JOURNAL OF DESIGN FOR RESILIENCE IN ARCHITECTURE & PLANNING

Research Article
Online: www.drarch.org
Volume 6, Issue 1 (20-39), 2025
DOI: 10.47818/DRArch.2025.v6i1155

Silo buildings: A new image in the urban landscape

Zeynep Kerem Öztürk[*]
Ahmet Kurnaz[**]

Abstract

Silo buildings, traditionally used for storing bulk commodities such as grain, cement, and seeds, have become emblematic of industrial heritage while increasingly facing obsolescence in modern cities. Their cylindrical forms, dictated initially by utilitarian priorities, have made them prominent landmarks in urban and rural landscapes. With advancements in agricultural technology, shifts in logistics, and urban expansion, many silos lost their primary functions, leading to their abandonment or demolition. Recognizing the cultural, historical, and architectural significance of these structures, this study examines the potential of adaptive reuse—mainly through façade modifications and structural alterations—to transform silo buildings into vibrant elements of the contemporary urban fabric. A qualitative multiple-case study methodology was adopted to analyze four exemplary projects: Portland Towers, The Silo, Gemini Residence in Copenhagen, and Sugar City in Amsterdam. Data collection involved the review of architectural documentation, historical records, and visual media, with site observations and, where possible, stakeholder interviews. This approach enabled an in-depth exploration of the strategies employed to convert monumental, monolithic silos into fully functional environments. Central to these transformations were façade interventions—such as the introduction of windows, balconies, and new cladding materials—that humanized previously austere exteriors and improved interior light and ventilation. Structural additions and interior reconfigurations were also critical, helping silo buildings comply with modern building standards and accommodate a range of new functions, including offices, residences, and cultural venues. Findings highlight how carefully balanced preservation and innovation can conserve industrial authenticity while meeting contemporary urban needs. These projects illustrate how adaptive reuse revitalizes obsolete buildings and contributes to urban regeneration by attracting economic investment, enhancing local identity, and promoting sustainability through the conservation of embodied energy. Moreover, preserving a silo's cylindrical core while introducing modern features fosters a sense of continuity between past and present, reinforcing communal memory. Ultimately, the case studies underscore adaptive reuse as a practical, culturally sensitive pathway for reimagining silo buildings—one that merges historical significance, architectural creativity, and sustainable development to produce dynamic new landmarks in evolving urban landscapes.

Keywords: adaptive reuse, architectural interventions, industrial heritage preservation, silo buildings, urban regeneration

1. Introduction

Silo buildings have long been emblematic features of industrial and agricultural landscapes, standing as towering testaments to the ingenuity and economic importance of the storage and distribution systems of agricultural products, seeds, cement, and fuel. Constructed between the late 19th and mid-20th centuries, these large, cylindrical structures were engineered to store bulk quantities of agricultural products such as grain, seeds, and other commodities essential to both local and global economies (Fernández-Fernández et al., 2017). Often strategically located near railways, ports, and urban centers, silos served as critical nodes in the agricultural supply chain, facilitating efficient storage, processing, and transport of goods.

Architecturally, silos are characterized by their imposing verticality, minimalist design, and robust construction materials like reinforced concrete and steel (Brooker & Stone, 2019). Their

*Assist. Prof. Dr., Istanbul Sabahattin Zaim University, Türkiye zeynep.keremozturk@izu.edu.tr
**(Corresponding author), Assist. Prof. Dr., Istanbul Sabahattin Zaim University, Türkiye ahmet.kurnaz@izu.edu.tr
Article history: Received 24 January 2025, Accepted 04 April 2025, Published 30 April 2025

utilitarian aesthetics reflect the functional priorities of the industrial era. However, many silos possess a stark monumental beauty that has made them significant landmarks within both rural and urban settings. These structures' sheer scale and distinctive forms have ingrained them into the collective memory and identity of the communities they once served.

However, the latter half of the 20th century brought significant changes that led to the obsolescence of many silo buildings. Advancements in agricultural technology, shifts in logistics and transportation methods, and the globalization of trade reduced the need for localized storage facilities (Bullen & Love, 2011). Additionally, urban expansion and changes in land use priorities rendered many silo sites prime targets for redevelopment (Shipley et al., 2006). As a result, numerous silos were decommissioned, leaving behind vacant structures that posed challenges related to safety, maintenance, and land utilization.

The abandonment of silo buildings presents a complex dilemma for urban planners, architects, and preservationists. On the one hand, these structures are industrial relics that embody historical, cultural, and architectural values worthy of preservation (Cantell, 2005; Edwards & Llurdés I Coit, 1996). On the other hand, their sheer size and specialized construction make it challenging to repurpose them without significant intervention (Douglas, 2006). Demolition, while clearing valuable land for new development, results in the loss of industrial heritage and contributes to environmental concerns related to waste and resource consumption (Bullen & Love, 2011).

Adaptive reuse has emerged as a sustainable and culturally sensitive strategy to address the challenges posed by obsolete industrial structures like silos (Plevoets & Van Cleempoel, 2012). This approach involves repurposing existing buildings for new functions, conserving resources, reducing environmental impact, and preserving historical identity (Bullen & Love, 2011). Adaptive reuse aligns with contemporary urban development principles emphasizing sustainability, heritage preservation, minimal intervention, and efficient utilization of existing building stock (Brooker & Stone, 2019).

In the context of silo buildings, adaptive reuse often necessitates innovative architectural interventions to make these structures suitable for new functions (Douglas, 2006). Façade modifications and structural additions enhance usability while retaining the building's historical authenticity. Façade changes play a pivotal role in transforming the image of silos within the urban environment. Architects can humanize these monolithic structures by introducing elements such as windows, balconies, and contemporary façade elements, improving their interaction with the surrounding urban fabric and altering public perception (Brooker & Stone, 2019).

The transformation of silo buildings through adaptive reuse has broader implications for urban identity and regeneration (Heath et al., 2013). As cities evolve, integrating repurposed industrial structures can contribute to a sense of continuity and place, bridging the past with the present (Yung & Chan, 2012). Such projects can revitalize neighborhoods and economic activity in the area and enhance cultural offerings, strengthening the city's unique character and charm (Couch et al., 2008).

This paper aims to explore the multifaceted process of transforming silo buildings within urban contexts through adaptive reuse, with a particular focus on architectural interventions to the façade. By examining detailed case studies of Portland Towers (DGA Architects, 2014), Gemini Residence/Frosilo (MVRDV, 2005) and The Silo (COBE, 2017) in Copenhagen, and Sugar City (SugarCity, 2007) in Amsterdam, the study seeks to:

- Understand the impact of adaptive reuse on the urban identity of silo buildings. This involves analyzing how the transformation of these structures influences their role as landmarks and their integration into the urban narrative.
- Identify the specific architectural interventions employed in these transformations. The focus is on façade modifications and structural additions that facilitate new functions while respecting the building's historical significance.

- Assess how these changes alter the perception of silo buildings within the urban landscape. The study examines public reception, cultural significance, and the contribution of these projects to urban regeneration efforts.

Through this exploration, the paper contributes to the broader discourse on sustainable urban development, heritage preservation, and architectural innovation (UNESCO, 2013). It highlights the potential of adaptive reuse as a practical solution for dealing with obsolete industrial structures and enriching the urban environment. By preserving the monumental presence of silo buildings and reimagining their purpose, cities can honor their industrial heritage while fostering new opportunities for cultural and economic growth (Cantell, 2005).

In an era where sustainability and heritage conservation are increasingly important, the adaptive reuse of silo buildings serves as a compelling example of how cities can navigate the challenges of modernization (Plevoets & Van Cleempoel, 2012). These projects demonstrate that with thoughtful design and strategic interventions, even the most utilitarian structures can find new life and relevance, becoming integral parts of the contemporary urban tapestry (Brooker & Stone, 2019).

Furthermore, recent scholarly debates have emphasized the importance of urban resilience in the context of adaptive reuse, particularly how post-industrial transformations can enhance the adaptive capacities of cities facing economic, social, and environmental challenges (Meerow et al., 2016). In addition, emerging digital heritage strategies, such as 3D scanning, Building Information Modelling (BIM), and virtual reality applications, have significantly impacted how industrial heritage structures are documented, conserved, and integrated into contemporary urban contexts (Affleck & Kvan, 2008; Logothetis et al., 2015). These innovative techniques facilitate the preservation and interpretation of heritage sites, enhancing public engagement and urban identity (Barbara et al., 2021).

2. Research Aims

The primary objective of this study is to investigate how the adaptive reuse of silo buildings, through significant architectural interventions, contributes to their transformation into functional and culturally significant elements within urban landscapes. Focusing on façade modifications and structural additions, the research seeks to understand the multifaceted impact of these changes on the buildings and the cities they inhabit.

Specifically, the study aims to:

- Analyze the influence of adaptive reuse projects on the urban identity of silo buildings. This involves examining how the conversion of silos from industrial storage facilities to new functions reshapes their roles as urban landmarks, affects public perception, and integrates them into the cultural and historical narratives of their surroundings (Heath et al., 2013; Carmona, 2021).
- Identify and critically assess the architectural interventions employed in the transformation of silo buildings. By detailing the specific design strategies—such as façade modifications and adding new structural elements—the research aims to highlight how these interventions balance the preservation of historical significance with introducing contemporary uses (Brooker & Stone, 2019; Douglas, 2006).
- Evaluate the impact of these architectural changes on the perception and experience of silo buildings within the urban landscape. This includes exploring how modifications influence the buildings' visual prominence, their interaction with the surrounding urban fabric, and their ability to engage the community and contribute to urban regeneration (Lynch, 1960; Couch et al., 2008).

Through this comprehensive examination, the study seeks to contribute to the broader discourse on sustainable urban development, industrial heritage preservation, and architectural innovation (UNESCO, 2011; Bullen & Love, 2011). The research aims to provide insights and best

practices for integrating repurposed industrial structures into contemporary urban environments by analyzing detailed case studies from diverse geographical and cultural contexts. The findings aspire to inform future projects involving transforming obsolete industrial buildings, emphasizing the importance of thoughtful design, cultural sensitivity, and the sustainable revitalization of architectural heritage.

3. Materials and Methods

This study adopts a qualitative research methodology, utilizing a multiple-case study approach to explore the adaptive reuse of silo buildings within urban environments (Creswell, 2013; Yin, 2009). The qualitative approach is appropriate for this research as it allows for an in-depth examination of complex phenomena, providing rich, contextual insights into the processes and outcomes associated with transforming industrial structures into functional and culturally significant urban landmarks. By focusing on specific instances of silo reuse, the study aims to identify patterns, strategies, and unique features that contribute to successful adaptive reuse projects.

The selection of case studies was conducted through purposeful sampling, focusing on projects that exemplify significant architectural interventions and represent a diversity of new functions and geographical contexts (Patton, 2014). The three silo buildings chosen for analysis are Portland Towers, Gemini Residence/Frosilo and The Silo in Copenhagen, and Sugar City in Amsterdam (Table 1). The criteria for selecting these case studies included the degree and clarity of available architectural documentation to allow comprehensive spatial analysis; projects demonstrating a clear integration of façade modifications, interior spatial configurations, and structural interventions; examples from diverse functional contexts (residential, office, mixed-use) to provide broader applicability and comparability; and cases which had demonstrable urban impacts through their regeneration roles within their respective urban settings.

Table 1 Case Studies on Adaptive Reuse of Silo Buildings (Author(s), 2024)

Name of Building	Location	Original Function	Year of Transformation	New Function
Portland Towers	Copenhagen-Nordhavn, Denmark	Cement storage silos	2014	Office spaces
The Silo	Copenhagen-Nordhavn, Denmark	Grain storage silos	2017	Mixed-use residential and cultural space
Gemini Residence	Brygge, Copenhagen, Denmark	Seed silos	2005	Luxury apartments
Sugar City	Halfweg, Netherlands	Sugar beet factory silos	2007	Modern office buildings and mixed-use space

Data collection involved gathering information from multiple sources to understand each case (Yin, 2009) comprehensively. Architectural plans, including detailed drawings, sections, elevations, and renderings, were analyzed to comprehend the design interventions and spatial reconfigurations implemented during the adaptive reuse. Project documentation, such as official descriptions, planning reports, and press releases, provided context on each transformation's objectives, methodologies, and challenges.

Historical records and archival materials were examined to offer insights into the original functions, construction techniques, and historical significance of the silo buildings (Ashworth, 2011). This historical context is essential for understanding each structure's architectural heritage and cultural values. A thorough review of existing literature—including scholarly articles, books, and reports on industrial heritage, adaptive reuse, and urban regeneration—was conducted to inform the study's theoretical framework and to situate the findings within the broader discourse on sustainable urban development.

Visual media, such as photographs and videos documenting the buildings before, during, and after their transformations, were analyzed on-site to observe the physical changes and their impact

on the structures and their surrounding urban landscapes. Where accessible, interviews with architects, planners, or stakeholders involved in the projects were conducted to gain firsthand perspectives on the adaptive reuse initiatives' design decisions, implementation processes, and outcomes (Kvale & Brinkmann, 2009).

The data analysis focused on evaluating the architectural interventions and their influence on the functionality, aesthetics, and urban integration of the silo buildings. Particular attention was given to façade modifications, assessing how changes to the exterior—such as the introduction of windows, terraces, and modern cladding systems—enhanced the buildings' aesthetic appeal and usability while respecting their historical essence (Brand, 1995). Structural additions and interior reconfigurations were analyzed to understand how the internal spaces were reorganized to accommodate new functions, improve circulation, and enhance user experience.

The study also examined the functional adaptation of each silo building, analyzing the success of integrating new uses within the existing structures and their urban contexts. Factors such as user accessibility, contribution to the local community, and the buildings' roles in stimulating economic and cultural activities were considered. By synthesizing findings across the different cases, the research aimed to identify best practices and critical factors that contribute to the successful adaptive reuse of silo buildings.

Throughout the research process, measures were taken to ensure the rigor and validity of the study. Data triangulation was employed by cross-referencing information from multiple sources, including architectural documentation, historical records, literature, visual media, and interviews (Denzin, 2009; Flick, 2022). This approach enhanced the credibility of the findings and provided a holistic understanding of each case. Ethical considerations were addressed by attributing all sources, respecting intellectual property rights, and ensuring the confidentiality of any interview participants (Israel & Hay, 2006).

This study utilized a qualitative multiple-case study approach to explore the adaptive reuse of silo buildings, focusing on the architectural interventions that facilitate their transformation into functional and culturally significant elements within urban landscapes. The research provides valuable insights into how industrial heritage structures can be effectively integrated into contemporary urban environments by examining detailed cases from diverse geographical and cultural contexts and employing comprehensive data collection and analysis methods.

A critical holistic perspective guided the methodological framework of this study. Architectural interventions, particularly façade modifications, were analyzed for their aesthetic contribution and in relation to internal spatial organization, structural coherence, and functional adaptability.

4. Theoretical Background

4.1. Industrial Heritage and Adaptive Reuse

Industrial heritage refers to the physical remnants of industrialization, including buildings, machinery, sites, and landscapes with historical, technological, social, architectural, or scientific value (Douet, 2012). These structures are tangible representations of past industrial activities and are integral to understanding the socio-economic evolution of societies (Edwards & Llurdés i Coit, 1996). Despite falling into disuse, industrial heritage sites like silo buildings embody the technological advancements and cultural narratives of their time, offering insights into historical production methods, labor relations, and economic conditions (Palmer, 1998; Douet, 2012).

Adaptive reuse has emerged as a pivotal strategy for conserving industrial heritage by repurposing obsolete buildings for new functions while retaining their historical and architectural significance (Bullen & Love, 2011; Plevoets & Van Cleempoel, 2012; Cantell, 2005). This approach aligns with sustainable development principles by minimizing environmental impacts associated with demolition and new construction, such as waste generation, energy consumption, and resource depletion (Bullen & Love, 2011). Adaptive reuse conserves the embodied energy within

existing structures, reduces material waste, and preserves cultural heritage, thereby contributing to environmental, economic, and social sustainability (Shipley et al., 2006; Yung & Chan, 2012).

In the context of silo buildings, adaptive reuse presents unique challenges and opportunities due to their monumental scale, robust construction, and specialized design (Cantell, 2005; Shipley et al., 2006). Transforming silos into functional spaces requires innovative architectural interventions that address issues of accessibility, lighting, spatial layout, and compliance with contemporary building codes (Douglas, 2006; Plevoets & Van Cleempoel, 2012). Common adaptive reuse projects for silos include conversions into residential units, hotels, museums, cultural centers, and mixed-use developments (Xie, 2015). These projects often necessitate significant modifications, such as introducing new floor levels, creating openings for windows and doors, and installing new structural and mechanical systems while striving to maintain the building's historical integrity (Bullen & Love, 2011).

Conservation theory provides crucial guidance for balancing historical preservation with contemporary functionality in adaptive reuse projects. According to Feilden's conservation principles, it is essential to preserve not only the physical fabric of the building but also its historical authenticity and symbolic meanings (Feilden, 2003). Additionally, Jokilehto highlights that a successful conservation approach should evaluate the extent of interventions carefully, ensuring minimal yet effective modifications (Jokilehto, 2017). Thus, assessing conservation-use balance becomes pivotal, and case studies can illuminate how this balance is practically implemented.

4.2. The Role of Silos as Urban Landmarks

Urban landmarks are prominent physical features within a city that serve as reference points, contribute to its identity, and aid in spatial orientation. In his seminal work, "The Image of the City," Kevin Lynch emphasizes the importance of landmarks in enhancing the legibility of urban environments, fostering a sense of place, and facilitating navigation (Lynch, 1960). Landmarks are distinguished by their unique form, scale, historical significance, or visual prominence within the urban context.

Silo buildings inherently possess qualities that make them natural urban landmarks. Their towering height, distinctive cylindrical forms, and robust construction materials like concrete and steel set them apart within the urban skyline (Stratton, 2003; Martinat et al., 2018). Historically, silos were often situated near transportation hubs such as railways, ports, and industrial districts, making them focal points within the urban fabric (Edwards & Llurdés i Coit, 1996). As functional structures, they symbolized industrial progress and economic vitality, contributing to the collective memory and identity of the communities they served (Xie, 2015).

Through adaptive reuse, silos can retain and even enhance their status as urban landmarks by acquiring new meanings and functions that resonate with contemporary urban life (Rautenberg, 2012). The transformation of silos into publicly accessible spaces like museums, cultural centers, or residential complexes allows these structures to continue contributing to the city's identity and cultural narrative (Plevoets & Van Cleempoel, 2019). By integrating modern architectural elements while preserving historical features, adaptive reuse projects can create visually compelling landmarks that bridge the past and present, enriching the urban landscape and fostering a sense of continuity (Bullen & Love, 2011).

4.3. Façade Modifications and Urban Perception

The façade of a building serves as the interface between the internal and external environments, playing a critical role in shaping aesthetic appeal, functional performance, and symbolic expression (Schittich, 2012). In the adaptive reuse of silo buildings, façade modifications are often essential to accommodate new functions, improve environmental performance, and enhance visual integration with the surrounding urban context (Wong, 2017).

Initially designed for utilitarian purposes, silo façades typically lack fenestration and ornamentation, presenting blank, monolithic surfaces that can be perceived as imposing or

inaccessible (Martinat et at., 2018). To transform these structures into habitable and inviting spaces, architects often introduce new openings such as windows, balconies, and entrances, allowing natural light penetration, providing views, and establishing connections with the urban environment (Brooker & Stone, 2019). Adding contemporary cladding materials or façade treatments can update the building's appearance, reflecting modern design aesthetics while respecting the original industrial character (Douglas, 2006).

Façade modifications significantly influence urban perception by altering how the building is experienced visually and spatially (Schittich, 2012). Thoughtful design interventions can humanize the scale of silos, making them more relatable and engaging to pedestrians (Wong, 2017). Enhancing transparency and permeability, façade changes encourage public interaction and integration with surrounding urban activities (Heath et al., 2013). The juxtaposition of old and new architectural elements creates a dynamic visual narrative that celebrates the building's history while highlighting contemporary design innovation (Plevoets & Van Cleempoel, 2019).

In the context of urban regeneration, transforming silo façades can catalyze revitalization in adjacent areas, attract investment, and foster community pride (Roberts, 2000). Successful façade interventions not only improve the functionality and aesthetics of the building itself but also contribute positively to the streetscape and urban realm, enhancing the overall quality and experience of the urban environment (Couch et al., 2008). By redefining the visual and functional attributes of silos, façade modifications play a pivotal role in their integration into the contemporary urban fabric and in altering public perception from obsolete industrial relics to vibrant urban assets (Bullen & Love, 2011).

5. Case Studies: Transforming Silos into Urban Icons

This section examines four exemplary cases where silo buildings have been successfully transformed through adaptive reuse into vibrant urban landmarks. These case studies—Portland Towers, The Silo, Gemini Residence/Frosilo in Copenhagen, and Sugar City in Amsterdam—demonstrate how architectural interventions can revitalize obsolete industrial structures and integrate them into the contemporary urban fabric while preserving their historical significance.

5.1. Portland Towers, Copenhagen-Nordhavn, Denmark

Portland Towers are in the new neighborhood of Århusgadekvarteret in Nordhavn, Copenhagen, and stand as one of the area's tallest and most iconic buildings. Initially built in 1979 by Aalborg Portland for cement storage, these former industrial silos were transformed into office spaces between 2013 and 2014 by NCC Property Development and Design Group Architects (DGA Architects, 2014) (Figure 1).

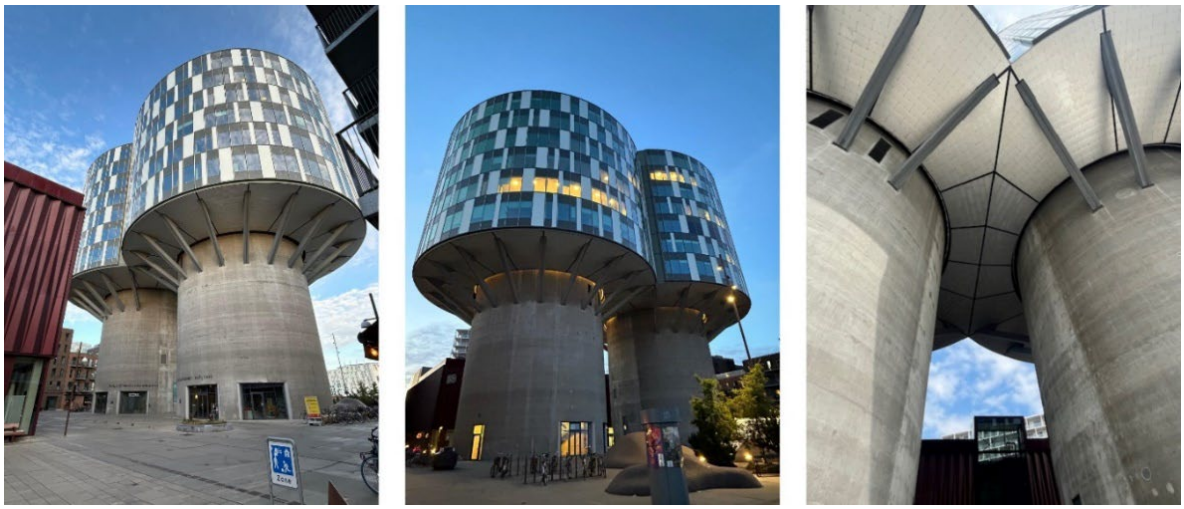

Figure 1 Portland Towers (Author(s), 2024)

5.1.1. Architectural Interventions

The transformation concept preserved the cylindrical shape of the silos while adding a light glass structure surrounding the concrete silos (DGA Architects, 2014). This circular glass structure emphasizes the industrial form, while the façade's composition, inspired by clouds in the blue sky, creates a transparent and modern office building. A significant architectural intervention was the addition of seven floors, beginning twenty-four meters above ground, adding 12,727 m² of office space. The buildings also achieved BREEAM certification, indicating their high level of sustainability, particularly in energy efficiency and material selection (NCC Property Development, 2014).

5.1.2. Functional Transformation and Urban Impact

Portland Towers have become a landmark of Copenhagen's sustainable urban development, especially in the context of the Nordhavn district, which aims to balance economic, social, and environmental aspects in its development (The Housing Agency, 2024). The office complex now hosts multiple companies, contributing to the district's revitalization as a business hub. The silos' industrial roots, reflected in their design, add a layer of cultural memory to this modernized area.

5.2. The Silo, Copenhagen-Nordhavn, Denmark

The Silo in Copenhagen is another prime example of a silo's adaptive reuse, where a former grain storage facility was converted into a mixed-use residential and cultural space. Designed by COBE Architects and completed in 2017, this 17-story, 62-meter-tall silo is a key feature of the Nordhavn district's urban redevelopment (COBE, 2017) (Figure 2).

Figure 2 The Silo (Author(s), 2024)

5.2.1. Architectural Interventions

The Silo's brutalist concrete exterior was preserved while galvanic steel panels were added to the façade, giving it a modern, industrial look (COBE, 2017). The building's unique architectural approach involved maintaining the original grain storage bins inside while converting them into various apartment layouts (ArchDaily, 2017). Each floor differs in design due to the structural challenges posed by the silo's original use, creating a rich spatial diversity. The top floor was also transformed into a public restaurant, offering panoramic views of Copenhagen and Sweden (COBE, 2017).

5.2.2. Functional Transformation and Urban Impact

As part of a broader redevelopment of Nordhavn, The Silo has become an urban landmark, admired for its blend of modern design and industrial heritage (Griffiths, 2017). The public restaurant and event spaces ensure that the building is accessible despite being primarily residential. The Silo serves as a model for combining luxury living with cultural spaces, enhancing

Copenhagen's urban identity while promoting the adaptive reuse of industrial structures (COBE, 2017).

5.3. Gemini Residence/Frosilo, Brygge, Denmark

Gemini Residence, formerly known as Frosilo, is a conversion of two seed silos in the Brygge harbor district of Copenhagen. Initially built in 1963 for the Dansk Soyakagefabrik company, the twin silos were transformed into luxury apartments between 2003 and 2005 by MVDRV Architects (MVRDV, 2005) (Figure 3).

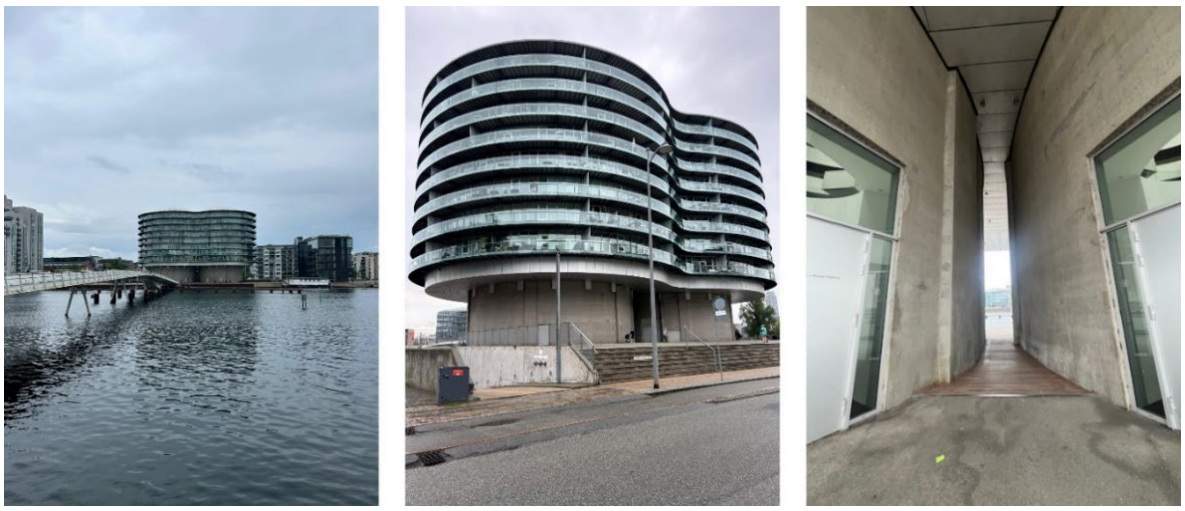

Figure 3 Gemini Residence/Frosilo (Author(s), 2024)

5.3.1. Architectural Interventions

The architectural challenge of converting these 42-meter-high silos was met by cutting large openings in the concrete structure to allow for balconies and windows (MVRDV, 2005). The apartments were built outside the silos' original cores, while the central silos were preserved as circulation spaces housing elevators and staircases (Archello, 2005; Frearson, 2015). The design maintains the industrial essence of the building while integrating contemporary elements like glass-clad balconies that offer stunning views of the city.

5.3.2. Functional Transformation and Urban Impact

The Gemini Residence is now one of Copenhagen's most sought-after residential buildings, combining its industrial heritage with modern luxury (Copenhagen Architecture, 2016). The project won the "Best Building" award from the City of Copenhagen in 2005, demonstrating the successful fusion of functionality and design (MVRDV, 2005). Its transformation has significantly contributed to the regeneration of the Brygge area, reinforcing the role of adaptive reuse in urban development (Couch et al., 2008).

5.4. Sugar City, Halfweg, Netherlands

The Sugar City complex, located in Halfweg, Netherlands, is a former sugar beet factory that closed in 1992 and was later redeveloped into a mixed-use space by Soeters van Eldonk Architects. Two prominent silos within the complex were converted into modern office buildings (SugarCity, 2007) (Figure 4).

Figure 4 Silo buildings in Sugar City (Author(s), 2024)

5.4.1. Architectural Interventions

The silos underwent both interior and exterior modifications, including the addition of elevators, staircases, and facilities to meet contemporary office standards (SugarCity, 2007). The exterior retained its industrial character, with aluminum and glass cladding emphasizing the cylindrical shape (World Aluminium, 2007). Diamond-shaped windows framed in aluminum allow natural light to flood the interior while maintaining the original silhouette. At night, the silos are illuminated by LED lights, adding to their iconic status within the urban landscape.

5.4.2. Functional Transformation and Urban Impact

The transformation of Sugar City has garnered international recognition for its contribution to industrial heritage preservation. It has received numerous awards, including the Prix d'Excellence for Environmental Preservation 2012 (FIABCI, 2012). Sugar City is now a thriving hub for offices, retail, and events, demonstrating the potential of adaptive reuse to breathe new life into industrial structures while promoting economic and cultural growth in the surrounding area (SugarCity, 2007).

5.5. Comparative Insights

The transformation of industrial silos into functional urban landmarks highlights the potential of adaptive reuse in enriching the urban landscape while preserving historical significance (Bullen & Love, 2011). In examining Portland Towers, The Silo, Gemini Residence/Frosilo, and Sugar City, several key themes emerge regarding the role of architectural interventions, sustainability, and urban regeneration. Despite the differences in geographic location, cultural context, and intended use, these projects share common strategies for preserving the essence of the original structures while integrating them into modern urban life.

5.5.1. Preservation of Historical Identity

All four case studies demonstrate a deep respect for the historical integrity of the original silo structures. Each project prioritized retaining key elements such as the cylindrical form and robust concrete façades, recognizing these features as integral to the silos' industrial heritage. This approach allowed the buildings to maintain a tangible connection to their past functions while serving new purposes.

In the case of Portland Towers and The Silo, the cylindrical forms of the silos were carefully preserved. At the same time, contemporary materials like glass and steel were introduced to give the buildings a modern aesthetic without erasing their industrial roots. Similarly, Gemini Residence retained the concrete cores of the twin silos as central circulation spaces, highlighting their

historical significance. Sugar City kept the towering silos intact, using them as visual landmarks within a broader industrial complex.

By retaining these key elements, the projects honored the industrial past and contributed to the urban memory of their respective locations (Lynch, 1960). This balance between preservation and transformation illustrates how adaptive reuse can safeguard industrial heritage while allowing buildings to evolve.

5.5.2. Innovative Architectural Interventions

Façade modifications played a crucial role in redefining the visual identity of each silo. Architects introduced modern design elements such as windows, balconies, and cladding systems to humanize the silos' monolithic forms and make them more relatable to their urban contexts.

Portland Towers and The Silo both used glass and steel additions to introduce transparency and light, enhancing the interaction between the buildings and their surroundings. In the case of Gemini Residence, glass balconies were attached to the exterior of the silos, offering residents expansive views while preserving the cylindrical form. Sugar City used aluminum cladding and distinctive diamond-shaped windows to modernize the silos without obscuring their industrial character.

These interventions were not only aesthetic but also functional. The addition of balconies, windows, and new façade treatments allowed for natural light and ventilation to penetrate deep into previously dark interiors, transforming the silos into habitable and inviting spaces (Wong, 2017). Structural modifications, such as adding new floor slabs and elevators, ensured that the buildings complied with contemporary building codes and accessibility standards while maintaining their industrial essence (Douglas, 2006) (Table 2).

Table 2 Architectural Interventions (Author(s), 2024)

Name of Building	Façade Modifications	Structural Additions	Preservation of Historical Elements
Portland Towers	Added light glass structure; façade inspired by clouds	Added seven floors starting 24 meters above ground	Preserved cylindrical shape of silos
The Silo	Added galvanized steel panels to façade	Maintained original grain bins; unique apartment layouts	Preserved brutalist concrete exterior
Gemini Residence	Cut large openings for balconies/windows; glass-clad balconies	Built apartments outside original cores; central silos as circulation spaces	Retained industrial essence of silos
Sugar City	Aluminum and glass cladding; diamond-shaped windows	Added elevators, staircases, modern facilities	Retained industrial character and original silhouette

5.5.3. Functional Adaptation and Urban Regeneration

Each of the adaptive reuse projects transformed the silos into new, functional spaces that contributed to the economic, social, and cultural vitality of their urban environments (Langston et al., 2008).

Portland Towers and The Silo were both repurposed as office and residential spaces, respectively, injecting new life into the Nordhavn district of Copenhagen, which has undergone significant redevelopment. These projects not only preserved the silos but also enhanced the area's appeal as a vibrant, sustainable neighborhood. Through its transformation into luxury apartments, Gemini Residence played a similar role in revitalizing the Brygge harbor district, making it one of Copenhagen's most sought-after residential areas.

In the case of Sugar City, the silos were converted into office spaces, and the surrounding industrial complex was transformed into a mixed-use development. This adaptive reuse project contributed to the economic revitalization of Halfweg, turning a previously derelict site into a thriving commercial and cultural hub. The development of Sugar City demonstrated how adaptive reuse can stimulate economic growth by attracting new businesses, residents, and tourists to previously underutilized areas.

5.5.4. Sustainability and Environmental Impact

Adaptive reuse inherently supports sustainability by conserving resources, reducing waste, and minimizing the environmental impact of new construction. All four case studies adhered to sustainable development principles, incorporating energy-efficient systems, sustainable materials, and strategies to reduce the buildings' environmental footprints.

Portland Towers achieved BREEAM certification for their energy-efficient designs, emphasizing the importance of sustainable building practices in contemporary urban development. Using lightweight materials like aluminum and glass in Sugar City and Gemini Residence helped reduce the buildings' energy consumption. At the same time, retaining the original concrete structures conserved embodied energy and reduced the need for new construction materials.

These projects also exemplified the environmental benefits of adaptive reuse. By repurposing existing buildings rather than demolishing them, they avoided the significant waste generation and carbon emissions associated with demolition and new construction (Bullen & Love, 2011). This sustainable approach not only contributed to environmental goals but also aligned with broader urban policies focused on reducing the carbon footprint of cities (UNESCO, 2011).

5.5.5. Integration into the Urban Fabric

The successful integration of these repurposed silos into their urban environments was another shared characteristic of the projects. Each project aligned with local development goals and urban policies that supported sustainability, heritage preservation, and economic growth.

Portland Towers and The Silo became iconic landmarks within the Nordhavn district, contributing to the area's identity as a forward-thinking, sustainable urban neighborhood. Similarly, Gemini Residence was seamlessly integrated into the Brygge harbor area, reinforcing the district's character as a modern, upscale residential area. Sugar City stood as a symbol of industrial heritage within Halfweg while offering the region new economic opportunities and cultural experiences.

These projects underscore the importance of considering the broader urban context when undertaking adaptive reuse initiatives. By aligning with local development objectives, the transformations not only revitalized the individual silos but also contributed to the cultural, economic, and social vitality of their surrounding areas.

In summary, the adaptive reuse of silo buildings, as seen in Portland Towers, The Silo, Gemini Residence, and Sugar City, demonstrates the transformative potential of architectural interventions to breathe new life into obsolete industrial structures. These projects succeeded by balancing preserving historical identity with introducing innovative design elements, enhancing functionality, promoting sustainability, and integrating into the urban fabric. They stand as powerful examples of how cities can honor their industrial heritage while meeting the needs of contemporary urban development (Table 3).

Table 3 Comparative Analysis of Architectural Interventions (Author(s), 2024)

Aspect	Portland Towers	The Silo	Gemini Residence	Sugar City
Façade Treatment	Glass structure inspired by clouds	Galvanized steel panels	Glass-clad balconies	Aluminum and glass cladding
Structural Changes	Added seven floors	Unique layouts due to original bins	Apartments built outside cores	Added elevators and staircases
Interior Reconfiguration	Modern office spaces	Diverse apartment designs	Luxury apartments	Modern office facilities
Public Accessibility	Office complex	Public restaurant on top floor	Residential building	Offices, retail, and event spaces

However, it is crucial to critically assess the extent to which these case studies observe a balanced conservation-use approach. For instance, Portland Towers preserved the external form substantially, yet extensive additions could be perceived as diminishing its industrial authenticity. Conversely, The Silo project demonstrates a more careful balance by retaining significant structural

elements, such as internal grain bins, thus preserving historical authenticity. Similarly, Sugar City's use of adaptive digital methods facilitated minimal intrusion into the original structure, enhancing both preservation and usability. These examples illustrate the varying degrees of conservation strategies employed, underscoring the importance of clearly defining conservation prerequisites in adaptive reuse projects.

Moreover, critical comparative discussions reveal notable differences regarding how effectively spatial coherence and function-structure harmony were achieved. With its externalized residential modules, Gemini Residence managed to retain internal coherence and clearly delineated functional spaces. In contrast, Portland Towers faced challenges regarding internal spatial clarity due to the extensive additions above the original structure, potentially affecting the integrity of its industrial identity. The Silo, by preserving internal grain bins, established a direct structural-functional harmony between old and new. Sugar City's minimal but strategically placed structural additions allowed clear functional integration, representing an optimal example of spatial and structural harmony.

6. Results

The adaptive reuse of silo buildings, as demonstrated in the case studies of Portland Towers, The Silo, Gemini Residence, and Sugar City, illustrates how industrial heritage structures can be successfully transformed into functional urban landmarks. These transformations reveal the potential of architectural interventions, particularly façade modifications and structural additions, in reshaping the identity and functionality of these imposing structures.

In The Silo, the application of galvanized steel cassettes to the façade resulted in expansive panoramic windows and balconies. Consequently, the monotony of the concrete façade was broken, allowing natural light to reach the interior spaces effortlessly. Updating the façade in this manner facilitated the transformation of the silo from a monumental and cold-surfaced industrial structure into a glamorous residential complex that can harmoniously integrate with the surrounding urban fabric.

In Portland Towers, adding a circular, cantilevered glass structure modernized the visual appeal, creating a transparent and dynamic façade and introducing critical spatial coherence challenges. The extensive structural addition altered the original industrial scale, affecting the building's internal spatial harmony and historical authenticity. Although visually appealing, the intervention raises questions regarding the balance between aesthetic modernization and structural integration, reflecting a potential misalignment with conservation theory principles advocating minimal intervention.

In the Frosilo-Gemini Residence, two silos were connected at the upper levels, transforming them into a residential complex that appears as a single building. The apartments were suspended outside the existing silo structure due to limited and complex possibilities for openings in the concrete rings. This approach allowed each room to benefit from maximum views and plan flexibility while creating two enormous atriums (Mies Award, 2007). There are floor-to-ceiling windows and balconies. Both cores are covered with a glazed roof, and at the base of the silos, the raw concrete was left exposed to highlight the building's history. The gap between the two silos connects the street with the harbor.

Nevertheless, the primary emphasis on façade aesthetics and externalized apartment modules highlights a potential oversight in fully addressing structural coherence, a critical aspect of adaptive reuse according to conservation and resilience theories. This focus on external imagery could imply a limited integration of deeper theoretical principles related to structural adaptation and internal spatial functionality.

In the conversion of the Sugar Silos into offices at Halfweg Sugar City, sustainability was at the forefront of the agenda. For example, the Sugar Silos were awarded an 'A' energy rating, and sustainable energy is utilized thanks to the ATES system. The Sugar Silos provide a dazzling array of

colors through hundreds of colored LED lights installed in the window frames. In the silos' repurposing project, the exterior façade was characterized by the buildings' round shape, and this process could be conducted seamlessly thanks to the high flexibility of aluminum. The glass and aluminum cladding were specially molded to fit the curved surface. A more refined approach was adopted by adding rhombus-shaped windows made of solar-control glass surrounded by aluminum frames to the original façade (World Aluminium, 2007).

As observed in the four case studies, structural additions and interior reconfigurations were crucial in adapting the silos to accommodate new functions while respecting their historical essence. The inherent architectural challenges, such as vast, uninterrupted interior volumes and lack of accessibility arising from the silos' original designs, were skillfully addressed with innovative solutions (Figure 5).

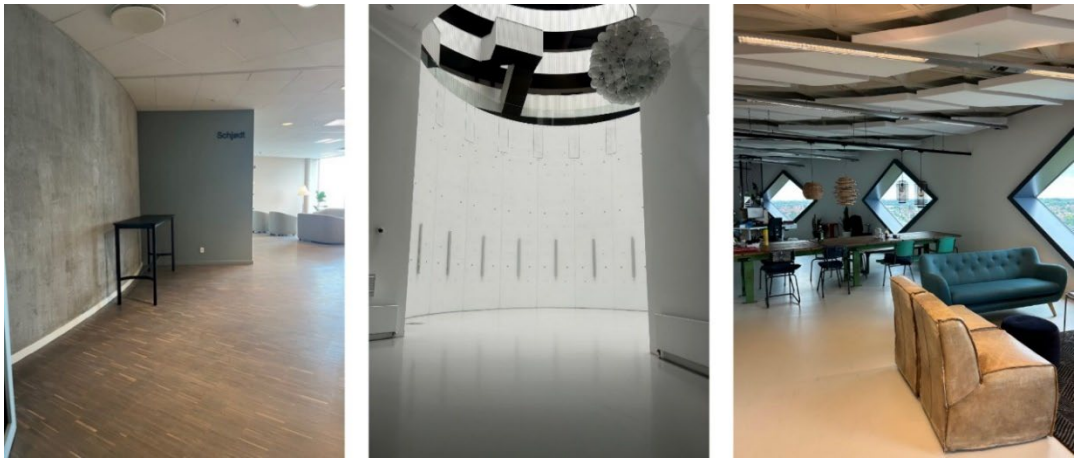

Figure 5 Interiors of Portland Towers (left), Gemini Residence (center), and Sugar City (right) (Author(s), 2024)

A significant outcome of these projects is the role that façade modifications played in altering the perception of the silos. Designed initially with utilitarian, monolithic exteriors, these buildings underwent substantial visual changes that enhanced their aesthetic appeal and improved their interaction with the urban environment (DGA Architects, 2014; MVRDV, 2005; COBE, 2017; SugarCity, 2007). The introduction of windows, balconies, and contemporary cladding materials helped humanize the scale of these once-imposing structures, allowing them to blend seamlessly into their modern contexts. For example, the glass and steel façade of Portland Towers transformed the silo into a transparent, dynamic office space, while the galvanized steel panels added to The Silo in Copenhagen helped preserve its industrial character while creating a modern residential and public space.

In terms of functional transformation, these projects demonstrate how silo buildings can be repurposed to meet contemporary urban needs. The adaptive reuse of these structures as office spaces, residences, or cultural venues has revitalized their surrounding areas, contributing to economic growth and urban regeneration. Portland Towers and The Silo both played critical roles in the redevelopment of the Nordhavn district in Copenhagen, bringing new life to the area through their commercial and residential functions. Similarly, transforming Gemini Residence into luxury apartments elevated the Brygge harbor district into one of Copenhagen's most desirable residential neighborhoods. The Sugar City project, with its conversion of sugar storage silos into office spaces, has also become a key driver of economic activity and cultural engagement in Halfweg.

The transformation of The Silo and Portland Silo into mixed-use complexes has enhanced the attractiveness of the Nordhavn region, promoting sustainable urban living and encouraging further investment. In Halfweg Sugar City, the two iconic silo structures converted into offices, along with other historic buildings in the area still undergoing transformations and new constructions to be built, have brought mixed-use development to its pinnacle. These projects demonstrate how adaptive reuse revitalizes individual buildings and contributes to the broader urban environment by enhancing cultural amenities, increasing social cohesion, and stimulating economic growth.

However, a deeper critical analysis of these cases reveals varying degrees of success in integrating theoretical frameworks such as conservation theory, urban resilience, and digital heritage approaches. Despite significant aesthetic appeal and energy efficiency, Portland Towers struggled to fully integrate structural coherence with spatial functionality, highlighting a potential gap in aligning conservation theory with actual architectural interventions. In contrast, The Silo exhibited a more holistic implementation of conservation theory, balancing minimal intervention principles with innovative spatial reuse. Gemini Residence's approach successfully integrated urban resilience principles by creating flexible residential spaces adaptable to changing urban demands, yet it relied heavily on façade aesthetics, potentially overlooking deeper structural harmony. Sugar City uniquely incorporated digital heritage techniques through advanced façade treatments and energy-efficient adaptations, setting a benchmark for balancing contemporary functionality and industrial authenticity. These comparisons underscore the necessity of comprehensive theoretical integration to achieve sustainable and culturally meaningful adaptive reuse outcomes.

A critical factor in the success of these transformations is the careful balance between preservation and innovation (Cantell, 2005). In each case, the core identity of the silo buildings—their cylindrical forms and robust concrete structures—was retained, ensuring a strong connection to their industrial heritage. However, these historical elements were enhanced with modern design features, such as glass facades and steel structures, which aligned the buildings with contemporary architectural standards. This delicate balance allowed the silos to maintain their historical significance while serving new, functional roles in modern urban environments (Bullen & Love, 2011).

Another important outcome is these adaptive reuse projects' cultural and economic impact. By repurposing industrial structures, cities can preserve important historical landmarks while promoting economic activity (Shipley et al., 2006). These transformed silos have become focal points for urban regeneration, attracting businesses, residents, and tourists alike. The adaptive reuse of silo buildings has also fostered greater cultural engagement, as seen in The Silo's public restaurant and event spaces, which allow the public to interact with the building and its history in new ways. The Sugar City project, which includes office spaces and event venues, demonstrates how adaptive reuse can create multifunctional spaces that benefit the local economy and cultural life.

Sustainability is another significant result of these transformations. By reusing existing structures, these projects have minimized the environmental impact of demolition and new construction (Langston et al., 2008). The retention of the silos' original concrete cores conserved embodied energy, while the introduction of energy-efficient systems and materials further reduced the buildings' environmental footprints. Portland Towers achieved BREEAM certification, underscoring the importance of sustainability in these adaptive reuse projects.

Overall, the results of these case studies highlight the transformative power of adaptive reuse in preserving industrial heritage while contributing to the cultural, economic, and environmental sustainability of cities (Plevoets & Van Cleempoel, 2019). Through thoughtful architectural interventions, silo buildings can be successfully integrated into modern urban contexts, enriching the urban landscape while honoring their historical roots (Table 4). These projects demonstrate that adaptive reuse is a practical solution for dealing with obsolete structures and a powerful tool for urban regeneration and cultural preservation.

Table 4 Theoretical Concepts Applied in Case Studies (Author(s), 2024)

Theoretical Concept	Description	Examples from Case Studies
Preservation of Historical Identity	Retaining key historical elements to maintain connection to the past	All projects preserved silos' forms and concrete structures
Innovative Architectural Interventions	Introducing contemporary design elements to adapt buildings for new uses	Façade modifications, structural additions, modern materials used in all cases

Functional Adaptation and Urban Regeneration	Repurposing structures to meet contemporary needs and revitalize areas	Silo buildings transformed into offices, residences, cultural spaces
Sustainability and Environmental Impact	Minimizing environmental footprint through adaptive reuse	Achieved BREEAM certification, conserved embodied energy, reduced waste
Integration into Urban Fabric	Blending repurposed structures into modern urban contexts	Projects aligned with local development goals, contributed to urban identity

7. Discussion

The analysis of the adaptive reuse of silo buildings highlights the transformative potential of architectural interventions in revitalizing obsolete industrial structures. The projects explored—Portland Towers, The Silo, Gemini Residence, and Sugar City—demonstrate that adaptive reuse is not merely a practical solution to dealing with redundant industrial buildings but also a powerful tool for preserving industrial heritage and contributing to urban regeneration. By reimagining these monumental structures, cities can maintain a tangible connection to their industrial past while addressing contemporary urban needs (Cantell, 2005).

One of the central themes emerging from the case studies is the delicate balance between preservation and innovation. Preserving key historical elements of silo buildings, such as their distinctive cylindrical forms and robust concrete façades, is essential for maintaining their historical significance and identity within the urban landscape. At the same time, innovative architectural interventions are necessary to adapt these structures for new functions and to integrate them seamlessly into modern urban contexts. The façade modifications observed in the case studies played a pivotal role in this transformation. By introducing windows, balconies, terraces, and contemporary cladding materials, creating new horizontal and vertical circulations, and creating different spaces for new functions, architects were able to humanize the scale of the silos, enhance their aesthetic appeal, and improve their functionality. These changes allowed natural light and ventilation into previously dark and inaccessible interiors while creating visually engaging façades that contribute positively to the surrounding urban fabric. It has been observed that good coordination is needed for the mutual exchange of information between different disciplines during the study process and for the maximum utilization of technological products.

Functional adaptation was another crucial element of these transformations. The structural reconfigurations needed to accommodate new uses, such as office spaces, residential units, and cultural venues, required significant architectural creativity. For example, in the case of Gemini Residence, the conversion of seed silos into luxury apartments involved cutting large openings into the concrete structure for windows and balconies while preserving the core circulation spaces. These interventions enabled the creation of functional, modern living spaces while retaining the industrial essence of the building. Similarly, The Silo in Copenhagen preserved the original grain storage bins while transforming the internal spaces into unique residential layouts that reflect the building's industrial heritage. These projects demonstrate how innovative design solutions can overcome the challenges of repurposing large industrial structures, ensuring they remain relevant and functional in contemporary urban environments.

The economic and cultural impacts of adaptive reuse projects are significant. By repurposing silo buildings, cities can preserve important landmarks that embody their industrial heritage, reinforcing a sense of place and historical continuity. These transformed structures become focal points within the urban landscape, fostering community pride and engagement (Lynch, 1960; Carmona, 2021). The case studies illustrate how adaptive reuse can stimulate economic activity by attracting new residents, businesses, and tourists. For example, the transformation of Sugar City into office spaces and event venues revitalized the Halfweg area, turning it into a thriving hub for business and cultural activity. Similarly, Portland Towers and The Silo played a key role in the regeneration of Copenhagen's Nordhavn district, contributing to its emergence as a vibrant and sustainable urban neighborhood.

Sustainability is another important consideration in the adaptive reuse of silo buildings. By reusing existing structures rather than demolishing them, these projects minimize the environmental impact of new construction. Retaining the original concrete structures conserves embodied energy while introducing energy-efficient systems and materials further reduces the buildings' environmental footprints (Langston et al., 2008). Portland Towers achieved BREEAM certification, highlighting their commitment to sustainable building practices. These projects demonstrate that adaptive reuse is a culturally sensitive approach to urban development and an environmentally responsible one.

However, adaptive reuse projects are not without challenges. Financial constraints, technical difficulties, and the complexity of working with large, structurally unique buildings can pose significant hurdles (Douglas, 2006). The case studies reveal that the success of such projects often depends on collaborative efforts between public and private stakeholders, supportive urban policies, and careful planning. For example, the success of Sugar City and The Silo was facilitated by local government support, which provided the necessary incentives and regulatory frameworks to make these projects viable. Additionally, the technical expertise required to retrofit industrial buildings for new uses underscores the importance of collaboration between architects, engineers, and urban planners.

In conclusion, the adaptive reuse of silo buildings demonstrates a progressive approach to urban development that honors the past while embracing the future. By preserving the core identity of these industrial structures and integrating them into the modern urban fabric, cities can create meaningful and functional spaces. These transformed silos become living monuments that tell the story of a city's evolution, fostering a sense of continuity and belonging among residents. The case studies of Portland Towers, The Silo, Gemini Residence, and Sugar City provide valuable insights into how adaptive reuse can contribute to sustainable urban development, cultural preservation, and economic growth. As cities continue to face the challenges of modernization and sustainability, the adaptive reuse of silo buildings offers a compelling model for how heritage and progress can coexist in the creation of dynamic, culturally rich, and sustainable urban environments.

8. Conclusion

The adaptive reuse of silo buildings stands as a compelling example of how obsolete industrial structures can be transformed into vibrant, functional, and culturally significant urban landmarks. Through innovative architectural interventions, particularly façade modifications and structural reconfigurations, these buildings have been repurposed to meet contemporary needs while preserving their historical essence. The case studies of Portland Towers, The Silo, Gemini Residence, and Sugar City demonstrate that the transformation of these monumental structures is not only possible but also beneficial for cities aiming to balance heritage preservation with urban development. Thus, they created a rich texture in the urban environment by combining a historical building with contemporary architectural elements.

One of the most significant revelations from these projects is the transformative power of façade modifications. Designed initially with imposing and utilitarian exteriors, silos often lacked visual and spatial engagement with their surroundings (Schittich, 2012). However, the introduction of windows, balconies, terraces, and contemporary cladding materials in these case studies humanized the silos and made them more relatable to their urban environments. These interventions allowed for natural light to penetrate interiors and created visually compelling façades that harmonized with modern urban aesthetics while retaining the industrial character of the structures. Such changes revitalized the buildings and contributed positively to the surrounding urban landscape, fostering a connection between the past and the present.

The functional transformation of silos into office spaces, residential units, and cultural venues further emphasizes the versatility of these industrial structures. By reimagining their purpose, these projects injected new life into previously derelict areas, contributing to economic growth, urban regeneration, and cultural enrichment. Portland Towers and The Silo played key roles in the

revitalization of Copenhagen's Nordhavn district. At the same time, Gemini Residence and Sugar City similarly contributed to the regeneration of their respective urban areas. These projects demonstrate that adaptive reuse can catalyze broader urban renewal, turning abandoned industrial buildings into dynamic components of the contemporary urban fabric.

Sustainability is another critical outcome of adaptive reuse. By repurposing existing buildings rather than demolishing them, these projects minimized the environmental impact of new construction, conserving embodied energy and reducing waste (Langston et al., 2008). The retention of the original concrete cores in all the case studies exemplifies the environmental benefits of adaptive reuse. In addition, integrating energy-efficient systems and sustainable materials in the transformations of Portland Towers, which achieved BREEAM certification, underscores the importance of sustainable practices in contemporary architectural projects. These projects demonstrate that adaptive reuse can align with broader environmental goals, making it a viable and responsible strategy for urban development.

Despite the challenges associated with adaptive reuse—such as financial constraints, technical difficulties, and the complexity of working with large industrial structures—the case studies reveal that these hurdles can be overcome through innovative design solutions and collaborative efforts. The successful transformation of these silos was facilitated by supportive urban policies, financial incentives, and the collaboration of architects, planners, and stakeholders who recognized the cultural and economic value of preserving these industrial relics. These examples highlight the importance of creating frameworks that encourage the preservation and repurposing of industrial heritage within urban planning agendas.

In conclusion, the adaptive reuse of silo buildings offers a progressive approach to urban development that respects the past while addressing the needs of the present. By preserving the core identity of these industrial structures and integrating them into the modern urban context, architects and planners can create functional and meaningful spaces. These transformed silos not only serve as living monuments to a city's industrial heritage but also contribute to the cultural, economic, and environmental sustainability of urban environments. The insights gained from the case studies of Portland Towers, The Silo, Gemini Residence, and Sugar City provide valuable guidance for future projects, illustrating how adaptive reuse can foster a harmonious balance between heritage and progress. The transformation of silo buildings represents a vision for urban development that is inclusive, dynamic, and reflective of a city's unique historical narrative, ensuring that these structures continue to serve as vital elements of the urban landscape.

References

Affleck, J., & Kvan, T. (2008). A virtual community as the context for discursive interpretation: A role in cultural heritage engagement. *International Journal of Heritage Studies*, *14*(3), 268 280. https://doi.org/10.1080/13527250801953751

ArchDaily. (2017). The Silo / Cobe. Retrieved August 15, 2024, from https://www.archdaily.com/874698/the-silo-cobe

Archello. (2005). Gemini Residences / Frosilo. Retrieved May 5, 2024, from https://archello.com/project/gemini-residences-frosilo

Ashworth, G. (2011). Preservation, conservation and heritage: Approaches to the past in the present through the built environment. *Asian Anthropology*, *10*(1), 1 18. https://doi.org/10.1080/1683478X.2011.10552601

Barbara, J., Koenitz, H., & Bakk, Á. K. (2021). The ethics of virtual reality interactive digital narratives in cultural heritage. *In International Conference on Interactive Digital Storytelling* (pp. 288-292). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-92300-6_27

Brand, S. (1995). *How buildings learn: What happens after they're built*. Penguin Books.

Brooker, G., & Stone, S. (2019). *Re-readings: 2: Interior Architecture and the principles of remodelling existing buildings* (1st ed.). RIBA Publishing. https://doi.org/10.4324/9780367814601

Bullen, P. A., & Love, P. E. (2011). Adaptive reuse of heritage buildings. *Structural Survey*, *29*(5), 411-421. https://doi.org/10.1108/02630801111182439

Cantell, S. F. (2005). *The adaptive reuse of historic industrial buildings: Regulation barriers, best practices and case studies* (Master's thesis). Virginia Polytechnic Institute and State University.

Carmona, M. (2021). *Public places urban spaces: The dimensions of urban design*. Routledge. https://doi.org/10.4324/9781315158457

COBE. (2017). The Silo. Retrieved August 7, 2024, from https://www.cobe.dk/projects/the-silo

Copenhagen Architecture. (2016). Gemini Residence by MVRDV. Retrieved July 9, 2024, from https://copenhagenarchitecture.dk/gemini-residence-by-mvrdv/

Couch, C., Fraser, C., & Percy, S. (Eds.). (2008). *Urban regeneration in Europe*. John Wiley & Sons.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Sage Publications.

Denzin, N. K. (2009). *The research act: A theoretical introduction to sociological methods* (1st ed.). Routledge. https://doi.org/10.4324/9781315134543

DGA Architects. (2014). Portland Siloerne. Retrieved September 21, 2024, from https://dga.dk/project/portland-siloerne/

Douet, J. (2012). *Industrial heritage re-tooled: The TICCIH guide to industrial heritage conservation*. Routledge.

Douglas, J. (2006). *Building adaptation*. Routledge. https://doi.org/10.4324/9780080458519

Edwards, J. A., & Llurdés i Coit, J. (1996). Mines and quarries: Industrial heritage tourism. *Annals of Tourism Research*, *23*(2), 341-363. https://doi.org/10.1016/0160-7383(95)00067-4

Feilden, B. M. (2003). *Conservation of historic buildings*. Routledge. https://doi.org/10.4324/9780080502915

Fernández-Fernández, M. V., Marcelo, V., Valenciano, J. B., & López-Díez, F. J. (2017). History, construction characteristics and possible reuse of Spain's network of silos and granaries. *Land Use Policy*, *63*, 298-311. https://doi.org/10.1016/j.landusepol.2017.01.017

FIABCI. (2012). Prix d'Excellence. Runner up: SugarCity Silos (The Netherlands). Retrieved July 8, 2024, from https://fiabciprix.com/past-winner/?id=134

Flick, U. (2022). *An introduction to qualitative research*. Sage Publications.

Frearson, A. (2015). Frosilo apartments offer a "great combination of old and new" says MVRDV's Jacob van Rijs. Dezeen. Retrieved August 3, 2024, from https://www.dezeen.com/2015/08/14/frosilo-apartments-offer-great-combination-old-new-mvrdv-movie-jacob-van-rijs-copenhagen/

Griffiths, A. (2017). Cobe transforms Copenhagen grain silo into apartment block with faceted facades. Deze en. Retrieved September 3, 2024, from https://www.dezeen.com/2017/06/28/cobe-transforms-copenhagen-grain-silo-apartment-block-faceted-facades/

Heath, T., Oc, T., & Tiesdell, S. (2013). *Revitalising historic urban quarters*. Routledge. https://doi.org/10.4324/9780080516271

Israel, M., & Hay, I. (2006). *Research ethics for social scientists*. Sage Publications.

Jokilehto J. (2017). *A history of architectural conservation*. Routledge. https://doi.org/10.4324/9781315636931

Kvale, S., & Brinkmann, S. (2009). *InterViews: Learning the craft of qualitative research interviewing* (2nd ed.). Sage Publications.

Langston, C., Wong, F. K., Hui, E. C., & Shen, L. Y. (2008). Strategic assessment of building adaptive reuse op portunities in Hong Kong. *Building and Environment*, *43*(10), 1709 1718. https://doi.org/10.1016/j.buildenv.2007.10.017

Logothetis, S., Delinasiou, A., & Stylianidis, E. (2015). Building information modelling for cultural heritage: a review. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *2*, 177-183. https://doi.org/10.5194/isprsannals-II-5-W3-177-2015

Lynch, K. (1960). *The image of the city*. MIT Press.

Martinat, S., Navratil, J., Hollander, J. B., Trojan, J., Klapka, P., Klusacek, P., & Kalok, D. (2018). Re-reuse of regenerated brownfields: Lessons from an Eastern European post-industrial city. *Journal of Cleaner Production*, *188*, 536-545. https://doi.org/10.1016/j.jclepro.2018.03.313

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38-49. https://doi.org/10.1016/j.landurbplan.2015.11.011

Mies Award. (2007). Gemini Residence. Retrieved July 18, 2024, from https://miesarch.com/work/1487

MVRDV. (2005). Frøsilo. Retrieved July 11, 2024, from https://www.mvrdv.com/projects/143/fr%C3%B8silo

NCC Property Development. (2014). Portland Towers. Retrieved September 21, 2024, from https://www.ncc.com/our-projects/portland-towers/

Palmer, M. (1998). *Industrial archaeology: Principles and practice*. Routledge. https://doi.org/10.4324/9780203022993

Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage Publications.

Plevoets, B., & Van Cleempoel, K. (2012). Adaptive reuse as a strategy towards conservation of cultural heritage: A survey of 19th and 20th century theories. *In Proceedings of the 2012 International Conference Reinventing Architecture and Interiors: the past, the present and the future* (RIE).

Plevoets, B., & Van Cleempoel, K. (2019). *Adaptive reuse of the built heritage: Concepts and cases of an emerging discipline*. Routledge. https://doi.org/10.4324/9781315161440

Rautenberg, M. (2012). Industrial heritage, regeneration of cities and public policies in the 1990s: elements of a French/British comparison. *International Journal of Heritage Studies*, *18*(5), 513 525. https://doi.org/10.1080/13527258.2011.637945

Roberts, P. (2000). *The evolution, definition and purpose of urban regeneration*. In P. Roberts & H. Sykes (Eds.), Urban Regeneration: A Handbook (pp. 9 36). Sage Publications. https://doi.org/10.4135/9781446219980.n2

Schittich, C. (Ed.). (2012). *Building in existing fabric: Refurbishment, extensions, new design*. Walter de Gruyter.

Shipley, R., Utz, S., & Parsons, M. (2006). Does adaptive reuse pay? A study of the business of building renovation in Ontario, Canada. *International Journal of Heritage Studies*, *12*(6), 505–520. https://doi.org/10.1080/13527250600940181

Stratton, M. (2003). *Industrial buildings: Conservation and regeneration*. Taylor & Francis. https://doi.org/10.4324/9780203362471

SugarCity. (2007). About SugarCity. Retrieved July 17, 2024, from https://www.sugarcity.com/en/about-sugarcity/

The Housing Agency. (2024). Sustainable Compact Development - International Case Study Analysis. Retrieved November 7, 2024, from https://www.housingagency.ie/sites/default/files/202411/Sustainable_Compact_Development_International_Case_Study_Analysis.pdf

UNESCO. (2011). Recommendation on the historic urban landscape. UNESCO. Retrieved April 17, 2024, from https://whc.unesco.org/uploads/activities/documents/activity-638-98.pdf

UNESCO. (2013). New life for historic cities: The historic urban landscape approach explained. United Nations Educational, Scientific and Cultural Organization (UNESCO).

Wong, L. (2017). Adaptive Reuse: Extending the Lives of Buildings. Birkhäuser.

World Aluminium. (2007). Sugar City Silos. Green Building. Retrieved June 27, 2024, from https://greenbuilding.world-aluminium.org/benefits/flexible/sugar-city-silos/

Xie, P. F. (2015). *Industrial heritage tourism* (Vol. 43). Channel View Publications.

Yin, R. K. (2009). *Case study research: Design and methods* (5th ed.). Sage Publications.

Yung, E. H., & Chan, E. H. (2012). Critical social sustainability factors in urban conservation: The case of the Central Police Station Compound in Hong Kong. *Facilities*, *30*(9/10), 396 416. https://doi.org/10.1108/02632771211235224

Resume

Zeynep Kerem Ozturk was born in Istanbul. After attending primary, secondary, and high school at Kultur College, she graduated from the ITU Department of Architecture in 1978. 1993 she completed her PhD in Urban and Regional Planning at ITU Institute of Science and Technology. She worked in Istanbul Metropolitan Municipality between 1980-2008. She worked as a Manager in the Directorate of Housing and Squatter Affairs and as a Control Engineer in the Directorate of Structural Affairs and retired in 2008. After working as a construction site chief in a private company related to antiquities, she has been an assistant professor at Istanbul Sabahattin Zaim University Department of Architecture since 2015. Her areas of interest are urbanism and zoning Law, urban and regional planning, urban conservation, urban sociology, urban planning, urban transformation, and industrial and historical building re-functionalization. Her hobbies include oil painting and watercolor painting.

Ahmet Kurnaz graduated from Kabatas High School in 2008, received his bachelor's degree from the Middle East Technical University Department of Architecture in 2013, Master's degree from Yildiz Technical University Department of Architecture in 2021, and PhD degree from Istanbul Sabahattin Zaim University Department of Architecture in 2024. He is an assistant professor in the Architecture Department at the Istanbul Sabahattin Zaim University. His research interests include conservation, architectural design, heritage, interior design, sustainable design, refunctioning historical buildings, architectural tourism, and museums.