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Globalization and Architecture: Urban Homogenization and Challenges for Unprotected Heritage. The Case of Postmodern Buildings with Complex Geometric Shapes in the Ensanche of San Sebastián †

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Abstract: Globalization has profoundly impacted architecture by promoting urban homogenization, where global styles and materials overshadow local character. This shift prioritizes standardized functionality and energy efficiency over cultural identity, erasing regional architectural distinctiveness. In historical urban centers, globalization-driven interventions—such as ventilated facades or external thermal insulation systems (ETISs)—often simplify original compositions and alter building materiality, texture, and color. The Ensanche of San Sebastián serves as a case study highlighting this issue. Despite its architectural richness, which includes neoclassical and modernist buildings primarily constructed with sandstone from the Igeldo quarry, unprotected buildings are at risk of unsympathetic renovations. Such changes can distort the identity of what is considered "everyday heritage", encompassing the residential buildings and public spaces that shape the collective memory of cities. This study presents a replicable methodology for assessing the vulnerability of buildings to facade interventions. By utilizing tools like digital twins, point cloud modeling, and typological analysis, the research establishes criteria for interventions aimed at preserving architectural values. It emphasizes the importance of collaborative efforts with urban planning authorities and public awareness campaigns to safeguard heritage. Ultimately, protecting architectural identity requires balancing the goals of energy efficiency with cultural preservation. This approach ensures that urban landscapes maintain their historical and social significance amidst globalization pressures.

Keywords: facade simulation; everyday heritage; vulnerability assessment; artificial intelligence; AI; loss of identity

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1. Introduction

Globalization in architecture refers to the adoption of universal styles, materials, colors, and technologies that tend to prioritize global demands over local contexts. This trend promotes a homogenization of the urban landscape [1], minimizing local differences and gradually leading to the loss of regional construction traditions and techniques in favor of standardized functionality [2].

As a result, cities are becoming increasingly uniform, putting local architectural identities at risk. This phenomenon is driven by dominant global influences [3] resulting in what is often referred to as the "global city", which focuses on developing functional and homogeneous infrastructures [1]. There is a strong emphasis on standardizing architectural languages, which are frequently associated with the international style [4]. Consequently, architecture begins to lose its connection to specific cultural and geographical contexts.

Although processes of homogenization have historically accompanied the processes of globalization, they are frequently followed by processes of "vernacularisation" [5]. This phenomenon can be observed in the diverse neoclassical architectures of European cities, where variations arise due to differences in latitude, local materials, and building traditions. Contemporary architectural homogenization typically lacks the differentiation that could be achieved through adaptation to local customs. This issue not only has aesthetic implications, but also psychological ones, leading to a growing disconnection between the population and its built environment. In many cases, the population perceives globalization as the cause of "impoverishing uniformity" and views it as a threat to their culture, identity, and values [6]. While these designs may be efficient and functional, the loss of the ornamental, material, compositional, and chromatic characteristics of each region contributes to what is termed "urban forgetfulness" [7]. This highlights the importance of preserving local traditions amid their gradual decline.

Facades play a crucial role in defining any city's character; they serve as functional, aesthetic, and representative elements within the urban fabric. As Luis Barragán noted, facades possess an emotional and spiritual dimension, fostering a dialogue between privacy and community [8]. The historical significance of buildings is often assessed through an examination of their facades, making them vital in both architectural and urban contexts. While the processes of globalization and homogenization tend to have limited impact on historic centers—usually protected by regulations—less significant buildings often lack such protection. Recent studies indicate that these structures are at risk of being demolished or altered to conform to global standards, often without due regard for their aesthetic and cultural values [9].

The processes of architectural homogenization vary in intensity and significance. Fast-growing cities are experiencing irreparable losses due to the replacement of old buildings and neighborhoods—built using traditional techniques—with new buildings that bear no relation to the surrounding environment. This process is particularly evident in some cities in Latin America [10]. In many cases, globalization prioritizes economic factors over aesthetics, resulting in urban landscapes that lack a sense of belonging [11]. Furthermore, this architectural homogenization displaces cultural and social narratives associated with the past [12]. Another noticeable trend in various cities around the world is the chromatic alteration of urban environments. This change is generally prompted by the availability of an almost infinite range of artificial paints that have replaced the colors of local materials [13]. Equally concerning is the trend of covering traditional facades with coatings such as external thermal insulation systems (ETISs) or ventilated facades to enhance energy efficiency. These coverings alter the composition of facades and, in many cases, their materiality and color. This often leads to bland, generic results that do not align with the logic of modern buildings, ultimately distorting the identity of the traditional urban fabric [14].

The risk extends beyond merely losing monumental buildings; it includes the loss of structures of lesser heritage significance, often referred to as "everyday heritage". This encompasses residential buildings, commercial ground floors, and public spaces that collectively contribute to a location's identity. The concept of cultural heritage has evolved over the years, and its protection now requires societal awareness that involves not only public administrations but also the community as a whole [15]. Therefore, it is essential to implement measures aimed at protecting built heritage. These should include inventorying and cataloging, establishing protective regulations, promoting education and public awareness, advancing research and specialized studies, encouraging responsible tourism, and supporting adequate restoration and conservation initiatives. These efforts must be accompanied by additional measures tailored to the specific characteristics of each asset.

In the context of the global loss of urban identity, a specific issue has been observed in Spain, particularly regarding the built stock in the Basque Country. Public administrations are implementing initiatives to promote the rehabilitation of existing buildings [16], such as the new Next Generation EU recovery instrument [17]. In this context, Royal Decree 853/2021 of 5 October was published, regulating aid programs related to residential rehabilitation and social housing of the Recovery, Transformation and Resilience Plan [18]. Component 2 of this plan focuses specifically on promoting rehabilitation and improvement actions for the existing building stock. Therefore, the Basque Country has experienced a significant increase in the use of ventilated facades and external thermal insulation systems (ETISs). Additionally, series of laws have been enacted, both at the national and local levels, to promote the improvement of energy efficiency in buildings [19–21].

Consequently, there has been a proliferation of energy improvement projects for the facades of existing buildings in our cities driven by these grants. New external skins are often added using ETISs or ventilated facades on all types of buildings, regardless of their age, style, material, or color [22]. While numerous materials, colors, and installation methods are available, most interventions have led to a significant simplification of facade compositions, resulting in homogenization and impoverishment of facades. These changes, intended to meet global energy efficiency goals, receive approval from local public administrations. Such actions conflict with the good practice guide for renewable energy and cultural heritage published by ICOMOS [23], which emphasizes that any energy efficiency improvement should carefully consider its impact on both the tangible and intangible values of cultural property. The guide stresses the importance of ensuring sustainable integration of these interventions with heritage conservation. It also highlights the need to adapt traditional conservation methodologies to reconcile the goals of climate action with those of heritage preservation [24]. Therefore, it is essential to establish applicable recommendations, based on scientific studies that support criteria for intervention in existing buildings [25].

The issues encountered in the Basque Country are diverse. On one hand, there are interventions made in housing complexes constructed from a single architectural project. In these instances, the lack of regulations has resulted in different solutions being implemented for each building, negatively affecting the overall appearance of these developments, which ultimately becomes compromised [26]. It becomes challenging to identify the original style or period of the buildings, as the distinctive details that made them recognizable have vanished. A significant loss is caused by the replacement of materials like exposed brick with large pieces of neutral-colored materials that lack the texture and warmth characteristics of the original construction. Lastly, in urban centers, numerous protected buildings exist; however, the "everyday" unprotected heritage is being altered. This not only impacts the buildings themselves and their architectural features but also affects the image and identity of the urban center, which constitutes cultural heritage of undeniable value.

The importance of preserving the identity of historic centers has led to a case study focusing on the Ensanche of San Sebastián, located in northern Spain (For context, until the mid-19th century, San Sebastián was a fortified military stronghold, closed in on itself. It was in 1854 when the city became the capital of Gipuzkoa, transforming into the political and administrative center of the province. This development led to the immediate demolition of the city. On 30 July 1862, the City Council announced a competition for the planning of the future city expansion. By the end of that year, architect Antonio Cortázar won first prize with his plan for the new city. This expansion is known as Ensanche Cortazar. In later years, the Eastern and Goicoa extensions were built. In this article, the term Ensanche refers to these three extensions located in the city center). This area is recognized for its beauty and unique character, offering value that extends beyond its architectural heritage; it serves as a significant attraction for tourism and contributes to the city's wealth. The unprotected buildings inserted in the urban fabric of the Ensanche of San Sebastián have been studied. This case study examines unprotected buildings within the urban fabric of the Ensanche of San Sebastián. These buildings have not received protection for various reasons but are situated in a region known as the "romantic area", which holds acknowledged environmental significance. The Ensanche began construction in the mid-nineteenth century, and the existing buildings primarily showcase neoclassical, eclectic, or modernist styles. The materiality of these buildings is somewhat limited: a small percentage features white plaster, while a larger percentage is composed of sandstone ashlar sourced from the Igeldo quarry. This material not only shapes the color and texture of the urban landscape but also serves as a tangible expression of the genius loci, reflecting the identity and spirit of the place and connecting the architecture to its natural environment.

The facade protection regulations set by the San Sebastián City Council have not been updated to reflect the new reality of facade rehabilitation aid. Currently, the existing regulations permit the installation of thermal insulation systems on facades, but only with certain limitations for those classified with protection grades B, C, and D [27]. For non-protected buildings, however, there are no restrictions on the composition of the facade or the types of materials that can be used, and there is no established color palette. Although the volume of buildings is regulated and protected, their materiality is not adequately safeguarded in the current regulations. This lack of protection has led to distortions in the character of the Ensanche area, which must be addressed through the implementation of this project. Various structured strategies have been developed and applied to comprehensively tackle the issues at hand.

The primary objective of this research is to develop effective strategies for protecting non-listed buildings in the Ensanche, with the aim of preserving their architecture, identity, and the environmental value they contribute to the urban fabric. This article focuses on the analysis of postmodern buildings with unique volumetric designs, addressing their challenges through a holistic approach that combines rigorous research with awareness-raising strategies. The goal is to promote interventions on facades that respect and preserve both their architectural significance and cultural relevance, ensuring the sustainability of these structures as integral components of the built heritage.

The specific objectives of this research are detailed as follows: establishing a replicable methodology for safeguarding the identity of historic centers through the development of flexible yet rigorous intervention criteria tailored to the unique characteristics of facade modifications. This includes identifying vulnerable buildings in the Ensanche of San Sebastián through detailed analyses of stylistic, material, and chromatic elements and evaluating their protection under current heritage regulations, particularly the Special Plan for the Protection of Urban Built Heritage (PEPPUC). A systematic approach is adopted to classify buildings into typological families using parameterized digital models, enabling structured data collection and automated analysis to guide intervention strategies. Additionally, prototypes are developed to assess building vulnerability, focusing on the impact of exterior thermal insulation systems (ETISs) and ventilated facades on architectural composition. This study aims to establish specific technical guidelines for intervention, including tailored technical sheets for each building, and to collaborate with the Department of Urban Planning of San Sebastián to integrate findings into local policies. Emphasis is also placed on raising public awareness about heritage conservation, fostering appreciation for everyday heritage through targeted educational and community activities. Furthermore, this research explores digital twin technology as a tool for simulation and analysis, enhancing decision-making processes and promoting interdisciplinary collaboration in urban heritage conservation efforts.

2. Materials and Methods

2.1. Main Methodology

In this research, the Design Science Research Methodology (DSRM) served as the overarching framework, providing a structured approach to designing, developing, and evaluating solutions to address the identified challenges. The Design Science Research Methodology (DSRM) is a systematic and application-oriented approach aimed at generating applied knowledge through the design and development of innovative technological or practical solutions. This method involves iterative stages, including problem identification, artifact design, evaluation, and continuous refinement, integrating theory and practice. Authors, such as Akram et al. [28] or Cash et al. [29], state that this research method is often motivated by theoretical or practical challenges. It provides contributions that not only fill knowledge gaps but also lay the groundwork for future research and discoveries [30].

According to Voordijk [31], the DSRM is a prescriptive research approach that generates knowledge aimed at improving aspects of the built environment, in contrast to descriptive methods that seek to explain phenomena within that environment. The prescriptive nature of DSRM makes its results applicable in real-world settings.

Johannesson and Perjons [32] note that the DSRM generates an artificial construct or 'artifact' that solves a problem, which can be either a physical object, a set of guidelines, or an ICT solution. Authors such as Van Aken [33] and Romme [34] point out that the application of the DSRM can bridge the gap between theory and practice due to its inherent ability to produce knowledge that enhances existing theories.

Starting with the examination of the problem and utilizing existing knowledge on the issue, a solution is developed, evaluated, and refined until it reaches the version suitable for application in the problem environment (see Figure 1). The designed prototype not only addresses a specific demand but also contributes to the enhancement of the knowledge base.

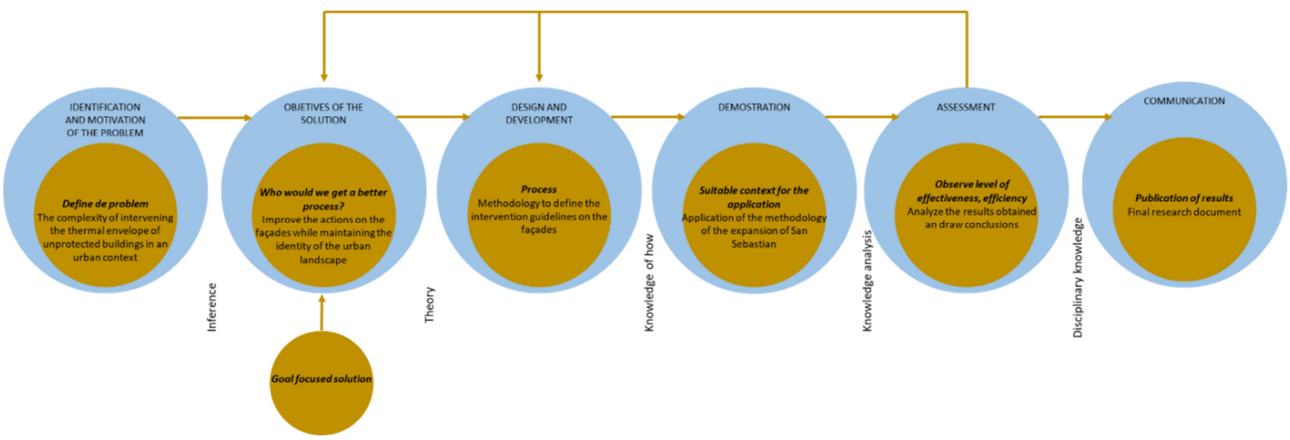

Figure 1. DSRM simplified flow diagram.

The process incorporates feedback from the development and evaluation of the proposal, which enhances understanding of the issue and refines the initial approach. The adopted research methodology is outlined in Figure 1.

2.1.1. Identification and Motivation of the Problem

The problem to be addressed has been clearly defined. This research addresses the distortion in the urban landscape of historical city centers caused by energy improvement interventions on facade envelopes. This includes systems like external thermal insulation systems (ETISs) and ventilated facades, which lack proper regulation.

2.1.2. Objectives of the Solution That the Proposed Methodology Aims to Achieve

Clear objectives have been established for the design of the artifact. The main objective is to create a replicable methodology to establish the general and specific criteria for intervention in these buildings, paving the way for regulations that prevent distortion in historic centers.

2.1.3. Artifact Design

The proposed artifact has been developed as a replicable methodology (PROTOTYPE 01) aimed at the objective definition of intervention criteria. This approach is organized into three main phases, during which general forms and structured data sheets are designed to subsequently apply this methodology to any building:

- Phase 1: Characterization and classification of buildings
  In this phase, general forms and standardized structured data sheets are created to categorize buildings into various scenarios and sub-scenarios. The classification criteria include architectural, typological, and compositional characteristics, such as construction materials, texture, arrangement of cladding, volume, color, and specific architectural elements like railings, balconies, and roofs.
- Phase 2: Vulnerability analysis
  Structured data sheets and templates are designed to record and quantitatively analyze the vulnerability of buildings to potential rehabilitation interventions, such as ventilated facade systems (VFS). These sheets include variables related to the geometry, reliefs, ornamental elements, texture, materiality, and color of facades, as well as details like carpentry, railings, and suspended ceilings.
- Phase 3: Establishment of intervention criteria
  Based on the information collected in the forms and structured data sheets designed in the previous phases, a framework of general criteria is developed to facilitate the planning and guidance of interventions. This ensures a systematic and adaptable approach suitable for various types of buildings.

2.1.4. Demonstration of the Prototype in a Suitable Case Study

The designed artifact's performance is tested in a specific environment. In this case, the Ensanche of San Sebastián and, specifically, the unprotected buildings in it, were chosen to evaluate the device and validate the results obtained. This choice is based on the fact that this area possesses high heritage value and is emblematic of the city's image. Its size is manageable, as it was constructed mainly between 1865 and 1940, during periods of eclecticism, historicism, and modernism, showcasing clear compositional, ornamental, and stylistic connections.

2.1.5. Evaluation of the Prototype

An evaluation is carried out to determine the effectiveness and efficiency of the device. Authors such as Hevner et al. [35] emphasize that evaluation is essential and requires researchers to demonstrate the utility, quality, and effectiveness of a design prototype using rigorous evaluation methods. The proposed prototype has undergone evaluation in several workshops, where a panel of experts analyzed and assessed the methodology. The focus group included specialists such as architects with expertise in urban planning and building typologies, architects proficient in construction systems and rehabilitation, and historians. This method involves the presence of a moderator who facilitates the session, starting by introducing the topic and posing guiding questions to encourage interaction and discussion among the participants. The benefits of using workshops and focus groups are as follows:

- Validation of the methodology or artifact: Experts evaluate whether the proposed artifact meets the objectives and criteria previously defined.
- Identification of potential improvements: Interaction and discussion among specialists provide qualitative feedback that can lead to adjustments or refinements in the design.
- Verification of applicability: Through the analysis of hypothetical cases or real scenarios, the applicability and practical effectiveness of the artifact are assessed.

The corrections and improvements proposed in the workshops restart the process from the artifact design point, continuing with the demonstration of the prototype in a suitable case study, and ending again with the evaluation of the prototype. In this way, the process is iterative, substantially improving the artifact from the initial phases, until it obtains the final prototype.

2.1.6. Communication

The results and findings are shared with the community, whether academic or professional. This step is crucial to validate the impact of the work, encourage its adoption and feedback, and contribute to the existing body of knowledge. In addition, social awareness is a crucial component of the heritage protection strategy. To foster this awareness, community engagement methodologies have been adopted. Various actions have been implemented to disseminate research findings and, most importantly, to increase awareness within society about existing issues related to heritage.

2.2. Application of Specific Techniques and Methods

2.2.1. Building Mapping

This technique allows for the cataloging and analysis of architectural, historical, and cultural characteristics, facilitating their integration into conservation plans [36]. The geographic and architectural mapping of the study area was conducted using a pre-existing plan, which was refined and adapted to meet the study's objectives. This process involved the following:

- Working with the original plan to identify and mark the location of unprotected buildings.
- Applying a color-coded legend to visually represent the distribution of buildings by style, construction period, and other relevant criteria, facilitating a clear understanding of spatial and temporal patterns.

2.2.2. Inventory and Cataloging

An exhaustive inventory and cataloging process was carried out to document the buildings. This involved the following:

- On-site inspections.
- Compilation of historical and architectural data.
- Cross-checking municipal archives and cadastral data to ensure data accuracy.

2.2.3. Data Collection of Selected Buildings

Comprehensive data collection methodologies were applied, including the following:

- High-resolution digital imaging.
- Scans made with a Leica brand scanner, model RTC 360 (Leica Geosystems, Hexagon AB, Heerbrugg, Switzerland), for creating precise 3D models of selected structures.

2.2.4. 3D Modeling and Rendering of Selected Buildings

Selected buildings were modeled and rendered to create digital twins. The model was used to carry out simulations of facade interventions. This process utilized advanced computational tools, such as the following:

- Autodesk's Recap software (Autodesk, Inc., San Rafael, USA).
- Autodesk's Rvit software. (Autodesk, Inc., San Rafael, USA).
- 3ds Max software (Autodesk, Inc., San Rafael, USA), in order to model other elements requiring more detail.
- Chaos Group's V-Ray rendering engine (Chaos Group, Sofia, Bulgaria).
- Various additional plug-ins such as RailClone (iToo Software, Valencia, Spain), Forest Pack (iToo Software, Valencia, Spain), and FloorGenerator (CG-Source, Havkaervej, Denmark) were also used.

2.2.5. Building Analysis and Characterization

Detailed analyses of the architectural and chronological characteristics of the buildings were carried out. The following results were generated:

- A spreadsheet with the parameters that categorize each building.
- A sheet was filled out for each building.
- Based on the analysis carried out, the buildings were categorized into scenarios and sub-scenarios.

2.2.6. Vulnerability Assessment

Vulnerability assessments were conducted using a scoring system to evaluate parameters present in the studied facades. The process included the following:

- Developing an Excel table to characterize and evaluate each building's facade.
- Iterative refinement and correction of the table to enhance accuracy and applicability.
- Application of the table to each building to determine vulnerability.
- Scoring parameters to assess the feasibility of installing external thermal insulation systems (ETISs) or ventilated facades on the facades.
- Classification of buildings were based on their scores as follows:
    - Scores less than 2: Low vulnerability.
    - Scores between 2 and 4: Medium vulnerability.
    - Scores greater than 4: High vulnerability.

2.2.7. Intervention Criteria Sheets

Customized intervention criteria sheets were developed for each building to guide facade modifications. These sheets covered the following:

- General description of the building: summary of the architectural and structural characteristics.
- General guidelines for facade intervention: establishment of general principles for the treatment of the facade.
- Criteria for specific areas of the facade, including the following:
    - Blind areas of the facade.
    - Openings, including window frames.
    - Railings and balconies.

- ○ False ceilings.
- Ground floor intervention criteria: providing general recommendations for modifications at ground level.
- Defined parameters: assessment of the feasibility of ventilated facades or ETISs, together with color and material specifications for the various facade components.

2.2.8. Stakeholder Engagement Periodic Consultations with the Municipal Authorities Were Conducted to Validate Findings and Refine Methodologies

These interactions included the following:

- Structured workshops.
- Iterative review sessions.

2.2.9. Community Awareness and Sensitization Public Awareness Initiatives Were Implemented to Foster Community Engagement

Activities included the following:

- Educational campaigns.
- Interactive sessions aimed at disseminating findings and promoting heritage conservation.

3. Results

The unprotected buildings of the Ensanche of San Sebastián have been studied. The systematic inventory and structural characterization of these buildings have allowed for the identification of a group of structures that share similar characteristics and belong to an architectural typology from the 1970s. Out of the 105 buildings studied, 10 buildings have been identified as "postmodern sculptural stone buildings".

These structures feature facades with stone coverings that create a rich interplay of shadows and an intricate arrangement of planes that project and recede. In Figure 2, the facades of some of these buildings are displayed.

Figure 2. Buildings in the Ensanche of San Sebastián classified as stone sculptures.

These buildings are notable for their volumetric facade solutions, in which stone plays a significant role due to its distinctive texture and greater material thickness. These innovative architectural designs are part of an international trend that, in the case of the Ensanche, has been contextualized by employing traditional materials. This adaptation achieves a coherent integration in terms of materiality and color, despite its radically contrasting and disruptive forms.

In recent years, two of these buildings have been modified through the installation of ventilated facades, representing 20% of the total in this category (Figure 3). These alterations have affected the facade composition, materiality, and color, leading to a simplification of their design and changes to their architectural characteristics. Such modifications undermine the cultural and architectural heritage value by transforming the buildings and stripping them of their stylistic identity and defining attributes associated with a specific historical period (Figure 4).

Figure 3. Site plan with the unprotected buildings of the Ensanche, the postmodern buildings with unique volumetry, and the San Martín 37 building.

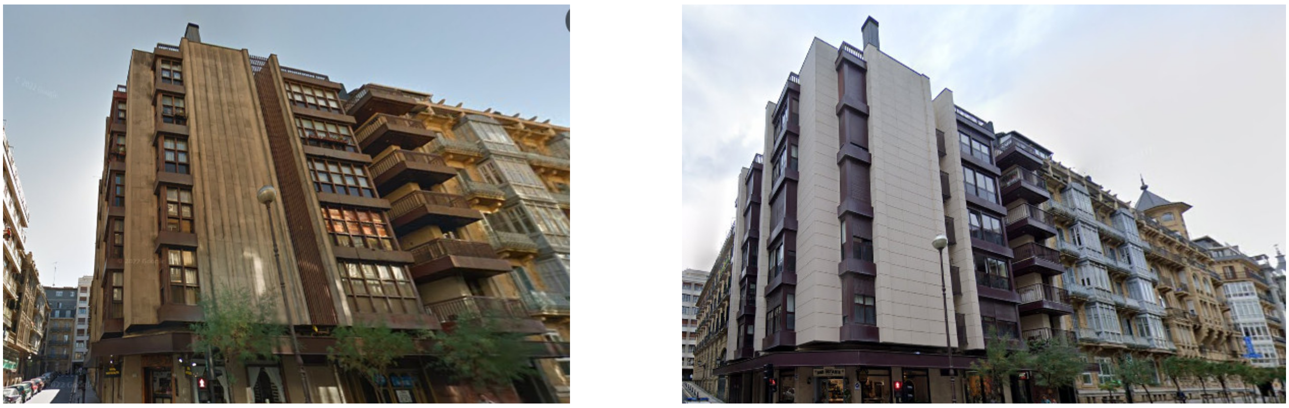

Figure 4. Photograph of the building located on Marina 8 street, prior to facade intervention (2013) and post-intervention (2022). Source: Google Maps.

This article outlines the application of a methodological framework to the building located at 37 San Martín Street in the Ensanche of San Sebastián. This building, constructed in 1976, is situated between two party walls. Its facade is symmetrical and features small balconies that project outward from the facade alignment, along with two viewpoints that harmonize aesthetically with the balconies. The building has been categorized among stone sculptural buildings due to the variety of planes on the balconies and viewpoints, which are inclined at various angles (upward, downward, and vertically along the parapets). The facade is covered with a sandstone veneer, which, despite its modern composition, enables the building to blend into the visual context of the surrounding street complex. Figure 5 illustrates the facade alignment of the building under study.

Figure 5. Building front of the odd numbers of C/San Martín. Case study building located at number 37, framed in a red rectangle. Restitution obtained with the free software Hugin (Hugin 2022.0.0).

3.1. Building Characterization and Building Vulnerability Assessment Case Study

The facade of the case study building has been analyzed according to the established methodology. It features a sandstone veneer with a medium rough texture and reticular detailing. The unique volume of the facade is highlighted by curved elements that extend from the alignment, serving as balcony and viewpoint parapets. The protection for these projecting balconies consists of a portion of the parapet covered with sandstone veneer, complemented by a metal railing that has horizontal elements, topped with a wooden handrail. The carpentry is made of wood, and the blinds are brown. Based on this characterization and the defined scenarios (Figure 6), the facade has been classified as belonging to the category of stone sculptural facades.

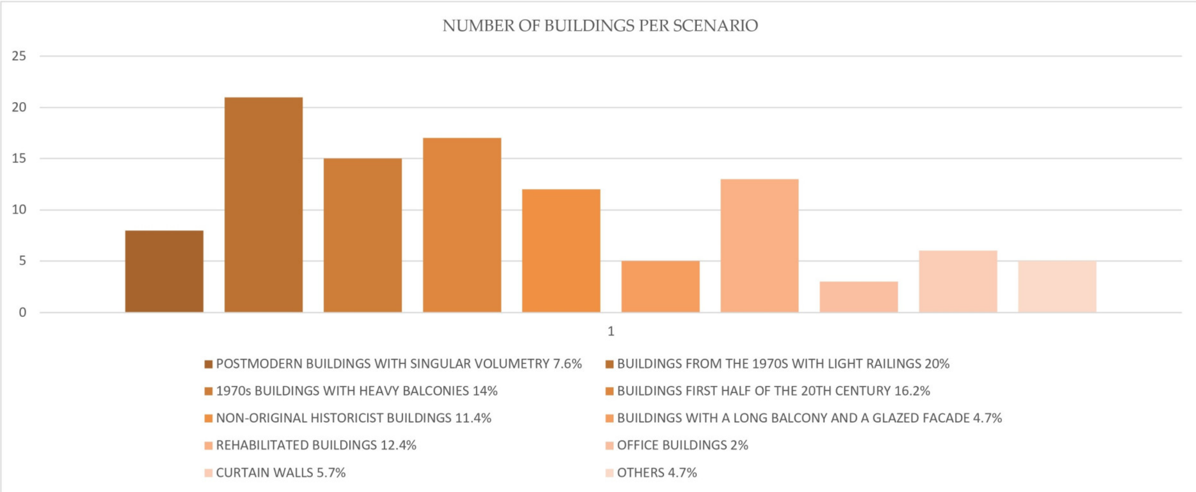

Figure 6. Number of unprotected buildings in the Ensanche classified by scenario.

The identified characteristics facilitated the establishment of parameters to assess the vulnerability of buildings to facade interventions. These parameters are particularly linked to the compositional complexity of the facades. Interventions involving exterior ventilated facades were identified as posing a risk of excessive simplification of the facades and alterations to the overall landscape. For vulnerability assessment, various parameters were considered, including the number of alignments of different planes, the inclinations of the planes, the presence of recessed and protruding elements, and distinctive features such as curved elements, vertical or horizontal moldings, ornamental details, striped textures, and reliefs around openings, among others.

The parameters identified in the analyzed facades were evaluated using a scoring system. Buildings were classified according to their score: those scoring below 2 were categorized as having low vulnerability, scores between 2 and 4 indicated medium vulnerability, and scores above 4 denoted high vulnerability. Figure 7 presents an example of the file created to characterize the building for classification within a specific scenario, along with the file employed to assess its vulnerability.

FACADE	
CLADDING OR FACADE MATERIAL	PLATED OR VENEERED STONE
TEXTURE OF THE FACADE MATERIAL	MEDIUM ROUGHNESS
FACADE MATERIAL EXPLODATION	GRID
COLOR OF THE FACADE CLADDING	SAND COLOR
FACADE VOLUMETRY	SINGULAR VOLUMETRY
CARPENTRY COLOR	NATURAL WOOD
COLOR OF BLINDS OR SHUTTERS	BROWN
BALCONIES AND RAILINGS	
BALCONY TYPE	BALCONY IN FLIGHT
RAILING TYPE	BUILT BALCONY + RAILING
RAILING COLOR	BROWN
FALSE CEILING COLOUR	NATURAL WOOD
SCENARIO AND SUB-SCENARIO	
SCENERY	SCENARIO 1
SUB-SCENARIO	SUB-SCENARIO SANDSTONE

VULNERABILITY DEGREE OF THE BUILDING

CRITERIA	YES/NO	ASSESS
HAS TWO OR MORE PLANE ALIGNMENTS	YES	1
HAS THREE OR MORE PLANE ALIGNMENTS	NO	0
IT HAS PLANES INCLINED UP AND/OR DOWNWARDS	YES	1
IT HAS OUTGOING AND INCOMING DIAGONAL PLANES.	NO	0
IT HAS CURVED ELEMENTS	YES	1
IT HAS VERTICAL STRIPES	NO	0
IT HAS HORIZONTAL MOLDINGS	NO	0
IT HAS POINTUAL ORNAMENTS	NO	0
IT HAS CONSTRUCTION PLANTERS	NO	0
IT HAS RELIEF HOLLOW FRAMES	NO	0
IT HAS A HORIZONTAL STRIPED TEXTURE	NO	0
HAS VERTICAL STRIPED TEXTURE	NO	0
DOES IT HAVE A FLOOR FACADE (WHICH IS NOT A GROUND FLOOR) WITH EXPENSED MASONRY?	NO	0
DOES IT HAVE AN UPPER FLOOR FACADE (WHICH IS NOT A GROUND FLOOR) WITH VIEWED ASHLAR?	YES	3
DOES IT HAVE A GROUND FLOOR FACADE WITH EXPOSED MASONRY?	NO	0
DOES IT HAVE A GROUND FLOOR FACADE WITH VIEWED ASHLAR?	YES	1
TOTAL		**7**

Figure 7. Characterization sheet of a building in the stage and sub-scenario and evaluation sheet of the vulnerability of a building in the stage and sub-scenario of a stone sculptural building.

Consequently, the building under study exhibits a high vulnerability to facade rehabilitation interventions that risk altering its original character. Its design features multiple planar alignments, diagonal protruding and recessed surfaces, horizontal moldings, and curved elements. For these reasons, the installation of a ventilated facade is not advisable. Moreover, due to its sandstone cladding, the application of an ETIS is also not recommended.

Therefore, any insulation intervention should be conducted internally, ensuring the preservation of the facade's defining characteristics.

3.2. Scanning, Modeling, and Rendering Process

Additionally, the objective is to facilitate decision-making through the use of realistic and well-validated images, employing graphic expression as a tool for urban planning processes [37]. The survey of the case study building was conducted by scanning the facade from the exterior. During this process, measurements were taken of the facade's dimensions, including balconies, viewpoints, and window openings. Both color and black-and-white point cloud treatments were applied, and a 360° panoramic view was captured. The initial version of the point cloud was created using a Leica brand scanner, model RTC 360. Figure 8 illustrates the scanning points and the point cloud obtained for the facade of the case study building.

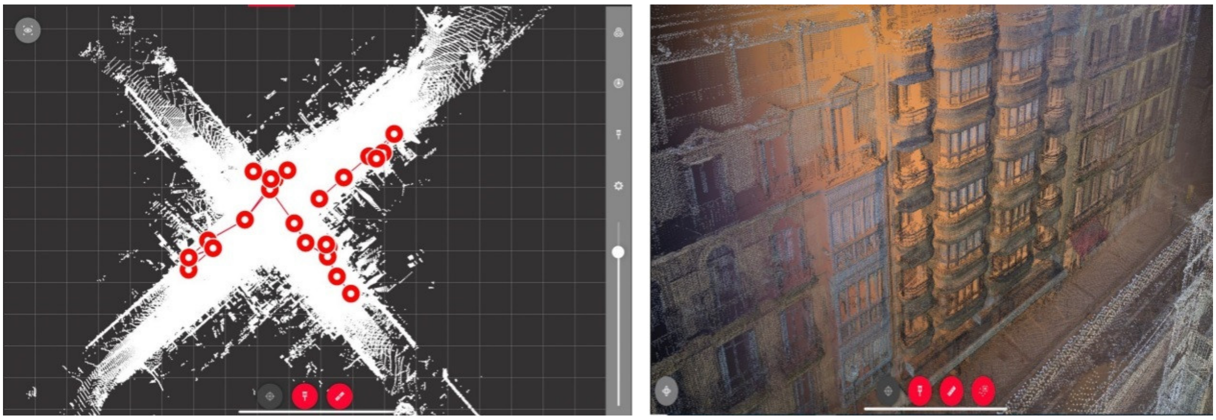

Figure 8. Scanning points at the intersection between Easo and San Martín streets and point cloud obtained for the survey of the facade of 37 San Martín Street.

Prior to the scanning process, comprehensive planning was conducted. Approximately 22 scans were captured, both from the street and from the balconies of a building across the street [38]. Diagonal scans were performed to accurately capture the internal faces of the facade.

After linking and registering the point clouds obtained, they have been imported into Autodesk's Recap software to be able to transfer the cloud to the BIM software.

After linking and registering the obtained point clouds, they were imported into Autodesk's Recap software, which facilitated the transfer of the cloud data to the Building Information Modeling (BIM) software. Autodesk Revit was then used to model the current state of the building and to test new options for ventilated facade coverings. The point cloud in .rcp format, linked to this program, served as the foundation for modeling the facade with the greatest possible fidelity to reality.

The model was rendered to provide realistic colors and textures. Figure 9 illustrates the elevation of the facade extracted from the 3D model created in Revit, alongside the corresponding rendered facade [39,40].

Figure 9. Model of the current state of the facade of the case study in Revit software and rendered image with finishes and textures.

Given that current regulations do not govern facade rehabilitation actions in these types of buildings, several tested solutions have proved inadequate and have caused significant distortions in the environment of the San Sebastián expansion. Based on the existing condition of the building, these interventions have utilized inappropriate materials and oversimplified the sculptural geometry of the facade [41]. Figure 10 illustrates a possible intervention using a standardized white system for the building's envelope.

Figure 10. Simulation of a possible intervention of the envelope with the substitution of material and color and simplification of the geometry; cladding detail on the front of the curved balcony and replacement of metal railings with translucent glass.

The ventilated facade systems used in the simulations mimic the materials most commonly utilized in contemporary interventions, aiming to standardize and economize their use. These materials typically have a uniform appearance and a smooth texture, which starkly contrasts with the materials originally used in the facades. Additionally, current trends in facade materials and carpentry favor pure white and a range of greys, moving away from the sand and raw colors that defined the original buildings.

However, the standardization of materials limits the complexity of the original facade designs. In the case study, the diversity of inclined planes, curved volumes, and other sculptural elements of the facade has been significantly simplified in the proposed intervention. For instance, the upwardly inclined planes and downwardly inclined planes of the balcony parapets have disappeared, and the original curved volumes have reverted to flat, chamfered planes. Furthermore, metal railings with horizontal bars that once offered views into the facade have been replaced with translucent glass railings, introducing a new plane and altering the facade's volume.

It is important to note that for buildings situated between party walls, the area of the blind panels covered by the ventilated facade is often minimal. Most of the facade's surface actually consists of windows and balcony railings. Consequently, the energy efficiency gained through the insulation of these blind panels by adding a ventilated facade is quite limited, as demonstrated in the case study.

Additionally, the effectiveness of the modeling and rendering techniques used to simulate a hypothetical degrading intervention has been assessed. While the generated models are highly realistic and of good quality, rendering programs tend to create a homogenized environment. As a result, buildings undergoing degrading intervention often blend in with their surroundings, leading to idealized representations with diffused lighting that obscure the unique characteristics of the original structures.

3.3. Simulation of Facade Interventions Through Artificial Intelligence

Artificial intelligence (AI) has proven to be an effective tool in the early stages of architectural design, facilitating visualization and decision-making processes [42,43]. The use of technology in built heritage conservation presents specific challenges, particularly for buildings that are not officially protected. The goal is not to create arbitrary changes but to fully understand and respect the cultural, historical, and architectural values of each building. This approach aims to preserve the identity of the location, adhering to guidelines such as those provided by UNESCO for heritage conservation in the digital age [44].

This study compares traditional architectural modeling and rendering methods with various artificial intelligence software. The primary objective is to determine whether the image simulations generated by AI can achieve quality and precision levels similar to those produced by conventional techniques.

The simulations generated with AI have been evaluated based on specific criteria, including the visual quality of the results, fidelity to the original design, and respect for heritage elements. Additionally, the materials and time resources required for producing these simulations have been analyzed and compared to those needed for traditional modeling and rendering. This approach not only assesses the viability of AI platforms in heritage contexts but also identifies their limitations and potential future applications.

In this case study, the capacity of various artificial intelligence (AI) platforms to respond to instructions designed to carry out minimal interventions that preserve the architectural essence of the building under analysis has been examined. Multiple AI platforms were used with a clear and specific prompt requesting a superficial cleaning of the building's facade. The prompt stated the following:

> "I want to edit the photo of a building between party walls. Do not change the shape of the building or its architectural elements. Only modify the sandstone facade. Clean the sandstone so that it looks homogeneous and with a light sand color, as if it had recently been rehabilitated. Do not touch the windows, doors or elements of neighboring buildings."

Despite the precision of the prompt, the results obtained show a recurring tendency for the platforms to make substantial modifications, altering architectural elements or even the overall composition of the building. This behavior suggests limitations in the ability of AI to interpret specific guidelines within the context of heritage interventions, where minimal design is required but extensive knowledge is necessary.

The following section presents examples generated with different platforms, allowing for a comparison of the results and a discussion of the implications of these tools in the practice of architectural conservation (Figure 11). This analysis highlights the need to adjust AI algorithms to ensure that proposed interventions respect heritage values, thereby promoting a more responsible approach to the use of these technologies.

Figure 11. Simulations performed from the image on the left in different AI software (top Archivinci (Cigraph, Milan, Italy), middle Copilot (Microsoft 365 Copilot, 2025), and bottom PromeAI (PromeAI, 2025)).

The necessity of conducting a comparative analysis of various artificial intelligence (AI) platforms designed for generating architectural images is a crucial step in this area of research. In this context, a rigorous study is necessary to evaluate the performance of these tools. Such a study should provide reliable data regarding the time and financial resources required to achieve the desired results. Additionally, it is crucial to compare the outcomes generated by AI with the original project requirements in order to measure the precision and accuracy of the produced images. This analysis would not only enhance our understanding of the current capabilities of AI platforms in architecture but also pave the way for new research avenues aimed at optimizing their use and developing more specific applications in the future.

3.4. Preparation of Intervention Criteria Sheet

Based on the specific scenario and sub-scenario associated with each building, general intervention criteria have been established. These criteria are tailored to each building and documented in specially designed files. After analyzing all scenarios and sub-stages, greater emphasis has been placed on stone sculptural buildings due to their complexity in determining appropriate intervention strategies. The goal has been to systematize the regulatory framework by developing a specific methodology. The creation of this tool involved collaboration with a panel of experts who validated the outcomes. This panel comprised PhD researchers from diverse fields, including architects specializing in construction, rehabilitation, and Building Information Modeling (BIM), as well as historians focused on typological and compositional analysis.

A standardized sheet has been developed and applied to all the buildings analyzed. This sheet was refined following the DSRM, resulting in a final version (Figure 12) that establishes specific intervention criteria for the building in question. The sheet provides detailed recommendations for interventions on the facade's blind panels, railings, and carpentry, specifying parameters such as texture, cutting, color, and volume.

a.21 RESIDENTIAL OF ENSANCHE ANTIGUO EASO18/SAN MARTIN 37

Eugenio Usabiaga Lasa, 1973.

These are two residential buildings, located between party walls, joined on the ground floor, basement and roof, which have a façade on two perpendicular streets (without occupying the chamfer). Both have two basement floors for parking and a ground floor plus seven floors of housing. It is a project by Eugenio Usabiaga from 1973, in which the powerful volumetry of the façade stands out. The composition starts from a base plane of sandstone veneer from which curved balconies and viewpoints composed of various planes, both parallel and inclined, fly. If on San Martín Street there are two parallel viewpoints in the center, flanked by two rows of balconies at the ends, on Easo Street, a single central viewpoint, twice as wide, occupies the entire center of the façade with two rows of balconies on the sides.

In both streets, there is a considerable flight canopy on the ground floor. In addition, there are the commercial premises and the entrance to the garage. The composition of the ground floor uses a completely flat log, with a limestone veneer. In this way, under the canopy, the compositional quality is the flat cloth with a relief veneer and on it the volume emerges in a very striking way.

The original layout is preserved in most of the building. Some of the carpentry and railings are original.

Figure 12. *Cont.*

INTERVENTION CRITERIA

GENERAL INTERVENTION CRITERIA
The present building has a very high vulnerability in a façade rehabilitation due to the risk of suffering a modification that distorts its original character. It has several plane alignments, it has diagonal outgoing and incoming planes, it has horizontal moldings and curved elements. This is why the execution of a ventilated façade is not recommended. Furthermore, since it has a sandstone veneer, the placement of SATE is not recommended either. Therefore, any intervention to insulate the building should be carried out from the inside, trying to maintain the characteristics of the façade.
BLIND FACADE AREA
It is recommended to keep the sandstone of the facade in its original color. It should maintain the original appearance of the facade, texture and joints. The implementation of ventilated façade systems is not recommended, as is the installation of an Exterior Thermal Insulation System (SATE).
OPENING: SILL, MOCHET, LINTEL, TRIM MOLDING
It is recommended to avoid moving the carpentry to the exterior alignment of the façade, with the aim of preserving the setback, maintaining dimensions similar to the existing ones.
CARPENTRY/BALCONIES: DEFENSES (RAILINGS AND WALLS), FALSE CEILINGS, WALL FRONTS
CARPENTRY_ The design should be maintained, including the proportion in elevation of the surface of the profile and glass of the carpentry. The original material or the same tone of existing wood should be maintained (unified in all carpentry, railings, false ceilings and blinds on the façade) and with a similar breakdown. In any case, it is recommended to adopt the same solution on the entire façade. DEFENSE/RAILING_ The design should be maintained. The original material or the same tone of existing wood should be maintained (unified in all carpentry, railings, false ceilings and blinds on the façade) and with a similar breakdown. In any case, the same solution should be adopted on the entire façade. It is recommended not to close balconies with fixed elements and, especially, with translucent and/or colored, reflective or metallic glass. FALSE CEILING/BALCONY SLAB_ The design should be maintained. The same or similar original material should be maintained in the heterogeneous tones of the existing wood (unified in all carpentry, railings, false ceilings and blinds on the façade). In any case, the same solution should be adopted on the entire façade. FORGING FRONTS_ It is advisable to keep them covered by the existing stone veneer.
OTHER ELEMENTS (SUN PROTECTIONS, CANOPIES, CORNICES, ETC.)
BLINDS_ The original material or the same tone of existing wood should be maintained (unified in all carpentry, railings, false ceilings and blinds on the façade). In any case, it is recommended to adopt the same solution on the entire façade.
GROUND FLOOR FACADE COMPOSITION
The configuration of openings, the materiality and the color of the ground floor façade of the building should have a unitary character.

Figure 12. The sheet used to establish the specific intervention criteria for this building.

Given the high vulnerability of all the buildings in this context, the installation of a ventilated facade is not recommended. Furthermore, as the buildings are clad in stone, the use of an ETIS is also deemed unsuitable.

3.5. Presentation to Local Authorities

This work included a phase of collaboration with local authorities through a technical working group. This interaction is vital because public administrations play a crucial role in the protection of cultural heritage [45]. The sessions conducted aimed to highlight the identified issues and propose potential lines of action. The goal of this approach is not only to share the concerns stemming from the study but also to establish a collaborative link with the Department of Urban Planning. This collaboration aims to formulate and implement specific corrective measures for interventions on the facades of the area being analyzed.

3.6. Awareness Plan

The awareness plan focuses on cultural heritage in general while also addressing the specific buildings studied. As a result, no unique actions were implemented for this particular building. The underlying belief is that valuing and protecting cultural heritage should extend beyond individual cases; it should be encouraged as a collective cultural practice. This approach aims to foster broad social awareness that goes beyond specific assets, ultimately establishing a sustainable culture of respect and preservation for heritage as a whole.

Given that this building is highly vulnerable, an educational video was created to highlight buildings with unique volumes, discussing their general characteristics, heritage significance, and the risks of modifications that could compromise their value. This video was shared through dedicated channels on social media (see the link https://www.instagram.com/p/C87n05ZNfuL/, accessed on 2 February 2025). Additionally, an educational article is being written with a more academic focus about this group of volumetric shaped buildings. This article will be published in the most widely circulated newspaper in San Sebastián as part of the awareness strategy.

As part of this effort, a parallel project was developed with Graphic Expression students in the Degree in Technical Architecture program, utilizing active learning methodologies. Additionally, participatory interventions in heritage have taken place, including discussions and debates involving professionals who are directly engaged in facade rehabilitation.

Another strategy for disseminating research is participation in international conferences and publication in high-impact journals. However, defending heritage requires the engagement of society as a whole. Therefore, it is essential to develop strategies that are more aligned with the interests of the local community. To facilitate this, multichannel communication strategies have been established. Digital tools are being utilized to enhance visibility of information related to local heritage and encourage social interactions [46]. A social media account (@ck_armin) has been created to publish educational videos directly related to this research (Figure 13). Furthermore, the project has been featured on regional radio, and educational articles are being developed for local newspapers.

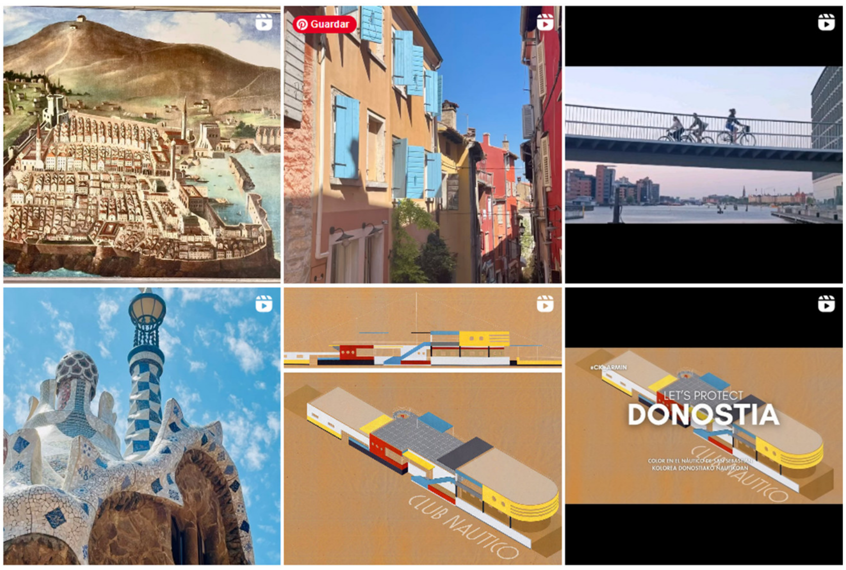

Figure 13. @ck_armin social media account in Instagram.

4. Discussion

In this study, multiple tasks were carried out for the analysis and conservation of unprotected facades, known as "everyday heritage". This research enabled the characterization of different building ensembles, specifically postmodern buildings with a singular singular volumetry. The identification and cataloging of a set of buildings sharing architectural characteristics and similar chronologies facilitate the recognition of their heritage value by integrating them into a common stylistic or typological framework. The inventorying of buildings is a fundamental conservation tool for establishing this value, ultimately leading to their legal protection [47].

A fundamental finding of this research was the successful implementation of a prototype for assessing the vulnerability of facades to modifications that could distort their original character. This tool, based on objective and quantifiable parameters, was validated by a panel of experts, ensuring the robustness and relevance of the developed criteria. Its application to a sample of 105 buildings allowed for the diagnosis of their conservation status and the identification of the most appropriate interventions, reinforcing its utility as an instrument for the management and protection of architectural heritage.

Intervention criteria for these buildings were established. Among the main achievements, the development of a technical sheet stands out, providing clear and consistent parameters to guide interventions from a heritage perspective, complementing technical construction regulations with conservation and restoration criteria.

The results obtained are consistent with previous research highlighting the complexity of protecting architectural heritage due to the multitude of factors involved in this process [48,49]. Furthermore, the findings underscore the need to adopt a methodology that prioritizes limited and periodic interventions to ensure the preservation of built heritage. The systematic inventorying and cataloging of architectural heritage are fundamental processes [50].

The increasing adoption of digital tools for vulnerability assessment confirms a trend towards the incorporation of digital technologies in cultural heritage management [51–55]. However, despite technological advances, the interpretation of digital representations of interventions continues to pose challenges. Several studies have pointed out that limitations in the accuracy of these representations can lead to visual distortions, affecting the proper evaluation of implemented interventions [56,57].

This study represents a significant contribution to the development of methodologies for the conservation of architectural heritage. Both the vulnerability assessment sheet and the intervention criteria sheet have been consolidated as valuable tools, not only for vulnerability evaluation but also for the planning and execution of interventions in buildings of heritage interest.

Moreover, collaboration with the Department of Urban Planning of the San Sebastián City Council demonstrates the direct impact that research findings can have on the public management of urban heritage. Social awareness regarding the protection of architectural heritage was enhanced through activities aimed at both citizens and the educational community [58]. The expansion of the project to a new area of high heritage interest reinforces the replicability and validity of the developed methodological model.

Despite the achievements, this study presents several limitations. First, the need for specific knowledge to use the prototype restricts its applicability to non-specialized users. Second, the digital representations generated by the digital twin, while useful, require extensive post-production work to ensure a faithful representation of potential interventions.

The methodology employed was validated in a sample of 105 unprotected buildings in the Ensanche, of which only 10 were originally postmodern buildings with matching unique or singular volumetry, and two of them had already been altered at the beginning of this research. This limited representation of such a scenario constitutes a restriction of the study, highlighting the need to expand the sample and apply the methodology in other neighborhoods. Expanding the sample will not only strengthen the validity of the criteria used but also allow for the evaluation of their applicability in diverse urban contexts.

The results of this research have important implications for the conservation of unprotected architectural heritage. The intervention sheets have been consolidated as key tools for defining clear and coherent criteria for the protection of heritage buildings.

Furthermore, continued research on improving the digital representation of interventions is essential to ensure an accurate and realistic assessment of their effects. In this regard, significant advances are expected in future studies with the use of artificial intelligence and its rapid development.

Finally, collaboration with public institutions and the expansion of the project to other areas open up new lines of research that will allow for the validation and refinement of the developed methodological model, strengthening its role as a comprehensive tool for the management and conservation of urban heritage.

5. Conclusions

This research has confirmed the architectural and heritage significance of the analyzed buildings, particularly the group of structures from the 1970s to which the case study pertains. Additionally, this study has identified the key factors that contribute to the vulnerability of buildings to facade rehabilitations that compromise their identity [59].

The tools and processes employed to assess the impact of interventions and establish clear protection criteria have been validated. This study also underscored the importance of the technical sheet as a critical instrument for guiding interventions that respect the distinctiveness of facades.

The findings highlight the necessity of protecting this category of buildings from indiscriminate interventions, emphasizing their contribution to the local architectural identity and their harmonious integration with the environment. These results have the potential to be extrapolated to similar buildings, providing a foundation for future research on postmodern heritage.

This study focused on an area of Ensanche characterized by relative architectural homogeneity, featuring a high proportion of protected buildings that collectively define a strong identity, alongside unprotected structures grouped into ten generic architectural styles. While this delimitation facilitated a focused analysis, it also represents a methodological limitation. It is therefore essential to extend this approach to areas with greater typological and architectural diversity. Broadening the scope will enable the validation of the findings and the refinement of the developed methodologies.

Furthermore, the simulations conducted proved to be effective analytical tools, despite requiring substantial investments of time and effort. Future research should incorporate simulations powered by artificial intelligence to evaluate and compare both traditional and AI-based systems in terms of result quality, operational efficiency, and cost-effectiveness. This approach has the potential to enhance both the accuracy of analyses and the practicality of their implementation.

This research has opened new avenues for the protection and valorization of architectural heritage. The comprehensive characterization of Ensanche buildings has highlighted the necessity of conducting a chromatic study, encompassing both protected properties and those without such classification. This analysis is crucial for recommending and potentially establishing regulations regarding the application of colors on Ensanche facades, ensuring visual harmony and respect for the historical and urban context.

Moreover, the findings underscore the importance of extending this chromatic analysis to other areas of the city. Such an approach will form a robust foundation for developing specific recommendations in the technical sheets for architectural interventions, ensuring these guidelines are grounded in rigorous aesthetic and heritage criteria. Incorporating this methodology into future research will significantly contribute to the creation of more comprehensive and contextually informed urban and heritage policies.

This study also confirms the urgent need to disseminate research findings to society, thereby enhancing awareness and engagement among all stakeholders, including citizens, rehabilitation professionals, and public administrations. The analysis demonstrates that regulatory protections for certain buildings are critical for minimizing damage during facade interventions. However, gaps remain that must be addressed to ensure comprehensive protection. Everyday heritage, which embodies the collective memory of our cities, continues to be marginalized in the agendas of involved stakeholders.

To address this issue, it is essential to diversify and expand dissemination efforts through channels such as newspapers, radio, and social media, while maintaining educational and informational initiatives in universities and technical forums. The protection of built heritage begins with fostering collective consciousness. The preservation of both the buildings and the cultural identity embedded within them can only be achieved through sustained and coordinated efforts.

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