *12*(7). https://doi.org/10.3390/buildings12070959

Brand, S. (1994). *How buildings learn: What happens after they're built*. Penguin Books.

Brandonisio, G., De Luca, A., De Martino, A., & Mautone, G. (2013). Restoration through a traditional intervention of a historic unreinforced masonry building "Palazzo Scarpa" in Naples. *International Journal of Architectural Heritage*, *7*(4), 479–508. https://doi.org/10.1080/15583058.2011.632468

Brandt, E., & Rasmussen, M. H. (2002). Assessment of building conditions. *Energy and Buildings*, *34*(2), 121–125. https://doi.org/https://doi.org/10.1016/S0378-7788(01)00102-5

Brás, A., & Gomes, V. (2015). LCA implementation in the selection of thermal enhanced mortars for energetic rehabilitation of school buildings. *Energy and Buildings*, *92*, 1–9. https://doi.org/10.1016/j.enbuild.2015.01.007

British Standards Institution [BSI]. (2008). *Buildings and constructed assets—Service-life planning - Part 8: Reference service life and service-life estimation* (BS ISO 15686-8:2008).

BSI. (2011a). *Sustainability of construction works—Assessment of environmental performance of buildings—Calculation method* (BS EN 15978:2011).

BSI. (2011b). *Buildings and constructed assets—Service life planning*

- Part 1: General principles and framework data from practice (BS ISO 15686-1:2011).

BSI. (2013). *Guide to the conservation of historic buildings* (BS 7913:2013).

BSI. (2017a). *Conservation of cultural heritage—Guidelines for improving the energy performance of historic buildings* (BS EN 16883:2017).

BSI. (2017b). *Buildings and constructed assets—Service life planning - Part 7: Performance evaluation for feedback of service life data from practice* (BS ISO 15686-7:2017).

BSI. (2019). *Conservation of cultural heritage—Main general terms and definitions* (BS EN 15898:2019).

BSI. (2020). *Buildings and civil engineering works—Vocabulary - Part 1: General terms* (BS ISO 6707-1:2020).

BSI. (2021). *Sustainability of construction works—Framework for assessment of building and civil engineering works* (BS EN 15643:2021).

Broadbent, G. (1980). *Design in architecture*. John Wiley & Sons.

Bruno, R., Bevilacqua, P., Ferraro, V., & Arcuri, N. (2021). Reflective thermal insulation in non-ventilated air-gaps: Experimental and theoretical evaluations on the global heat transfer coefficient. *Energy and Buildings*, *236*. https://doi.org/10.1016/j.enbuild.2021.110769

Bruno, S., De Fino, M., & Fatiguso, F. (2018). Historic building information modelling: Performance assessment for diagnosis-aided information modelling and management. *Automation in Construction*, *86*, 256–276. https://doi.org/https://doi.org/10.1016/j.autcon.2017.11.009

Buxadé, C. (2014). Sagrada Familia's Crypt: Reinforcement for the existing foundations. *Structural Engineering International*, *24*(1), 74–81. https://doi.org/10.2749/101686614X13830788505955

Candelas-Gutiérrez, A., & Borrallo-Jimenez, M. (2020). Methodology of restoration of historical timber roof frames. Application to traditional Spanish structural carpentry. *International Journal of Architectural Heritage*, *14*(1), 51–74. https://doi.org/10.1080/15583058.2018.1506833

Carpino, C., Bruno, R., & Arcuri, N. (2018). Social housing refurbishment in Mediterranean climate: Cost-optimal analysis towards the n-ZEB target. *Energy and Buildings*, *174*, 642–656. https://doi.org/10.1016/j.enbuild.2018.06.052

Carpino, C., Bruno, R., & Arcuri, N. (2020). Social housing refurbishment for the improvement of city sustainability: Identification of targeted interventions based on a disaggregated cost-optimal approach. *Sustainable Cities and Society*, *60*, 102223.

Carratt, A., Kokogiannakis, G., & Daly, D. (2020). A critical review of methods for the performance evaluation of passive thermal retrofits in residential buildings. *Journal of Cleaner Production*, *263*, 121408. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.121408

Cascone, S., & Sciuto, G. (2018). Recovery and reuse of abandoned buildings for student housing: A case study in Catania, Italy. *Frontiers of Architectural Research*, *7*(4), 510–520. https://doi.org/10.1016/j.foar.2018.08.004

Cassese, P., Menna, C., Occhiuzzi, A., & Asprone, D. (2021). Experimental behavior of existing RC columns strengthened with HPFRC jacket under concentric and eccentric compressive load. *Buildings*, *11*(11). https://doi.org/10.3390/buildings11110521

Cescatti, E., da Porto, F., & Modena, C. (2018). In-situ destructive testing of ancient strengthened masonry vaults. *International Journal of Architectural Heritage*, *12*(10th International Conference on Structural Analysis of Historical Constructions (SAHC)-Anamnesis, Diagnosis, Therapy, Controls), 350–361. https://doi.org/10.1080/15583058.2017.1323243

Coady, J., & Duquette, J. (2021). Towards a cost-effective remote community energy system model: Evaluating trade-offs between supply and demand-side interventions. *Energy and Buildings*, *244*. https://doi.org/10.1016/j.enbuild.2021.111021

Conde, M. J. M., Liñán, C. R., & de Hita, P. R. (2014). Use of ultrasound as a nondestructive evaluation technique for sustainable interventions on wooden structures. *Building and Environment*, *82*, 247–257. https://doi.org/10.1016/j.buildenv.2014.07.022

Construction Specifications Insti-

tute [CSI]. (2013). *OmniClass A Strategy for Classifying the Built Environment: Table 11 - Construction entities by function*.

Cornaro, C., Puggioni, V. A., & Strollo, R. M. (2016). Dynamic simulation and on-site measurements for energy retrofit of complex historic buildings: Villa Mondragone case study. *Journal of Building Engineering*, *6*, 17–28. https://doi.org/10.1016/j.jobe.2016.02.001

Coronelli, D., Caggioni, B., & Zanella, F. (2015). Cathedral of Milan: Structural history of the load-bearing system. *International Journal of Architectural Heritage*, *9*(4), 510–528. https://doi.org/10.1080/15583058.2013.821541

Corradi, M., Di Schino, A., Borri, A., & Rufini, R. (2018). A review of the use of stainless steel for masonry repair and reinforcement. *Construction and Building Materials*, *181*, 335–346. https://doi.org/10.1016/j.conbuildmat.2018.06.034

Corredor, A. G., Facelli, G., Gowda, C. C., Roldan-Zamarron, E., Valente, I. B., & Branco, J. M. (2016). Structural assessment of *Companhia Aurificia*, a 19th century industrial building located in Northern Portugal. *International Journal of Architectural Heritage*, *10*(6), 777–796. https://doi.org/10.1080/15583058.2015.1136711

Cunha, S., Pinto, J., Paiva, A., Briga-Sá, A., Soares, N., Varum, H., & Ferreira, D. (2015). A contribution for the improvement in thermal insulation of *tabique* walls coated with metal corrugated sheets. *Building Services Engineering Research & Technology*, *36*(4), 439–454. https://doi.org/10.1177/0143624414558720

D'Agostino, D., Becchio, C., Crespi, G., & Corgnati, S. P. (2023). Assessment of passive and active buildings resilience to gas supply disruption in winter across European climates. *Sustainable Cities and Society*, *92*, 104461. https://doi.org/https://doi.org/10.1016/j.scs.2023.104461

D'Agostino, D., Parker, D., Melia, P., & Dotelli, G. (2022). Optimizing photovoltaic electric generation and roof insulation in existing residential buildings. *Energy and Buildings*, *255*. https://doi.org/10.1016/j.enbuild.2021.111652

Dall'O, G., Ferrari, S., Bruni, E., & Bramonti, L. (2020). Effective implementation of ISO 50001: A case study on energy management for heating load reduction for a social building stock in Northern Italy. *Energy and Buildings*, *219*. https://doi.org/10.1016/j.enbuild.2020.110029

Dall'O', G., Galante, A., & Pasetti, G. (2012). A methodology for evaluating the potential energy savings of retrofitting residential building stocks. *Sustainable Cities and Society*, *4*(1), 12–21. https://doi.org/10.1016/j.scs.2012.01.004

Daniotti, B., Masera, G., Bolognesi, C. M., Spagnolo, S. L., Pavan, A., Iannaccone, G., Signorini, M., Ciuffreda, S., Mirarchi, C., Lucky, M., & Cucuzza, M. (2022). The development of a BIM-based interoperable toolkit for efficient renovation in buildings: From BIM to digital twin. *Buildings*, *12*(2). https://doi.org/10.3390/buildings12020231

De Berardinis, P., Rotilio, M., Marchionni, C., & Friedman, A. (2014). Improving the energy-efficiency of historic masonry buildings. A case study: A minor centre in the Abruzzo region, Italy. *Energy and Buildings*, *80*, 415–423. https://doi.org/10.1016/j.enbuild.2014.05.047

De Fino, M., Scioti, A., Cantatore, E., & Fatiguso, F. B. (2017). Methodological framework for assessment of energy behavior of historic towns in Mediterranean climate. *Energy and Buildings*, *144*, 87–103. https://doi.org/10.1016/j.enbuild.2017.03.029

de Santoli, L., Fraticelli, F., Fornari, F., & Calice, C. (2014). Energy performance assessment and a retrofit strategies in public school buildings in Rome. *Energy and Buildings*, *68*, 196–202. https://doi.org/10.1016/j.enbuild.2013.08.028

Di Giuseppe, E., Iannaccone, M., Telloni, M., D'Orazio, M., & Di Perna, C. (2017). Probabilistic life cycle costing of existing buildings retrofit interventions towards nZE target: Methodology and application example. *Energy and Buildings*, *144*, 416–432. https://doi.org/10.1016/j.enbuild.2017.03.055

Dias, I. S., Silva, A., Cruz, C. O., Ferreira, C., Flores-Colen, I., & de Brito, J. (2022). Insurance policies for condition-based maintenance plans

of ETICS. *Buildings 12*(6). https://doi.org/10.3390/buildings12060707

Domínguez-Amarillo, S., Fernández-Agüera, J., Sendra, J. J., & Roaf, S. (2019). The performance of Mediterranean low-income housing in scenarios involving climate change. *Energy and Buildings*, *202*. https://doi.org/10.1016/j.enbuild.2019.109374

Douglas, J. (2006). *Building adaptation*. Routledge.

Dukanovic, L., Radivojevic, A., & Rajcic, A. (2016). Potentials and limitations for energy refurbishment of multi-family residential buildings built in Belgrade before the World War One. *Energy and Buildings*, *115*(1st International Academic Conference on Places and Technologies 2014), 112–120. https://doi.org/10.1016/j.enbuild.2015.04.047

Duran, Ö., & Lomas, K. J. (2021). Retrofitting post-war office buildings: Interventions for energy efficiency, improved comfort, productivity and cost reduction. *Journal of Building Engineering*, *42*, 102746. https://doi.org/https://doi.org/10.1016/j.jobe.2021.102746

Efthymiopoulos, S., Altamirano, H., & Aktas, Y. D. (2021). The effect of the airflow pattern inside air gaps on the assessment of interstitial mould: A theoretical approach. *Building Services Engineering Research & Technology*, *42*(6), 639–651. https://doi.org/10.1177/01436244211020470

Eliopoulou, E., & Mantziou, E. (2017). Architectural energy retrofit (AER): An alternative building's deep energy retrofit strategy. *Energy and Buildings*, *150*, 239–252. https://doi.org/10.1016/j.enbuild.2017.05.001

Elvarsson, A. B., Martani, C., & Adey, B. T. (2021). Considering automated vehicle deployment uncertainty in the design of optimal parking garages using real options. *Journal of Building Engineering*, *34*. https://doi.org/10.1016/j.jobe.2020.101703

European Committee for Standardization [CEN]. (2020). *Assessment and retrofitting of existing structures (PD CEN/TS 17440:2020)*.

Famuyibo, A. A., Duffy, A., & Strachan, P. (2013). Achieving a holistic view of the life cycle performance of existing dwellings. *Building and Environment*, *70*, 90–101. https://doi.org/10.1016/j.buildenv.2013.08.016

Fantucci, S., & Serra, V. (2019). Investigating the performance of reflective insulation and low emissivity paints for the energy retrofit of roof attics. *Energy and Buildings*, *182*, 300–310. https://doi.org/10.1016/j.enbuild.2018.10.003

Fenoglio, E., Fantucci, S., Serra, V., Carbonaro, C., & Pollo, R. (2018). Hygrothermal and environmental performance of a perlite-based insulating plaster for the energy retrofit of buildings. *Energy and Buildings*, *179*, 26–38. https://doi.org/10.1016/j.enbuild.2018.08.017

Ferrarini, G., Bison, P., Bortolin, A., & Cadelano, G. (2016). Thermal response measurement of building insulating materials by infrared thermography. *Energy and Buildings*, *133*, 559–564. https://doi.org/10.1016/j.enbuild.2016.10.024

Ferraz, G. T., de Brito, J., de Freitas, V. P., & Silvestre, J. D. (2016). State-of-the-Art review of building inspection systems. *Journal of Performance of Constructed Facilities*, *30*(5), 4016018. https://doi.org/10.1061/(ASCE)CF.1943-5509.0000839

Ferreira, C., Dias, I. S., Silva, A., de Brito, J., & Flores-Colen, I. (2021). The impact of temporary means of access on buildings envelope's maintenance costs. *Buildings*, *11*(12). https://doi.org/10.3390/buildings11120601

Ferreira, C., Silva, A., de Brito, J., Dias, I. S., & Flores-Colen, I. (2021a). Definition of a condition-based model for natural stone claddings. *Journal of Building Engineering*, *33*. https://doi.org/10.1016/j.jobe.2020.101643

Ferreira, C., Silva, A., de Brito, J., Dias, I. S., & Flores-Colen, I. (2021b). The impact of imperfect maintenance actions on the degradation of buildings' envelope components. *Journal of Building Engineering*, *33*, 101571. https://doi.org/https://doi.org/10.1016/j.jobe.2020.101571

Ferriss, L. (2021). Sustainable reuse of post-war architecture through life cycle assessment. *Journal of Architectural Conservation*, *27*(3), 208–224. https://doi.org/10.1080/13556207.2021.1943260

Filippi, M. (2015). Remarks on the green retrofitting of historic build-

ings in Italy. *Energy and Buildings*, *95*, 15–22. https://doi.org/https://doi.org/10.1016/j.enbuild.2014.11.001

Flores-Colen, I., & de Brito, J. (2010). A systematic approach for maintenance budgeting of buildings facades based on predictive and preventive strategies. *Construction and Building Materials*, *24*(9), 1718–1729. https://doi.org/10.1016/j.conbuildmat.2010.02.017

Fodde, E., & Cooke, L. (2013). Structural consolidation of mud brick masonry. *Journal of Architectural Conservation*, *19*(3), 265–281. https://doi.org/10.1080/13556207.2014.858296

Forster, A. M., Kate, C., Phillip F.G., B., & and Kayan, B. (2011). Green maintenance for historic masonry buildings: an emerging concept. *Building Research & Information*, *39*(6), 654–664. https://doi.org/10.1080/09613218.2011.621345

Galbiati, G., Medici, F., Graf, F., & Marino, G. (2021). Methodology for energy retrofitting of Modern Architecture. The case study of the Olivetti office building in the UNESCO site of Ivrea. *Journal of Building Engineering*, *44*. https://doi.org/10.1016/j.jobe.2021.103378

Galli, C., & Conserva, F. (2016). The restoration and repair of Bolognese timber ceilings: Material culture and decoration. *Journal of Architectural Conservation*, *22*(2), 101–125. https://doi.org/10.1080/13556207.2016.1208479

Garavaglia, E., Basso, N., & Sgambi, L. (2018). Probabilistic life-cycle assessment and rehabilitation strategies for deteriorating structures: A case study. *International Journal of Architectural Heritage*, *12*(6), 981–996. https://doi.org/10.1080/15583058.2018.1431727

García-Esparza, J. A. (2011). Barracas on the Mediterranean coast. *International Journal of Architectural Heritage*, *5*(1), 27–47. https://doi.org/10.1080/15583050903186532

Gaspar, P. L., & Santos, A. L. (2015). Embodied energy on refurbishment vs. demolition: A southern Europe case study. *Energy and Buildings*, *87*, 386–394. https://doi.org/10.1016/j.enbuild.2014.11.040

Ginks, N., & Painter, B. (2017). Energy retrofit interventions in historic buildings: Exploring guidance and attitudes of conservation professionals to slim double glazing in the UK. *Energy and Buildings*, *149*, 391–399. https://doi.org/10.1016/j.enbuild.2017.05.039

Gocer, C. (2024). A field investigation to evaluate the effects of prevailing wind and solar radiation on water-induced damage to the eaves of wooden fiber-board covered roofs. *Engineering Failure Analysis*, *159*, 108135. https://doi.org/https://doi.org/10.1016/j.engfailanal.2024.108135

Gonçalves, J., Mateus, R., Dinis Silvestre, J., Pereira Roders, A., & Vasconcelos, G. (2022). Selection of core indicators for the sustainable conservation of built heritage. *International Journal of Architectural Heritage*, *16*(7), 1047–1062. https://doi.org/10.1080/15583058.2020.1863518

Guidetti, E., & Ferrara, M. (2023). Embodied energy in existing buildings as a tool for sustainable intervention on urban heritage. *Sustainable Cities and Society*, *88*, 104284. https://doi.org/https://doi.org/10.1016/j.scs.2022.104284

Guizzardi, M., Derome, D., Vonbank, R., & Carmeliet, J. (2015). Hygrothermal behavior of a massive wall with interior insulation during wetting. *Building and Environment*, *89*, 59–71. https://doi.org/10.1016/j.buildenv.2015.01.034

Gunaydin, M., Demirkir, C., Altunisik, A. C., Gezer, E. D., Genc, A. F., & Okur, F. Y. (2023). Diagnosis and monitoring of historical timber Velipasa Han building prior to restoration. *International Journal of Architectural Heritage*, *17*(2), 285–309. https://doi.org/10.1080/15583058.2021.1919239

Hacene, M. A. B., & Sari, N. E. C. (2020). Energy efficient design optimization of a bioclimatic house. *Indoor and Built Environment*, *29*(2), 270–285. https://doi.org/10.1177/1420326X19856668

Hall, M. R., Casey, S. P., Loveday, D. L., & Gillott, M. (2013). Analysis of UK domestic building retrofit scenarios based on the E.ON retrofit research house using energetic hygrothermics simulation - Energy efficiency, indoor air quality, occupant comfort, and mould growth potential. *Building and*

Environment, *70*, 48–59. https://doi.org/10.1016/j.buildenv.2013.08.015

Hamdy, G., Kamal, O., Al-Hariri, O., & El-Salakawy, T. (2018). Plane and vaulted masonry elements strengthened by different techniques - Testing, numerical modeling and nonlinear analysis. *Journal of Building Engineering*, *15*, 203–217. https://doi.org/10.1016/j.jobe.2017.11.009

Hamilton, I. G., Shipworth, D., Summerfield, A. J., Steadman, P., Oreszczyn, T., & Lowe, R. (2014). Uptake of energy efficiency interventions in English dwellings. *Building Research & Information*, *42*(3), 255–275. https://doi.org/10.1080/09613218.2014.867643

Hawkins, D., & Mumovic, D. (2017a). Evaluation of life cycle carbon impacts for higher education building redevelopment: A multiple case study approach. *Energy and Buildings*, *150*, 507–515. https://doi.org/10.1016/j.enbuild.2017.05.058

Hawkins, D., & Mumovic, D. (2017b). Evaluation of life cycle carbon impacts for higher education building redevelopment: An archetype approach. *Energy and Buildings*, *147*, 113–122. https://doi.org/10.1016/j.enbuild.2017.04.043

Heo, Y., Choudhary, R., & Augenbroe, G. A. (2012). Calibration of building energy models for retrofit analysis under uncertainty. *Energy and Buildings*, *47*, 550–560. https://doi.org/10.1016/j.enbuild.2011.12.029

Hurst, L. J., & O'Donovan, T. S. (2019). A review of the limitations of life cycle energy analysis for the design of fabric first low-energy domestic retrofits. *Energy and Buildings*, *203*, 109447. https://doi.org/https://doi.org/10.1016/j.enbuild.2019.109447

Ibañez Iralde, N. S., Pascual, J., & Salom, J. (2021). Energy retrofit of residential building clusters. A literature review of crossover recommended measures, policies instruments and allocated funds in Spain. *Energy and Buildings*, *252*, 111409. https://doi.org/https://doi.org/10.1016/j.enbuild.2021.111409

ICOMOS International Committee on Twentieth Century Heritage. (2017). *Approaches to the conservation of twentieth century cultural heritage–Madrid-New Delhi Document*. ICOMOS Paris, France.

ICOMOS Turkey. (2013). *Mimari mirasın korunması bildirgesi [In Turkish]*.

Iglesias, L. M. P., & Bernardo, G. (2022). The industrial heritage as text and pretext for contemporary architecture. *Journal of Architectural Conservation*, *28*(2), 102–114. https://doi.org/10.1080/13556207.2022.2061140

Ignjatovic, N. C., Ignjatovic, D., & Stankovic, B. (2016). Possibilities for energy rehabilitation of typical single family house in Belgrade-Case study. *Energy and Buildings*, *115*(1st International Academic Conference on Places and Technologies 2014), 154–162. https://doi.org/10.1016/j.enbuild.2015.08.010

Illampas, R., Silva, R. A., Charmpis, D. C., Lourenço, P. B., & Ioannou, I. (2017). Validation of the repair effectiveness of clay-based grout injections by lateral load testing of an adobe model building. *Construction and Building Materials*, *153*, 174–184. https://doi.org/10.1016/j.conbuildmat.2017.07.054

International Council for Research and Innovation in Building and Construction [CIB] Working Commission W60. (1982). *Publication 64 - Working with the Performance Approach in Building*.

International Standard of Organization [ISO]. (2013). *Guidelines for simplified seismic assessment and rehabilitation of concrete buildings* (ISO 28841).

ISO. (2016). *Framework for specifying performance in buildings* (ISO 19208:2016).

Iyer-Raniga, U., & Wong, J. P. C. (2012). Evaluation of whole life cycle assessment for heritage buildings in Australia. *Building and Environment*, *47*, 138–149. https://doi.org/10.1016/j.buildenv.2011.08.001

Juliá, P. B., Stellacci, S., & Poletti, E. (2024). Evaluation of retrofitting techniques for historical adobe constructions using a multi-criteria decision analysis: The case study of Chile. *International Journal of Architectural Heritage*, *18*(1), 40–63. https://doi.org/10.1080/15583058.2022.2103476

Kloiber, M., Frankeova, D., Slizko-

va, Z., & Kunecky, J. (2023). Repair of old timber log house using cavity filling with compatible natural materials. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020550

Kou, H. Y., Chalana, M., & Zhou, J. (2020). Diverse approaches to the preservation of built vernacular heritage: case study of post-disaster reconstruction of the Xijie Historic District in Dujiangyan City, China. *Journal of Architectural Conservation*, *26*(1), 71–86. https://doi.org/10.1080/13556207.2019.1684641

Kroftová, K., & Zigler, R. (2023). Building and architectural details of tenement houses built at the turn of the 19th and 20th centuries in Central European region—Hygrothermal analysis. *Buildings*, *13*, 451. https://doi.org/10.3390/buildings13020451

Liberotti, R., Cluni, F., Faralli, F., & Gusella, V. (2022). Natural FRCM and heritage buildings: Experimental approach to innovative interventions on "Wall Beams". *Buildings*, *12*(8). https://doi.org/10.3390/buildings12081076

Lignola, G. P., & Manfredi, G. (2011). Damage assessment and design of structural interventions for Monte di Pietà in Naples, Italy. *International Journal of Architectural Heritage*, *5*(6), 647–676. https://doi.org/10.1080/15583058.2010.483565

Litti, G., Audenaert, A., & Lavagna, M. (2018). Life cycle operating energy saving from windows retrofitting in heritage buildings accounting for technical performance decay. *Journal of Building Engineering*, *17*, 135–153. https://doi.org/10.1016/j.jobe.2018.02.006

Loli, A., & Bertolin, C. (2018). Towards zero-emission refurbishment of historic buildings: A literature review. *Buildings 8*(2), 22. https://doi.org/10.3390/buildings8020022

Lstiburek, J. W. (2018). Avoiding mass failures how to insulate mass buildings on the interior and not get into trouble. *ASHRAE Journal*, *60*(5), 62–69.

Macchi, G., & Macchi, S. (2015). Retrofitting alternatives for Pavia's Cathedral. *Structural Engineering International*, *25*(4), 442–449. https://doi.org/10.2749/101686615X14355644771135

Marcus, B., Ziegert, C., Paganoni, S., Mahdy, H., & Muhammad, S. (2019). Conservation and structural stabilization of al Hayla tower in the Liwa Oasis, Abu Dhabi. *Journal of Architectural Conservation*, *25*(1–2), 104–116. https://doi.org/10.1080/13556207.2019.1619985

Maria Calama-Gonzalez, C., Symonds, P., Luis Leon-Rodriguez, A., & Suarez, R. (2022). Optimal retrofit solutions considering thermal comfort and intervention costs for the Mediterranean social housing stock. *Energy and Buildings*, *259*. https://doi.org/10.1016/j.enbuild.2022.111915

Marin-Garcia, D., Bienvenido-Huertas, D., Carretero-Ayuso, M. J., & Della Torre, S. (2023). Deep learning model for automated detection of efflorescence and its possible treatment in images of brick facades. *Automation in Construction*, *145*. https://doi.org/10.1016/j.autcon.2022.104658

Marinic, G. (2016). Internal appropriations: Multiculturalism and the American shopping mall. *Journal of Interior Design*, *41*(3), 47–67. https://doi.org/10.1111/joid.12079

Markus, T. A., Whyman, P., Morgan, J., Whitton, D., Maver, T., Canter, D., & Fleming, J. (1972). *Building performance*. John Wiley & Sons.

Martinez-Millana, E., & Alcaraz, A. C. (2020). Domesticity "Behind Bars": Project by Rem Koolhaas/OMA for the renovation of a Panopticon Prison in Arnhem. *Buildings*, *10*(7). https://doi.org/10.3390/buildings10070117

Martín-Garín, A., Millán-García, J. A., Terés-Zubiaga, J., Oregi, X., Rodríguez-Vidal, I., & Baïri, A. (2021). Improving energy performance of historic buildings through hygrothermal assessment of the envelope. *Buildings*, *11*(9). https://doi.org/10.3390/buildings11090410

Marzouk, M., Eissa, A., & ElSharkawy, M. (2020). Influence of light redirecting control element on daylight performance: A case of Egyptian heritage palace skylight. *Journal of Building Engineering*, *31*. https://doi.org/10.1016/j.jobe.2020.101309

McKenna, R., Merkel, E., Fehrenbach, D., Mehne, S., & Fichtner, W. (2013). Energy efficiency in the German residential sector: A bottom-up building-stock-model-based analy-

sis in the context of energy-political targets. *Building and Environment*, *62*, 77–88. https://doi.org/https://doi.org/10.1016/j.buildenv.2013.01.002

Menconi, M. E., & Grohmann, D. (2014). Model integrated of life-cycle costing and dynamic thermal simulation (MILD) to evaluate roof insulation materials for existing livestock buildings. *Energy and Buildings*, *81*, 48–58. https://doi.org/10.1016/j.enbuild.2014.06.005

Milone, D., Peri, G., Pitruzzella, S., & Rizzo, G. (2015). Are the best available technologies the only viable for energy interventions in historical buildings? *Energy and Buildings*, *95*, 39–46. https://doi.org/10.1016/j.enbuild.2014.11.004

Montoliu-Hernández, J., & Rodríguez-Alvarez, J. (2017). Renascent urbanism: reviving derelict structures in the wake of the crisis. *Architectural Science Review*, *60*(4), 286–298. https://doi.org/10.1080/00038628.2017.1336979

Morgado, J., Flores-Colen, I., de Brito, J., & Silva, A. (2017). Maintenance planning of pitched roofs in current buildings. *Journal of Construction Engineering and Management*, *143*(7). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001316

Moropoulou, A., Lampropoulos, K., Apostolopoulou, M., & Tsilimantou, E. (2021). Novel, sustainable preservation of modern and historic buildings and infrastructure. The paradigm of the Holy Aedicule's rehabilitation. *International Journal of Architectural Heritage*, *15*(6), 864–884. https://doi.org/10.1080/15583058.2019.1690076

Muñoz-González, C. M., León-Rodríguez, A. L., & Navarro-Casas, J. (2016). Air conditioning and passive environmental techniques in historic churches in Mediterranean climate. A proposed method to assess damage risk and thermal comfort pre-intervention, simulation-based. *Energy and Buildings*, *130*, 567–577. https://doi.org/10.1016/j.enbuild.2016.08.078

Musso, S. F., & Franco, G. (2015). The conservation of the "modern": Franco Albini and the Museum of the Treasury of San Lorenzo, Genoa. *Journal of Architectural Conservation*, *21*(1), 30–50. https://doi.org/10.1080/13556207.2015.1026142

Nadkarni, R. R., & Puthuvayi, B. (2020). A comprehensive literature review of Multi-Criteria Decision Making methods in heritage buildings. *Journal of Building Engineering*, *32*, 101814. https://doi.org/https://doi.org/10.1016/j.jobe.2020.101814

Ohene, E., Hsu, S.-C., & Chan, A. P. C. (2022). Feasibility and retrofit guidelines towards net-zero energy buildings in tropical climates: A case of Ghana. *Energy and Buildings*, *269*, 112252. https://doi.org/https://doi.org/10.1016/j.enbuild.2022.112252

O'Riain, M., & Harrison, J. (2016). Cost-optimal passive versus active nZEB. How cost-optimal calculations for retrofit may change nZEB best practice in Ireland. *Architectural Science Review*, *59*(5), 358–369. https://doi.org/10.1080/00038628.2016.1184130

Österbring, M., Mata, E., Thuvander, L., & Wallbaum, H. (2019). Explorative life-cycle assessment of renovating existing urban housing-stocks. *Building and Environment*, *165*. https://doi.org/10.1016/j.buildenv.2019.106391

Pallis, P., Braimakis, K., Roumpedakis, T. C., Varvagiannis, E., Karellas, S., Doulos, L., Katsaros, M., & Vourliotis, P. (2021). Energy and economic performance assessment of efficiency measures in zero-energy office buildings in Greece. *Building and Environment*, *206*. https://doi.org/10.1016/j.buildenv.2021.108378

Pallis, P., Gkonis, N., Varvagiannis, E., Braimakis, K., Karellas, S., Katsaros, M., & Vourliotis, P. (2019). Cost effectiveness assessment and beyond: A study on energy efficiency interventions in Greek residential building stock. *Energy and Buildings*, *182*, 1–18. https://doi.org/https://doi.org/10.1016/j.enbuild.2018.10.024

Palma, P., Gouveia, J. P., & Barbosa, R. (2022). How much will it cost? An energy renovation analysis for the Portuguese dwelling stock. *Sustainable Cities and Society*, *78*. https://doi.org/10.1016/j.scs.2021.103607

Pankhurst, C., & Harris, A. (2013). Conservation and innovation - The challenge of "Eco" renovation in heritage buildings. *Journal of Architectural Conservation*, *19*(1), 18–34. https://doi.

org/10.1080/13556207.2013.787017

Parker, J., Farmer, D., Johnston, D., Fletcher, M., Thomas, F., Gorse, C., & Stenlund, S. (2019). Measuring and modelling retrofit fabric performance in solid wall conjoined dwellings. *Energy and Buildings*, *185*, 49–65. https://doi.org/10.1016/j.enbuild.2018.12.010

Patiño-Cambeiro, F., Armesto, J., Bastos, G., Prieto-López, J. I., & Patiño-Barbeito, F. (2019). Economic appraisal of energy efficiency renovations in tertiary buildings. *Sustainable Cities and Society*, *47*. https://doi.org/10.1016/j.scs.2019.101503

Pedro, J., Paiva, J., & Vilhena, A. (2008). Portuguese method for building condition assessment. *Structural Survey 26(4), 322-335. (2008)*. https://doi.org/10.1108/02630800810906566

Pellegrino, M., Simonetti, M., & Chiesa, G. (2016). Reducing thermal discomfort and energy consumption of Indian residential buildings: Model validation by in-field measurements and simulation of low-cost interventions. *Energy and Buildings*, *113*, 145–158. https://doi.org/10.1016/j.enbuild.2015.12.015

Pereira Roders, A. R. (2007). *Re-architecture: lifespan rehabilitation of built heritage* [Phd. Diss.]. Eindhoven University of Technology.

Perez-Monserrat, E. M., Fort, R., & Varas-Muriel, M. J. (2018). Monitoring facade soiling as a maintenance strategy for the sensitive built heritage. *International Journal of Architectural Heritage*, *12*(5), 816–827. https://doi.org/10.1080/15583058.2017.1419312

Philokyprou, M. (2014). Adaptation of new university uses in old buildings: The case of rehabilitation of listed buildings in Limassol Cyprus for University Purposes. *International Journal of Architectural Heritage*, *8*(5), 758–782. https://doi.org/10.1080/15583058.2012.738282

Pieczka, M., & Wowrzeczka, B. (2021). Art in post-industrial facilities-strategies of adaptive reuse for art exhibition function in Poland. *Buildings*, *11*(10). https://doi.org/10.3390/buildings11100487

Pierangioli, L., Cellai, G., Ferrise, R., Trombi, G., & Bindi, M. (2017). Effectiveness of passive measures against climate change: Case studies in Central Italy. *Building Simulation*, *10*(4), 459–479. https://doi.org/10.1007/s12273-016-0346-8

Pomponi, F., & D'Amico, B. (2017). Holistic study of a timber double skin facade: Whole life carbon emissions and structural optimisation. *Building and Environment*, *124*, 42–56. https://doi.org/10.1016/j.buildenv.2017.07.046

Pomponi, F., Piroozfar, P. A. E., Southall, R., Ashton, P., & Farr, E. R. P. (2015). Life cycle energy and carbon assessment of double skin facades for office refurbishments. *Energy and Buildings*, *109*, 143–156. https://doi.org/10.1016/j.enbuild.2015.09.051

Porritt, S. M., Cropper, P. C., Shao, L., & Goodier, C. I. (2012). Ranking of interventions to reduce dwelling overheating during heat waves. *Energy and Buildings*, *55*, 16–27. https://doi.org/10.1016/j.enbuild.2012.01.043

Porritt, S., Shao, L., Cropper, P., & Goodier, C. (2011). Adapting dwellings for heat waves. *Sustainable Cities and Society*, *1*(2), 81–90. https://doi.org/10.1016/j.scs.2011.02.004

Posani, M., Veiga, M. D. R., & de Freitas, V. P. (2021). Towards resilience and sustainability for historic buildings: A review of envelope retrofit possibilities and a discussion on hygric compatibility of thermal insulations. *International Journal of Architectural Heritage*, *15*(5), 807–823. https://doi.org/10.1080/15583058.2019.1650133

Pourebrahimi, M., Eghbali, S. R., & Pereira Roders, A. (2020). Identifying building obsolescence: towards increasing buildings' service life. *International Journal of Building Pathology and Adaptation*, *38*(5), 635–652. https://doi.org/10.1108/IJBPA-08-2019-0068

Prieto, A. J., Silva, A., Tori, F., & Carpio, M. (2022). Estimating functional and physical service life of timber buildings concerning thermal performance simulations. *Buildings*, *12*(9). https://doi.org/10.3390/buildings12091299

Prudon, T. (2017). Preservation, design and modern architecture: the challenges ahead. *Journal of Architectural Conservation*, *23*(1–2), 27–35. https://doi.org/10.1080/13556207.2017.1327193

Ramos, L. F., García, A. C. N., Fernandes, F. M., & Lourenço, P. B. (2016).

Evaluation of structural intervention in the *Quartel das Esquadras*, Almeida (Portugal). In K. VanBalen & E. Verstrynge (Eds.), *Structural Analysis of Historical Constructions: Anamnesis, Diagnosis, Therapy, Controls* (Issues 10th International Conference on Structural Analysis of Historical Constructions (SAHC)-Anamnesis, Diagnosis, Therapy, Controls, pp. 1664–1671).

Ray, N. (2014). Repairs to the Hall, Pembroke College Cambridge. *Journal of Architectural Conservation*, *20*(1), 56–66. https://doi.org/10.1080/13556207.2014.897431

Resende, M. M., Gambare, E. B., Silva, L. A., Cordeiro, Y. D., Almeida, E., & Salvador, R. P. (2022). Infrared thermal imaging to inspect pathologies on facades of historical buildings: A case study on the Municipal Market of Sa tilde o Paulo, Brazil. *Case Studies in Construction Materials*, *16*. https://doi.org/10.1016/j.cscm.2022.e01122

Rodrigues, F., Matos, R., Alves, A., Ribeirinho, P., & Rodrigues, H. (2018). Building life cycle applied to refurbishment of a traditional building from Oporto, Portugal. *Journal of Building Engineering*, *17*, 84–95. https://doi.org/10.1016/j.jobe.2018.01.010

Ruggeri, A. G., Calzolari, M., Scarpa, M., Gabrielli, L., & Davoli, P. (2020). Planning energy retrofit on historic building stocks: A score-driven decision support system. *Energy and Buildings*, *224*, 110066. https://doi.org/https://doi.org/10.1016/j.enbuild.2020.110066

Ruiz, D. M., Barrera, N., Reyes, J. C., López, C., & Restrepo, M. (2023). An approach to Colombian Andean earthen architecture in urban environments: a case study of Bogota Historic Centre. *Journal of Architectural Conservation*, *29*(2), 168–192. https://doi.org/10.1080/13556207.2022.2160556

Rush, R. D. (1986). *American Institute of Architects: The building systems integration handbook*. Butterworth-Heineman/American Institute of Architects.

Sahin Güçhan, N., & Kuleli, A. E. (2018). Repair phases of Suleymaniye complex in Damascus. *METU Journal of the Faculty of Architecture*, *35*(2), 1–28. https://doi.org/10.4305/METU.JFA.2018.2.3

Salman, M., Malik, S., Tariq, F., & Khilat, F. (2018). Conservation analysis of Gali Surjan Singh: a study of architectural and social aspects. *Journal of Architectural Conservation*, *24*(2), 134–151. https://doi.org/10.1080/13556207.2018.1488203

Salmeron, A., Climent, M.-A., & Ivorra, S. (2022). Violin ceramic joist slabs: Evaluation and proposal for intervention with duplex-type stainless steel. *Buildings*, *12*(7). https://doi.org/10.3390/buildings12070942

Salvalai, G., Malighetti, L. E., Luchini, L., & Girola, S. (2017). Analysis of different energy conservation strategies on existing school buildings in a Pre-Alpine Region. *Energy and Buildings*, *145*, 92–106. https://doi.org/10.1016/j.enbuild.2017.03.058

Sandoval, C., Serpell, R., Araya-Letelier, G., & Calderón, S. (2021). Shear behavior of single- and triple-thickness masonry panels strengthened by bed-joint structural repointing. *Construction and Building Materials*, *286*. https://doi.org/10.1016/j.conbuildmat.2021.122925

Sarihi, S., Mehdizadeh Saradj, F., & Faizi, M. (2021). A critical review of façade retrofit measures for minimizing heating and cooling demand in existing buildings. *Sustainable Cities and Society*, *64*, 102525. https://doi.org/https://doi.org/10.1016/j.scs.2020.102525

Semprini, G., Marinosci, C., Ferrante, A., Predari, G., Mochi, G., Garai, M., & Gulli, R. (2016). Energy management in public institutional and educational buildings: The case of the school of engineering and architecture in Bologna. *Energy and Buildings*, *126*, 365–374. https://doi.org/10.1016/j.enbuild.2016.05.009

Serrano-Jimenez, A., Barrios-Padura, A., & Molina-Huelva, M. (2017). Towards a feasible strategy in Mediterranean building renovation through a multidisciplinary approach. *Sustainable Cities and Society*, *32*, 532–546. https://doi.org/10.1016/j.scs.2017.05.002

Serrano-Jiménez, A., Barrios-Padura, A., & Molina-Huelva, M. (2018). Sustainable building renovation for an ageing population: Decision support system through an integral assessment

method of architectural interventions. *Sustainable Cities and Society*, *39*, 144–154. https://doi.org/10.1016/j.scs.2018.01.050

Serrano-Lanzarote, B., Ortega-Madrigal, L., García-Prieto-Ruiz, A., Soto-Francés, L., & Soto-Francés, V. M. (2016). Strategy for the energy renovation of the housing stock in Comunitat Valenciana (Spain). *Energy and Buildings*, *132*, 117–129. https://doi.org/10.1016/j.enbuild.2016.06.087

Serrrano-Lanzarote, B., Cerdán-Castillo, V., Ortega-Madrigal, L., & Almerich-Chulia, A. (2020). Use of reinforced ceramics for slabs in an autarchy period. Pathology and intervention strategies. *Case Studies in Construction Materials*, *13*. https://doi.org/10.1016/j.cscm.2020.e00437

Shimoda, I., So, S., & Chan, V. (2022). Damage assessment and guidelines for restoration methods of ancient brick structures at Sambor Prei Kuk, Cambodia. *International Journal of Architectural Heritage*, *16*(9), 1366–1381. https://doi.org/10.1080/15583058.2021.1884319

Shrestha, K. C., Aoki, T., Miyamoto, M., Wangmo, P., & Pema. (2020). In-plane shear resistance between the rammed earth blocks with simple interventions: Experimentation and finite element study. *Buildings*, *10*(3). https://doi.org/10.3390/buildings10030057

Simpson, K., Whyte, J., & Childs, P. (2020). Data-centric innovation in retrofit: A bibliometric review of dwelling retrofit across North Western Europe. *Energy and Buildings*, *229*, 110474. https://doi.org/https://doi.org/10.1016/j.enbuild.2020.110474

Soler-Estrela, A., & Soler-Verdú, R. (2016). Restoration techniques applied to tile dome conservation in the Western Mediterranean. Valencia, Spain. *International Journal of Architectural Heritage*, *10*(5), 570–588. https://doi.org/10.1080/15583058.2015.1010127

Stastny, P., Gasparik, J., & Makys, O. (2021). Analysis of moisture and salinity of historical constructions before and after the application of REMEDIATIONS. *Journal of Building Engineering*, *41*. https://doi.org/10.1016/j.jobe.2021.102785

Stazi, F., Bonfigli, C., Tomassoni, E., Di Perna, C., & Munafò, P. (2015). The effect of high thermal insulation on high thermal mass: Is the dynamic behaviour of traditional envelopes in Mediterranean climates still possible? *Energy and Buildings*, *88*, 367–383. https://doi.org/10.1016/j.enbuild.2014.11.056

Stazi, F., Tittarelli, F., Politi, G., Di Perna, C., & Munafo, P. (2014). Assessment of the actual hygrothermal performance of glass mineral wool insulation applied 25 years ago in masonry cavity walls. *Energy and Buildings*, *68*, 292–304. https://doi.org/10.1016/j.enbuild.2013.09.032

Stellacci, S., Rato, V., Poletti, E., Vasconcelos, G., & Borsoi, G. (2018). Multi-criteria analysis of rehabilitation techniques for traditional timber frame walls in *Pombalino* buildings (Lisbon). *Journal of Building Engineering*, *16*, 184–198. https://doi.org/10.1016/j.jobe.2018.01.001

Suárez, R., & Fernández-Agüera, J. (2015). Passive energy strategies in the retrofitting of the residential sector: A practical case study in dry hot climate. *Building Simulation*, *8*(5), 593–602. https://doi.org/10.1007/s12273-015-0234-7

Sugár, V., Talamon, A., Horkai, A., & Kita, M. (2020). Energy saving retrofit in a heritage district: The case of the Budapest. *Journal of Building Engineering*, *27*. https://doi.org/10.1016/j.jobe.2019.100982

Tagliabue, L. C., Di Giuda, G. M., Villa, V., De Angelis, E., & Ciribini, A. L. C. (2018). Techno-economical analysis based on a parametric computational evaluation for decision process on envelope technologies and configurations. *Energy and Buildings*, *158*, 736–749. https://doi.org/10.1016/j.enbuild.2017.10.004

Taylor, S., Peacock, A., Banfill, P., & Shao, L. (2010). Reduction of greenhouse gas emissions from UK hotels in 2030. *Building and Environment*, *45*(6), 1389–1400. https://doi.org/10.1016/j.buildenv.2009.12.001

Theodossopoulos, D. (2016). The catastrophic repairs of Holyrood Abbey Church in 1760. *International Journal of Architectural Heritage*, *10*(7), 954–974. https://doi.org/10.1080/15583058.2016.1160302

Tian, W., & de Wilde, P. (2011).

Uncertainty and sensitivity analysis of building performance using probabilistic climate projections: A UK case study. *Automation in Construction*, *20*(8), 1096–1109. https://doi.org/10.1016/j.autcon.2011.04.011

Timur, B. A., Basaran, T., & Ipekoglu, B. (2022). Thermal retrofitting for sustainable use of traditional dwellings in Mediterranean climate of southwestern Anatolia. *Energy and Buildings*, *256*. https://doi.org/10.1016/j.enbuild.2021.111712

Tokede, O. O., Love, P. E. D., & Ahiaga-Dagbui, D. D. (2018). Life cycle option appraisal in retrofit buildings. *Energy and Buildings*, *178*, 279–293. https://doi.org/10.1016/j.enbuild.2018.08.034

Tovarovic, J. C., Ivanovic-Sekularac, J., & Sekularac, N. (2017). Renovation of existing glass facade in order to implement energy efficiency and media facade. *Energy and Buildings*, *152*, 653–666. https://doi.org/10.1016/j.enbuild.2017.07.049

Ultav, Z. T., & Savasir, G. (2012). The erasure of history in the remodeling of the Grand Efes Hotel in Izmir. *Interiors-Design Architecture Culture*, *3*(3), 181–202. https://doi.org/10.2752/204191212X13470263746870

Unuk, Z., Lukic, I., Leskovar, V. Z., & Premrov, M. (2021). Renovation of timber floors with structural glass: Structural and environmental performance. *Journal of Building Engineering*, *38*. https://doi.org/10.1016/j.jobe.2021.102149

Valença, J. M. D., de Almeida, C., Botas, J. L. M., & Júlio, E. (2015). Patch restoration method: A new concept for concrete heritage. *Construction and Building Materials*, *101*, 643–651. https://doi.org/10.1016/j.conbuildmat.2015.10.055

Valluzzi, M. R., Modena, C., & de Felice, G. (2014). Current practice and open issues in strengthening historical buildings with composites. *Materials and Structures*, *47*(12), 1971–1985. https://doi.org/10.1617/s11527-014-0359-7

van der Bent, H. S., van den Brom I, P., Visscher, H. J., Meijer, A., & Mouter, N. (2021). The energy performance of dwellings of Dutch non-profit housing associations: Modelling actual energy consumption. *Energy and Buildings*, *253*. https://doi.org/10.1016/j.enbuild.2021.111486

Varriale, F. (2016). Forecasting future demand for domestic thermal insulation in Wales. *Indoor and Built Environment*, *25*(7), 1096–1113. https://doi.org/10.1177/1420326X16660354

Verbist, M., Branco, J. M., Poletti, E., Descamps, T., & Lourenco, P. B. (2018). Experimentations on the retrofitting of damaged single step joints with self-tapping screws. *Materials and Structures*, *51*(4). https://doi.org/10.1617/s11527-018-1234-8

Vilches, A., Garcia-Martinez, A., & Sanchez-Montañes, B. (2017). Life cycle assessment (LCA) of building refurbishment: A literature review. *Energy and Buildings*, *135*, 286–301. https://doi.org/https://doi.org/10.1016/j.enbuild.2016.11.042

Vilhena, A., Silva, C., Fonseca, P., & Couto, S. (2017). Exterior walls covering system to improve thermal performance and increase service life of walls in rehabilitation interventions. *Construction and Building Materials*, *142*, 354–362. https://doi.org/10.1016/j.conbuildmat.2017.03.033

Vissilia, A. M., & Villi, M. (2010). Adobe and timber ties as main construction materials for an historic Greek dwelling. *International Journal of Architectural Heritage*, *4*(4), 295–319. https://doi.org/10.1080/15583050902934973

Vos, E., & Storgaard, E. (2018). Teaching re-use strategies for modernist buildings: a case study handbook for a joint European Master in Architecture. *Joelho: Revista de Cultura Arquitectonica*, 186–201. https://doi.org/10.14195/1647-8681_9_11

Watson, V. (2022). Restoration, expansion and the building art: Contemporary issues in the life of Mies van der Rohe's Museum of Modern Art (New National Gallery) in Berlin. *Journal of Historic Buildings and Places*, *1*, 113–124.

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

Wittocx, L., Buyle, M., Audenaert, A., Seuntjens, O., Renne, N., & Craeye, B. (2022). Revamping corrosion dam-

aged reinforced concrete balconies: Life cycle assessment and life cycle cost of life-extending repair methods. *Journal of Building Engineering*, *52*. https://doi.org/10.1016/j.jobe.2022.104436

Xiong, X. R., Wang, Y. H., Ma, C., & Chi, Y. W. (2023). Ensuring the authenticity of the conservation and reuse of modern industrial heritage architecture: A case study of the large Machine Factory, China. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020534

Zendri, E., Falchi, L., Izzo, F. C., Morabito, Z. M., & Driussi, G. (2017). A review of common NDTs in the monitoring and preservation of historical architectural surfaces. *International Journal of Architectural Heritage*, *11*(7), 987–1004. https://doi.org/10.1080/15583058.2017.1331477

Zhang, Y., & Dong, W. (2021). Determining minimum intervention in the preservation of heritage buildings. *International Journal of Architectural Heritage*, *15*(5), 698–712. https://doi.org/10.1080/15583058.2019.1645237

Zhou, X. H., Derome, D., & Carmeliet, J. (2017). Hygrothermal modeling and evaluation of freeze-thaw damage risk of masonry walls retrofitted with internal insulation. *Building and Environment*, *125*, 285–298. https://doi.org/10.1016/j.buildenv.2017.08.001