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Beyond the Factory Town: Sustainable New Uses and Cultural Continuity of Olivetti's Architectural Heritage in Ivrea, Italy

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Abstract

Adaptive reuse is increasingly central to the conservation and enhancement of twentieth-century architectural heritage, where contemporary functions and regulatory requirements must be reconciled with architectural and cultural values. This study investigates how these demands are reconciled in four buildings of different scales, spatial configurations, and original functions within the UNESCO World Heritage site "Ivrea, Industrial City of the 20th Century". A qualitative multiple-case study was carried out through archival and bibliographic research, architectural drawings, technical documentation, direct observation, and interviews. For each case study, the original configuration (T0) was systematically compared with the post-reuse current configuration (T1). The resulting transformations were assessed through a common interdisciplinary framework comprising eight indicators related to spatial and functional adaptability, social and urban impacts, heritage integrity and conservation, and environmental and technological performance. The cross-case analysis identified recurring strategies and context-specific differences in the adaptive reuse process. The findings suggest that continued use of contemporary heritage buildings depends not only on the preservation of their material fabric, but also on the capacity of reuse interventions to accommodate new or renewed programs without undermining the buildings' spatial structure, constructional logic, architectural identity, and relationship with their wider urban context. The study therefore conceptualizes cultural continuity as a multidimensional condition encompassing material, spatial, functional, social, and territorial dimensions, and provides an operational framework for critically evaluating adaptive reuse interventions in modern architectural heritage.

Keywords: adaptive reuse; contemporary architectural heritage; industrial heritage; sustainable restoration; energy efficiency in heritage buildings; architectural conservation; building performance upgrading; UNESCO World Heritage; Olivetti architecture

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1. Introduction

The transformation of the existing building stock is a central component of European climate and energy policies. Buildings account for nearly 40% of final energy consumption in the European Union and are responsible for approximately 36% of its CO_2 emissions [1–3], which contribute substantially to climate change [4–6]. The 2015 Paris Agreement reinforced the European commitment to decarbonizing the building sector by assigning a central role to energy efficiency and supporting the objective of reducing greenhouse gas emissions by 80–95% compared with 1990 levels [2,7].

Buildings constructed during the second half of the twentieth century account for approximately 45% of the existing European building stock [8] and represent a particularly critical component of modern architectural heritage. Many were designed according to construction practices, technical standards, and functional models that no longer satisfy current requirements for energy efficiency, environmental comfort, safety, and accessibility [9]. Their limited insulation, air-permeable envelopes, and technically obsolete systems have made them primary targets for renovation. Interventions frequently focus on envelope optimization [10,11] and may reduce energy consumption by up to 70% [12,13].

The upgrading of modern architectural heritage nevertheless involves two opposing risks. The relatively late recognition of its cultural significance has often led to extensive alteration or replacement without sufficient consideration of architectural quality, material characteristics, or energy performance [9]. Integral reglazing, complete façade replacement, and extensive internal reconfiguration may improve particular technical parameters while altering the material and spatial features through which the significance of contemporary architecture is expressed. Conversely, highly restrictive conservation approaches, often derived from practices developed for much older historic buildings, may prevent the modifications required to improve energy performance, comply with current regulations, meet contemporary comfort standards, and accommodate new functions. The adaptive reuse of contemporary architecture therefore requires an approach capable of preserving significant features while enabling the transformations necessary for continued occupation.

Within this debate, adaptive reuse has increasingly emerged as a conservation and design strategy that addresses the preservation of heritage values alongside the transformations required to accommodate new or continued use. Plevoets and Van Cleempoel [14,15] position adaptive reuse at the intersection of architectural design and heritage conservation, examining intervention strategies through typological, technical, and architectural perspectives and, more broadly, framing the transformation of existing buildings as an emerging field of architectural practice.

More recently, Arfa et al. [16] conceptualize adaptive reuse as a structured process aimed at preserving heritage values while adapting buildings to present uses and transferring them to the future. Their ten-step model links building analysis and heritage-value assessment to the identification of reuse potential, design strategy, implementation, maintenance, and subsequent evaluation. These issues are particularly relevant to twentieth-century architectural heritage, whose conservation increasingly depends on its capacity to accommodate change. Henket [17] argues for extending the conservation of Modern Movement heritage beyond the restoration of canonical works towards the reuse and transformation of the broader modern building stock, linking this approach to a circular mindset of reuse, reduction, and recycling. Tostões [18] similarly identifies material and technological reuse, spatial and functional transformation, and adaptation to changing regulatory and socio-cultural conditions as central challenges in the conservation of modern architecture. From a design perspective, Kuipers and de Jonge [19] place the assessment of tangible and intangible heritage values at the basis of conservation and transformation strategies, emphasizing the relationship between continuity and change and the role of research-based design in reconciling heritage significance with continued use. Research has increasingly addressed architectural conservation, functional adaptation, and energy upgrading as interconnected components of adaptive reuse. Existing studies have developed methods addressing cost-optimal renovation, energy modeling, economic feasibility, environmental impacts, and the assessment of heritage values. However, these dimensions are still frequently examined through separate disciplinary frameworks, and their integration remains particularly challenging in twentieth-century architectural heritage. Much of the available literature concerns older historic buildings [20–23], although buildings constructed between 1940 and 1990 offer considerable potential for reducing energy consumption [4]. Energy performance, architectural conservation, functional compatibility, social value, and economic feasibility are also often assessed separately, despite their close interdependence in reuse processes.

The challenge becomes more complex when modern heritage forms an extensive urban and territorial system rather than consisting of an isolated building. The decline or reorganization of industrial production has left a substantial legacy of factories, offices, welfare facilities, and workers' housing whose original functions have disappeared or been significantly reduced. In these contexts, cultural significance is expressed through the relationships among architecture, productive activities, social services, residential areas, open spaces, infrastructure, and the surrounding territory. The transformation of individual buildings consequently affects the interpretation and continuity of the wider historical, social, and spatial project to which they belong. This broader perspective is particularly important for industrial heritage, whose significance extends beyond the material characteristics of individual buildings. Industrial sites embody historical, technological, architectural, social, and cultural values and act as repositories of collective memory and place identity. Liu et al. [24], for example, identify social life, sense of belonging, historical memory, cultural influence, and the relationship with the surrounding context among the dimensions through which the social value of industrial heritage can be assessed. Adaptive reuse consequently involves not only the conservation of physical fabric but also the continuity or reinterpretation of the social and cultural relationships associated with former productive environments. More recent research has further expanded this perspective. Mehan [25] frames adaptive reuse as a form of heritage-led urban regeneration rather than as a building-scale intervention alone, relating the reuse of industrial heritage to circular resource use, urban resilience, social inclusion, cultural continuity, and community-oriented regeneration, emphasizing that its long-term sustainability depends on the capacity to preserve historical and social narratives while responding to contemporary urban needs. From this perspective, the reuse of industrial heritage concerns not only the conservation of physical fabric, but also the possibility of reactivating the cultural and relational values embedded in former productive landscapes. This raises the broader question of cultural continuity through processes of transformation. In heritage studies, cultural continuity has been associated with the persistence of cultural values and meanings through processes of change. Nasser [26] relates cultural continuity to the integration of cultural values into contemporary conservation and regeneration, thereby sustaining the meaning of historic places over time. Building on this perspective, cultural continuity is understood here as the capacity of adaptive reuse to sustain or coherently reinterpret over time the cultural significance of a heritage place and the relationships through which it is expressed. In the context of this study, this concept is examined through the continuity of material, spatial, functional, and social relationships, recognizing that these dimensions may persist, change, or be reinterpreted to different degrees through adaptive reuse.

Ivrea provides a particularly relevant case for examining these issues. Located in the Piedmont region of northern Italy, the city became the main center of the Olivetti company during the twentieth century and the setting for an extensive program of industrial, architectural, urban, and social experimentation promoted by the entrepreneur Adriano Olivetti. Between the 1930s and the 1960s, some of the most prominent Italian architects and urban planners designed factories, administrative buildings, research facilities, welfare services, cultural spaces, and housing for the company's employees.

In 2018, this urban and architectural system was inscribed on the UNESCO World Heritage List as "Ivrea, Industrial City of the 20th Century" [27]. The site extends over more than 71 hectares and includes 27 buildings and architectural complexes, almost en-

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tirely under private ownership (Figure 1). Its significance does not derive exclusively from the architectural quality of individual works; it lies in the material expression of an integrated industrial, urban, economic, and sociocultural project in which production, welfare, housing, and territorial development were conceived as interdependent components.

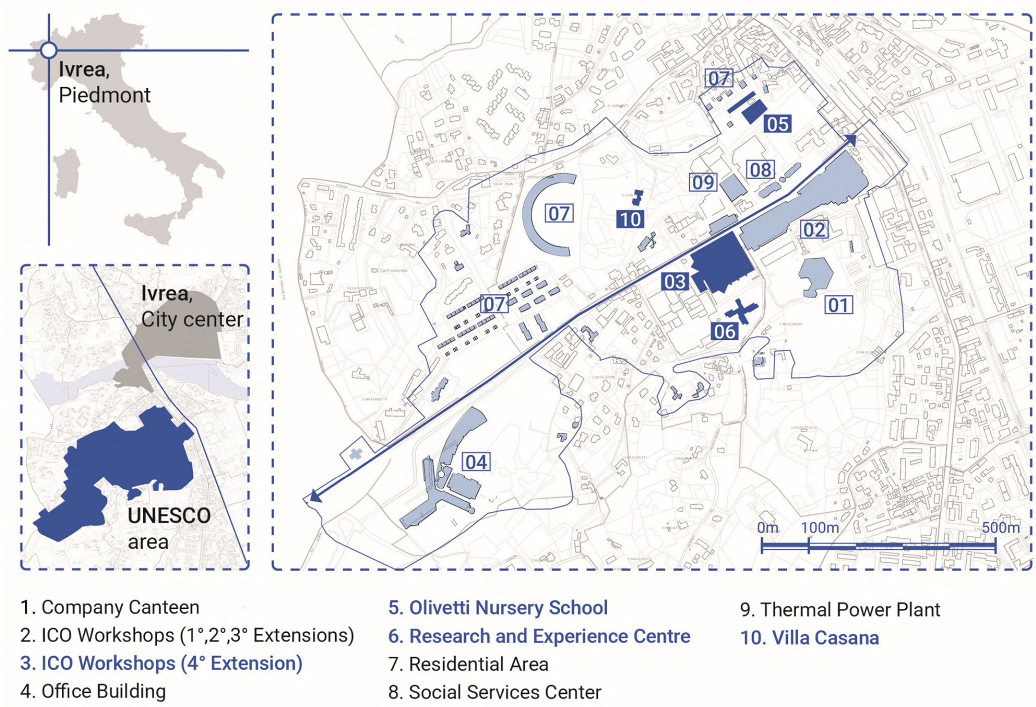

Figure 1. Territorial framework of the UNESCO World Heritage Site "Ivrea, Industrial City of the 20th Century". Source: elaboration by the authors.

The value of the site is closely connected to the economic and social program from which its architecture emerged. Ivrea became the spatial manifestation of the policies promoted by the *Movimento Comunità*, founded in the city in 1947 and inspired by Adriano Olivetti's reflections on a political and administrative order based on the concept of community [28]. Within this model, the factory was conceived as the economic foundation of the community and as the center of a wider network of social and cultural relations. Industrial production was therefore embedded within a broader project concerned with workers' welfare, collective services, cultural development, and territorial organization.

The financial and organizational resources of the Olivetti company enabled the translation of these principles into concrete architectural and urban interventions. Ivrea consequently became an experimental setting for twentieth-century debates on industrialization, social organization, and urban development. The city was transformed through the gradual insertion of industrial, residential, educational, social, and cultural facilities into the existing urban fabric and the surrounding productive landscape. This process distinguishes Ivrea from other industrial sites included in the World Heritage List. It cannot be classified as a conventional company town because it was not constructed ex novo according to a predetermined relationship between factory and settlement. The Olivetti system was progressively integrated into an existing city over approximately thirty years. Ivrea also differs from utopian and philanthropic industrial communities because it resulted from the concrete implementation of an economic and social program that supported industrial development throughout the second half of the twentieth century.

The cultural significance of Ivrea therefore depends on the relationships among its buildings, open spaces, infrastructure, productive history, and territorial context. The UNESCO site must be interpreted as a unitary system rather than as a collection of autonomous architectural objects. This interpretation is particularly relevant to its current conservation and transformation, since the site's continuity depends on identifying new uses that remain compatible with the architectural, spatial, social, and cultural values embedded in the original Olivetti project.

The decline and restructuring of the Olivetti production system led to the disappearance of many of the original functions of the non-residential buildings. Several properties subsequently experienced abandonment, underuse, or progressive deterioration. Their recovery is particularly complex because of their scale, morphology, construction systems, spatial organization, and environmental performance. These buildings were designed according to standards of comfort, safety, accessibility, and energy efficiency established more than fifty years ago. Their adaptation to contemporary uses may therefore require substantial functional, spatial, technical, and energy efficiency interventions, often involving significant economic resources.

This condition creates a critical relationship between architectural conservation and performance upgrading. The buildings are recognized works of contemporary architecture with considerable historical, cultural, and design value. Their long-term preservation, however, depends on their ability to support viable functions and meet current requirements for accessibility, safety, comfort, and environmental performance. Legal recognition and heritage protection can prevent inappropriate alterations, but they do not resolve the conditions that contribute to vacancy or underuse.

The extent and territorial distribution of the Olivetti heritage reinforce this challenge. The identification of appropriate uses cannot be treated exclusively as a design problem concerning individual properties. Each intervention takes place within a wider system whose significance derives from relationships among buildings with different original functions and scales.

Despite the growing literature on modern heritage and adaptive reuse, limited attention has been paid to how different reuse processes affect individual components of a unitary industrial and territorial system. Existing research frequently examines conservation, energy upgrading, or functional adaptation at the scale of the single building. Less systematic consideration has been given to how different degrees of functional and material transformation affect cultural continuity and the continuing role of individual buildings within a broader heritage network. A further gap concerns the comparative analysis of reuse strategies that range from continuing the original function to introducing entirely different or mixed programs.

This study addresses these gaps through a comparative analysis of four buildings within the Olivetti architectural heritage in Ivrea, as thoroughly described in Section 2. The selected case studies include the Olivetti nursery school designed by Luigi Figini and Gino Pollini; the research and experience center designed by Eduardo Vittoria; the fourth extension of the ICO Workshops, also known as the former turnery; and the Villa Casana Olivetti administrative office building. The cases do not represent the entire UNESCO site, nor are they treated as autonomous examples detached from their urban context. Three research questions guide the analysis:

1. How do different degrees of functional continuity influence the spatial adaptation and intervention intensity required to accommodate contemporary uses in the selected Olivetti buildings?
2. How do adaptive reuse interventions negotiate heritage conservation with technological and environmental upgrading, and what trade-offs emerge in relation to authenticity, architectural legibility, and building performance?

3. How is cultural continuity maintained or reinterpreted across reuse trajectories characterized by different degrees of material transformation and functional continuity within the wider Olivetti heritage system?

The study's original contribution lies in comparing four distinct adaptive reuse trajectories within the same integrated heritage system. Rather than assessing the success of the interventions exclusively in terms of physical conservation or functional occupation, the paper examines the relationships among necessary transformation, architectural compatibility, and continuity of use.

2. Materials and Methods

This study adopted a qualitative multiple-case study design to investigate the adaptive reuse of contemporary architectural heritage within the urban and territorial system of Ivrea. The UNESCO site was considered the contextual case, while the four Olivetti buildings constituted the units of analysis. The research followed a four-stage workflow: (1) case-study selection, (2) data collection, (3) case study analysis, (4) cross-case evaluation.

2.1. Case Study Selection

The cases were selected through purposive sampling based on two groups of criteria. The first concerned the architectural and historical significance of the buildings. Eligibility was established through one or more of the following conditions:

- Recognition in historical or systematic studies of modern architecture;
- Publication in national or international architectural journals;
- Relevance to the development of Italian architectural culture;
- Contribution to the evolution of a building type;
- Experimentation with materials, construction technologies, spatial organization, or environmental systems;
- Authorship by recognized architects; and architectural significance within the urban context.

The second group of criteria concerned the comparative aims of the article. The selected cases provide variation in:

- Original and current functions;
- Building type and scale;
- Degree of functional continuity;
- Spatial and structural configuration;
- Intensity of material and technical transformation;
- Collective and cultural role;
- Relationship with the wider Olivetti system;
- Availability of historical and post-intervention documentation.

The resulting sample represents four distinct reuse trajectories, enabling the comparison of different degrees of functional continuity, spatial adaptation, program diversification, and intervention intensity across buildings that share the same cultural and productive history.

2.2. Data Collection

Data collection was based on the triangulation of documentary, graphic, bibliographic, observational, and testimonial sources. Depending on availability in each case, the materials examined included the following sources:

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- Primary sources: original documentation derived from archival records, historical photographs, conversations, interviews, site visits, photographic surveys (direct); official project documentation, administrative documents, catalogs, bibliographies (indirect).
- Secondary sources: research reports, scientific literature.
- Tertiary sources: based on the processing of secondary sources, such as dissemination articles derived from research reports.

Archival research was carried out mainly at the Olivetti Historical Archive Association (AASO) in Ivrea, which provided access to several collections including Fondo Annibale Fiocchi, Fondo Ludovici, Fondo Berengo Gardin, Fondo Egidio Bonfante, Fondo Direzione Servizi e Formazione, Catalogo Mostra "costruire la città dell'uomo", Raccolta documentale Giovanni Maggia, Fondo Ottavio Cascio, Fondo Architettura (Ex Zorzi).

Qualitative evidence was collected through four guided open-ended expert interviews conducted between March and May 2026. Participants were purposively selected for their knowledge of the buildings and documented involvement in the project's design, use, or management. The interviews were guided by the case-study analysis sheet developed before data collection, which covered the building's original condition and use (T0), subsequent transformations (T1), project objectives, regulatory and conservation constraints, functional requirements, technical choices, and modifications introduced during construction. The interview format remained flexible, allowing the sequence and depth of the questions to vary according to each participant's expertise. Interviews were conducted either in person or online. They were not audio-recorded, as the researchers took contemporaneous notes and subsequently consolidated them into written records. The four key informants were (i) an architect formerly working in the Olivetti technical office, with direct knowledge of the buildings during earlier phases of their use and transformation; (ii) an architect associated with the Olivetti family, who provided personal and family-based testimony concerning the history and subsequent transformations of the four buildings; (iii) the representative of the association responsible for the enhancement of the UNESCO heritage, based within the Nuova ICO complex; and (iv) the engineer responsible for the recent intervention performed on the Olivetti nursery school. Informal conversations with users encountered at Nuova ICO and Villa Casana were treated separately as contextual evidence and were not included in the four formal interviews. Interview evidence was cross-checked against drawings, technical reports, archival sources, and direct observation. It was treated as testimonial and interpretative evidence rather than as independent verification of building performance.

The collected information was organized through two standardized records developed within the broader research project.

- Sheet A: documenting the *ante operam* configuration and the post-reuse condition of each building based on the architectural and technical characteristics.
- Sheet B: recording the functional, spatial, material, and technical actions undertaken during recovery and reuse.

2.3. Case Study Analysis

Each case was analyzed through the comparison of two temporal conditions:

- T0—Original configuration: the building as initially designed and constructed, establishing the building's significance within the Olivetti heritage;
- T1—Transformations and current configuration: the condition resulting from the recovery and adaptive reuse process examined in the study.

This two-stage framework was applied consistently to all four cases. Earlier extensions, alterations, damage, and changes in use were considered when necessary to reconstruct the history of the buildings and distinguish the effects of different interventions. However, they were not classified as a separate analytical phase. For both T0 and T1, the analysis recorded authorship and date, function, spatial organization, structural configuration, envelope characteristics, materials and architectural details, passive environmental systems, active technical systems, external spaces, and relationships with the wider Olivetti complex. Information derived from incomplete or conflicting sources was marked as uncertain and was not used to support definitive conclusions.

2.4. Case Study Evaluation and Comparison

Each building was first evaluated independently by systematically comparing its original configuration (T0) with its post-reuse or current configuration (T1). The interventions responsible for the transformation were then classified in a common matrix using the same functional, spatial, architectural, technological, and cultural criteria across all four cases. The criteria, described in Table 1, integrate three complementary perspectives corresponding to the objectives and specific conditions of adaptive reuse: (i) the capacity of the intervention to accommodate renewed functional and social requirements; (ii) the conservation of the architectural and cultural significance of the existing heritage; and (iii) the capacity of the transformed building to respond to contemporary user and environmental requirements. Accordingly, the eight assessment dimensions do not derive from a single pre-existing evaluation system but integrate criteria originating from adaptive reuse objectives, conservation theory, and the Italian performance-based approach to building requirements. This integrated structure is also consistent with recent sustainable conservation approaches, which emphasize that environmental upgrading should be evaluated alongside its effects on heritage significance and through transparent, multidisciplinary assessment frameworks [29].

Spatial configuration assesses whether the existing spatial system can accommodate new or renewed functional requirements through improved usability, accessibility, adaptability of building services, and functional flexibility. Programmatic social impact assesses the potential of the reuse program to support collective use, inclusiveness, and social, urban, and cultural reactivation, based on documented changes in accessibility, functional openness, user profiles, and public or cultural activities rather than on measured post-occupancy outcomes.

Conservation and enhancement evaluate the transformation against established conservation principles, including compatibility, reversibility, distinguishability, minimum intervention, and the preservation and enhancement of the site's architectural character, with reference to the principles set out in the Italian Charter of Restoration (1972). Identity continuity was introduced specifically to operationalize the concept of cultural continuity examined in this study, distinguishing the persistence or coherent reinterpretation of material, spatial, and functional–social relationships.

User well-being, Energy efficiency, Environmental impact, and Resource circularity derive from the Italian performance-based approach to building requirements established by UNI 8289:1981 and subsequently extended towards environmental sustainability and rational resource use by UNI 11277:2008 [30]. Within this framework, User well-being addresses indoor air quality and thermal, visual, and acoustic comfort; Energy efficiency examines documented measures affecting envelope and energy performance; Environmental impact considers the interaction between the intervention and environmental resources through water use, soil permeability, and carbon emissions; and Resource circularity addresses the preservation and efficient use of material resources through maintainability, repairability, material sourcing, recycling and recyclability, and construction and supply-chain strategies. Energy efficiency and environmental impact were assessed qualitatively based on documented design measures, technical specifications, and implemented upgrades. Quantitative design parameters are reported where available as supporting evidence. However, the absence of consistent pre- and post-intervention operational datasets across the four case studies precluded comparative calculations of energy consumption, carbon emissions, and post-occupancy environmental performance. Within the assessment framework, cultural continuity is operationalized through the Identity continuity dimension, which examines material, spatial, and functional–social continuity between T0 and T1. These criteria do not assume that continuity requires the unchanged preservation of each component but allow for their coherent reinterpretation where this maintains the cultural significance of the building.

The cross-case comparison identified recurring strategies, differences associated with building type and use, relationships between functional continuity and intervention intensity, features that facilitated or constrained adaptation, and conflicts between conservation and contemporary performance requirements.

Table 1. Assessment framework and indicators used to analyze the transformations of the case studies from their original configuration (T0) to their post-reuse or current configuration (T1). The indicators integrate criteria drawn from environmental and technological design, architectural conservation, and architectural design and composition.

Class	Indicator
Spatial configuration	Improvement of spatial usability Enhancement of spatial and building services adaptability Improvement of universal accessibility Enhancement of functional flexibility
Programmatic social impact	Strengthening of stakeholder participation and inclusiveness Contribution to urban regeneration Contribution to social regeneration Enhancement of cultural and social capital
Conservation and enhancement	Compatibility of the intervention Reversibility of the intervention Legibility and distinguishability of the intervention Principle of minimum intervention Enhancement of genius loci
Identity continuity	Material continuity Spatial continuity Functional and social continuity
User well-being	Improvement of indoor air quality Improvement of thermal comfort Improvement of visual comfort Improvement of acoustic comfort
Energy efficiency	Thermal bridge mitigation Condensation prevention Improvement of the thermal performance of the building envelope Reduction in energy consumption
Environmental impact	Water use efficiency Increase in soil permeability Reduction of carbon emissions
Resource circularity	Maintainability Repairability Use of locally sourced materials Use of recycled materials Use of recyclable materials Optimization of construction and supply chain logistics

3. Results

3.1. Case Study 1. The Fourth Extension of the ICO Workshops

T0—Original configuration. The fourth extension of the ICO Workshops, known as *Nuova ICO*, designed by Luigi Figini and Gino Pollini and constructed between 1955 and 1958, represents the fourth extension of the Olivetti industrial complex along Via Jervis (Figures 2–5).

Figure 2. General information on the fourth extension of the ICO Workshops. Source: elaboration by the authors.

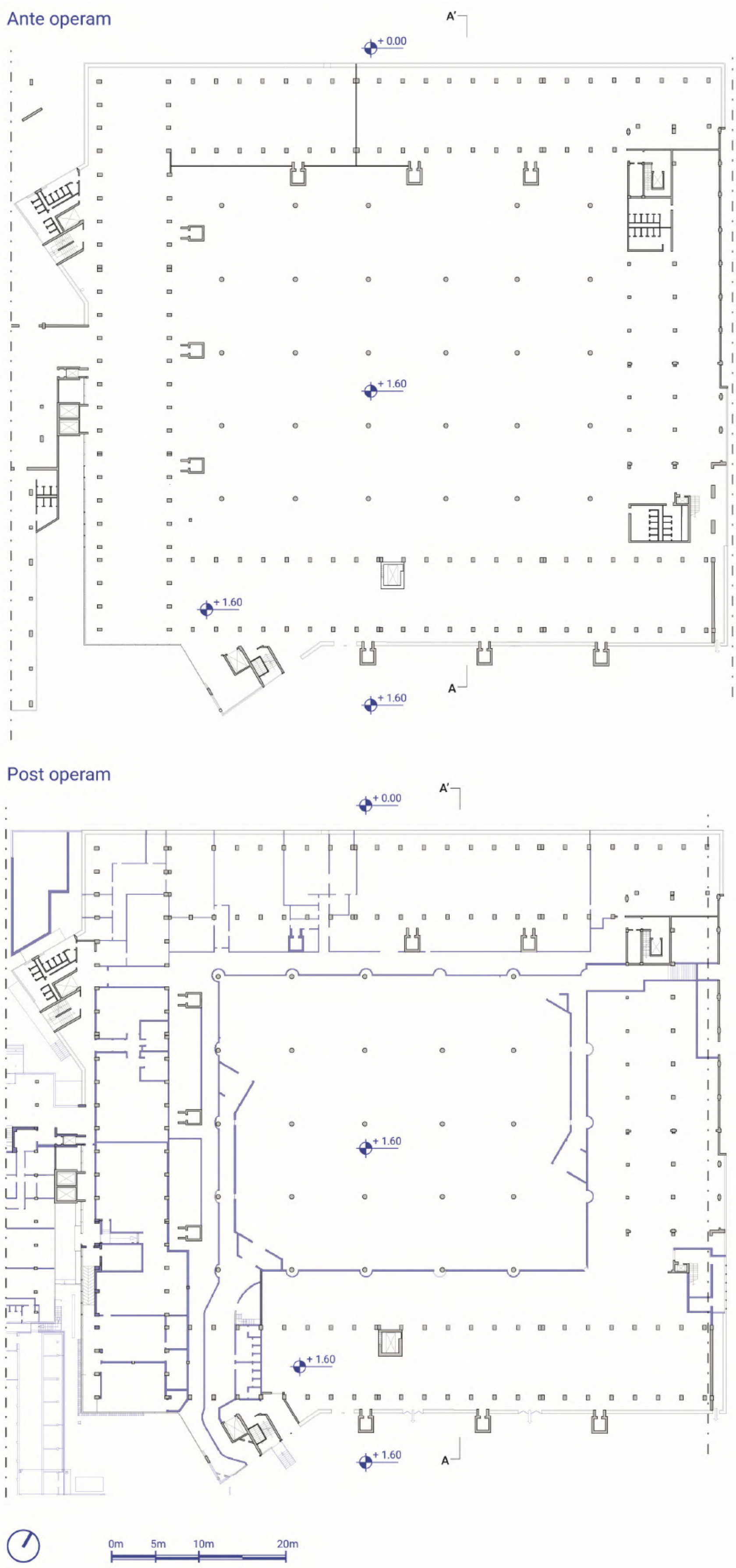

Figure 3. Original and current floor plan configurations of the fourth extension of the ICO Workshops, with transformations highlighted in blue. Source: elaboration by the authors.

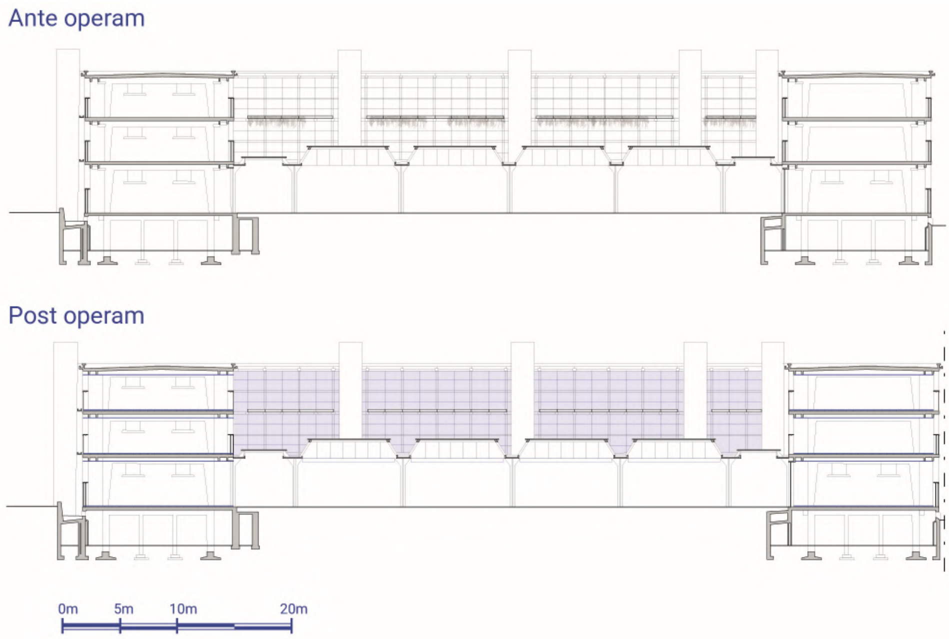

Figure 4. Original and current section of the fourth extension of the ICO Workshops, with transformations highlighted in blue. Source: elaboration by the authors.

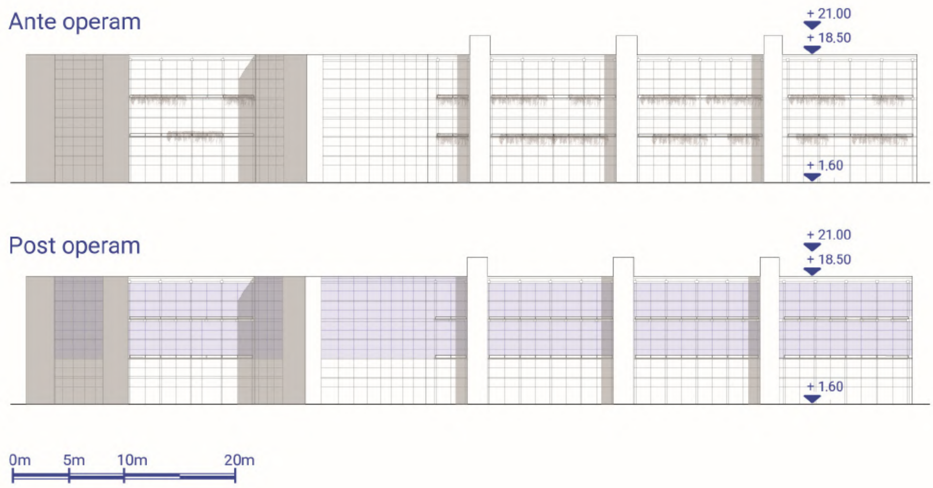

Figure 5. Original and current elevation of the fourth extension of the ICO Workshops, with transformations highlighted in blue. Source: elaboration by the authors.

The project completed the existing production frontage by adding three new factory buildings connected to the third expansion and organized around a large central courtyard [18]. Compared with the previous extensions, the building introduced a new organization of the production cycle. The large industrial halls were no longer conceived as completely undifferentiated spaces but were instead assigned to specific manufacturing phases. Assembly activities were accommodated within the main production blocks. At the same time, mechanical processing was located in the area later known as the former machine shop *ex Torneria*, covered by the saw-tooth steel roof designed by Eduardo Vittoria [28].

The building comprises one basement level and three stories above ground. The ground floor has a greater floor-to-floor height to accommodate the main production departments, whereas the upper levels were designed for manufacturing activities requiring lower internal clearances. To ensure completely unobstructed production areas, staircases, service cores, and part of the building services were concentrated within independent triangular-plan volumes positioned outside the main building footprint and clad with grey clinker tiles.

The building services were also organized according to a principle of separation between served spaces and service distribution areas. Vertical service networks were housed within square-section service towers clad in yellow ceramic tiles, located along the central courtyard and secondary elevations, and directly connected to the underground tunnel system that distributed utilities throughout the entire industrial complex.

The load-bearing structure consists of reinforced concrete portal frames with an 11.40 m structural grid, providing large-span spaces free of intermediate supports. Two pairs of longitudinal beams house the air-conditioning system ducts, while reinforced-concrete brackets support the curtain wall façade system.

The building envelope further develops the glazed façade concept adopted in the previous extensions by introducing a double-skin façade. The elevation consists of two layers of glazing separated by a naturally ventilated cavity containing Venetian blinds for solar shading. The increased number of vertically sliding sash windows enhances the natural ventilation of the cavity and contributes to the regulation of the indoor microclimate [31].

Compared with the earlier buildings of the complex, the curtain wall adopts a more articulated configuration. A projecting perimeter beam protects the glazed surfaces from weather exposure, while continuous reinforced concrete planters interrupt the linearity of the façades facing the internal courtyard and the secondary elevations. By contrast, the continuity of the glazed frontage along Via Jervis is preserved, reinforcing the unified architectural identity of the entire industrial complex [32].

T1—Transformations and current configuration. The gradual decommissioning of industrial production led to the loss of the building's original function and initiated a multi-phase adaptive reuse process (Figures 2–5). A pivotal event in this transformation was the 1986 fire, which affected the second floor without causing irreversible damage to the reinforced concrete structural frame.

Subsequent interventions primarily focused on strengthening the reinforced-concrete portal frames and the roof slab, thereby enabling the building's recovery while preserving its original structural system.

The most substantial modifications concerned the building envelope. The original double-skin façade was replaced with a curtain wall system incorporating thermally broken aluminum frames and high-performance energy-efficient glazing. While the spacing of the mullions, the proportions of the glazed panels, and the color of the framing members were preserved, the second glazing layer, the naturally ventilated cavity, and the integrated solar-shading system were removed. In addition, some of the original vertically sliding windows were replaced with tilt-and-turn units, altering the building's original natural ventilation strategy.

The building's environmental performance was also fundamentally redefined. Whereas indoor environmental control had originally relied on the ventilated double-skin façade and passive solar regulation, thermal comfort is now ensured through low-emissivity glazing and a four-pipe HVAC system installed on the roof and distributed throughout the building via fan-coil units.

The adaptive reuse process also involved a comprehensive reconfiguration of the internal layout. The large open-plan production halls were subdivided into a modular arrangement organized around central corridors to accommodate offices, educational facilities, and service areas. Building services were upgraded through the installation of raised access floors and continuous suspended ceilings, allowing the distribution of electrical, ICT, and mechanical systems without altering the primary structural framework.

The internal courtyard and the former machine area *ex Torneria* also underwent extensive rehabilitation. The industrial space was converted into a multifunctional venue for cultural, educational, and conference activities while preserving Eduardo Vittoria's characteristic saw-tooth steel roof and the workshop's original spatial configuration.

Today, the building accommodates a diverse mix of functions, including administrative offices, university and professional training facilities, commercial activities, service spaces, a fitness center, and an auditorium. The redistribution of these new uses extends throughout the entire building, replacing the former single-purpose industrial organization with a mixed-use configuration that integrates professional, educational, cultural, and recreational activities.

The intervention primarily transformed the building's technological systems and functional organization while leaving its structural framework, volumetric composition, and overall façade configuration largely unchanged. The most significant changes concern the performance of the building envelope, the mechanical systems, and the internal spatial organization, all of which were upgraded to accommodate the building's new program and patterns of use.

3.2. Case Study 2. Olivetti Nursery School

T0—Original configuration. The Olivetti nursery school was designed by Luigi Figini and Gino Pollini and constructed between 1939 and 1941 as part of the company's social services program to support its employees (Figures 6–9). The building was one of the earliest facilities within the welfare system established by the company. It formed part of a broader corporate welfare program that would, in subsequent years, extend to several aspects of community life [33].

The building was located at the edge of the new residential district planned by the same architects. It was designed to accommodate both nursery and preschool functions, with an overall capacity of approximately 150 children. The functional program included classrooms, playrooms, a dining hall, kitchens, medical and administrative rooms, staff accommodation on the raised level, and service areas, laundry facilities, storage rooms, and the boiler room in the basement.

All spaces intended for children were arranged on a single level, eliminating internal changes in floor elevation and limiting the use of staircases. The rooms were organized around a sequence of patios and open spaces that provided natural lighting, ventilation, and continuity between indoor and outdoor environments. The classrooms opened directly onto the courtyards through large floor-to-ceiling glazed surfaces, protected by canopies and shading systems that reduced direct solar exposure during the summer months [34].

Outdoor space formed an integral part of the educational program. In addition to the internal courtyards, the complex included a play area on the rear slope, equipped with a pergola, a shallow pool, planted areas, sandpits, and covered spaces for outdoor activities. The plan configuration and arrangement of the open spaces provided a high degree of separation from the surrounding road network and supported continuity between educational activities and the outdoor environment [35].

From a construction perspective, the building is characterized by *opus incertum* rubblestone masonry, combined with stone piers and a continuous reinforced-concrete beam that defines the upper edge of the building. A brick lining, separated from the external masonry by a narrow cavity, was installed along the inner faces of the perimeter walls to improve thermal insulation. The roof structure consists of prefabricated concrete beams. At the same time, the classroom openings comprise large, glazed units with horizontally sliding panels in the lower section and fixed and top-hung elements in the upper section, allowing the natural ventilation of the rooms [36].

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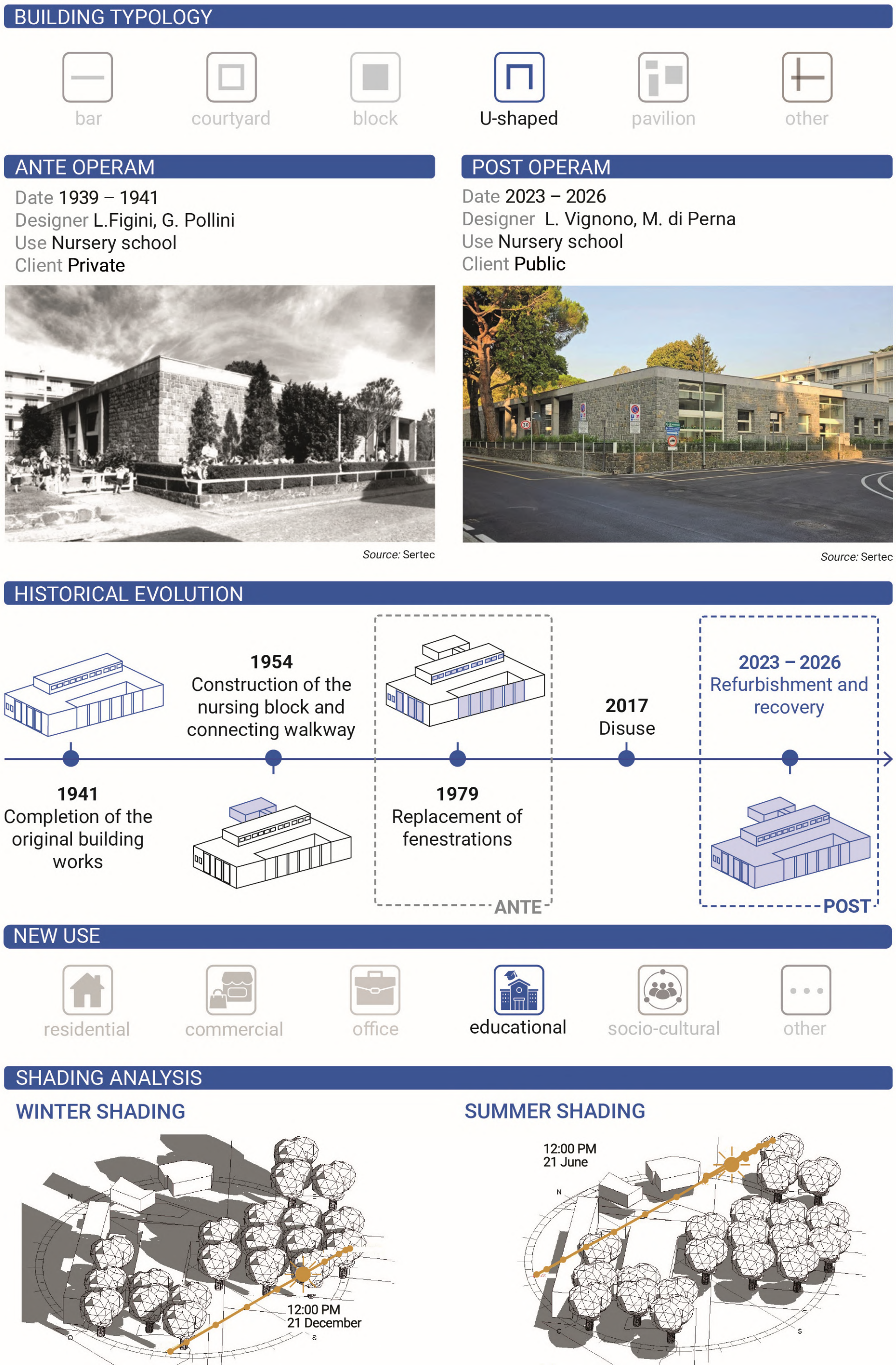

Figure 6. General information on the former Olivetti nursery school. Source: elaboration by the authors.

Finishing materials were selected according to the use of the different spaces. Linoleum-cork flooring was installed in the areas occupied by children, while ceramic flooring was used in the service rooms. The furniture, designed by the Olivetti Technical Office, formed an integral part of the building's spatial organization.

In 1952, the complex was extended through the construction of a small building for healthcare services. The addition adopted the same materials and compositional principles as the nursery school, maintaining architectural and constructional continuity with the main building.

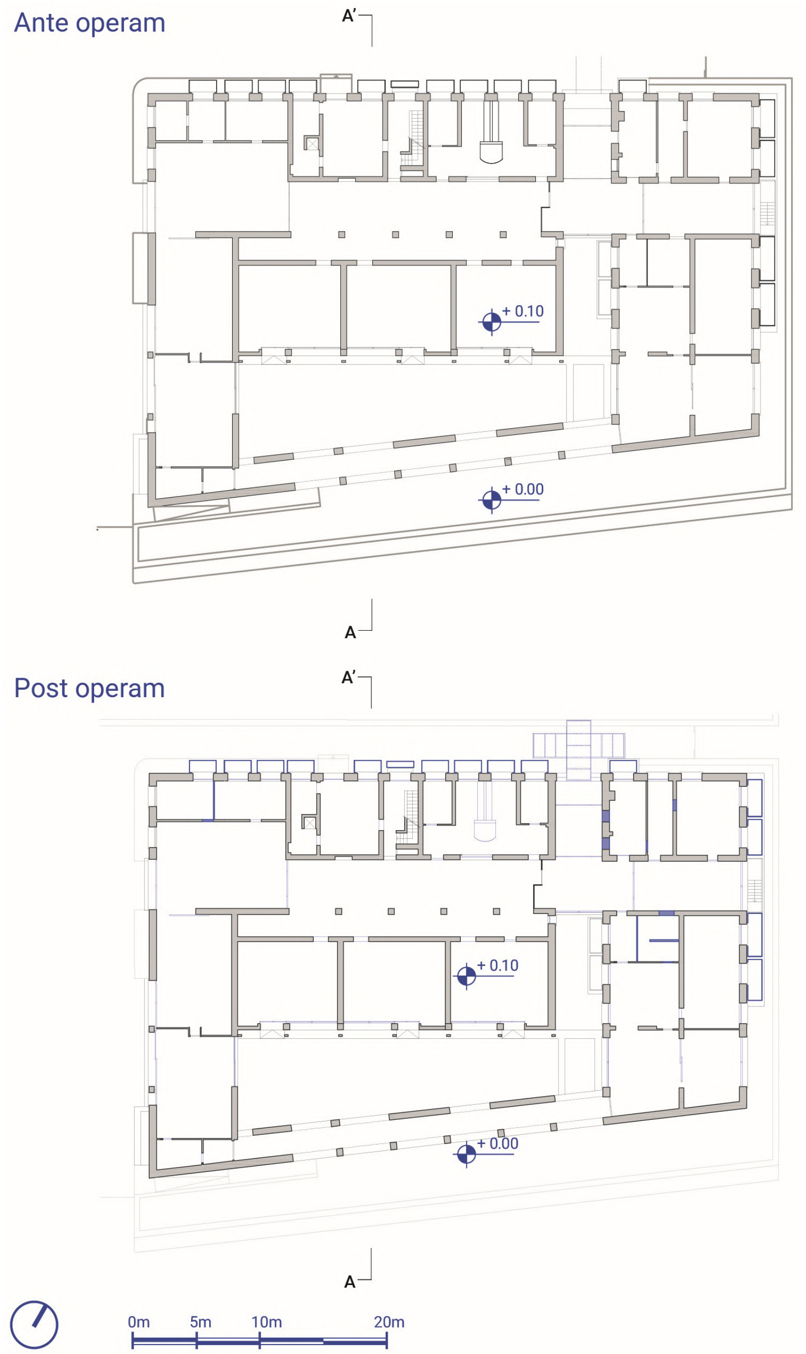

Figure 7. Original and current floor plan configurations of the former Olivetti nursery school, with transformations highlighted in blue. Source: elaboration by the authors.

T1—Transformations and current configuration. During the second half of the twentieth century, the building retained its original function and was primarily subject to maintenance works and building services upgrades. Among the most significant interventions were the replacement of the original windows with PVC frames and the installation of an independent natural gas-fired heating plant, required following the decommissioning of the district heating network previously supplied by the industrial complex.

In 2017, the building was closed because it no longer complied with current safety and accessibility regulations. In 2025, a conservation-led restoration and regulatory upgrading program was initiated through funding provided by the Italian National Recovery and Resilience Plan (PNRR) to restore the building's functionality while preserving its original educational use (Figures 6–9).

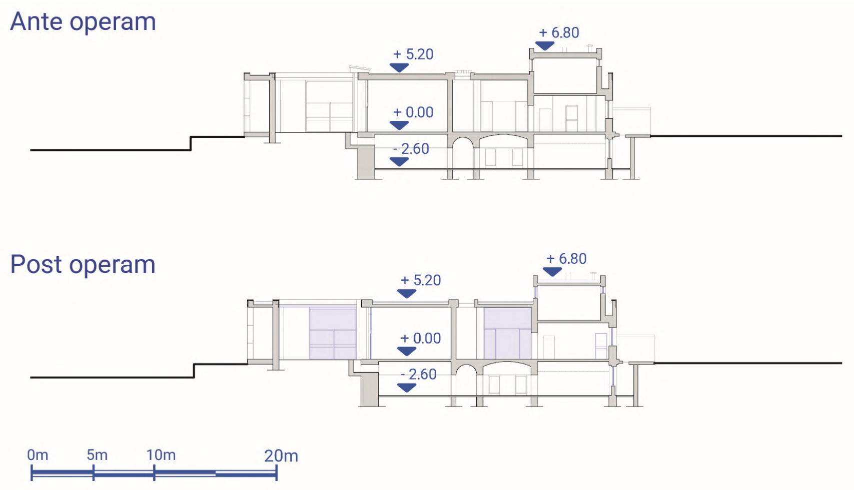

Figure 8. Original and current section of the former Olivetti nursery school, with transformations highlighted in blue. Source: elaboration by the authors.

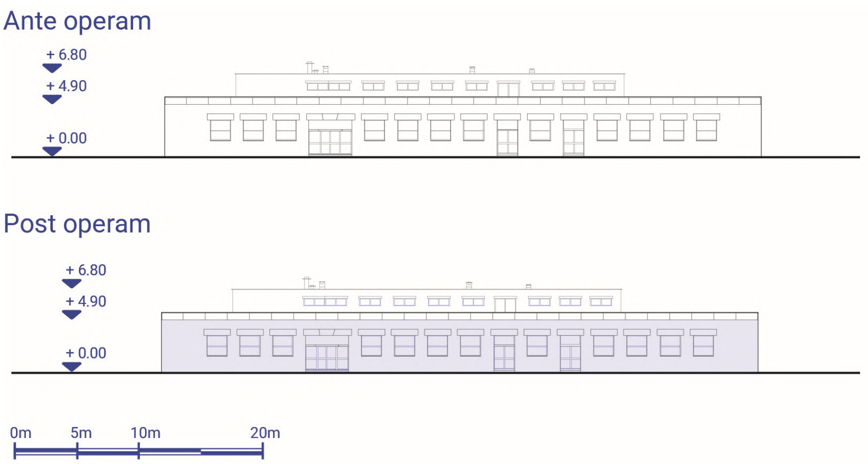

Figure 9. Original and current elevation of the former Olivetti nursery school, with transformations highlighted in blue. Source: elaboration by the authors.

The intervention primarily focused on improving the roof's thermal performance by installing high-performance insulation and replacing the waterproofing system, along with installing a photovoltaic array. To minimize the impact on the historic façades, no external wall insulation was introduced, and the existing window frames were retained, favoring localized interventions compatible with the building's original construction and architectural character.

The upgrade of the building services included the installation of new heating, ventilation, air conditioning, and fire protection systems, along with the technological infrastructure required to comply with current regulations. The new services were integrated within the existing building fabric while limiting alterations to the original structure. In contrast, the seismic strengthening works were carried out primarily from the basement level, minimizing interference with the educational spaces.

The intervention also included the restoration of the external façades, metalwork, historic boundary fences, and landscaped areas. Additional works involved replacing the courtyard shading devices with new mechanized systems, upgrading the external lighting, and rehabilitating the green areas, preserving both the existing mature trees and the original landscape layout. The playgrounds and outdoor spaces retained the overall configuration established by Figini and Pollini's original design, with modifications limited to deteriorated elements or those no longer compliant with current safety standards.

Unlike the other case studies, the adaptive reuse process of the Olivetti Nursery School did not involve a change in the building's original function. The interventions primarily focused on performance upgrades, safety improvements, energy retrofitting, and modernization of the building services, while preserving the original spatial organization and the relationship between the indoor environments and the outdoor spaces, which remain defining characteristics of the original design.

3.3. Case Study 3. The Research and Experience Center

T0—Original configuration. Eduardo Vittoria designed the Olivetti research and development center between 1951 and 1954 to accommodate the research, design, and development of new Olivetti products (Figures 10–13). Unlike the production buildings designed by Luigi Figini and Gino Pollini, the new facility was conceived as an autonomous building dedicated to design activities, physically separating research from manufacturing operations [37].

The building is located uphill from the industrial complex along Via Jervis, adjacent to the canteen designed by Ignazio Gardella. It is organized around a plan consisting of four asymmetrical wings arranged around a central circulation core. The latter accommodates the main staircase, lifts, freight elevators, and service rooms, thereby freeing the four wings from internal service functions. The varying wing widths, ranging from approximately 9 to 12 m, accommodated different design departments within a modular spatial framework that could be readily reconfigured to meet changing operational requirements [38].

The internal layout comprised individual offices overlooking the terraces together with large open-plan spaces dedicated to design activities. The basement accommodated laboratories, storage rooms, and specialized facilities for acoustic testing, including an anechoic chamber and, subsequently, a reverberation chamber. The main entrance was on the eastern elevation, with a large glazed wall leading into the central distribution hall. In contrast, the service entrance was located on the opposite side adjacent to the loading and unloading area.

The load-bearing structure consists of a reinforced concrete frame expressed externally through perimeter columns and edge beams that define the rhythm of the façades. The infill walls are slightly recessed with respect to the structural frame, creating a narrow shadow line that emphasizes the distinction between the load-bearing structure and the external enclosure.

The building envelope is characterized by glazed blue clinker tile cladding combined with the exposed reinforced concrete frame, originally finished in white. The windows, manufactured in cast iron and painted dark red, contribute to the building's chromatic composition together with the horizontal spandrel bands, glazed surfaces, and ceramic finishes [32].

Particular attention was devoted to natural lighting. The limited depth of the building wings and the extensive glazed surfaces ensured high levels of daylight within the working areas. At the same time, the central circulation core was illuminated by a perspex skylight protected by glass blocks and supported by a steel structure. Daylight entering through the roof was distributed into the circulation spaces through fully glazed internal partitions, eliminating the need for artificially lit internal areas.

Artificial lighting also formed an integral part of the architectural design. Vittoria designed bespoke indirect lighting fixtures integrated into the building, contributing to the visual quality of the working environment. The heating and air-conditioning systems were supplied by the industrial power plant through the technological tunnel running beneath Via Jervis, according to the centralized energy distribution system serving the entire industrial complex [39].

https://doi.org/10.3390/su18189248

Figure 10. General information on the Olivetti research and experience center. Source: elaboration by the authors.

T1—Transformations and current configuration. The first transformations involved the extension of the building without altering its original compositional scheme. In 1965, Ottavio Cascio extended the eastern wing by two structural bays to accommodate additional design spaces, adopting the same materials, colors, and construction techniques as the original building. Between 1966 and 1968, the basement of the western wing was enlarged through the construction of a reverberation chamber adjacent to the existing anechoic chamber. Both interventions were fully integrated into the original composition and are scarcely distinguishable from the initial building fabric.

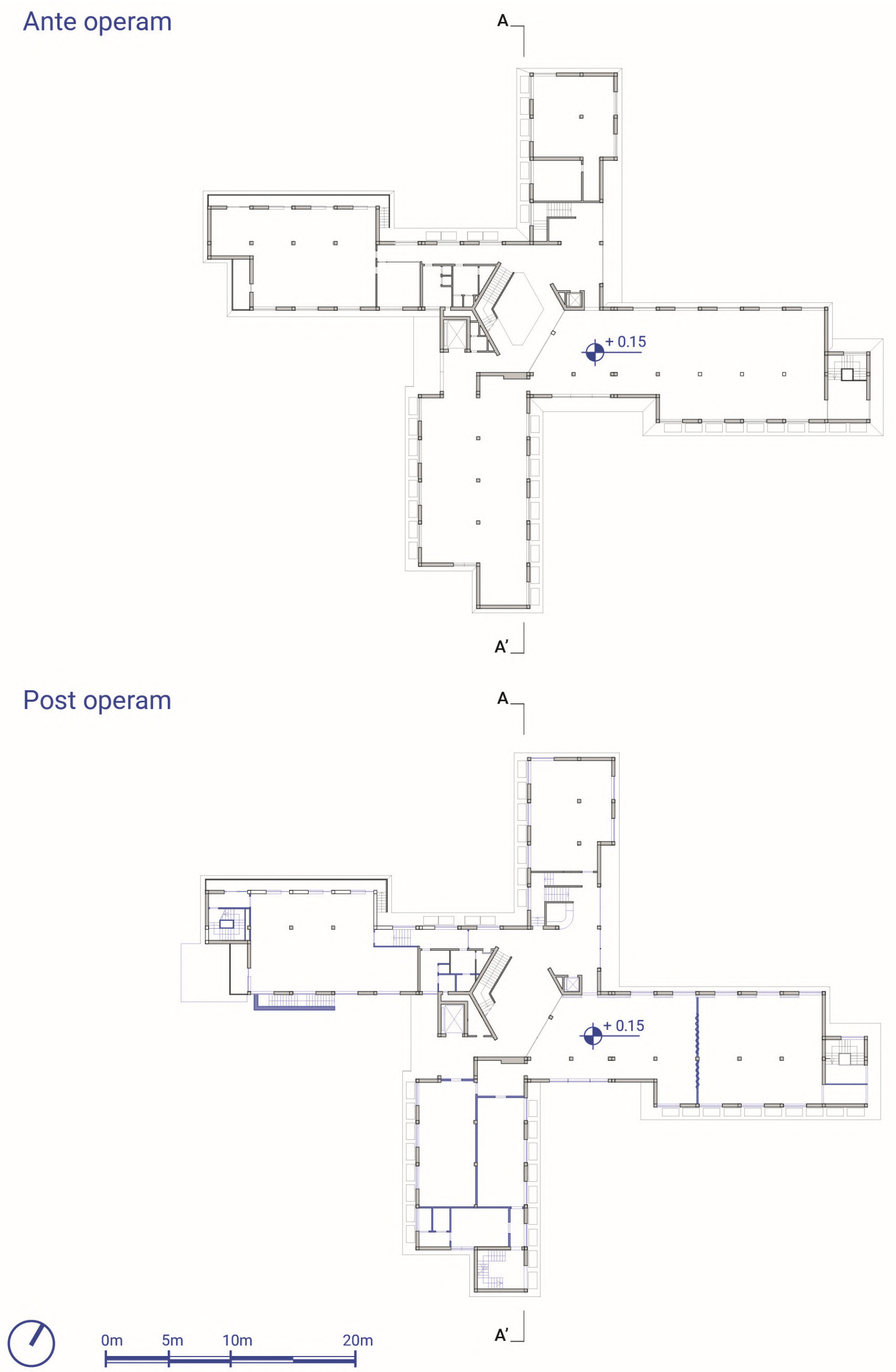

Figure 11. Original and current floor plan configurations of the Olivetti research and experience center, with transformations highlighted in blue. Source: elaboration by the authors.

Subsequent interventions primarily addressed compliance with evolving building regulations. During the late 1980s, the parking areas were enlarged, and new external fire escape staircases were constructed. These additions were positioned away from the principal façades to minimize their visual impact on the architectural composition.

The most significant transformation took place between 1999 and 2000, when the building underwent an adaptive reuse process to accommodate an international school dedicated to interaction design (Figures 10–13). The new functional program required a comprehensive upgrading of the internal spaces and technological systems while preserving the building's original volumetric configuration.

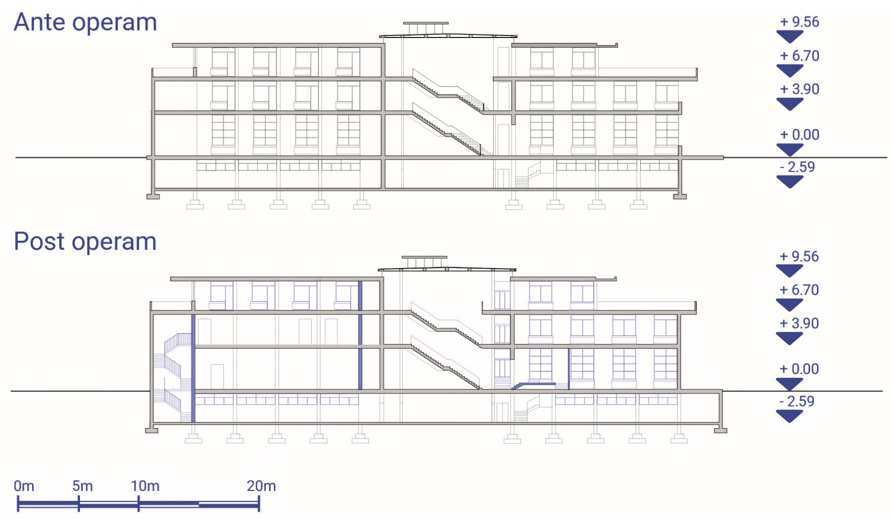

Figure 12. Original and current section of the Olivetti research and experience center, with transformations highlighted in blue. Source: elaboration by the authors.

Figure 13. Original and current elevation of the Olivetti research and experience center, with transformations highlighted in blue. Source: elaboration by the authors.

The intervention mainly affected the interior through the installation of sound-absorbing suspended ceilings to accommodate new building services, the refurbishment of the sanitary facilities, the upgrading of escape routes, and the installation of a new heating, ventilation, and air-conditioning system distributed by means of fan-coil units positioned beneath the windows. At the same time, thermal insulation was installed along the internal faces of the perimeter walls and beneath the roof structure without altering the building's external appearance.

The building envelope also underwent conservation and performance upgrading works. The original cast-iron windows were replaced with thermally broken aluminum frames while retaining their distinctive red finish. The glazed clinker tile cladding was restored by replacing deteriorated units with new tiles matching the original dimensions and color. The originally white horizontal spandrel bands were refinished with grey exposed aggregate, while the metal flashings along the terraces were replaced with stainless steel elements.

The intervention also modified selected architectural features within the building. The sinuous balustrade of the main staircase was partially screened with additional panels to comply with current safety regulations, while the original handrail was replaced with a new metal element. The perspex skylight and the glazed roof above the staircase were also restored, preserving the original top-lighting system.

The building has progressively changed its function, evolving from a research and design center to educational facilities, then to office accommodation, and more recently to spaces dedicated to digital innovation. Despite the successive functional and technological adaptations, the load-bearing structure, plan configuration, circulation system, and overall architectural character have remained substantially unchanged. The principal transformations concerned the upgrading of the building envelope, the integration of new building services, and the adaptation of the internal spaces to accommodate changing patterns of use, while preserving the compositional and constructional principles established by Eduardo Vittoria's original design.

3.4. Case Study 4. Villa Casana

T0—Original configuration. Villa Casana was constructed between 1880 and 1890 as a private residence on the summit of Montefiorito hill. The original building, developed over two stories above ground, was characterized by load-bearing stone and exposed brick masonry, a steeply pitched French-style roof with dormer windows, and an internal layout typical of late nineteenth-century residential architecture. The Villa was set within an extensive park and connected to Via delle Miniere by a private carriage road that formed an integral part of the original landscape design.

The acquisition of the property by Olivetti in 1952 marked the beginning of the building's transformation, initially intended to accommodate the company's Architectural Office. Between 1953 and 1954, Annibale Fiocchi, with structural engineer Antonio Migliasso, designed a vertical extension that fundamentally altered the relationship between the historic building volume and its roof. The original pitched roof was replaced by a flat reinforced brick-concrete roof supported around its perimeter by slender cylindrical reinforced concrete columns. At the same time, a continuous ribbon of steel-framed single-glazed windows visually separated the new roof slab from the existing masonry walls below. The intervention left the principal façades of the lower two stories largely unchanged, concentrating the transformation on the uppermost part of the building.

The new roof also performed a structural function through a reinforced concrete perimeter ring beam that tied together and stiffened the existing load-bearing masonry walls. Thermal insulation was achieved by means of a suspended ceiling incorporating a ventilated air cavity of variable depth. At the same time, the projecting roof overhang protected the continuous glazed ribbon against direct solar radiation.

In 1957, Ottavio Cascio completed the functional adaptation of the Villa to its new administrative use through the construction of an external steel staircase enclosed within a fully glazed façade, connecting the first and second floors (Figures 14–17). At the same time, the internal layout was reorganized, the representative spaces were enlarged, and new service rooms were introduced. In 1958, a lift was installed, while the heating system was connected to the industrial power plant through the technological distribution network serving the Olivetti industrial complex. These interventions completed the transformation of the nineteenth-century residence into an administrative building while preserving the original spatial framework of the Villa [32].

T1—Transformations and current configuration. After successively accommodating administrative functions, educational activities, and healthcare services, Villa Casana underwent a comprehensive adaptive reuse process between 1987 and 1988 to accommodate the Olivetti Historical Archive Association (Figures 14–17). This intervention represents the most significant transformation in the building's recent history, simultaneously affecting its internal layout, building services, structure, and building envelope.

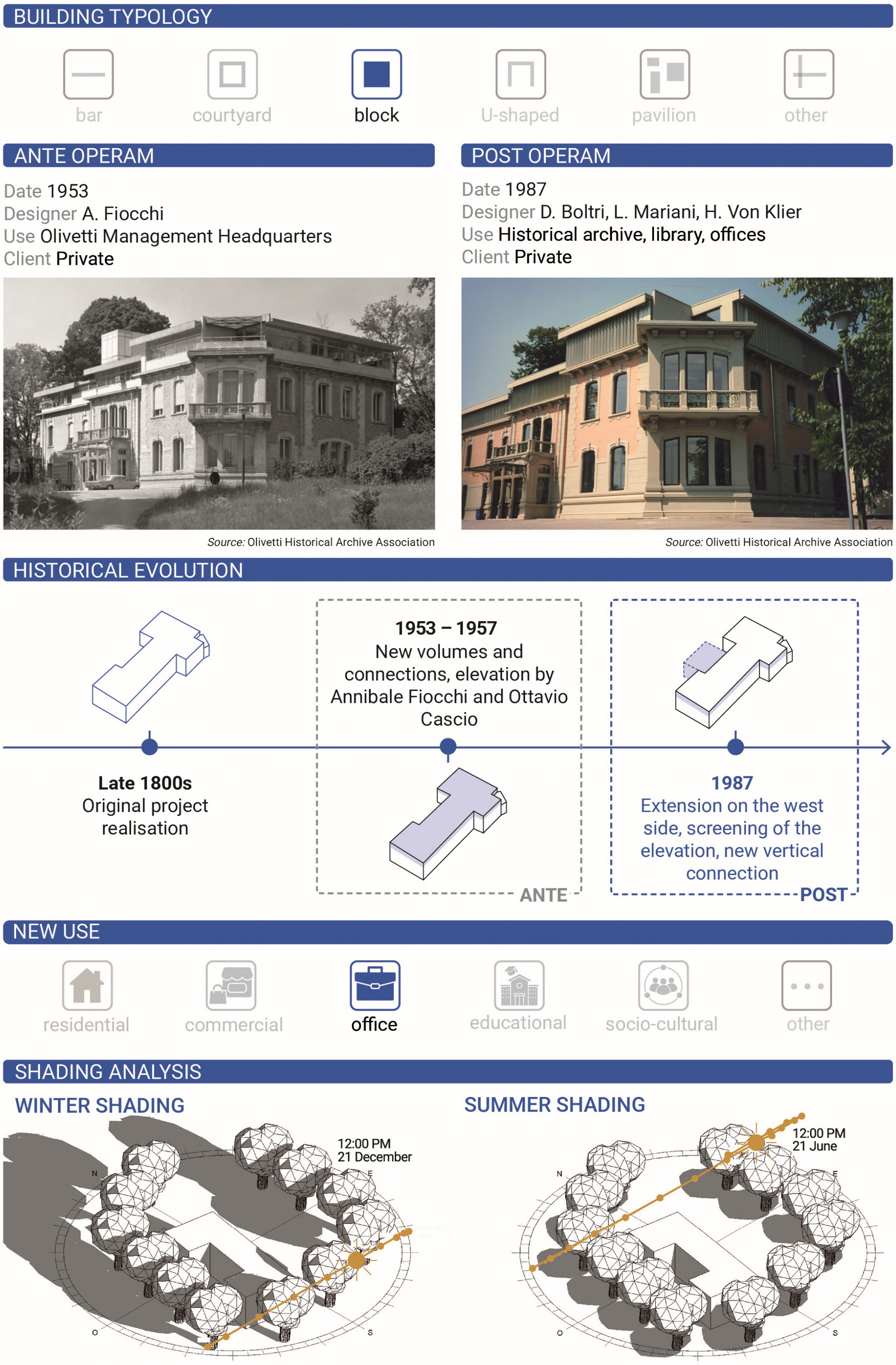

Figure 14. General information on the Olivetti administration office building Villa Casana. Source: elaboration by the authors.

The new functional organization allocated the ground floor to compact archival storage, the first floor to the library, and the second floor to offices, consultation areas, and a conference room. To accommodate the archival vault, the roof covering the internal courtyard was extended through the excavation of the underlying rock and the construction of a new volume illuminated exclusively by roof-mounted skylights.

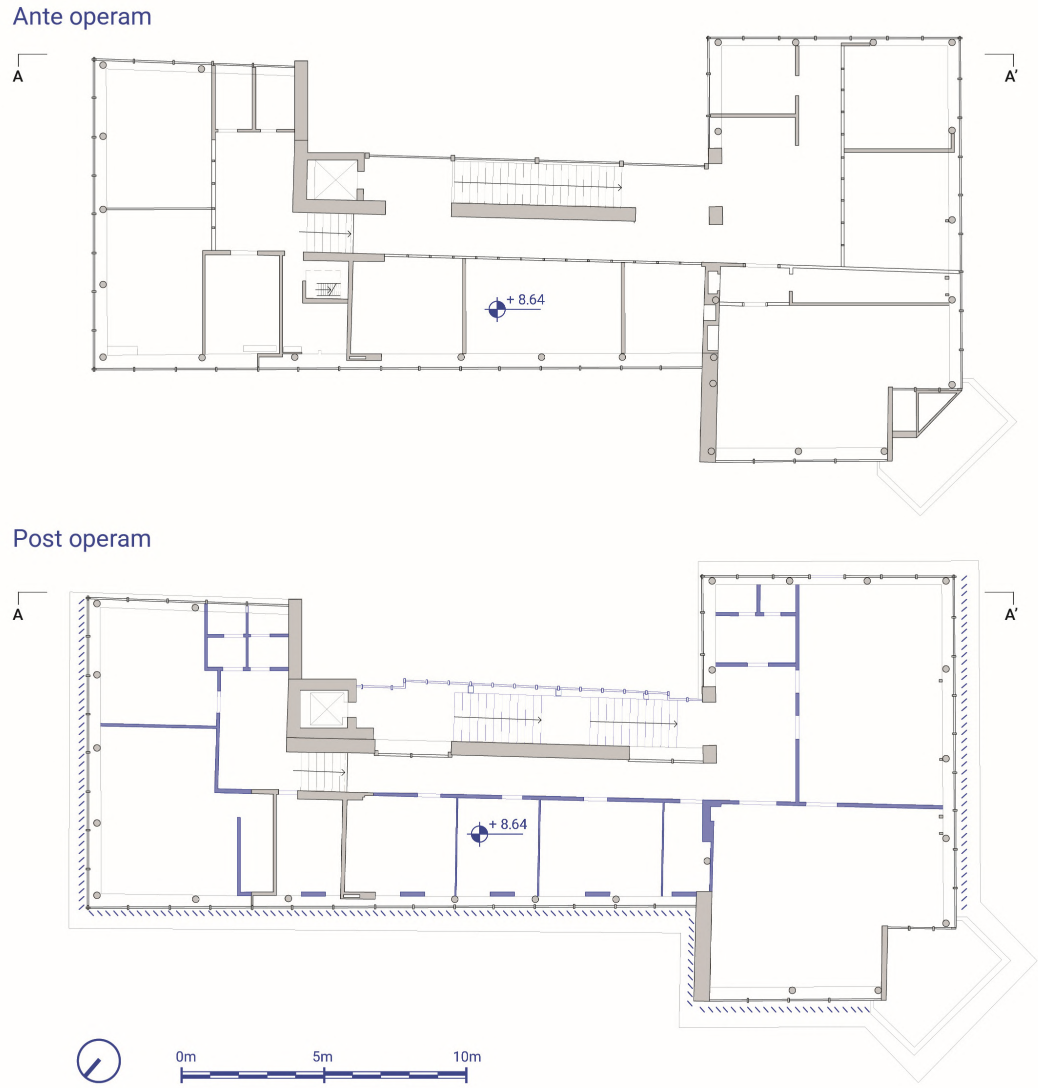

Figure 15. Original and current floor plan configurations of the Olivetti administration office building Villa Casana, with transformations highlighted in blue. Source: elaboration by the authors.

The intervention involved a comprehensive technological upgrading of the building. The mechanical and electrical systems were replaced, environmental control and security systems were integrated, a new hydraulic lift was installed, and the northern floor slab was structurally strengthened to withstand the high loads associated with archival storage. The vertical circulation between the first and second floors was also redesigned through the construction of a new timber staircase supported by a steel structure and incorporating an intermediate landing to comply with current building regulations.

The building envelope also underwent extensive performance upgrading. The original windows were replaced with high-performance insulated glazing units, while a self-supporting curtain wall replaced the glazed wall constructed in 1957 with reflective glazing. A system of motorized adjustable external louvers was also installed along the elevation of the upper extension to improve solar control.

The architectural appearance of the building was also substantially modified. The originally exposed brick façades were unified through the application of a thin, pink-colored render, while the reinforced concrete elements were refinished with grey silicate paint. At the same time, the window frames were replaced, the metal railings were restored, the external spaces were upgraded, and the forecourt and parking area were comprehensively redesigned.

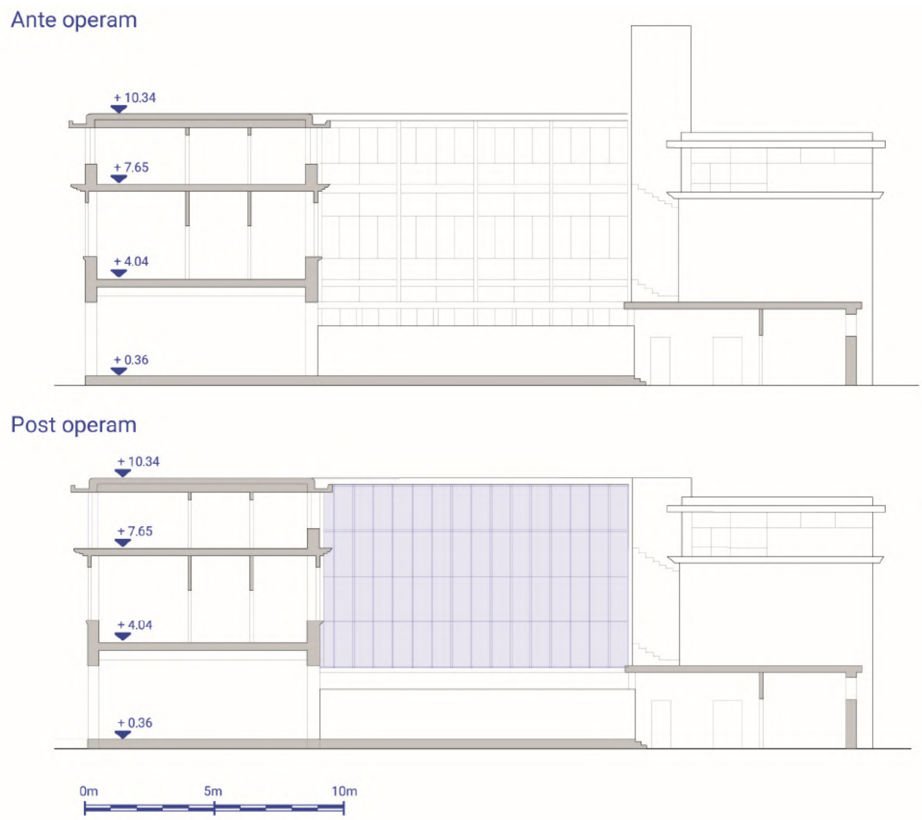

Figure 16. Original and current section of the Olivetti administration office building Villa Casana, with transformations highlighted in blue. Source: elaboration by the authors.

Figure 17. Original and current elevation of the Olivetti administration office building Villa Casana, with transformations highlighted in blue. Source: elaboration by the authors.

The building's current configuration is the result of the superimposition of successive interventions undertaken during different historical periods. The nineteenth-century Villa forms the original core onto which Fiocchi's modern vertical extension and the functional adaptations of the 1950s were added. At the same time, the 1987–1988 adaptive reuse introduced a further level of technological upgrading required for archival conservation. The evolution of the building demonstrates how its continued use has been ensured through successive adaptation works, in which modifications to the internal layout, building services, and environmental performance have played a more significant role than volumetric transformations.

4. Discussion

The proposed evaluation framework was used to critically interpret the available evidence, assess the four adaptive reuse interventions across the eight selected indicators, and subsequently conduct a cross-case comparison to identify common patterns, key differences, and the main adaptive reuse strategies adopted.

4.1. Case Study 1. The Fourth Extension of the ICO Workshops

Spatial configuration. The adaptive reuse of the fourth extension of the ICO Workshops enhances the building's spatial configuration through targeted interventions that improve usability, accessibility, building services adaptability, and functional flexibility, while preserving the original load-bearing structure. Usability has been expanded beyond the original industrial layout through the introduction of publicly accessible functions and spaces accommodating up to 400 users in *Officina H* space, in compliance with fire safety regulations. Universal accessibility is ensured through level entrances with height differences of less than 3 cm, ramps with a maximum slope below 8%, dedicated parking spaces, barrier-free sanitary facilities, and compliance with Italian Law No. 13/1989. Adaptability is achieved by restricting permanent partitions to service areas and integrating building services within suspended, fully accessible lattice structures, thereby avoiding interference with the existing structure. Functional flexibility relies on the open-plan configuration of *Officina H* and on reversible exhibition systems, including 11 motorized theatrical curtains, movable exhibition walls, and suspended fabric partitions that allow the space to be subdivided into seven exhibition pavilions and reconfigured for concerts, exhibitions, conferences, and cultural events.

Programmatic social impact. The adaptive reuse of *Nuova ICO* redefines the role of the building within the Olivetti industrial complex, transforming a disused production facility into a publicly accessible cultural and multifunctional center. Within this intervention, *Officina H* reactivates approximately 3000 m^2 of previously inaccessible space, now accommodating cultural, exhibition, and conference activities with a maximum capacity of 400 users. The construction of a new entrance from the Via Montenavale underpass reconnects the building to the circulation network of the Olivetti complex, strengthening its integration with existing functions, including offices, university facilities, and public services. The intervention also broadens the user base beyond the original industrial workforce by accommodating students, visitors, and participants in cultural events. However, no information is available regarding visitor numbers, event programming, or community engagement, preventing a quantitative assessment of the intervention's contribution to social regeneration.

Conservation and enhancement. The intervention prioritizes the conservation of the original architectural and structural features, limiting permanent alterations to those required for functional adaptation and regulatory compliance. The steel structure, shed roof, and glazed surfaces were restored, reinstating the original materials and colors wherever possible, including the wired glass of the roof. However, the replacement of the original double-skin façade and the removal of its naturally ventilated cavity and integrated shading system reduced the material and technological authenticity of the original envelope. Although the overall rhythm and appearance of the façade were largely preserved, the intervention weakened the legibility of the original environmental concept developed by Figini and Pollini. Newly introduced elements, such as the exposed LECA fire-resistant masonry walls, remain clearly distinguishable from the historic fabric while integrating coherently with the building's architectural language without altering its overall configuration. Exhibition installations, building services, and supporting lattice structures were designed as demountable and fully accessible systems. In contrast, irreversible interventions are limited to the resin flooring, new sanitary facilities, and localized structural strengthening. The external appearance of the building remains substantially unchanged, including the new emergency exit towards Via Montenavale, which is not visible from the main façade of the complex.

Identity continuity. The intervention preserves the principal material and spatial characteristics of *Officina H*, maintaining the legibility of its steel structure, shed roof, glazed surfaces, and industrial spatial configuration. At the scale of the wider complex, material continuity is more selective, particularly where the original façade technology and environmental systems were replaced. The internal layout has been adapted to accommodate new functions through reversible systems that preserve both the load-bearing structure and the perception of industrial space. Functional continuity has been reinterpreted by replacing industrial production with an integrated program of cultural, educational, administrative, and recreational activities, significantly expanding both the number and diversity of users while maintaining the building's role as a place of collective production and exchange.

User well-being. The intervention improves indoor environmental quality through the comprehensive refurbishment of the building's HVAC, ventilation, lighting, and acoustic control systems. *Officina H* is served by an all-air HVAC system designed for a conditioned volume of approximately 20,000 m^3, while the ancillary spaces are equipped with electronically controlled fan coil units. Indoor air quality is ensured through controlled mechanical ventilation and dedicated exhaust systems serving the sanitary facilities. Visual comfort benefits from the restoration of the original shed roof with wired glazing, the installation of 80 (4200 $\times$ 2000 mm) and 160 (2900 $\times$ 2000 mm) external shading modules, including 24 motorized units, and a programmable digital lighting system adaptable to different functional layouts. Acoustic comfort was enhanced through mitigation measures implemented following acoustic surveys conducted in 2001, which recorded noise levels of 62.3 dB(A). The control room is enclosed by partitions providing sound insulation of up to 48 dB, while the motorized theatrical curtains contribute to the acoustic compartmentalization of the open space. However, no post-occupancy data are available regarding ventilation rates, thermo-hygrometric conditions, or thermal comfort indicators such as Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD).

Energy efficiency. The intervention includes the refurbishment of the building services and the introduction of systems to improve the building's energy management. However, because consistent pre- and post-intervention operational data are not available, changes in energy consumption cannot be quantified. The replacement of the original HVAC system with electronically controlled fan coil units, together with the implementation of a centralized building management system, enables more efficient operational control. Adjustable external shading devices were installed over the approximately 1600 m^2 glazed roof to reduce summer solar heat gains. However, the available documentation provides no specific information on thermal bridge mitigation, condensation prevention measures, or improvements to the thermal performance of the building envelope, nor does it include data quantifying the reduction in energy consumption achieved through the adaptive reuse intervention.

Environmental impact. The available documentation does not identify specific design measures explicitly aimed at reducing the building's environmental impact. No strategies are reported for water conservation, increasing soil permeability, or quantifying the reduction in carbon emissions associated with the intervention. The principal design decisions focus on the reuse of the existing building and its functional adaptation. In contrast, the environmental benefits resulting from adaptive reuse are not supported by quantitative indicators or life cycle assessment (LCA) studies.

Resource circularity. The intervention incorporates several solutions consistent with the principles of resource circularity, particularly in terms of the maintainability and repairability of building services. Mechanical and electrical systems are installed on exposed, fully accessible lattice structures, facilitating maintenance operations and the replacement of individual components without affecting the existing structure. The principal building service installations and exhibition systems employ standardized components that are readily available on the market, while the centralized building management system supports continuous monitoring and planned maintenance. However, the available documentation provides no information regarding the use of local, recycled, or recyclable materials, nor does it describe specific strategies for optimizing construction-site logistics or the supply chain.

4.2. Case Study 2. Olivetti Nursery School

Spatial configuration. The adaptive reuse of the Olivetti nursery school primarily focuses on adapting the building to contemporary regulatory, technical, and educational requirements while preserving its original spatial organization. Interior space usability has been improved through structural roof strengthening, asbestos removal, complete refurbishment of building services, and replacement of interior finishes with materials better suited to educational environments, including linoleum flooring in classrooms, non-slip porcelain stoneware in sanitary facilities, and Poraver acoustic ceiling panels. The internal layout has been reorganized to accommodate 75 children distributed across four classrooms corresponding to two age groups. At the same time, the HVAC system has been redesigned with ceiling-mounted terminals, eliminating potentially hazardous elements from spaces occupied by children. Universal accessibility is ensured through a new access ramp with a maximum slope of 8%, a fully accessible sanitary facility, and the reorganization of the entrance areas. Spatial flexibility is achieved through limited alterations to the internal layout, including the creation of new internal connections and the reuse of restored historic doors, without affecting the building's overall spatial configuration.

Programmatic social impact. The intervention restores to the city an educational facility that had remained closed since 2017, reactivating a function historically intended to support families and the local community. In addition to reopening the nursery school, the project includes the rehabilitation of the historic garden, the reconstruction of the 1949 fountain, the restoration of the original porphyry paving, and the transformation of the former playground into a shaded outdoor area for educational activities. The building's cultural value is further enhanced through the adaptive reuse of the Aula Giardino and the Gatehouse as exhibition and information spaces dedicated to the UNESCO World Heritage Site. Furthermore, two classrooms have been converted into exhibition spaces visible from the outside, strengthening the relationship between the Olivetti heritage, the city, and its visitors.

Conservation and enhancement. The intervention adopts a predominantly conservation-oriented approach, prioritizing the preservation of original materials and construction techniques. Deteriorated stone elements were replaced using diorite from Traversella, sourced from the original historic quarry. At the same time, mortar joints were repointed using specially formulated mortars designed to reproduce the characteristics of the original materials. Most newly introduced elements are reversible, including the steel access ramp, safety films applied to the existing windows, and suspended acoustic ceilings. Contemporary additions remain clearly distinguishable from the historic fabric, as exemplified by the new linoleum flooring installed in the corridor. At the same time, demolition works were limited to those strictly required for regulatory compliance and functional adaptation. The project also preserves the historic relationship between the building, the landscaped garden, and the slopes of Monte Fiorito, integrating the new mechanical equipment through dedicated landscape design solutions.

Identity continuity. Among the four case studies, the Olivetti nursery school represents the highest degree of continuity between its original configuration and its current condition. The educational function has been maintained, with interventions limited to those required for structural upgrading, building services refurbishment, and energy performance improvements. Material continuity is likewise preserved through a conservation-led approach based on the restoration of existing elements and the use of materials consistent with the original construction. At the same time, spatial modifications are confined to the creation of new internal connections and the adaptation of spaces to meet the requirements of contemporary educational practices. The continuity of the original use contributes significantly to preserving both the building's identity and its historic role within the Olivetti industrial complex, now recognized as a UNESCO World Heritage Site.

User well-being. The intervention introduces building service solutions aimed at improving indoor environmental quality, with particular attention to the needs of preschool children. Indoor air quality is ensured by a mechanical ventilation system with heat recovery, supplemented by dedicated exhaust systems serving the restrooms and kitchen. Thermal comfort is provided by a reversible air-to-water heat pump coupled with wall-mounted fan coil units and a centralized Building Management System (BMS), designed to maintain indoor temperatures of 20 °C in winter. Visual comfort benefits from the restoration of the original glass-block skylight, the automation of the existing external shading devices, the application of solar control films to the glazed surfaces, and the replacement of the lighting system with high-efficiency LED luminaires. Acoustic comfort has been improved through suspended sound-absorbing ceilings and high-performance windows with a weighted sound reduction index (Rw) greater than 30 dB.

Energy efficiency. The intervention achieves a significant improvement in the building's energy performance through integrated measures involving both the building envelope and the building services. The roof was comprehensively refurbished with a new 16 cm insulation layer, reducing heat losses and mitigating the principal thermal bridges. The first-floor windows were replaced with thermally broken frames incorporating low-emissivity glazing, achieving thermal transmittance values below 1.1 W/m^2K. The building services are centered on a heat pump with a nominal coefficient of performance (COP) of no less than 3.9 with external air at +7 °C, powered in part by a rooftop photovoltaic system consisting of 64 modules with a total installed capacity of approximately 18.2 kWp.

Environmental impact. The environmental strategies address both resource management and the reduction of operational impacts. The project introduces water-saving fixtures, including timed taps fitted with aerators and dual-flush toilets, while restoring the historic rainwater drainage system through relining of the existing downpipes. Soil permeability is preserved by maintaining the existing landscaped areas and adopting a steel-grated access ramp together with traditional porphyry paving. The reduction of carbon emissions is pursued through the replacement of fossil fuel-based systems with a high-efficiency electric heat pump supported by the rooftop photovoltaic installation.

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Resource circularity. The intervention prioritizes the conservation and repair of existing building components over their replacement, thereby extending the service life of both the building and its constituent materials. Internal timber windows were restored through localized repair and replacement of deteriorated elements. At the same time, the stone masonry was conserved through non-abrasive cleaning, repointing of mortar joints, and structural grout injection. Material procurement follows the principle of continuity with the original construction by using diorite from Traversella sourced from the historic quarry and traditional materials for the external paving. However, the available documentation provides no information regarding the use of recycled or recyclable materials, nor does it describe specific strategies for optimizing construction-site logistics.

4.3. Case Study 3. The Research and Experience Center

Spatial configuration. The adaptive reuse of the research and experience center preserves the original structural layout while introducing predominantly reversible modifications to accommodate its new university function. Usability has been improved through the installation of an accessible lift equipped with Braille controls and audiovisual signals, the provision of sanitary facilities compliant with Italian Presidential Decree (DPR) 384, the use of rubber flooring suitable for wheelchair circulation, and the regulation of daylight through adjustable shading systems. Adaptability is primarily achieved through new lightweight plasterboard partitions and the raised access floor installed in the server room, allowing future spatial and building services reconfiguration without affecting the reinforced concrete structure. Flexibility mainly concerns the shared spaces, where sound-insulating movable curtains and blackout systems enable different functional layouts for teaching activities, conferences, exhibitions, and collaborative work. By contrast, elements such as the new sanitary facilities and the external steel emergency staircases introduce largely permanent spatial modifications.

Programmatic social impact. The change in use transforms a building originally dedicated to industrial research into a facility for higher education, significantly broadening both its user profile and its relationship with the surrounding urban context. The introduction of classrooms, laboratories, a library, an exhibition gallery, a conference hall, and a café create new functions that are also accessible to users beyond the university community, supporting cultural and educational activities. The presence of students, researchers, and academic staff from international backgrounds further enhances the relational capital of the Olivetti complex. At the same time, the redesigned access system and refurbished outdoor spaces strengthen the connection between the building and the city compared with its previous corporate configuration.

Conservation and enhancement. The intervention adopts a conservation-led approach aimed at preserving the architectural identity of the research and experience center, limiting replacements to elements that were irreparably deteriorated. The clinker brick façades, fulget surfaces, rendered finishes, and windows were restored or replaced while maintaining their original geometry, color, and proportions. The replacement of the original cast-iron windows illustrates a clear trade-off between environmental upgrading and material authenticity: geometry, color, and compositional rhythm were retained, while the original material and construction technology were lost. More generally, new interventions were designed to minimize visual contrast, prioritizing the perceptual and compositional continuity of the building even when complete material continuity could not be maintained. Reversibility varies according to the type of intervention. The new windows can be removed while retaining the original steel subframes, whereas localized replacement of clinker brickwork and rendered finishes constitutes essentially permanent modifications. The principal technical challenge concerns the interface between the original steel subframes and the new aluminum window frames, where the compatibility of dissimilar materials requires specific design solutions to prevent galvanic corrosion and differential deformation over time.

Identity continuity. The intervention preserves most of the building's material and compositional characteristics, maintaining the legibility of the principal architectural features of the original design. Spatial modifications, achieved through lightweight partitions and movable separation systems, do not alter the load-bearing structure and remain largely reversible. The most significant transformation concerns the building's function, which has evolved from an industrial research center into a university facility dedicated to education and research in the field of design. Although the new use broadens the building's user profile, it maintains continuity with the original vocation of the complex by continuing to accommodate activities related to research, experimentation, and knowledge production, now within an academic setting and accessible to a wider community.

User well-being. The intervention improves indoor environmental quality through the upgrading of the building's HVAC, ventilation, lighting, and acoustic control systems. Indoor air quality is ensured by an air handling unit serving the conference hall, with airflow rates modulated according to indoor CO_2 concentrations and fresh air supply of up to 32 m^3/h per occupant in the conference room. In offices and classrooms, air exchange is provided by fan coil units and mechanical exhaust systems serving the sanitary facilities. Thermal comfort is regulated through independent control systems for each room, designed to maintain indoor temperatures of 20 °C in winter and 27 °C in summer, with a relative humidity of 50 ± 5%. Visual comfort benefits from the reconfiguration of the interior spaces, adjustable solar shading devices, and new low-emissivity windows, while acoustic comfort has been enhanced through sound-absorbing suspended ceilings, insulated partitions, and high-performance movable acoustic curtains.

Energy efficiency. The intervention introduces localized improvements to the building's energy performance, primarily targeting the building envelope and construction details most susceptible to heat loss. Thermal bridge mitigation focuses on the window–subframe interface through the use of thermally broken profiles, polyamide thermal separators, and glass fiber insulation panels installed beneath the windowsills. Condensation prevention is achieved through elastomeric insulation applied to refrigeration pipework and vapor barriers incorporated into the principal envelope components. However, the design documentation does not include a comprehensive energy assessment or comparative data on energy consumption before and after the intervention. Moreover, the heating and cooling systems are supplied by the centralized energy network serving the Olivetti complex, preventing a direct assessment of the building's energy performance in terms of energy demand or consumption reduction.

Environmental impact. The environmental strategies are more limited than those adopted in the other case studies and are primarily focused on upgrading the existing infrastructure. The domestic hot water system incorporates a recirculation network served by a 500 L storage tank, reducing waiting times for hot water delivery. In contrast, the rainwater drainage system is designed exclusively for discharge into the sewer network, without provisions for rainwater harvesting or reuse. The landscape design preserves approximately 2600 m^2 of green areas but also includes the construction of new impermeable surfaces and the replacement of existing paving. The available documentation provides no quantitative information on carbon emission reductions or other operational environmental performance indicators.

Resource circularity. The intervention incorporates several solutions intended to facilitate the maintenance and replacement of building service components. Accessible suspended ceilings raised access floors, serviceable filtration systems, and building services networks designed for maintenance without demolition enable localized interventions throughout the building's operational life. Numerous components are also readily repairable or replaceable, including fan coil units, control valves, modular raised-floor panels, and windows installed using mechanical fixings. The project involves the reuse of part of the existing curbs within the external landscaping works and the recovery of selected materials generated during demolition. However, no specific strategies are identified regarding the use of local, recycled, or recyclable materials, nor are measures described for optimizing construction-site logistics.

4.4. Case Study 4. Villa Casana

Spatial configuration. The adaptive reuse of Villa Casana modifies the building's spatial configuration to accommodate the requirements of the Olivetti Historical Archive Association, improving accessibility, functionality, and archival storage capacity. Usability has been enhanced through the construction of a new internal staircase with an intermediate landing, the replacement of the existing lift with a hydraulic system, and the addition of an external emergency staircase. Adaptability is achieved through the integration of building services within accessible suspended ceilings, facilitating future maintenance and upgrading, and through the introduction of a secure archival vault and compact mobile shelving designed to optimize document preservation. Spatial flexibility is primarily provided by the mobile rail-mounted storage systems, which allow the storage capacity to be reconfigured according to operational requirements without altering the historic spaces.

Programmatic social impact. The change in use significantly expands the public role of Villa Casana, transforming a former administrative building into a center dedicated to the preservation and dissemination of the Olivetti cultural heritage. The opening of the libraries dedicated to Camillo and Adriano Olivetti, the Architectural Drawings Archive, and the *Edizioni di Comunità* collection makes documentary resources previously reserved for limited access available to a wider audience, supporting research, study, and public dissemination. The creation of a conference hall further provides a venue for conferences, meetings, and cultural events, strengthening the relationship between the building, the UNESCO World Heritage Site, and the local community. The coexistence of archives, libraries, offices, and event spaces consolidates Villa Casana as a cultural and research hub, considerably expanding its social role beyond its former administrative function.

Conservation and enhancement. The intervention combines the conservation of selected historic features with more extensive architectural transformations than those observed in the other case studies. The principal façades retain their original compositional layout, while the new color scheme, aluminum window frames, and contemporary external shading systems clearly distinguish the newly introduced elements. Building services are predominantly integrated within suspended ceilings, minimizing interference with the historic structure, while the archival storage installations are largely reversible. Nevertheless, several irreversible interventions were undertaken, including the demolition of the original roof, the removal of the lift tower, and the construction of new building volumes, resulting in a substantial transformation of both the architectural image and the constructional configuration of the building.

Identity continuity. Villa Casana exhibits the highest degree of material transformation among the four case studies. The replacement of the original roof, windows, and parts of the building envelope substantially alters the building's original technological characteristics. At the same time, the internal organization has been adapted to accommodate the requirements of the Olivetti Historical Archive Association through new archival storage systems and research facilities. Identity continuity is therefore primarily sustained by the building's new cultural function, which maintains a strong connection with the history and legacy of the Olivetti company.

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User well-being. The intervention improves indoor environmental quality through the upgrading of the building envelope and building services, with particular attention to the requirements for archival preservation and user comfort. Indoor air quality benefits from the application of silicate-based paints, which enhance the breathability of the masonry and help prevent moisture accumulation and condensation, as well as from the replacement of the existing windows with high-performance glazing systems. Thermal comfort is improved through roof insulation, the installation of adjustable external solar shading devices, and the integration of HVAC systems within accessible suspended ceilings. The new curtain wall, zenithal skylights, and adjustable external shading systems enhance visual comfort. In contrast, acoustic comfort primarily benefits from the new high-performance windows and the integration of building services, which reduce the transmission of external and mechanical noise. However, the available documentation provides no quantitative data on the thermal, hygrothermal, or acoustic performance achieved following the intervention.

Energy efficiency. The intervention introduces several measures intended to improve the building's energy performance through upgrades to both the building envelope and the building services. Replacing the original roof with a new insulated structure, together with installing aluminum-framed double-glazed windows, reduces heat losses and helps mitigate the principal thermal bridges. Condensation prevention is achieved through both the thermo-hygrometric control provided by the HVAC system and the application of silicate-based paints, which promote water vapor diffusion through the historic masonry. The building is also connected to the district heating network serving the Olivetti complex and is equipped with a centralized building management system designed to optimize energy consumption. However, the design documentation does not provide quantitative data on energy consumption before and after the intervention or report performance indicators for the upgraded building envelope.

Environmental impact. The documented environmental strategies primarily address the reduction of operational energy consumption. Improvements to the building envelope, the adoption of external solar shading systems, and the connection to the district heating network contribute to reducing heat losses and the emissions associated with space conditioning. The rehabilitation of the surrounding park, including the enhancement of landscaped areas and the planting of new trees, further strengthens the environmental and landscape value of the complex. However, the available documentation provides no information on water conservation measures, soil permeability, or other quantitative indicators of environmental sustainability.

Resource circularity. The resource circularity strategies primarily focus on the management and maintenance of building services. The integration of mechanical and electrical systems within accessible suspended ceilings, together with the installation of easily accessible external shading devices, facilitates inspection and maintenance activities without requiring invasive interventions on the historic fabric. In addition, the centralized building management system supports the long-term monitoring and efficient operation of the building services. However, the available documentation provides no information regarding the repairability of individual components, the use of local, recycled, or recyclable materials, or specific strategies for optimizing construction-site logistics.

4.5. Case Study Comparison

Given the purposive selection and limited number of cases, the cross-case comparison is not intended to identify universally recurring models of adaptive reuse, but to examine how different intervention strategies negotiate functional adaptation, conservation, technological upgrading, and cultural continuity within the same heritage system (Table 2). The four case studies reveal distinct balances among these dimensions, shaped by the architectural characteristics and condition of each building, the compatibility of the new use, and the objectives of the project.

Table 2. Synthesis of the main strategies and transformations identified across the four case studies according to the eight indicators of the assessment framework.

Indicator	Nuova ICO	Olivetti Nursery School	Research and Experience Center	Villa Casana
Spatial configuration	Open-plan industrial spaces adapted through reversible partitions and flexible exhibition systems; accessibility and service integration improved while retaining the original structure.	Original spatial organization and educational use largely maintained; targeted changes improve accessibility, safety and contemporary educational functionality.	Original structural layout retained; lightweight partitions, raised floors and movable systems support adaptation to academic functions.	More substantial spatial adaptation to archival use; accessibility and storage capacity improved through new circulation and mobile storage systems.
Programmatic social impact	Former industrial spaces transformed into a publicly accessible cultural and multifunctional center, broadening the range of users and reconnecting the building with the complex.	Historic educational function reactivated; garden and ancillary spaces restored and partially opened to cultural and exhibition uses.	Industrial research facility converted into an academic and cultural facility, broadening its user profile and strengthening connections with the city.	Former administrative building transformed into a cultural and research hub dedicated to the preservation and dissemination of Olivetti heritage.
Conservation and enhancement	Principal structural and spatial features preserved, with largely reversible additions; replacement of the original double-skin façade reduces technological authenticity.	Strong conservation-oriented approach, with repair of original materials, limited demolition and predominantly reversible additions.	Architectural character and geometry largely preserved; technological upgrading introduces some loss of material authenticity, particularly through window replacement.	Selected historic features retained, but extensive irreversible transformations affect the roof, envelope and overall constructional configuration.
Identity continuity	Industrial identity remains legible through the preservation of structural, volumetric and spatial characteristics despite substantial functional conversion.	Highest overall continuity: original educational function, spatial organization and much of the material character are maintained.	Change in use maintains continuity with the building's original vocation for research, experimentation and knowledge production.	Material continuity is limited, but strong cultural continuity is maintained through its function as the Olivetti Historical Archive.
User well-being	HVAC, ventilation, lighting, shading and acoustic systems upgraded to improve indoor environmental quality and support flexible cultural uses.	Integrated measures improve thermal, visual, acoustic and indoor air quality, with particular attention to preschool children.	HVAC, CO_2-based ventilation control, shading, low-e glazing and acoustic measures improve indoor environmental quality.	Envelope and building services upgraded to support both user comfort and archival preservation requirements.
Energy efficiency	Building services, centralized management and external shading upgraded to improve operational control and reduce summer solar gains.	Integrated energy upgrade combining roof insulation, high-performance windows, heat pump, BMS and photovoltaic generation.	Localized envelope improvements, thermal-bridge mitigation and condensation-control measures support improved energy performance.	Insulated roof, double glazing, external shading, HVAC/BMS and connection to district heating improve building energy performance.
Environmental impact	Environmental benefits primarily derive from retaining and reusing the existing building and adapting it to new functions.	Water-saving devices, preservation of soil permeability, electrification and photovoltaic generation address operational environmental performance.	Existing green areas are largely preserved, while infrastructure upgrades contribute to operational resource management.	Energy-related measures and park rehabilitation, including enhancement of landscaped areas and new tree planting, improve environmental and landscape performance.
Resource circularity	Accessible and maintainable building services and standardized components facilitate maintenance, repair and replacement.	Conservation and repair are prioritized over replacement, extending the service life of existing building components and materials.	Maintainable and replaceable technical systems are combined with the reuse of existing elements and recovery of selected demolition materials.	Accessible building services, shading devices and centralized management facilitate inspection, maintenance and long-term operation.

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The cases reveal significantly different approaches to spatial configuration. The Olivetti nursery school shows the greatest degree of functional and spatial continuity, as it retains its original use and requires only limited changes, mainly related to regulatory compliance and performance upgrading. The *Nuova ICO* and the research and experience center introduce greater flexibility through reversible partitions, new shared spaces, and layouts capable of accommodating activities different from those originally intended. Villa Casana involves a more substantial reorganization of the interior, required by the highly specialized environmental, structural, and operational demands of archival use.

Similar differences emerge in conservation strategies. The nursery school and the research and experience center adopt predominantly conservation-oriented approaches, seeking to preserve materials, spatial organization, and architectural character while integrating technological upgrades with limited impact on the existing fabric. The *Nuova ICO* underwent a more extensive functional transformation. Nevertheless, its original industrial identity remains recognizable, although the subdivision of the production halls has altered the perception of their original spatial continuity. Villa Casana represents the case of greatest material transformation, with interventions affecting the roof, building envelope, and several construction elements. Despite these changes, it maintains strong cultural continuity with the Olivetti heritage through its current use as the Olivetti Historical Archive Association.

The cross-case analysis also shows that the outcomes of the interventions are not evenly distributed across the eight dimensions of the assessment framework. Spatial configuration, cultural continuity, and conservation and enhancement are the most clearly documented dimensions and allow the different design strategies adopted in the four buildings to be distinguished. By contrast, evidence concerning user well-being, energy efficiency, environmental impact, and resource circularity is more uneven. It depends closely on the availability of technical documentation and the period in which each intervention was carried out.

All four cases show particular attention to functional adaptation and building performance, especially through improved accessibility, upgraded technical systems, and better indoor comfort. Energy strategies, however, differ considerably. More recent projects, such as the intervention on the nursery school, incorporate high-efficiency systems, renewable energy technologies, and measures consistent with current sustainability objectives. Earlier projects focused mainly on improving the building envelope and upgrading the systems available at the time. Measures addressing environmental impact and resource circularity are also more explicit in projects developed after 2000. In earlier interventions, these issues were addressed mainly through indirect strategies, including the retention and reuse of the existing building, the conservation of selected construction components, and improvements in maintainability. These differences also reflect the broader tension between environmental upgrading and heritage conservation identified in recent research. Sustainable conservation approaches emphasize that improvements in building performance should be considered together with their effects on heritage significance [29], while Mathew et al. [40] describe the relationship between energy efficiency, lifecycle carbon, and architectural conservation as a trade-off in which optimizing one objective may compromise another. This tension is visible in the Olivetti cases: in the Nuova ICO and the research and experience center, performance upgrading involved the replacement of original technological components, whereas the more recent nursery school intervention combines substantial energy upgrading with a more conservation-oriented approach.

Further findings concern the relationship between the extent of material transformation and cultural continuity. The two dimensions are not necessarily directly correlated. This result is consistent with broader interpretations of industrial heritage that associate its significance not only with physical fabric but also with social relations, place identity, collective memory, and cultural meanings [24,25]. The nursery school retains both its original function and much of its material and spatial configuration, representing the case of greatest overall continuity. Villa Casana, by contrast, underwent the most substantial constructional changes but maintains strong cultural continuity through its role as the Olivetti Historical Archive Association. Similarly, the research and experience center has changed use while retaining its original vocation as a place for production, exchange, and dissemination of knowledge. Finally, the *Nuova ICO* demonstrates that even substantial functional conversion can preserve a building's industrial identity when its principal structural, volumetric, and architectural features remain legible.

5. Conclusions

The comparison of the four Olivetti buildings shows that adaptive reuse in twentieth-century industrial heritage cannot be interpreted through a linear relationship between the amount of physical transformation and the continuity of heritage values. Functional continuity generally reduces the need for spatial transformation, as demonstrated by the nursery school, but it is not a prerequisite for cultural continuity. Conversely, substantial changes in use and material fabric may remain culturally compatible when the new program maintains or coherently reinterprets the building's spatial logic, architectural identity, historical vocation, and relationship with the wider heritage system. The four cases therefore reveal different reuse trajectories rather than a single optimal model.

The outcomes of the four interventions reflect different constraints, including the difficulty of accommodating non-industrial uses within exceptionally large and highly specialized production spaces, heritage protection requirements that restrict substantial passive and active energy upgrading, and the technological limitations of reuse projects developed before the emergence of current energy and environmental performance standards. Nevertheless, each building has remained in use or has been reactivated through functions that respond to contemporary local needs, unlike other properties within the Ivrea UNESCO site that remain vacant or underused. Their continued occupation has therefore been achieved through context-specific compromises between conservation, performance, and functional adaptation, confirming that the long-term safeguarding of such an extensive heritage system cannot realistically rely on the musealization of all its components.

The contribution of the study lies in combining two levels of interpretation that are often considered separately: the transformation of individual buildings and their continuing role within a shared industrial, social, and cultural system. By comparing buildings belonging to the same Olivetti heritage context but characterized by different functions, scales, degrees of functional continuity, and intervention intensities, the study isolates how different reuse strategies negotiate conservation, adaptation, and performance requirements under a common cultural framework. The assessment framework supports this comparison by making these trade-offs explicit across complementary dimensions rather than reducing adaptive reuse to either physical conservation or functional occupation.

A central finding of the comparison concerns cultural continuity. The four cases indicate that it cannot be reduced to either material preservation or functional occupation, but emerges from the persistence or reinterpretation of material, spatial, functional, social, and territorial relationships. These dimensions are complementary but not interchangeable. A socially valuable new use does not compensate for the unnecessary loss of significant architectural features, just as the preservation of physical fabric does not guarantee continuity when a building remains inaccessible or underused. The most effective strategies are therefore those that align new uses with existing spatial characteristics, retain significant constructional and environmental systems where feasible, and introduce new

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components that are compatible, identifiable, accessible for maintenance, and removable whenever possible.

At the scale of the UNESCO site, the study also confirms that the Olivetti buildings should not be assessed as isolated objects. Their heritage significance derives from their role within a broader urban, industrial, social, and cultural system. The long-term continuity of the UNESCO site consequently depends not only on the quality of individual projects, but also on coordinated management, public accessibility, shared interpretation, and functional and spatial connections among its different components.

The scope of these findings is subject to several limitations. First, the study is based on a purposively selected sample of four buildings within a single and highly specific twentieth-century industrial heritage system. The cases were selected to maximize variation in function, scale, degree of functional continuity, and intervention intensity rather than to provide a statistically representative sample. The findings should therefore not be generalized to industrial or modern heritage as a whole. Second, the interventions were developed in different periods and under different regulatory, technical, and economic conditions, which necessarily influence both the design strategies adopted and the availability of evidence. Third, the assessment is predominantly qualitative. Documentary evidence is particularly strong for spatial transformation, conservation, and identity continuity, but remains uneven for user well-being, operational energy performance, environmental impact, resource circularity, and post-occupancy social outcomes. Consequently, the proposed framework should be understood as a comparative analytical structure rather than as a validated universal assessment model. Its application to other heritage contexts would require adaptation to their specific building types, cultural values, regulatory conditions, scales, and available evidence. Future research should test the framework across a larger and more diverse sample and complement qualitative assessment with post-occupancy evaluation, user and community surveys, environmental monitoring, operational energy data, life-cycle assessment, and long-term maintenance records.

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