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Redrawing commercial ruins: an integrated methodology for adaptive reuse

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Abstract

The ongoing "retail apocalypse" affecting European commercial buildings, largely driven by the rise of e-commerce, underscores the urgent need to develop strategies for the reuse and management of vacant building stock. This context is aggravated by the concerning mismatch between the targets set in the framework of the Sustainable Development Goals and the slow progress toward climate neutrality, which calls for more sustainable and eco-friendly approaches in the construction sector as well. Therefore, formulating adaptive reuse models that reconcile economic viability, promote the introduction of social programs, as well as energy-efficiency retrofitting, is both challenging and imperative for vacant retail boxes. This study proposes a scalable and replicable methodology for the adaptive reuse of disused and decommissioned retail buildings, grounded in comparative analyses of historical and suburban contexts.

The approach integrates typo-morphological evaluations with evolutionary assessments to identify both obsolete and persistent architectural components over time. Its aim is to reconceive vacant retail spaces as catalysts for new social and spatial processes, combining BIM-based quantitative analysis with qualitative insights that are often overlooked in architectural practice.

Applied to the Austrian context through the regeneration of a suburban building near Vienna, the method demonstrates the value of drawing and representation as cognitive and design instruments for codifying architectural language and identifying recurring spatial patterns. The case study highlights the potential of adaptive reuse as a strategy for sustainable suburban redevelopment, one that avoids over-commercialisation and limits further land consumption. The proposed model offers a structured evaluative framework for comparable cases and establishes a basis for future forms of automated assessment through advanced representational technologies.

Keywords: Adaptive reuse, vacant buildings, typo-morphological analysis, building patterns codification, BIM

1. Introduction

Currently, European trade trends have shown significant recovery from the 2020 COVID pandemic according to EuroCommerce monitoring. Indeed, a new balance between online and physical trade has been achieved in recent years based on the European E-Commerce Reports of 2024 and 2025. However, the success of digital retail has marked a profound change in social and economic habits regarding the performance of the sector, as stated by the Observatory of Digital Innovation in Retail at the Polytechnic of Milan, resulting in the widespread abandonment of physical retail units. Their shrinkage and relocation to more profitable areas, as well as to more compact stores, have led to a gradual abandonment of medium- to large-scale venues in European cities. As commercial facilities have been often grown decentralized from inner city centers worldwide [1], following processes of suburbanization, commercial big boxes and malls in suburban areas undergo such failure and abandonment phenomena, accelerating

their technical obsolescence, yet also raising significant environmental issues related to the management of demolition waste and embodied energy loss [2]. Dead malls' closure and abandonment in North America became iconic examples of this commercial desertification since the beginning of the new millennium [3, 4]. As a consequence, such dynamics have also spread across Europe, more significantly since the COVID pandemic, which has accelerated e-commerce preferences over physical trade. The survival of retail parks and shopping centers in Europe has been affected, such as with the former shopping mall Le Acciaierie in Bergamo, Italy, where about 64,000 store closures have been registered nationwide since 2016 according to the National Observatory of Commerce of Italy. Those are not standalone examples, as multiple dead malls can be found in Germany, such as the Blautal-Center Ulm in Ulm, yet also in the United Kingdom, where Hull, Glasgow, and Liverpool experienced most store closures in the last few decades [5]. These trends, commonly referred to as "retail apocalypse" (RA) or de-malling [5–8], pose urgent challenges for urban planning and sustainability, in line with land consumption reduction targets posed within the Sustainable Development Goals and the European Green Deal objectives. In fact, the European Environment Agency states that, between 2005 and 2023, the settlement area in the EU-27 increased by about 13%, raising land take and the responsibility of the construction sector in terms of greenhouse gas emissions. Under the strategic framework of Europe's climate policies, it is imperative to explore novel approaches for the reuse of underutilized commercial spaces, grounding on the sufficiency principle of enhancing the resources that already exist.

In this framework, adaptive reuse (AR) is increasingly recognized as an effective strategy to limit land consumption, preserve embodied energy, and foster social cohesion [9–11], providing new opportunities for regenerating decommissioned and abandoned buildings, as observed in several international cases [3, 4, 10] (Figure 1).

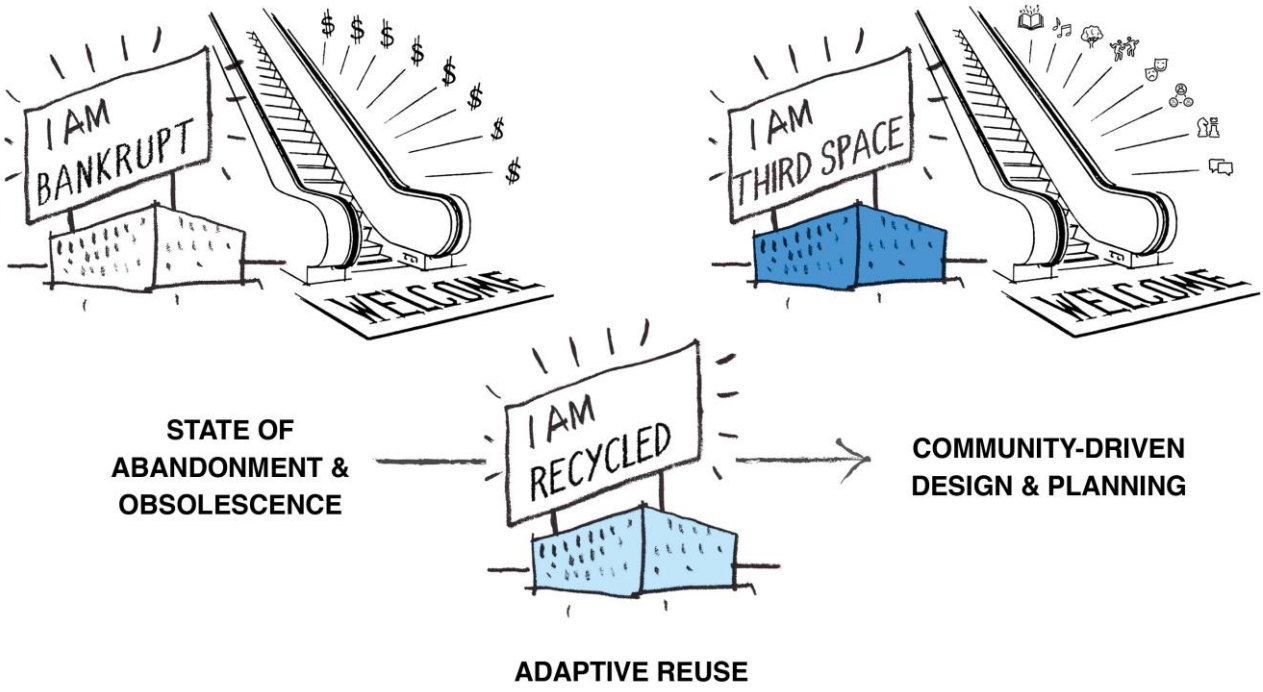

Figure 1 – Aim of the research: redrawing Venturi and Koolhaas to address architecture from the RA towards *third spaces*. © 2025, Suvieri, Bianconi, Filippucci, Lechner.

Between 2006 and 2021, the number of scientific articles increased by more than 1,000%, rising from dozens to hundreds of publications per year, numbers that highlight the centrality of the topic as well as its recent diffusion among research and professional practice. Given the intersection of architecture and design with planning activities and real estate development, recent contributions related to AR encompass strategic decision-making grounding on statistical analyses, involving multi-criteria decision-making (MCDM) methods. MCDM falls into a sub-discipline of operations research that provides a structured framework for evaluating a finite set of alternatives against multiple, often conflicting, criteria. Its primary objective is to support decision-makers in identifying the most suitable solution or ranking alternatives by aggregating diverse performance metrics into a coherent evaluative model. Such studies,

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which constitute a substantial section of AR-related research [12], have been primarily focusing on cultural and historical heritage reuse scenarios, where conservation and heritage values play a key role. In this perspective, major attention has been given to solutions influencing the historic, artistic and socio-cultural aspects, as well as to participatory approaches [13], while limited MCDM frameworks have been proposed regarding ordinary buildings, such as malls and retail boxes. Therefore, this research is grounded on the MCDM debate regarding industrial facilities' reuse [14], being recognized as the most similar and comparable building type to the commercial ones [2], also shifting to a non-manual traditional MCDM assessment by integrating automated metric calculations directly into a Building Information Modeling (BIM) environment.

This study, therefore, proposes a scalable and replicable methodology for AR practices for vacant and decommissioned retail facilities based on inductive representational investigations at the urban and architectural scales. By integrating survey and representation to analyze and reinterpret local architectural language rooted in historical memory [15, 16], design choices are thereby informed and subsequently evaluated through quantitative comparative scenario assessments. The study compares reuse with demolition scenarios through a mixed approach that combines qualitative investigations, concerning the communicative language of architecture, with quantitative analysis, conducted through custom Python scripts embedded in Dynamo for Revit. Therefore, the qualitative analyses are conducted by assessing how building transformations over time happen in response to contemporary habits and socio-cultural shifts, grounded in the concept of the built environment as a mirror of society. Subsequently, quantitative assessments for vacant building scenarios are proposed, evaluating and comparing reuse and retrofit solutions with demolition or abandonment options. The latter stage is developed within a BIM environment and is achieved based on the extraction of geometric and material data, enabling calculation of key indicators, ensuring transparent and reproducible comparison between the AR scenario and demolition, and fostering automated analysis of AR proposals.

2. AR: from theoretical to practical experimentations

AR is the practice of physically and functionally transforming existing buildings, a process that generates complex cause-and-effect relations across social, economic, cultural, humanitarian, aesthetic, and environmental spheres [10, 11]. Its central premise is to achieve the greatest possible functional and spatial gain with the least necessary physical intervention, while respecting embodied energy and preserving structures that remain materially and operationally viable [9, 10]. A related but broader concept is conveyed by the German term *Umbau*, which encompasses adaptation, renovation, restoration, and conversion, yet more fundamentally refers to transformation as an intrinsic condition of architecture itself [17]. Whether prompted by structural crisis, obsolescence, changing use, or broader cultural and environmental demands, *Umbau* describes a wide spectrum of interventions, from minor adjustments to extensive redevelopment. In this sense, it suggests that architectural design is never entirely detached from processes of transformation, whether these affect only the interior or extend to both indoor and outdoor spaces, and without being confined to predetermined typological limits.

Repurposing structures and buildings has been an age-old practice within European culture, such as during the Roman domination, when *spolia* reflected the main way of recovering and readopting existing construction materials and building components [9]. This procedure, comparable to the modern practice of urban mining, helped overcome the dissonance between the lifespans of construction materials and the raison d'être of buildings. However, while this extremely sustainable and affordable practice found much success both prior to and throughout the Medieval Age, the contemporary concept of AR emerged in the 1970s, with a pragmatic improvement in the last decades due to sustainability policies and, consequently, AR recognition as a heritage management tool [9, 18]. In that framework, industrial ruins have mostly proven to be successful objects of intervention, whose repurposing led to the acknowledgment of industrial architecture as a main testimony of recent history [9]. Similarly to the gradual abandonment of industrial heritage, the decline of physical retail has left vacant commercial buildings as a new frontier for experimentation. However, early-stage AR practices in former department stores as well as obsolete big-box stores and dead malls have shown major success when attention to fostering their attractiveness has been paid, focusing on "live-work-play" redevelopment [3]. This has been clearly stressed in the retrofit of Surrey Place Mall for Simon Fraser University interests in Surrey, British Columbia, and ACC Highland in Austin, Texas, along with other similar experiences documented within the retrofitting suburbia practices [1, 3, 6].

This contribution outlines an approach that fosters processes of AR of existing buildings, relying on the dynamic survey promoted by the Roman School of Roberto de Rubertis [15, 19], consistent with Saverio Muratori's earlier

morphological and typological studies [20]. Hence, architecture, understood as a living being, prone to processes of evolution, adaptation, and selection, is decoded, read, and interpreted through dynamic surveying capable of recognizing and categorizing the layers of cultural-historical stratification on an urban and architectural scale. This approach does not merely capture the current state of the building, but also interprets its history, signs, latent potential, and language, becoming a cognitive and design tool. It is then possible to formulate truly adaptive solutions informed by the evolutionary hidden stages of such buildings, guiding AR strategies with greater awareness, especially in marginal or degraded contexts, restoring identity and meaning to what appears obsolete and unattractive.

3. From survey to design: methodological interpretation of architectural language for AR

The research stands within the studies of representation and evaluation of land-use and landscape evolution, starting from the interpretation of the historic city as a structuring matrix, in which typological stratification has defined patterns established over time [2, 19, 20]. The interpretation of historical photos, drawings, cadastral images, and bibliographic sources plays a pivotal role in decoding architectural and urban components that have historically underpinned social, cultural, and economic success, implementing instruments for the understanding of the causes of their failure and the reuse of vacant commercial spaces.

The processes adopted in the methodology (Figure 2), proceeding inductively, consist of:

A. Research and identification of existing theories and practices concerning typological and morphological approaches for architectural semantics and transformation;
B. Analysis of the historical, representative, and geographically close context of the addressed marginal reality, through archival documents, historical photos, documented surveys, maps, and drawings;
C. Identification of typical and consistently repeated patterns of success in the historical area under investigation, comparing evolutionary stages;
D. Study of metrics, types, and typologies and recurring design solutions over the centuries;
E. Coding and interpretation of the forms and evolutionary manifestations of historical architecture selected as successful models;
F. Contextualization and evaluation of the marginal reality identified in the suburban context for the proposed AR;
G. Layering and interpretation of levels typical of the suburbia to which the case study belongs, with in-depth analysis of pedestrian and road flows, compared to the role of public infrastructure for connections to densely populated areas;
H. Study of the metrics, dimensions, human-building and building-landscape relationship in the suburban reality;
I. Recognition of recurring historic city types, intrinsically linked to the DNA of commercial buildings, in the suburban case study;
J. Elaboration of the AR scenario through enrichment of missing successful solutions and increased recognition of those already present, consistent with the principles of minimal physical intervention;
K. Evaluation and validation of the AR proposal through MCDM of the proposed retrofit compared to the demolished option and the abandoned one, applying *Analytic Hierarchy Process* (AHP) in Dynamo workflows for Revit geometric and material data.

3.1 Qualitative typo–morphological assessment: decoding architectural language

The aim of the qualitative assessment is to decode the architectural and urban qualities that have sustained the social, cultural, and economic success of buildings over time, and to trace the origins and cause-and-effect processes through which architectural specificity emerged in particular historical contexts. This interpretative framework can then be extended to the analysis of modern commercial spaces, making it possible to identify patterns of transformation and varying degrees of functional adaptability. In this perspective, a clearly articulated typological structure exceeds the mere fulfillment of programmatic requirements: it becomes a key condition of architectural quality by supporting adaptability, enabling future transformations, and fostering a design approach that anticipates and accommodates changing functions and uses (Lechner et al. 2024).

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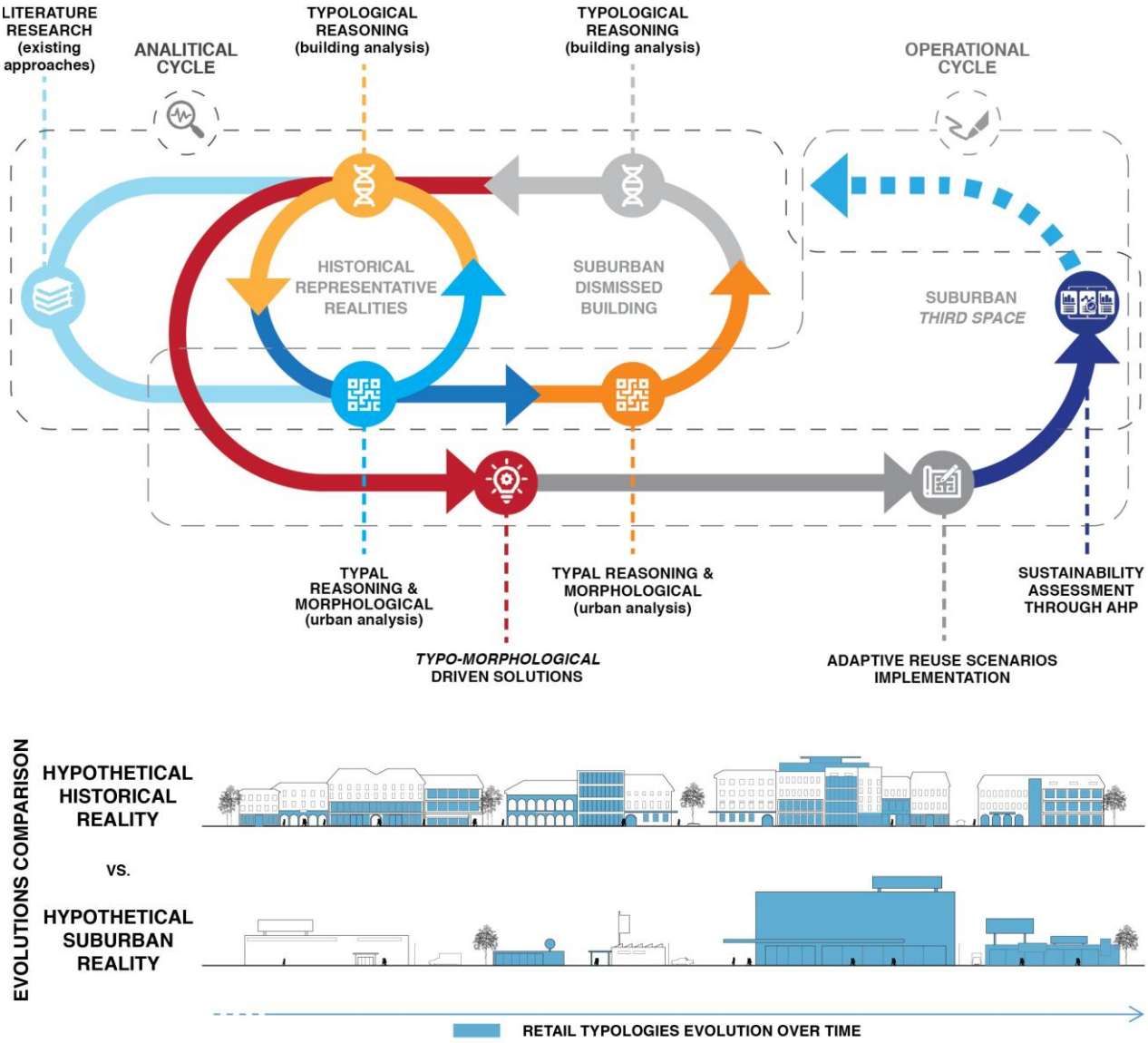


Figure 2 – Methodological research structure for the comparison of the evolution of urban landscape both for historical and suburban contexts. © 2025, Suvieri, Bianconi, Filippucci, Lechner.

Hence, steps A to I involve the recognition of compositional and construction processes that have endured over the centuries, adopting a comprehensive view that distinguishes types from styles as separate conceptual categories. The former are ordering principles open to adaptation while the latter are linked to specific formal expressions. Rooted in typological studies, the research begins with the analysis of the commercial type and its formal evolutions and variations over time, identifying partial obsolescence through a cluster-based approach that enables comparison and dialogue between different architectures and eras. Types, indeed, while considered as ordering principles, taxonomic categories, and primordial forms, nevertheless, are inherently evolving in response to socio-cultural and technological transformations while maintaining a structural role in architectural identity [21–23]. This adaptability acknowledges real-world conditions and supports the persistence of architectural forms despite evolving functions and contexts. By considering architectural artifacts as coherent ensembles, partial obsolescence can be identified and addressed to enhance long-term resilience [24].

The method intends to identify and recognize established patterns through typal reasoning, whereby a static classification of retail typology is not used, but rather a dynamic epistemological model that structures architectural knowledge. This model combines the rigor of typological reasoning, a mental process that defines a system of rules

and structures that change over time in response to social, functional, and construction needs [25], with the recognition of architecture as an evolutionary language [26]. Based on formal principles, the latter is transformed through material and technical variations while fulfilling global economic and functional criteria that reflect the history of society. This process is analyzed and interpreted through diagrammatic and typological representations, discerning the communicative and structural layers of architecture through metrics, coded semantics, and recurrent types, proceeding inductively from the particular to the general. Drawing, thus, is employed as a tool to identify the typological stratifications of architecture pertaining to the retail sphere, enabling comparisons between formal structures of the past and contemporary configurations. Such conditions often enter a state of crisis due to the loss of the Vitruvian values that once characterized architectural quality. Therefore, the qualitative dimension of the methodology, rather than applying a static taxonomic classification, adopts a dynamic epistemological framework and provides the conceptual foundation for defining AR strategies, ensuring that design interventions are rooted in both cultural continuity and spatial logic, while remaining open to functional innovation.

3.2 Quantitative BIM-based sustainability assessment: measuring scenarios' performance

The quantitative assessment, steps J to K, focuses on the evaluation of sustainability performance across three scenarios – current status (CS), state of reuse (SR), state of demolition (SD) – through a BIM-based comparative analysis, assessing the design stages through the phases. The process is conducted in Revit Autodesk 2025.4.2, where both geometric and material data extraction and processing are automated via DYNAMO v.3.3.0 workflows, supported by script nodes in CPython3 embedded in Dynamo. Indeed, thanks to BIM logics, which allow for construction information management, the sustainability analysis is based on environment- and energy-related parameters extracted from selected building elements. The developed sustainability assessment consists of three steps, which start from the extraction of quantities from key building components: roofing and glazed surfaces, interior paved surfaces, exterior walls and partitions, structural columns and beams, and exterior impermeable and permeable surfaces. These data enable the calculation of energy performance, including the number of installable photovoltaic panels and their potential based on geographic information, solar irradiation, indoor effects, required shading, embodied energy of structural components, as well as environmental performance, related to external surfaces' behavior to water and heat. Finally, performance indicators are normalized and weighted according to literature-based AHP criteria [14, 27], including energy efficiency, material management, construction costs, reusability of structural components, embodied energy, microclimatic performance, soil sealing, and access to greenery, within a pilot multi-criteria model developed in Dynamo to evaluate the sustainability of the three scenarios. To ensure the methodology's scalability in suburban contexts where historical documentation is often scarce and fragmented among properties, the BIM modeling required by the analysis aims at the development of LOD 200 models, according to international standards. In cases of limited archival sources, the model is populated using building archetypes and standardized construction assemblies consistent with the building's era, since commercial construction is generally associated with fast-paced, mass-produced, and cost-effective construction processes. This allows for a reliable sustainability assessment even when precise stratigraphic data is unavailable. Therefore, this research through design combines analogic and digital representational and surveying tools, which delve into both the communicative and linguistic layers of architecture, linked to their evolutionary nature [26], with its construction data in a BIM environment, complementing the qualitative assessment with performance-based indicators, allowing direct comparison between the CS, SR, and SD.

4. An Austrian case study: analysis of the Vienna - Stockerau axis

The methodology has been applied to analyze the RA phenomenon widely spread over the Austrian territory, as a direct outcome of the increase in total e-commerce compared to the retail sector in Europe, as proved by the European E-Commerce Report of 2024. Specifically, this approach falls within the framework of the research *Counterintuitive Building Types* [2], among which the retail complex near Stockerau in the Korneuburg district was selected. This retail box represents an exemplary case study for its conformation and its decentralized location with respect to the suburban center defined by the municipality to which it belongs, as well as for its aesthetics responsive to the globalized logics of mass commerce related to the lifestyle sector. The approach taken to the study of the Austrian context questions the concept of architectural work as an isolated object, emphasizing the fluid interaction between cultural production, material processes, and the broader socio-political and environmental contexts in which architecture operates.

4.1 The historical commercial street of Vienna: insights from pictures and drawings

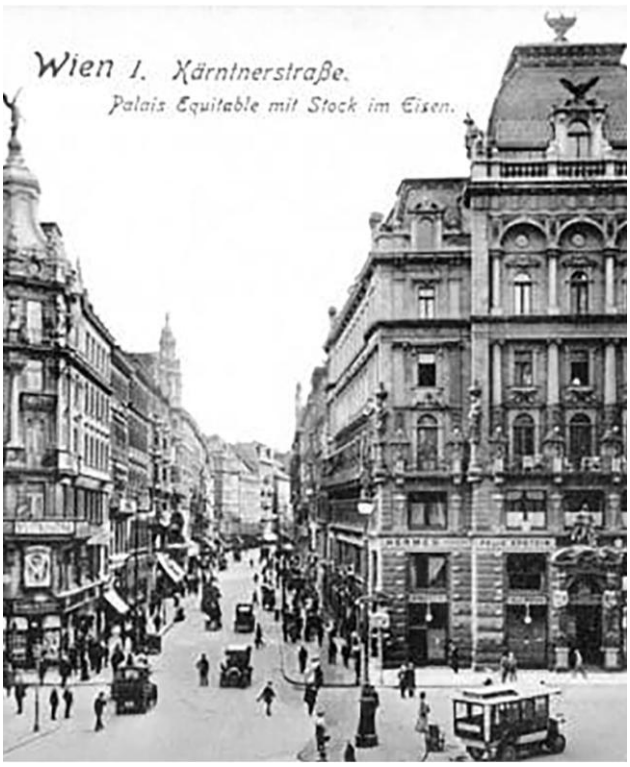
Kärntner Straße has been a significant crossroads for the architectural and commercial transformation of downtown Vienna, showcasing responsiveness to changes and innovations in the retail sector while retaining the charm and building fabric of a medieval layout. Extending from Stephansplatz to Karlsplatz, it transformed in the late 19th century into a vibrant shopping artery, with small craft stores and upscale department stores. Thus, Kärntner Straße has become an exemplary model of urban progress due to the great transformation of the street in the late 1800s (Figure 3).

The morphological structure of the contemporary urban layout has undergone a consistent process of transformation related to the appropriation of the ground and two upper floors for commercial use, shaping a bustling commercial street receptive to new business models. Kärntner Straße continues to be one of Vienna's main shopping streets, harboring one of the most pioneering works of the 19th century thanks to Otto Wagner's design for the Neumann department store, with which he introduced Jugendstil in Vienna. This building in Kärntner Straße 19, developed over an area of 812 m^2, is part of an urban modernization of the Habsburg capital's commercial functional fabric. Endowed with plasticity and elegance through the adoption of decorative materials like glazed ceramics, it innovates the communicative strategy of retail through its ability to capture attention as original architecture.

The design of the Neumann department store had responded to the new typological model defined in Paris, pioneered by the Bon Marchè, while evolving its conceptualization from the culture of the Habsburg capital, according to the tastes and customs of the empire [7, 28]. However, the history of the building and the communicative evolution of its facade were inextricably marked by World War II, being involved in an extensive fire in April 1945. The rubble of the department store testified to the crisis of the war-torn industry until 1949, when it was demolished. Then, architect Carl Appel oversaw the design of the new department store conceived according to postwar modernity, at first as Kaufhaus Neumann, characterized by a sober façade devoid of the decorative elements that had distinguished the Wagnerian design. In 1961, in a rebranding operation for the building's identity, the structure was renamed Steffl, for the neighboring Stephansdom, becoming a magnet for luxury shopping for the following decades. Multiple image strategies occurred for the department store's façade until the intervention of Hans Schmid in 2007, who promoted a strategic renewal of Steffl's identity toward the luxury and high-end fashion segment. Therefore, the evolution of Steffl in Kärntner Straße 19 constitutes an emblematic case of the transformations that affected Viennese commercial architecture between the 19th and 21st centuries, testifying to the transition from secessionist aesthetics to postwar functionalism, up to the most recent repositioning strategies in the luxury market.

The Steffl has been selected as an illustrative case study of Viennese retail architecture since field surveys, conducted along Vienna's streets and supported by historical records, confirm its representativeness within the city's commercial fabric. Moreover, its receptiveness to architectural changes over the last centuries marks it as a valuable reference for the broader analysis, despite the fragmented documentation available for nearby commercial buildings. The Steffl, indeed, provides a basis for codifying historical layer adaptations, interpreted through iterative processes that trace the ongoing transformations of the urban fabric (Figure 4). In addition, although the surviving sources are inherently limited, a comparative analysis was conducted between the Steffl and twelve other commercial buildings and retail storeys along Kärntner Straße and adjacent historical retail corridors, as shown in Figure 3. This comparative framework forms the basis of the analysis presented in Figure 5 and ensures its balance and contextual grounding. The transition from construction techniques such as load-bearing masonry to framed systems marked the history of retail, implementing the façade with large display windows, all the way to glass façades. Such typological hybridizations and evolutions of compositional solutions are manifested in addition in plan and elevation of extra surfaces and volumes, as well as the insertion, allowed by the urban layout, of alleys and covered commercial passageways on the street, as large lobbies and arcades, which are testimonies both from the medieval age and the modern era (Figure 5).

The stylistic transformations of the analyzed retail also involved communication solutions linked to the branding image, of which a trend toward simplification and the adoption of bright colors as well as larger lettering and logos was observed, submitting to the globalized logic of the market, which led to a gradual abandonment of fine materials and decorations. The metrics of the façade from 1895 to 2025 are marked by considerable and increasing fragmentation over time, supported by the ability of construction techniques to handle greater architectural complexity, as well as by increasingly elaborate research for department store rebranding strategies.



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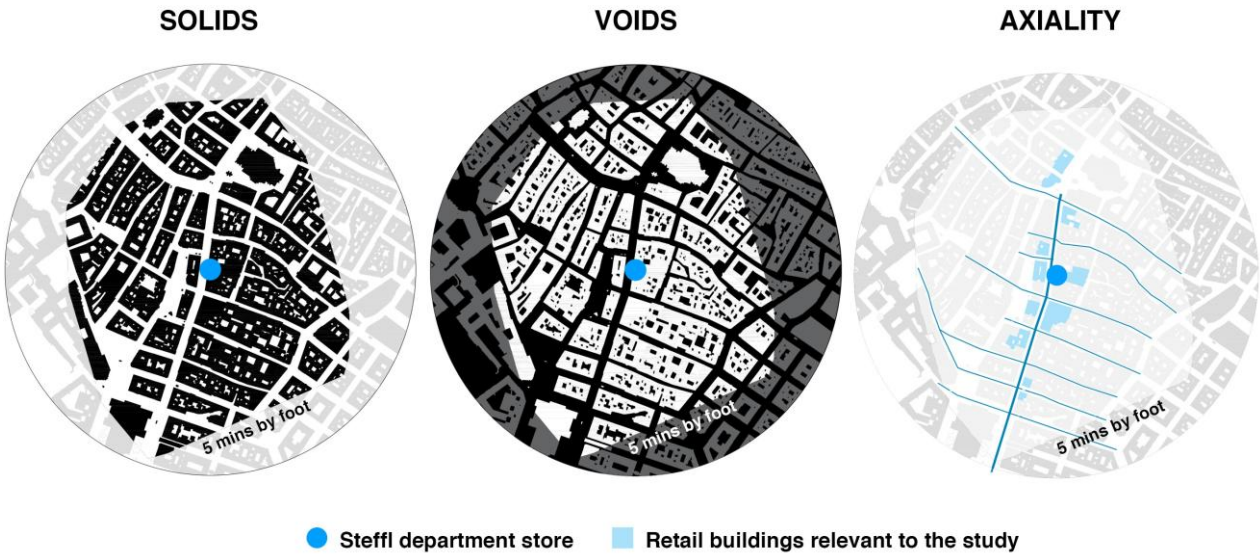

(c)

Figure 3 – (a) Historical postcard of Kärntner Straße from 1915; (b) Historical photo of Kärntner Straße from 1945; (c) Urban layers analysis for Kärntner Straße and proximities since the late 1800s. © 2025, Suvieri, Bianconi, Filippucci, Lechner.

Figure 4 – From Neumann store to Steffl department store: analytical study of façades evolution from 1895 to 2025. © 2025, Suvieri, Bianconi, Filippucci, Lechner.

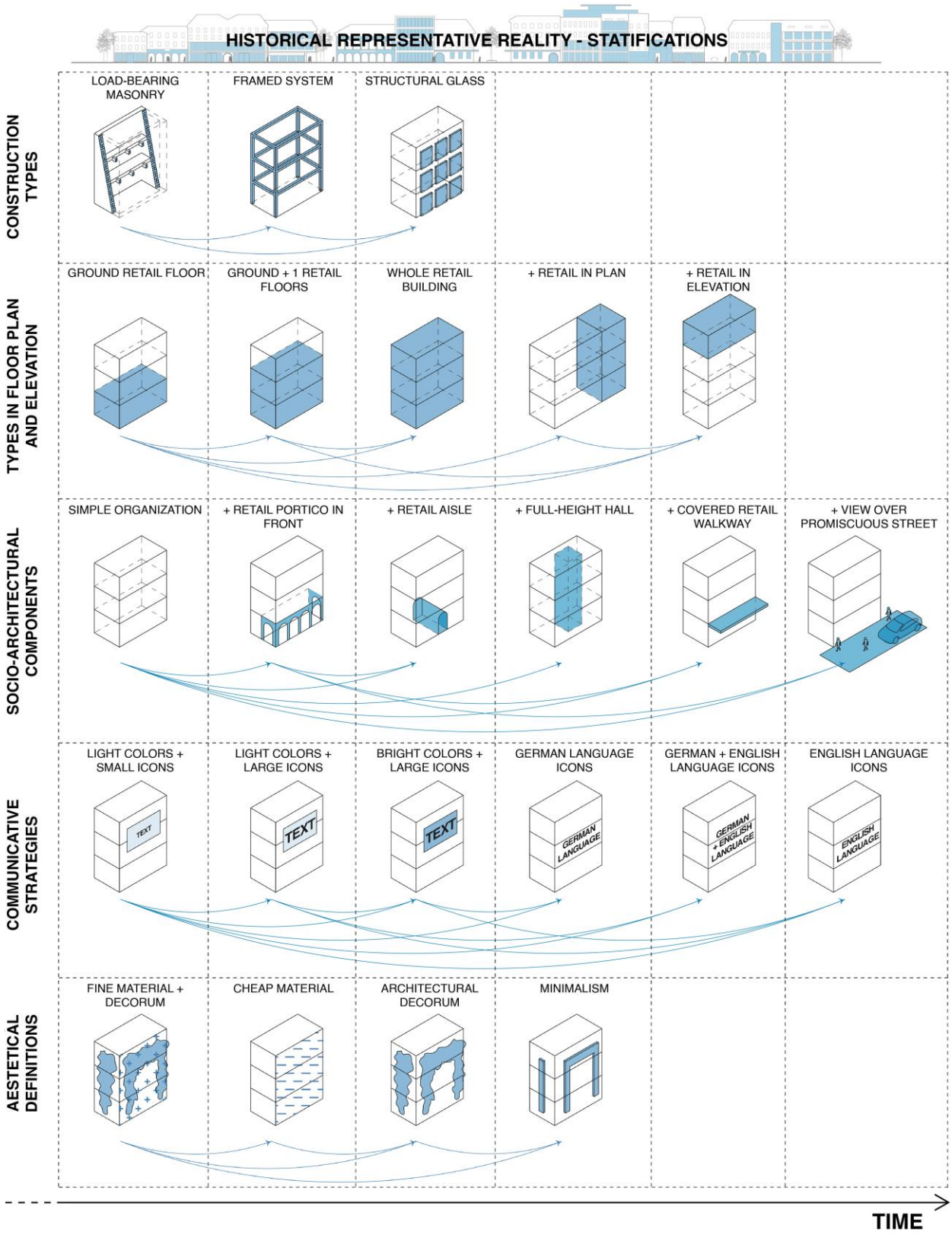

Figure 5 – Typological recurrences and evolutions overtime related to Kärntner Straße and Steffl department store analyzed in Vienna. © 2025 Suvieri, Bianconi, Filippucci, Lechner.

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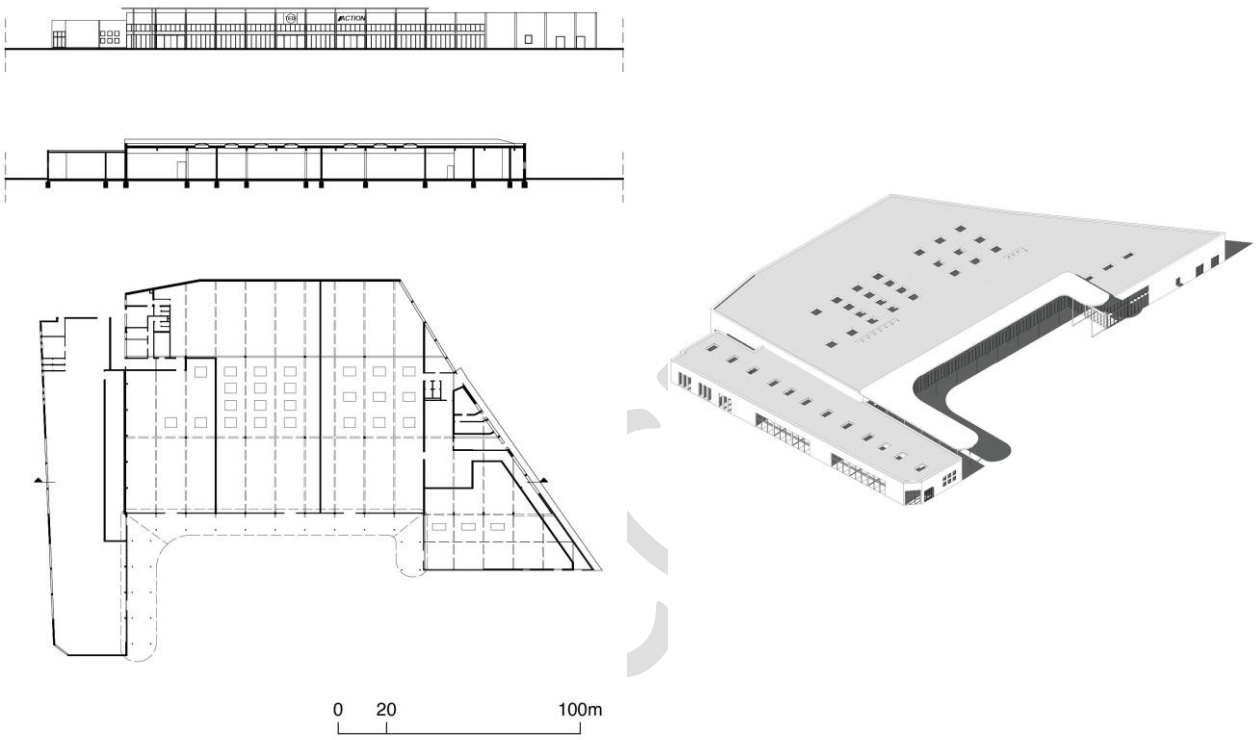
4.2 The retail system of the outskirts: a case study in Stockerau

The retail big box selected within the framework of the research is located in the federal state of Lower Austria, about 30 kilometers from Vienna and 10 kilometers from the closest suburban center, Korneuburg. The location of the building is strategic, as there is an infrastructure node served by the S5, A22, E59, and E49 arteries within 2 kilometers, connecting the Czech Republic to Vienna. This building (Figure 6) was constructed in the early 2000s as a retail outlet for the Zielpunkt chain. Following the company's declaration of insolvency, this complex was unused till the enlargement with the arrival of Dänisches Bettenlager, KIK, Tedi, Action, and Radatz.



(a) (b)

Figure 6 – Stockerau retail building: (a) prospect, section and plan; (b) 3D model of the building's CS. © 2025, Suvieri, Bianconi, Filippucci, Lechner.

Analyses on urban scale allowed reading by layers of the surrounding context, involving the identification of interspersed in the residential building fabric distributed widely throughout the territory (Figure 7). The single-story building conceived according to functional and standardized criteria reflects the monofunctional and peripheral logic typical of many retail structures, based on a large open-plan volume and direct vehicular access, but lacking qualified relations with the surrounding urban fabric. The building, whose history was revealed by reading the structural framework, underwent the addition of the block on the northern façade facing the street, occurring only afterward.

In addition to the evaluations conducted on the internal organization and its historical evolution (Figure 8a), the typologies previously identified for Vienna were also identified in the reality of the Austrian suburbs (Figure 8b), selected and balanced based on the broader set of retail buildings assessed within the research framework, distributed across the entire Austrian territory. Within this context, the illustrated building emerges as an emblematic example, synthesizing the main characteristics documented in the wider sample.

The potential value of the building mainly relates to aided vehicular access and its considerable interior size, as it has an area of 3,700 m^2, despite being a single-story building. During the analytical phase, critical issues related to orientation and spatial organization emerged, such as the fact that the façade on the street is completely blind and oriented to the north, while another, less accessible front is adjacent to a neighboring building to the southeast.

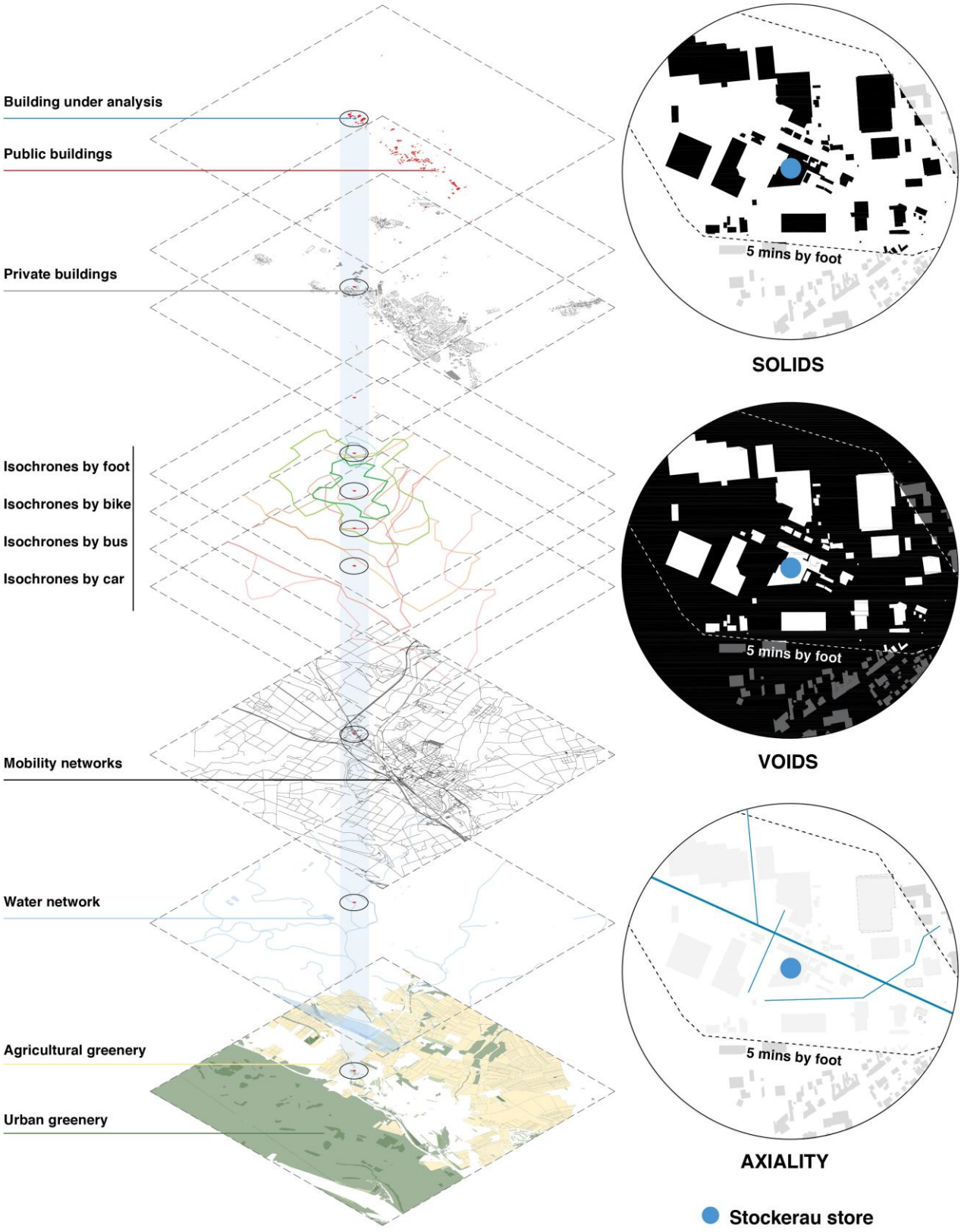
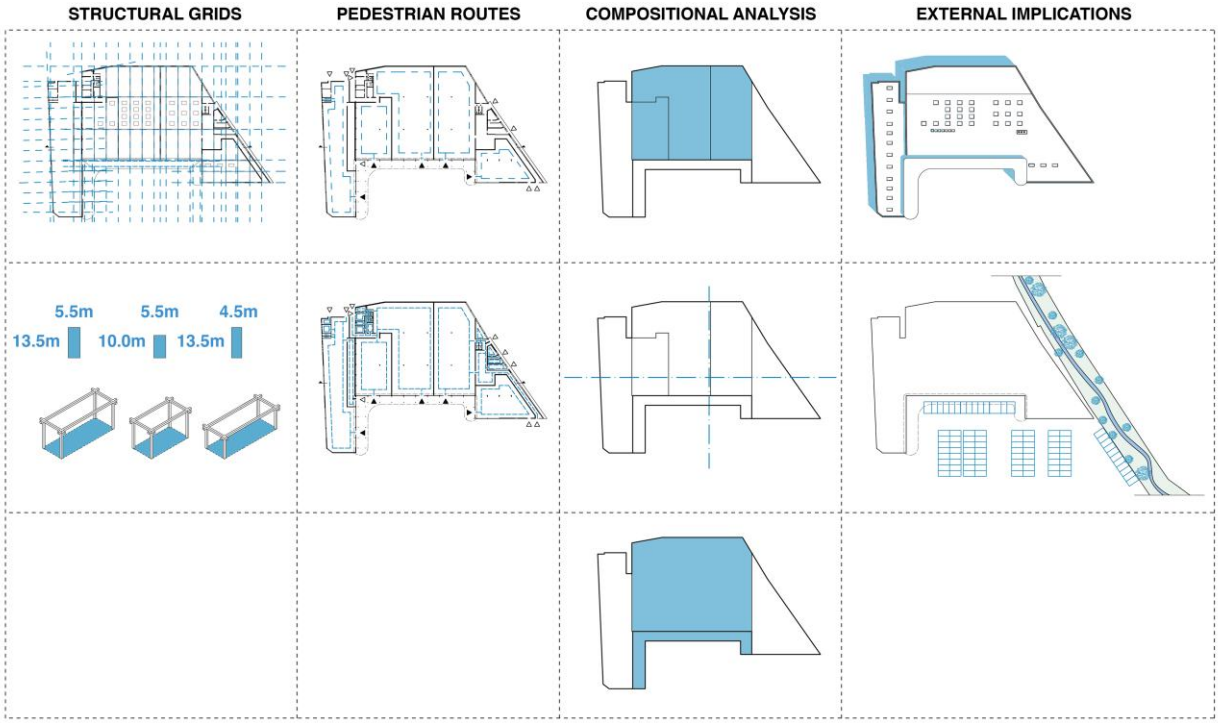


Figure 7 – Suburban layers analysis through surveys and geographical information. © 2025, Suvieri, Bianconi, Filippucci, Lechner.



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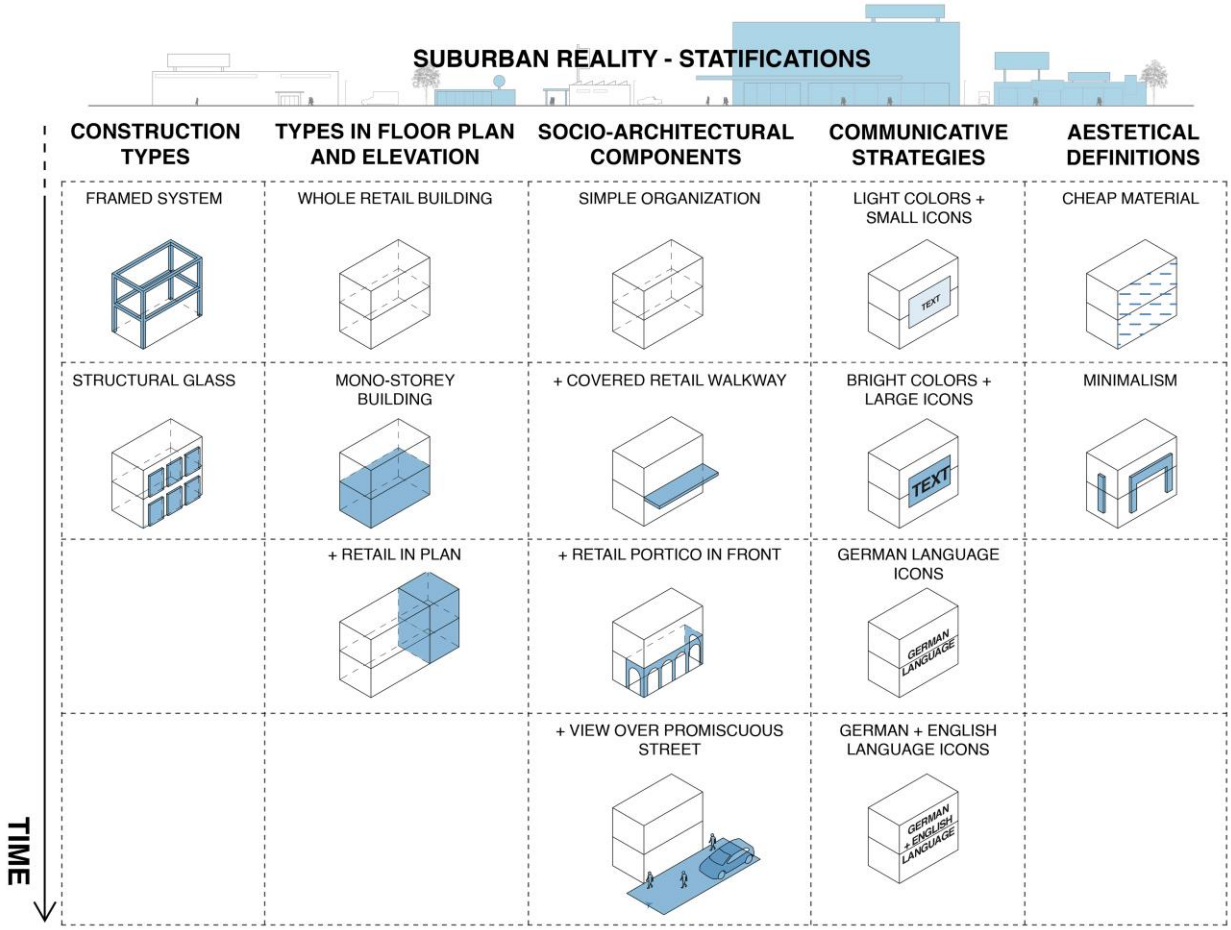


(b)

Figure 8 – (a) Suburban building analysis; (b) Typo-morphological recurrences in the Stockerau building in its CS.

5. Results: from typo-morphological decoding to scenarios assessment

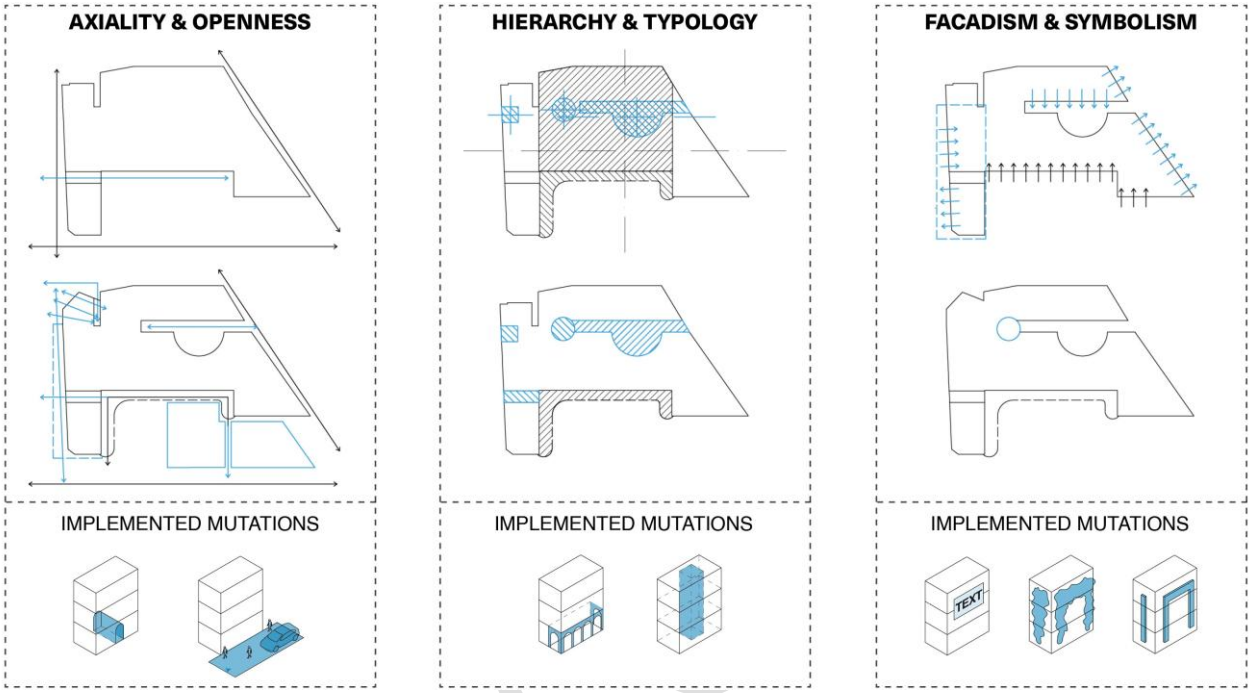
The dynamic survey involving steps A-I has provided a wide understanding of the Austrian retail types and their mutations over time, based on the representative case of the Steffl department store dynamics. As a matter of fact, such case study provides insights regarding the construction culture shift that happened with the advent of framed systems and structural glass, a significant component of this building typology, being strictly connected to its capability of being eye-catching for trade purposes. Moreover, the densification processes that often were proposed within the historical core of Vienna, involving both vertical and horizontal infill, were closely driven by architectural innovations and features such as the introduction of full-height halls, as well as external or internal passageways, promoting permeability and social interactions, a typical feature of high-stratified contexts. In addition, architectural components such as porticos and covered walkways, addressing pedestrians, figure balanced with retail icons and logos, while a process towards minimalism has been recorded along Kärntner Straße. Such cost-effective choices and simple, serial, and modular construction features were recognized also in the selected suburban case study, where the culture of retail framed by Venturi has been widely adopted. The extensive dimension of the commercial box, where the windowless space reaches depths of up to 40 meters, sustains a practice of alienation that connotes customers' experience in the retail spaces of the latter century. The presence of the exterior portico here echoes the architectural model seen in Vienna; however, it is limited to the view of the parking lot, while the street loses its role as a draw for pedestrians and remains primarily a reference point for cars. Although similar processes in the evolution of the big-box store in Stockerau have been identified, albeit on a limited time scale if compared with the department store in Vienna, there is a clear lack of architectural elements intrinsically linked to the design of a space intended for people as social interactors. Based on these comparative inter-scalar analysis processes, which highlight the symbiotic relationship between the historic center and the outskirts, three distinct intervention scenarios were defined. In the following sections, the baseline CS, the analyses-informed SR, and the SD option are examined in detail to provide a comprehensive evaluation of their performances. This quantitative comparative analysis complements the previous qualitative findings, serving as a dual-track guiding framework for the regeneration and reactivation of vacant and decommissioned commercial spaces.

5.1 SR scenario: a design informed by typo-morphological decoding

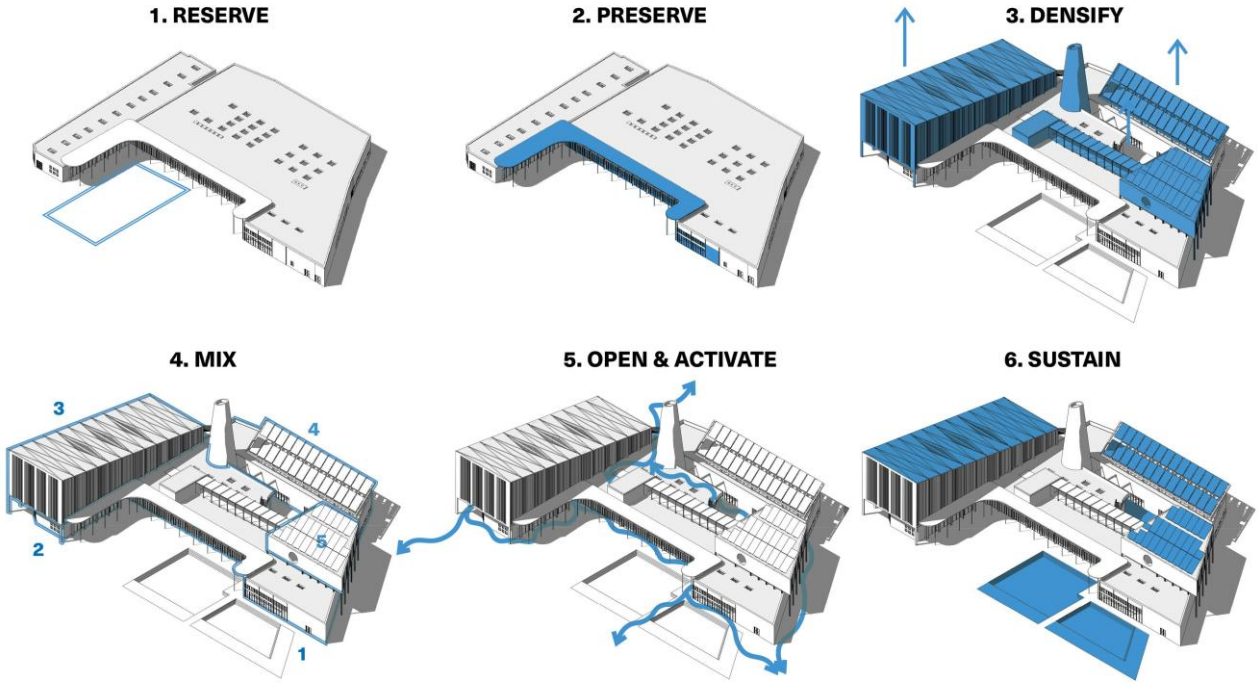
The SR scenario is developed as a technical response to the functional and spatial criticalities identified during the typo-morphological analysis. Instead of a traditional renovation, the proposal operates a transformation of the suburban big box by implementing architectural solutions derived from the historical commercial fabric of the Austrian context. The design process is structured around the re-interpretation of specific spatial archetypes, translated into a contemporary technological language to address the building's current obsolescence. Indeed, grounding on the de Rubertis legacy, the reactivation of space is proposed, enhancing the architectural components and type's mutations intrinsically linked to the collective memory of the Austrian-made retail architecture. Such solutions are balanced with the minimal physical intervention demanded by the contemporary conceptual definition of AR [2].

The proposal scenario, informed by the typo-morphological analyses, is shown in Figure 9, evolving around the principles of axiality and openness, hierarchy and typology, as well as facadism and symbolism. As a matter of fact, the re-interpretation of the commercial street archetype leads the permeability intervention, aiming to dissolve the building's current introversion and reshape the imbalanced hierarchy between the street and the main façade. Indeed, the primary typomorphological choice is the introduction of a covered gallery, a longitudinal axis that fragments the original 40-meter-deep windowless volume. This device serves to restore urban permeability, transforming a static, monofunctional enclosure into a porous organism. Therefore, by mirroring the spatial logic of historical Viennese passages, the design creates a new pedestrian interface that connects the internal activities with the surrounding suburban fabric, effectively reclaiming the social dimension of the commercial artifact. Such intervention also promotes the visual identification of the architectural space, no longer limited to its street icons. The cutouts that form a new courtyard, akin to a pedestrian path through greenery, are part of the process of introducing central atriums, both interior and exterior, which, extending to full height, facilitate the direct line of sight typical of department stores, thereby defining social interaction among shoppers. The final pair of principles, concerning facadism and symbolism, on the other hand, are reflected in the introduction of a golden tower designed as a bioclimatic device, which functions as a solar chimney and thus fosters a comfortable microclimate. However, it simultaneously takes on symbolic significance, becoming a recognizable landmark that distinguishes the site due to its elevation, both from the nearby highway and the pedestrian paths. Complementing this morphological restructuring, the technical and energy-efficiency strategies were developed to transition the building from a passive energy consumer to a responsive

environment. Indeed, the solar chimney solution is integrated with a comprehensive upgrade of the building envelope, including the implementation of dynamic shading systems, low-emissivity fixtures, photovoltaic systems, and green roofs. These solutions were modeled within the BIM environment to ensure a significant reduction in energy demand, estimated at over 70%, while prioritizing the preservation of the existing steel frame. This structural continuity is a core tenet of the sustainability strategy, as it minimizes the consumption of new resources and avoids the carbon footprint associated with demolition and reconstruction.



(a)



(b)

Figure 9 – (a) Principles influencing the SR, (b) 3D modeling in BIM of the SR. © 2025, Suvieri, Bianconi, Filippucci, Lechner.

As an AR proposal, the project inherently involves the introduction of new urban functions, which were delineated

as a synthesis of the territorial-scale analysis. The functional program is assigned based on the identification of missing functions and services in the nearby area through the isochrones analysis. Indeed, the lack of public and cultural spaces in the Stockerau outskirts guided the intuition to allocate a mixed-use program capable of fostering sociality and professional collaboration. The building is thus reconfigured to house two auditoriums, conference rooms, and an interactive showroom, complemented by a large ideas factory on the ground floor. This flexible co-working environment, equipped with reconfigurable modules, acts as a functional active layer that reoccupies the vacant retail space. By aligning the new use-cycle with the reclaimed architectural language, the SR scenario demonstrates how the reactivation of disused commercial spaces can be achieved through a design process where functional innovation is strictly informed by morphological resilience. The geometric and material impact of these transformations is quantitatively synthesized in Figure 10a, which illustrates the balance between the preserved structures and the newly introduced elements. Specifically, the diagram provides a clear breakdown of the additional material volumes and surface variations generated by the SR proposal. By mapping these physical changes against the original building's envelope, the figure clarifies the extent of the typomorphological re-coding, providing the necessary metric basis for the subsequent sustainability and performance assessments.

The technical validation of this complex architectural and functional reconfiguration was enabled by the computational workflow in Dynamo, where the algorithm developed in the framework of this research has assessed performance levels regarding energy efficiency, material management, costs, structural reusability, embodied energy, soil sealing, and access to greenery. All those aspects were evaluated and combined for the RS based on the SR model, developed by integrating the existing conditions of the building with the new features. Specifically, the material properties and technical assemblies assigned to the new envelope components were derived from standard technical databases and regional building archetypes. This allowed for the definition of a reliable performance profile within the BIM environment, ensuring that the comparative analysis between the baseline and the proposed design remains scientifically consistent and representative of the real-world energy and environmental gains.

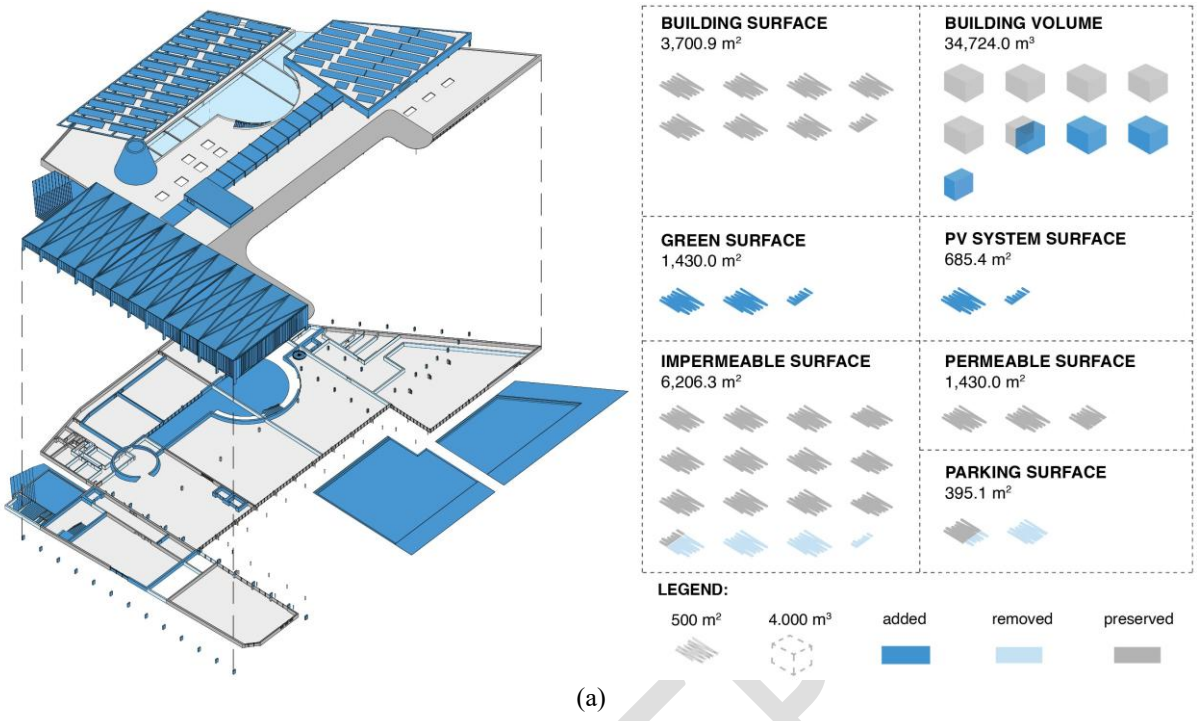
5.2 Comparative baselines: CS and SD modeling

The digital reconstruction in the BIM environment of the CS was conducted through an expedited modeling process, leveraging the technical drawings and construction specifications provided by the building's latest owners, collected in the framework of the research. For parameters not explicitly detailed in the available documentation, such as specific thermal transmittance values or internal stratigraphies, standard and recurring regulatory values for early 2000s Austrian commercial facilities were adopted. This allowed for the definition of a sufficiently reliable energy and structural profile, representing the building's as-is performance.

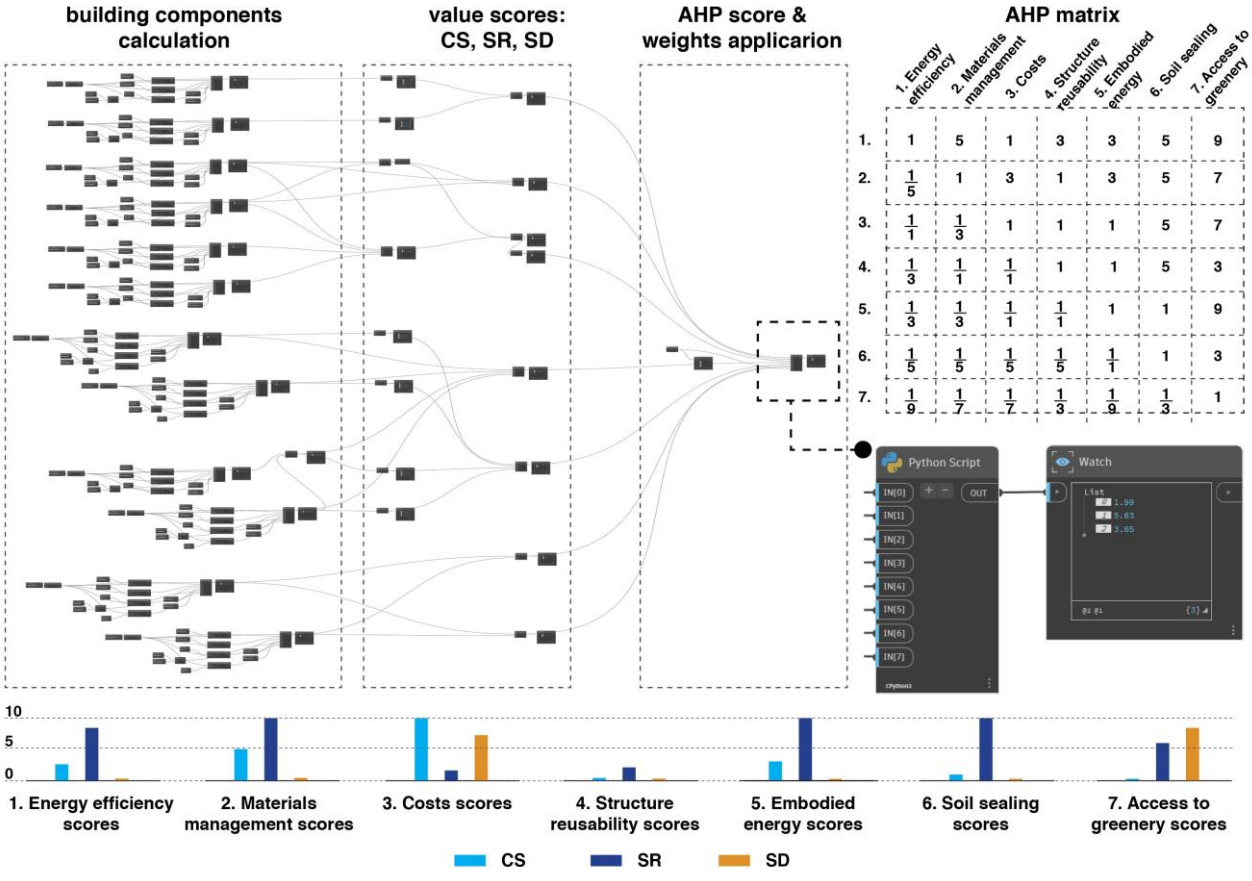
Conversely, the SD scenario was developed to quantify the environmental and economic impact of a demolition approach careless of deconstruction processes. This model therefore accounts for the total removal of the existing steel frame and the subsequent loss of the building's embodied energy, estimated also for the existing foundations, walls, and roofs. In the comparative pipeline, the SD serves as a critical benchmark to evaluate the burden of demolition waste management and the carbon footprint of new construction. By setting these two polar-opposite scenarios, addressed as passive preservation for the CS versus total removal for the SD, the research establishes the necessary boundaries to objectively measure the added value and sustainability of the SR proposal. Each of the seven criteria constituting the MCDM algorithm has been carried out for the three scenarios, adopting the weights illustrated in Figure 10b based on a pairwise comparison and existing literature for the development of the matrix.
Through the last steps of the methodology, the sustainability assessment results shown in Figure 11b highlight that, compared to the CS, the AR design is significantly more sustainable, overall, especially in terms of energy efficiency and building materials management.

5.3 MCDM-AHP algorithm: final comparison

The final stage of the methodology involves a comparative synthesis of the results, examining the SR metrics and features (Figure 10a) with the baselines represented by the CS and SD, as visualized through the AHP matrix and the subsequent scoring distributions (Figure 10b). The data highlights a significant divergence in performance across the three scenarios, providing a clear indication of the trade-offs inherent in suburban commercial regeneration. Indeed, the integrated assessment shows that the proposed interventions for the SR scenario would meet energy demand by more than 70% more than the SA, while also significantly reducing heat loss and improving the overall efficiency of the building envelope due to the adopted solutions.



(a)



(b)

Figure 10 – (a) SR of Stockerau building compared with CS; (b) CS, SR and SD scenarios evaluation through Dynamo algorithm for their sustainability assessment using AHP. © 2025, Suvieri, Bianconi, Filippucci, Lechner.

Although the SR presents a significantly higher initial investment than demolition, this cost is offset by the economic and social return from the regeneration of disused spaces capable of hosting new social, cultural, and work

functions. Added to these benefits are the results obtained in optimizing the permeability and impermeability of exterior surfaces, which improve stormwater management and mitigate the urban heat island effect, along with the adoption of targeted solutions to enhance microclimatic comfort. As a matter of fact, the SR scenario consistently outperforms the alternatives in the most critical environmental criteria, achieving the highest score for the energy efficiency and materials management categories.

Conversely, as evidenced by the bar charts in Figure 10b, the SD scenario figures competitively in terms of costs and access to greenery, as the demolition approach allows for an unconstrained redesign of the external permeable surfaces. However, this localized gain is heavily offset by the embodied energy management category. The CS option, while being the most cost-effective in the short term, remains the least resilient one, showing critical failures across all energy and social-related KPIs. The sustainability assessment via the analysis of model data in Revit confirms how the AR strategy, although more challenging from an initial economic point of view, represents the most advantageous and sustainable choice in the medium to long term, maximizing environmental and energy benefits. This quantitative assessment thus supports the architectural choices made, considering the type-morphological analyses conducted on the Austrian territory, which enabled the definition of an AR design based on an architectural language intent on reclaiming the attractiveness, typical of the charm of stratified historic centers, to ensure its survival, regardless of its temporary functions. These findings validate the scalability of the BIM-based MCDM pipeline, providing a replicable decision-making tool for the sustainable transformation of the European suburban landscape.

6. Conclusions

The investigation of architectural language through drawing and surveying, analyzed in relation to technological innovations and socio-economic shifts, proves to be an effective strategy for decoding the abandonment processes of commercial facilities and redefining their role within suburban contexts The research shows that the gradual erosion of architectural identity, often displaced by construction logics governed primarily by low cost and expediency, has been a major driver of the technical and social obsolescence of these building types. Yet, the inherent marginality of suburban locations combined with the absence of historical heritage constraints creates fertile ground for design experimentation, enabling AR strategies that transcend the limitations of standardized, globally replicated retail models, in favor of a locally rooted morphological resilience.

The research demonstrates how the critical reading of morphological transformations can inform operational tools for AR at both urban and architectural scales, further enhanced through automated, data-driven BIM-AHP analyses. Although its application has been developed within the European context, greater exploration in other areas of the world could enhance and provide invaluable consideration in terms of how architecture can be analyzed and interpreted. Moreover, major implementations of automated analysis through digital environments will be further developed to improve and incentivize outlined scalable and replicable design strategies for the metamorphosis of monofunctional retail boxes into multifunctional third places, capable of accommodating new practices of use and responding to the emerging demands of contemporary society.

In this sense, the research addresses the complexity of architectural communication by foregrounding the strategic importance of reconstructing typological stratifications and comparing them with historical reference models. The proposed method seeks to overcome functional rigidity and to restore the adaptive capacity of vacant, cost-driven retail structures, thereby offering a robust framework for urban regeneration. The recovery of architectural attractiveness and the improvement of environmental performance, supported by the BIM-AHP pipeline, are understood as central to the long-term survival and renewed social relevance of the built environment. More broadly, the project argues for a typo-morphological approach as a substantial basis for contemporary AR practice.

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8. Authors Contributions

L.S. Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing; F.B. Conceptualization, Project administration, Supervision, Writing – review & editing; M.F. Conceptualization, Project administration, Supervision, Writing – review & editing; A.L. Conceptualization, Project administration, Supervision, Writing – review & editing.

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