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Analytical examination of dynamic elements in modern architectural facades for advanced structural aesthetics

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Introduction: The visual appeal and distinctiveness of a building's external appearance can be enhanced by incorporating aesthetically pleasing and structurally coherent components, such as diagrids and external bracings. These components not only contribute to the building's visual appeal but also communicate its structural logic. The aim of this research is to investigate how architectural surfaces can contribute to a building's urban identity by integrating visually appealing and structurally sound structural systems.

Methods: The research focuses on analyzing and understanding the formal structure, generating diverse patterns, and assessing their impact on stability. The goal is to develop architectural surface components that are both aesthetically pleasing and proficient in their application. The study involves analyzing architectural projects that address surfaces in alignment with structural connections and various connecting and modulating mechanisms. Significant architectural achievements from different historical periods were examined to construct a comprehensive knowledge framework.

Results: The research conducted a detailed analytical and descriptive investigation into the intricate mechanisms of form surfaces within Modernity and Deconstruction architecture and their impact on structural relationships. The study revealed that by integrating structural connections and modulating mechanisms, it is possible to create architectural surface components that enhance a building's visual appeal, artistic expression, and urban identity while maintaining structural stability and balance.

Conclusion: The research concludes that integrating structural connections and modulating mechanisms into architectural surface components can significantly enhance a building's visual appeal, artistic expression, and urban identity. By developing aesthetically pleasing and structurally sound elements, such as diagrids and external bracings, architects can create buildings that not only

communicate their structural logic but also contribute to the overall urban fabric. This study provides valuable insights for architects and designers seeking to enhance the visual and structural qualities of their buildings.

KEYWORDS

architectural facades, structural dynamic, formal configuration, architectural trends, aesthetic

1 Introduction

Throughout the 20th century and continuing into the present, the architectural façade has been a space of extensive experimentation and innovation. This has led to a wide variety of architectural imagery, often lacking cohesion in the context of the post-modern era.

Moreover, facades can display symbolic components originating from culture, history, and so on. Symbolism is frequently exhibited in facade design by utilizing metaphoric, referential, or analogical tools. Essentially, the constructed environment within a specific society mirrors the culture and identity of that society, and the building facade is the most revealing aspect of this reflection. Individuals require living in a significant built environment, and this necessity can be expressed through symbols that signify something beyond their apparent form. Consequently, much of the world's architecture bears a symbolic weight. Cultural and societal identities are often reflected in the built environment within a society, regardless of the architect's original intentions.

Facades serve practical purposes in addition to their aesthetic functions. For example, exterior walls play a crucial role in creating a secure and comfortable interior environment that meets the needs of the building's occupants. Architectural design encompasses not only the conceptualization and arrangement of space but also the realization of structural elements. The facade acts as a physical barrier, offering protection to those who frequent or reside within a building. This fulfills a fundamental human requirement for shelter, safeguarding against adverse weather conditions and preserving privacy and property rights. A well-designed façade should effectively shield both inhabitants and the internal structure from environmental and climatic effects such as rain, snow, wind, heat, cold, moisture, noise, as well as artificially induced damages.

The evolution of building facades, encompassing their design, diversity, texture, and underlying connections, has played a pivotal role in shaping numerous traditional configurations. Advancements in technology and engineering have allowed architects to depart from conventional, static lines and embrace dynamic and continuously evolving modern designs. This departure introduces morphological variations and various sensory elements that contribute to both stability and formal balance. The design of building facades is influenced by the real climate and conveys various ideas, elements, and meanings (High-rise, 2014), (Sadeqi et al., 2019), (Morvan and Thibert, 2002).

Finally, the research problem was approached with meticulous attention to detail, employing an extensive theoretical framework that delved into the intricacies of building facades. The primary goal of the study was to uncover and illuminate the fundamental relationships that govern the integration of building facades within architectural structures. By delving into the theoretical aspects, the study sought to gain a comprehensive understanding of how building facades contribute to the overall structural stability and balance of a building (Bedon et al., 2018).

1.1 The research aims

Identify conventional aesthetic principles that convey attractiveness through the selection of specific building case studies. Establish a framework for defining, categorizing, and characterizing surface attributes. Additionally, conduct an applied study that combines analytical descriptions with practical applications to gain insights into the specific mechanisms of form surfaces within Modernity and Deconstruction architecture and their impact on structural relationships.

1.2 The research focuses on the following items

1- Analyzing the nature of the architectural facades and the structural relationships on which these facades are organized with the technological development in both the trend of modernity and deconstruction and its impact on stability and formal balance to understand the structure of the form.
2- Comparative analysis study of the most influential modern architects such as Lee Corbusier, Frank Lloyd Wright, and Hermann Hertz who left a lasting impression through their creative works as well as those of the most significant deconstructionist architects. The essential element of deconstructivism may be clearly grasped with a good understanding of how current architects apply it to their works by evaluating his architectural philosophy and aesthetics. In addition to the aforementioned pioneers, there are numerous other notable architects within the field of modern and deconstructive architecture. Some of these influential figures include Rem Koolhaas, Thom Mayne, and Bernard Tschumi, Daniel Libeskind, Frank Gehry, Zaha Hadid among others. These architects have significantly contributed to the evolution of architectural design through their bold and innovative concepts.
3- The primary connection between architectural facades and the traditional closed box shape is the source of the formal structure. By utilizing various modulation mechanisms, the designer can depart from this conventional design, leading to new formal configurations. Consequently, the nature of the facades is defined and clarified, along with the modification mechanisms used, ultimately simplifying the formal composition (Elmoghazy and Afify, 2023).

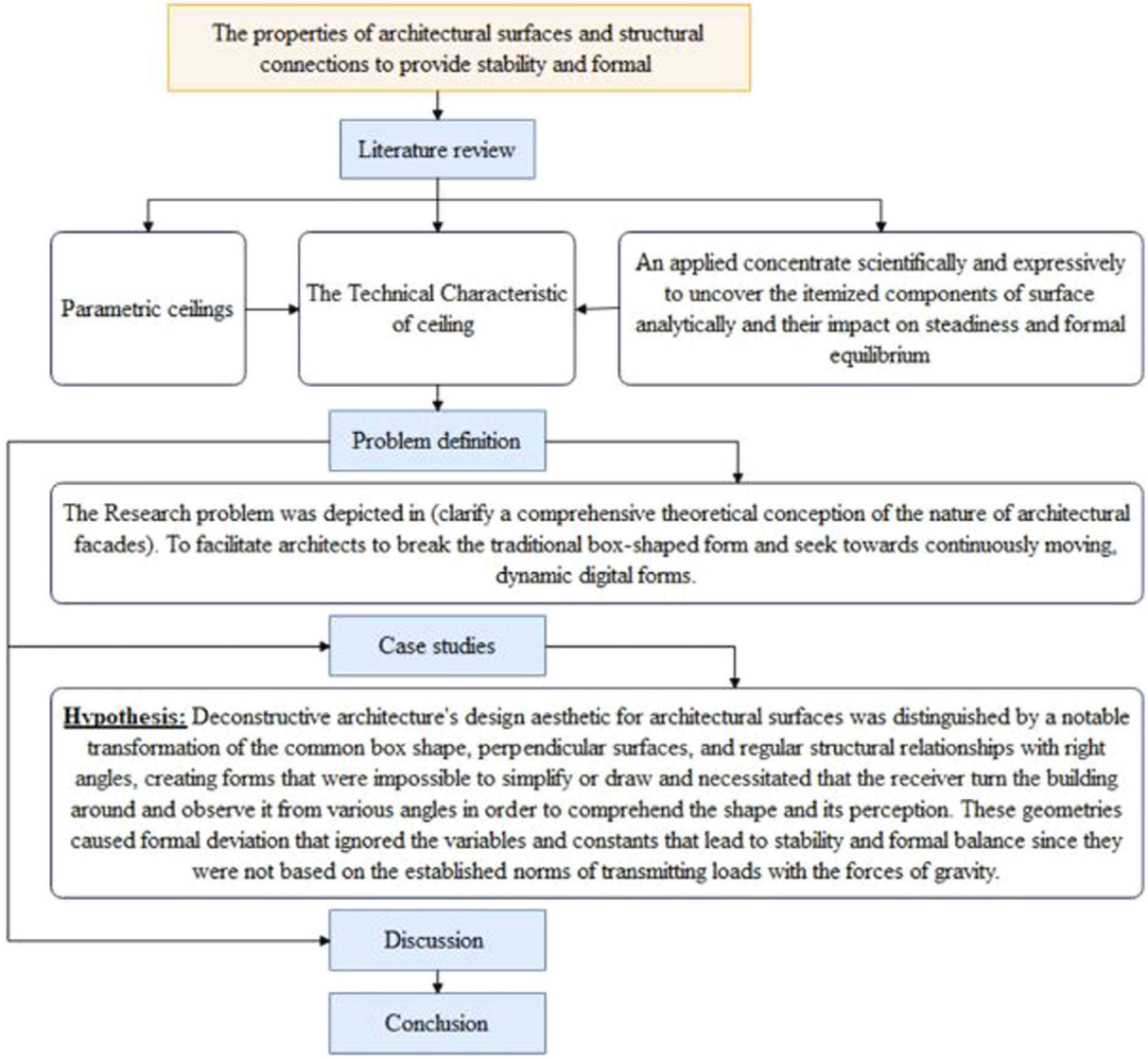


FIGURE 1
Research methodology.

1.3 Problem definition

The research problem centers on analyzing the dynamic elements present in modern architectural facades and their impact on advanced structural aesthetics. This involves delving into the various ways in which these dynamic elements contribute to enhancing the functionality and overall appearance of modern buildings, which enhances a variety of sensory elements of the building such as (tactile qualities, sound and acoustics, light and shadows, thermal comfort, olfactory elements, interaction and movement) as well as identifying potential challenges and limitations associated with their implementation. By conducting a thorough investigation through case studies, the goal is to gain valuable insights into the influence of dynamic elements on modern architectural design and their potential for further innovation in the field.

1.4 Research propositions and methodology

The research approach aims to develop a comprehensive understanding of the role of dynamic elements in modern architectural facades and their impact on advanced structural aesthetics. To achieve this, the approach is divided into three main aspects. A theoretical framework: This aspect involves reviewing previous studies and research on architectural surfaces to gather relevant information and build a foundation for the current investigation.

A knowledge framework: In this aspect, the research will define, classify, and examine the characteristics of different architectural surfaces and trends. This will provide a broader understanding of the various types of surfaces, their function, and their aesthetic contributions.

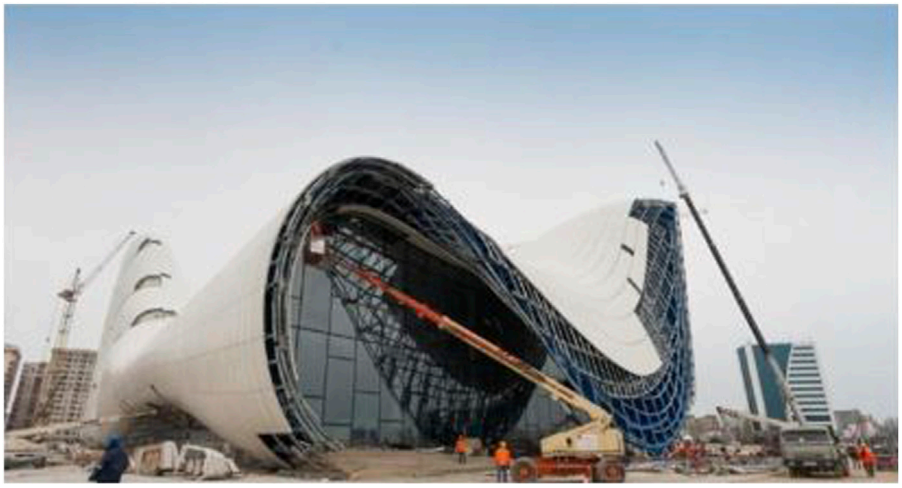


FIGURE 2
Shows curved facades using mechanical methods. Zaha Hadid Heydar Aliyev Cultural Center, Baku, Azerbaijan.

FIGURE 3
Shows the context of Gothic architecture, facades took on a sculptural form, featuring walls crafted from carved stone, sculptures, and embellishments around openings.

Conducting analytical study: The final aspect of the research approach involves conducting an applied study that uses both analytical and descriptive methods. This will help reveal the detailed mechanisms of surface composition and their effect on stability and formal balance. By examining these elements in depth, the study can provide insight into the ways in which modern architectural facades can be designed to enhance structural aesthetics and functionality. Through this multi-faceted approach, the research can generate valuable insights into the role of dynamic elements in modern architectural design and contribute to the development of advanced structural aesthetics in the field. As shown in Figure 1 the Research methodology.

2 Literature review

2.1 Aesthetics against structural expressionism

The study investigated the manipulation of shapes in flexible facades and the concept of curvature in architecture, along with the utilization of mechanical methods for curving facades in accordance with various standards and principles (Köhler, 2008). As shown in Figure 2 curved facades using mechanical methods. Zaha Hadid Heydar Aliyev Cultural Center, Baku, Azerbaijan. To achieve these curved facades, a combination of advanced engineering techniques

FIGURE 4
Architectural facades and their role in vertical load-bearing structures (Al Bahr Towers in the UAE).

FIGURE 5
Technological advances in structural solutions and new materials (Two International Finance Centre).

and construction methods was employed. The research specifically focused on dual-layered membrane facades, which advance material technology, construction techniques, and design approaches for achieving fluid, curved, and uninterrupted facades. This approach sometimes involves the structural modeling of the fabric to create innovative designs for facades and other interior environments, deviating from the conventional Cartesian spatial arrangement (Morvan and Thibert, 2002), (Paleologos et al., 2016).

2.2 The evolution of architectural facades

The study focused on the transformation of architectural facades through their ornamentation and examined the indications of both intellectual and material embellishments in various architectural styles (Mao et al., 2020). As shown in Figure 3, the context of Gothic architecture, where facades assumed a sculptural form, displaying walls meticulously crafted from carved stone. Architectural facades serve as a tangible medium for expressing ideas and conveying the distinctive characteristics of a particular structure. They act as a surface, akin to a layered canvas, which serves as a bridge between the interior and exterior of a building. The study confirmed that classical architectural facades were characterized by a rich abundance of intricate details and distinctive elements (Sadeqi et al., 2019), (Morvan and Thibert, 2002), (Chatzikonstantinou and Sariyildiz, 2017), (Riccobono, 2014).These facades employed symmetry and balance to distribute forces in accordance with the mathematical principles governing gravity. In the context of Gothic architecture, facades took on a sculptural form, featuring walls crafted from carved stone, sculptures, and embellishments around openings. This level of complexity reached its pinnacle, to the extent that the facades began to resemble ornamental textiles, particularly with the introduction of colored glass elements (Convertino et al., 2021)–(Agirbas, 2018).

In the expressionist style, facades started to draw inspiration from the organic flow of nature, characterized by curved lines. In the context of deconstructivism architecture, facades underwent a transformation to embody the ideology of breaking free from traditional constraints. This led to the creation of facades with multiple layers (Sadeqi et al., 2019), (Radić et al., 2010), (Soycan and Soycan, 2019). These facades were fragmented, concealed, fragmented, incomplete, and featured

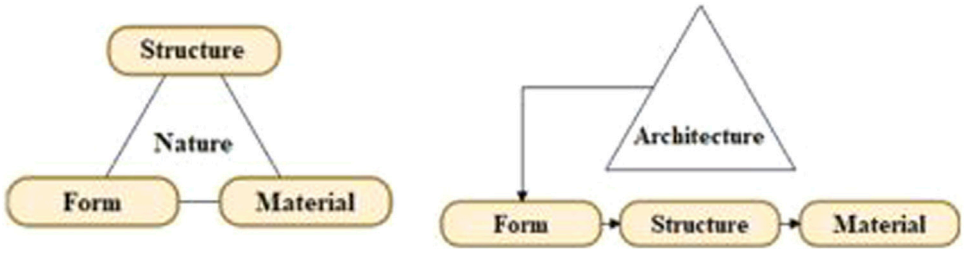


FIGURE 6
Difference in structure behavior loop between "Nature" and "Architecture".

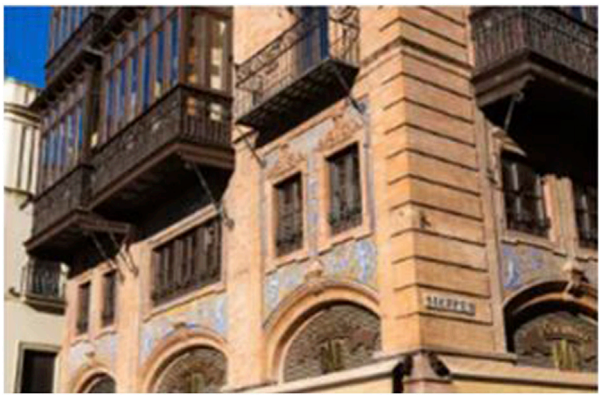


FIGURE 7
Traditional facades of houses with twisted forged balconies of the city of Seville, Andalusia.

slanted elements that emphasized chaos over order. The aim was to stimulate visual perception and create tension rather than conformity.

2.3 Defying gravity for construction

Explain the efficient development of support elements and the transfer of loads from facades and structures, as well as the dynamic interaction between these elements. The interaction between the primary structural elements and the external facades enclosing the space involves either revealing the structural components or enclosing the exterior with solid walls. The study demonstrated the potential for creating a closed form and spatial enclosure to offer a novel experience, considering a unique sense of balance (Riccobono, 2014), (Soycan and Soycan, 2019). The corner is a crucial element in defining the boundaries of a space. The study revealed that architectural facades serve as key elements in both vertical load-bearing structures affected by gravity and non-load-bearing components influencing the surrounding space. As shown in Figure 4, the Architectural facades and their role in vertical load-bearing structures (Al Bahr Towers in the UAE). As for structural facades, the external exterior is not only ornamental but also has the potential to provide enclosure, support, and stability, particularly against the forces of gravity (Soycan and Soycan, 2019), (Sayed and Fikry, 2019).

The direct consequences of technological advancements on architecture encompass changes in materials, construction methods, and execution approaches. As shown in Figure 5, the technological advances in structural solutions and new materials (Two International Finance Centre). This evolution is evident from modern architecture to the emergence of deconstructive architecture, coinciding with a significant shift in the realm of technological and digital progress. It represents a departure from conventional norms and practices related to material utilization and construction systems, aiming to introduce a new architectural language that challenges the established conventions. This architectural design sought to achieve the effect of distorting,

FIGURE 8
The dancing building- Hall Concert Disney Walt (Sharma and Mishra, 2021).

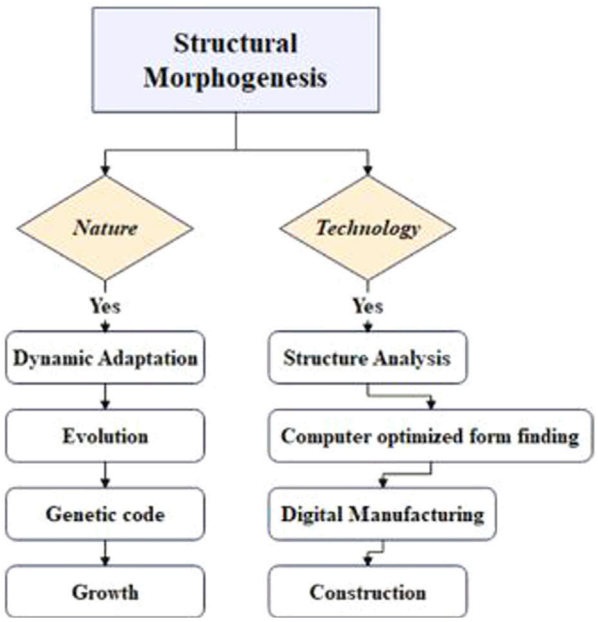


FIGURE 9
Structural Morphogenesis.

TABLE 1 The nature of the architectural facades and the structural relationships (Moderate).

Architecture treed	The modernity
Project name	Office building
Architect's name	Hermann Hertz
Years	1972

bending, curving, twisting, and strip-like shapes and facades in order to deviate from the conventional rectangular form (Convertino et al., 2021), (Biddulph, 2014). The facades smoothly transition, merge, and seamlessly flow from the rear to the front, guided by a well-thought-out structural framework examination (Bedon et al., 2018), (Sayed El Falafli, 2021), (Sekularac et al., 2012).

2.4 Morphology of the structure and self-organization

The study highlighted the design attributes of structural morphological configurations and their impact, both positive and negative, on the aesthetics of form and the directional flow of facades, shapes, forces, and space. The research primarily focused on analyzing how morphological changes occur in response to gravitational forces, as observed in natural entities such as plants and humans, as well as the designs of objects in our surroundings. The investigation of advanced tectonics is described, indicating that it determines the degree of structural dynamism. Engineering tectonics can either adhere to traditional norms or exhibit irregular patterns (Mao et al., 2020).

The architect needs to comprehend the principles governing the structure, its transformation, and its response to the loads placed upon it. For instance, shapes characterized by a central and horizontal axis around a common center at the design or exterior level should adhere to the objective rule in shaping them to achieve optimal aesthetics, much like the artistic creations seen in both modernity and ancient structures where the fundamental concept of tectonics is evident. Occasionally, these shapes deviate from uniformity, leading to unique designs on walls, ceilings, floors, or in construction, eliciting unconventional emotions that impact users (Hartwell et al., 2021), (Sharma and Mishra, 2021).

In the natural world, there exists an ongoing feedback loop that governs the concurrent processes of form development, structural extension, and material arrangement. The shape plays a crucial role in defining both the structure and the choice of materials, as architecture fundamentally revolves around the discipline of design (Riccobono, 2014).

Finally, the distinction in the behavioral loop of structures between "Nature" and "Architecture" is that natural structures evolve through self-organization in response to external forces, while architectural structures are designed and constructed by architects based on their understanding of structural principles and aesthetic considerations. As shown in Figure 6, the Difference in structure behavior loop between "Nature" and "Architecture".

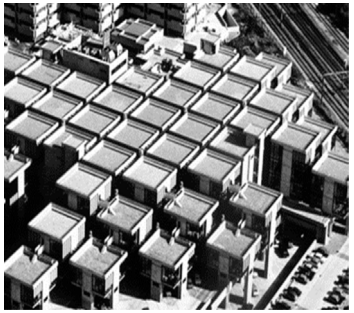
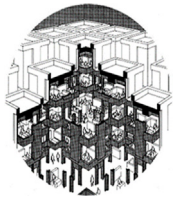
2.5 The main extraction from previous studies

1- The concept of architectural facades, both architectural and structural, has demonstrated that the interplay of facades plays a significant role in generating various designs. These designs encompass mathematical and conventional approaches that involve the arrangement of opposing facades to attain stability and formal equilibrium under the influence of gravitational forces. Additionally, these designs may incorporate techniques such as superposition, refraction, diagonal alignment, curvature, undulation, continuity, and dynamism (Morvan and Thibert, 2002), (Paleologos et al., 2016), (Mao et al., 2020), (Convertino et al., 2021), (Durmus and Gur, 2011).

2- Modern advancements in technology have enabled the creation of facades that adhere to various principles and regulations, resulting in a diverse range of traditional designs. These depart from the typical box-like shape and introduce various sensory elements that contribute to both stability and formal balance (Sadeqi et al., 2019), (Kasperski, 2022).

3- Architectural facades are contingent upon several factors, including their condition, the choice of building materials, ornamental details, surface characteristics, their orientation, as well as the interplay of opposing or overlapping connections between these facades. These elements, and the changes that occur on them, serve to channel the forces, and loads downwards in accordance with the laws of gravity, with implications for their influence on structural stability and equilibrium (Sadeqi et al., 2019), (Soycan and Soycan, 2019), (Sayed and Fikry, 2019), (Sharma and Mishra, 2021), (Kasperski, 2022), (Adeeb Fahmy Hanna, 2020).

TABLE 2 Analytical Examination of Dynamic Elements Case Study—Office building.

<table>
<tr><th colspan="6">Stability and formal balance</th><th rowspan="2">Structural relationships under which architectural surfaces are organized</th></tr>
<tr><th colspan="3">Degree of balance</th><th colspan="3">Balance type</th></tr>
<tr><td>Low</td><td>Med</td><td>Big</td><td>Unbalanced</td><td>Balance</td><td>Steady</td><td>Harmony surface mod. mechanisms and regular structure</td></tr>
<tr><td>--</td><td>--</td><td>√</td><td>--</td><td>√</td><td>--</td><td>√</td></tr>
<tr><td colspan="3">  </td><td colspan="3">  </td><td>  </td></tr>
<tr><td colspan="3">Herman Hertzberger Office Building “Central Beheer</td><td colspan="3" rowspan="2"></td><td rowspan="2">Removing portions of facades in horizontal and vertical architecture</td></tr>
<tr><td colspan="3">Project name Denver Museum of Art</td></tr>
</table>

<table>
<tr><td colspan="3">Systemic structural relationship</td></tr>
<tr><td colspan="2">V_L-V_L</td><td>V_L-H_Z</td><td>V_L-H_Z (Roof)</td></tr>
<tr><td colspan="4">Right angle link</td></tr>
<tr><td colspan="2">The directivity of Architectural surfaces</td><td colspan="2">The nature of architectural surfaces</td></tr>
<tr><td rowspan="2">Lake of directivity</td><td>Presence of direction</td><td>Surface texture/ color corresponds</td><td>Surface to gravity</td><td>The shape of (H_Z) surface</td><td>The shape of (VL) surface</td></tr>
<tr><td>Focus on the VL dir</td><td>Focus on the HZ dir</td></tr>
<tr><td colspan="2">Lake of directivity</td><td colspan="2">√</td><td colspan="2">Flat and segmented</td></tr>
</table>

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TABLE 3 The nature of the architectural facades and the structural relationships (Moderate).

Architecture treed	The modernity
Project name	Rothfield house
Architect's name	Great Rietveld
Year	1925

3 Knowledge framework for research

3.1 The theoretical part

Theoretical Study: This component involves a thorough examination of the principles and theories that govern the design, construction, and aesthetics of modern architectural facades. It includes an analysis of the relationship between structural integrity, material selection, and the visual appeal of the facade. It also considers the historical and cultural contexts that have influenced the development of modern architectural facades.

3.2 The formal composition

The formal composition of a design project is produced by taking into consideration functional, physical, psychological, and symbolic conditions. The designer analyzes all the facts related to the design problem, including the structure of the shape. The formal composition is generated from the relationship between the elements that form boundaries, such as ceilings, walls, and columns. These elements are organized in a way that allows the mind to perceive the formation. The surfaces form a closed space and unite to create architectural and urban forms.

Architecture is one of the arts that expresses its producers and users. The formal body in architecture is a product of the interaction between mental and material factors, translated through a specific manifestation strategy. A shape is perceived as a whole of its elements or as the connections between them. By correlating multiple architectural surfaces with different structural relationships, the characteristics of a group can be obtained. Studying architecture through a clear approach involves establishing logical rules based on specific intellectual situations and clarifying the potentials inherent in them.

3.3 The architectural facades forming the shape

The facades in architecture represent the movement of lines in a specific direction, forming an area with length and width that is surrounded by lines indicating external boundaries, which create volume. These facades can be horizontal, like floors and ceilings, or vertical, like walls and columns. The form, on the other hand, is an indication of the movement of a flat surface area in a direction to become a three-dimensional shape with length, width, and height. The facades that form the shape can be regular and geometric, such as cubes, pyramids, and spheres, or irregular, like organic shapes.

The mind can perceive space through the relationship between the elements that form its boundaries, which is represented by the regularity of the architectural surfaces. The way these surfaces are organized, whether in a continuous and immediately perceivable manner or in a more nuanced way where borders seem to disappear, is crucial in enabling the mind to perceive the formation of the shape (Durmus and Gur, 2011), (Kasperski, 2022). The designer analyzes functional, physical, psychological, and symbolic conditions to produce an architecture that expresses its producers and users. The architectural facades and their relationship to each other are the key elements that bring the shape to life and create the overall design (Durmus and Gur, 2011).

Design functions as a mode of artistic expression that mirrors the architect in design, the conventional shape arises from the interplay of both conceptual and tangible components within a unique symbolic process employed to communicate this idea (Morvan and Thibert, 2002). Gober defines the concept of form as something constructed from components that can be perceived in two distinct ways: either as a unified whole, considering the structural elements, or through the interconnected relationships among these elements. By amalgamating diverse architectural facades, whether they are horizontal, vertical, or oriented differently, we acquire the characteristics of the composition. Mitchell recommends approaching architecture as a pragmatic pursuit by establishing rational principles rooted in specific intellectual contexts and expounding upon the inherent possibilities therein (Approach, 2016), (Sung, 2016).

3.4 The optimization processes of architecture facades (shape and volume)

The configuration of a surface can be seen as a representation of the path traced by a line in a particular direction. This process results in the creation of an area defined by length and width, enclosed by lines that establish its outer limits, giving it dimension and volume. In the realm of architectural design, facades can assume both horizontal roles, like floors and roofs, and vertical roles, such as walls and columns (Mao et al., 2020), (Hartwell et al., 2021). The underlying concept suggests that when a flat surface extends in a specific direction, it evolves into a three-dimensional shape characterized by length, width, and height. The facades that make up this shape can follow regular and geometric patterns, resembling shapes like cubes, pyramids, circles, and others, or they may deviate from regularity, taking on irregular, natural, and unpredictable forms. Furthermore, the perception of space is influenced by the interaction among the elements defining its boundaries, a relationship that is conveyed through the consistent design of architectural facades (Hartwell et al., 2021), (Sharma and Mishra, 2021).

3.5 Customary facades

Customary facades refer to the traditional or commonly used architectural facades in a specific region or culture. These facades often reflect the historical, social, and environmental context of the area, and can include elements such as materials, colors, patterns,

TABLE 4 Analytical Examination of Dynamic Elements Case Study - Rothfield house.

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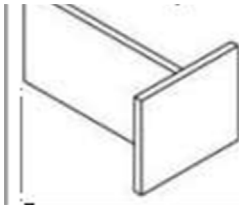
<tr><td colspan="3" rowspan="3">  </td><td colspan="3" rowspan="3">  </td><td rowspan="4">Removing portions of facades in horizontal and vertical architecture</td><td colspan="3">The directivity of Architectural surfaces</td><td colspan="3">The nature of architectural surfaces</td></tr>
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<tr><td>Focus on the VL dir</td><td>Focus on the HZ dir</td></tr>
<tr><td colspan="3">Herman Hertzberger Office Building “Central Beheer</td><td colspan="3">Disassemble/release and move the horizontal and vertical facades</td><td colspan="3">Lake of directivity</td><td>√</td><td>-</td><td colspan="2">Flat and segmented</td></tr>
<tr><td colspan="3">Project name Denver museum of Art</td><td colspan="3"></td><td colspan="6"></td></tr>
</table>

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TABLE 5 The nature of the architectural facades and the structural relationships (Moderate).

Architecture treed	The modernity
Project name	Pompidou Center
Architect's name	John portzman
Year	1977

and decorative features. As shown in Figure 7, the traditional facades of houses in the city of Seville, Andalusia, are adorned with intricately twisted forged balconies. Customary facades are an important aspect of architectural heritage and can help to create a sense of place and identity in built environments. Designers may incorporate elements of customary facades into contemporary buildings to create a connection with the local context and to honor the cultural traditions of a place.

3.6 Regular facades

To understand regular surfaces, horizontal and vertical facades need to be analyzed in detail. Horizontal facades typically include floors, ceilings, and roofs, while vertical surfaces comprise walls, columns, and other upright elements. These regular surfaces play a critical role in defining the overall structure and appearance of a building, as well as its functionality and efficiency.

3.7 Vertical facades

These facades are the most well defined for space and provide a feeling of a sense of finality and security to its clients, notwithstanding their job in the proper development and drawing the limits among inward and outer spaces and its primary functions that it plays in conveying flat facades. Now and again vertical facades go about as an additional cover wall and influence the shapes (Biddulph, 2014).

3.8 Horizontal facades

The horizontal orientation of architectural elements corresponds to the influence of gravity and stability. It remains relatively static, and horizontal facades often do not significantly affect the external appearance of the structure. However, their impact can manifest within the interior spaces. The architect's choice of whether to employ horizontal facades primarily depends on the conventional specifications of the framework (Ching, 2007). The tools at their disposal, provided by technology, shape, and their contribution to the visual aesthetics of the building's facade, play a significant role in this decision-making process.

These aspects are of utmost importance to the architect, as they influence the final form of the design, imbuing it with expressive qualities that captivate the eye, spirit, and emotions. A modification in the relationship between these facades results in various morphological configurations, as discussed in (Ching, 2007), (Sadeqi et al., 2019).

3.9 Unconventional aesthetic facades

Cutting-edge technology has contributed to the advancement of new technical and industrial systems. These systems enhance the designer's command over the model, allowing for easy modifications to the surface elements. This is achieved as organic and geometric shapes blend with irregular connections, resulting in unconventional forms and facades. Additionally, these systems rely on structural architectural elements to generate tangible shapes (Sayed and Fikry, 2019). The introduction of computers into the architectural design process significantly influenced design principles, becoming increasingly shaped by the capabilities of this tool. This process involved digital collaborators to generate a new iteration of digital constructions, an integrated approach that represented a novel way of computation in design, defining the dynamic realm of digital facade creation (Lin and Tsay, 2021). For the architect, it became essential to comprehend the principles governing form and the continuous transformation it undergoes under the applied loads. Structures that possess a central axis and symmetry about a median axis within the plan or the facade are subject to specific design principles aimed at achieving the desired form and ensuring stability under the influence of gravity (Sung, 2016), (Paech, 2016).

In modernity architecture, the design has become more intricate, encompassing walls, roofs, floors, and construction elements, resulting in elevated levels and numerous curves. These complex configurations evoke unique emotions that influence users (Lin and Tsay, 2021). The adoption of digital manufacturing methods has liberated facades from rigid, box-like mechanical conventions, introducing variability in material properties and flexibility in design solutions. This departure from traditional design principles has led to the establishment of a dynamic framework, marked by continuous shifts in the patterns and characteristics of floors, walls, and roofs, converging to create a novel spatial experience (Soycan and Soycan, 2019)

4 Various architectural facades with various modern and deconstructive architectural trends innovation

This type had a direct and profound impact on architecture throughout the 20th century, whether in terms of materials or construction techniques. This influence manifested itself through various architectural movements that emerged and thrived during the century, ranging from innovative architecture to deconstructive design. The architectural structure, conceived as a sculptural volume, takes on the form of a three-dimensional image, influenced by the interplay of light and shadow, as well as the inherent structural relationships between its components and the surrounding environment. The choice of structural or organic materials used on the facade, with its various segments and diverse surface characteristics, including brightness, texture, diversity, and encoded messages, all contribute to shaping the overall appearance and can evoke different emotional responses in viewers. As shown in Figure 8, the dancing building- Hall Concert Disney Walt. This transformative effect on the observer's perception triggers a responsive reaction. Le Corbusier defines architectural

TABLE 6 Analytical Examination of Dynamic Elements Case Study - Pompidou Center.

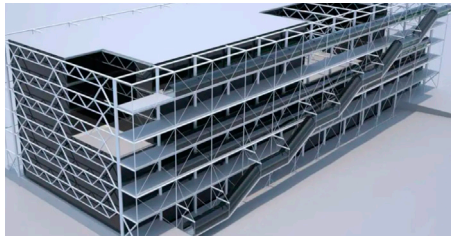
<table>
<tr><th colspan="6">Stability and formal balance</th><th rowspan="2">Structural relationships under which architectural surfaces are organized</th><th colspan="6" rowspan="2"></th></tr>
<tr><th colspan="3">Degree of balance</th><th colspan="3">Balance type</th></tr>
<tr><td>Low</td><td>Med</td><td>Big</td><td>Unbalanced</td><td>Balance</td><td>Steady</td><td>Harmony surface mod. mechanisms and regular structure</td><td colspan="3">Systemic structural relationship</td><td colspan="2">V_L-H_Z</td><td>V_L-H_Z (Roof)</td></tr>
<tr><td>--</td><td>-</td><td>√</td><td>--</td><td>√</td><td>--</td><td>√</td><td colspan="6">Right angle link</td></tr>
<tr><td colspan="3">  </td><td colspan="3">  </td><td rowspan="3">Removing portions of facades in horizontal and vertical architecture</td><td colspan="3">The directivity of Architectural surfaces</td><td colspan="3">The nature of architectural surfaces</td></tr>
<tr><td rowspan="2">Lake of directivity</td><td colspan="2">Presence of direction</td><td rowspan="2">Surface texture/ color corresponds</td><td rowspan="2">Surface to gravity</td><td rowspan="2">The shape of (H_Z) surface</td><td rowspan="2">The shape of (VL) surface</td></tr>
<tr><td colspan="3">The Pompidou Center, created by architect John Portzman, exemplifies modern architecture, distinguished by its tree-like design</td><td colspan="3">Editing facades and displaying the structural framework on vertical facades</td><td>Focus on the VL dir</td><td>Focus on the HZ dir</td></tr>
<tr><td colspan="3">Lake of directivity</td><td>-</td><td>-</td><td colspan="2">segmented</td></tr>
</table>

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TABLE 7 Deconstructivism Architecture - The dancing building.

Architecture treed	Deconstruction
Project name	The dancing building
Architect's name	Frank Gehry
Year	1990

engineering as the measure of the creator's ability to capture passion and provide pleasure and contentment to the observer by accentuating the fundamental relationships that constitute the architectural work and designing it in its final form. On the other hand, Frank Lloyd Wright, through his brilliance and the power of his imagination, skillfully integrated the essential elements of the natural surroundings into his profound connection with the environment. This allowed him to imbue his structures with a sense of belonging to their surroundings, with a particular focus on expansive horizontal facades, as exemplified in Fallingwater (Riccobono, 2014), (Durmus and Gur, 2011), (Xiang et al., 2021). Starting in the early 1980s, architecture embarked on a new trajectory, marked by the emergence of a deconstructionist trend in language and philosophy. Some architects applied the ideas of the French philosopher Jacques Derrida to architecture, which involved dismantling conventional norms and manipulating facades and spatial concepts (Lim et al., 2012).

These architects introduced unconventional structures marked by the characteristics of irregularities, deviating from traditional construction to create a new architectural language. The customary conventions governing these structures transformed into points of attraction (Soycan and Soycan, 2019). Architecture is in constant pursuit of innovative design tools, and modernity architects have been eager to leverage the latest available technologies to advance architectural concepts. As the 20th century ended and the 21st century began, modern digital technologies and their practical applications were harnessed to serve the creative process and produce architectural solutions with novel structural relationships. Consequently, it became imperative to examine the technological implications of the digital revolution and its applications in fields closely associated with architecture (Morvan and Thibert, 2002). These developments encompassed a range of approaches, including deconstructive, organic, hybrid, and radical architectural styles, among others. Deconstructive architecture involved the dismantling of the architectural mass into intricate components, followed by their reassembly, arrangement, and fusion in a manner that deviated from conventional and organic principles (Brzezicki, 2019), (Perricone et al., 2021). Numerous examples of this architectural direction can be found in the works of architects like Jerry, such as the Disney Walt Lobby Show in Los Angeles in 2003 and the dynamic building project, which serves as a prototype for deconstructive architecture with its emphasis on the exploration of unconventional forms, collisions, and inclined facades (Sharma and Mishra, 2021), (Charlier et al., 2015).

Corrugated shape architecture is a modernity design trend that has its roots in digital advancements and their applications within the field of architecture. This architectural approach leverages computer programs to manipulate form and introduce modifications, employing computational methods to transform static shapes into dynamic structures and devise flexible, digital designs that cannot be achieved through conventional design techniques. A prominent illustration of this architectural direction is the Music Feeling Building in the United States, designed by Gehry. In this design, Gehry's utilization of undulating facades is evident in the construction of the exterior structural mass (Tomiku et al., 2005).

5 The modern technologies of architectural facades and their structural connection relationship

- The academic and practical orientation of architects both locally and globally recognizes that a conventional structure consists of a series of interconnected elements with established associations and relationships. These connections can be rigid and straightforward, defining the structure in its fundamental state, or they may be dynamic and continuously evolving (Jabłońska et al., 2022).
- The structure is defined by both its inherent relationships and the variations in materials, with the visual attributes of its form becoming apparent at a deeper perceptual level. If we consider architecture as a language, its elements can be likened to vocabulary that comes together to form a sentence. Design elements, encompassing foundational components, facades, roofs, and more, represent established guidelines for the explicit expression of form and space in architecture (Perricone et al., 2021)
- Ching emphasized that the principles governing the arrangement of components in a building structure can be categorized into two groups: the first set is referred to as the foundational principles of design, and the second is known as the principles of organization (Ching, 1979). Architectural facades serve as a tangible means of translating ideas from mental perceptions into reality (Morvan and Thibert, 2002), (Lin and Tsay, 2021), (Węgrzyński et al., 2020). They are not merely superficial exteriors but rather constitute a profound physical realm situated between the interior and exterior, characterized by intricate connections and associations that culminate in a distinctive image etched in our memory through our presence in the world (Köhler, 2008). This image holds a particular significance and expression, stemming from its recognition of the entire architectural entity. The physical manifestations of external facades encompass a foundational layer of support and an external surface within a bonding relationship, incorporating elements like color, texture, and material with unique attributes. The form of these facades alludes to the comprehensive organization of physical components (facades) in representing the visible aspect of the architectural context (Elmoghazy and Afify, 2023), (Approach, 2016), (Paech, 2016).
- The innovation in construction played a crucial role in shaping the spatial arrangement of the roof's supporting structure and its relationship with architectural space. This transformation is vividly illustrated by the introduction of iron as the primary structural material in architecture. It brought about significant alterations in the spatial relationships within our buildings,

TABLE 8 Analytical Examination of Dynamic Elements Case Study—The dancing building.

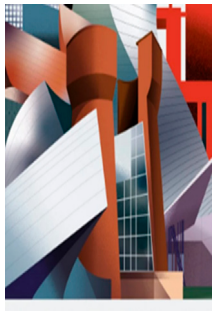
<table>
<tr><th colspan="6">Stability and formal balance</th><th colspan="7" rowspan="2">Structural relationships under which architectural surfaces are organized</th></tr>
<tr><th colspan="3">Degree of balance</th><th colspan="3">Balance type</th></tr>
<tr><td>Low</td><td>Med</td><td>Big</td><td>Unbalanced</td><td>Balance</td><td>Steady</td><td>Harmony surface mod. mechanisms and regular structure</td><td colspan="7">Systemic structural relationship</td></tr>
<tr><td colspan="6"></td><td colspan="3">V_L-V_L</td><td colspan="2">V_L-H_Z</td><td>V_L-H_Z (Roof)</td></tr>
<tr><td>√</td><td>--</td><td>--</td><td>√</td><td>--</td><td>--</td><td>√</td><td colspan="7">Right angle link</td></tr>
<tr><td colspan="3" rowspan="2">  </td><td colspan="3" rowspan="2">  </td><td rowspan="2">  </td><td colspan="3">The directivity of Architectural surfaces</td><td colspan="4">The nature of architectural surfaces</td></tr>
<tr><td rowspan="2">Lake of directivity</td><td colspan="2">Presence of direction</td><td rowspan="2">Surface texture/ color corresponds</td><td rowspan="2">Surface to gravity</td><td rowspan="2">The shape of (H_Z) surface</td><td rowspan="2">The shape of (VL) surface</td></tr>
<tr><td colspan="6">Lack of readily plottable unambiguous modulation mechanisms</td><td>Focus on the VL dir</td><td>Focus on the HZ dir</td></tr>
<tr><td colspan="6"></td><td colspan="3">Focus on the vertical and horizontal Direction</td><td colspan="2">√</td><td>Curved and mated</td><td>Breaking waves</td></tr>
</table>

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TABLE 9 Deconstructivism Architecture - Cultural center Chengdu.

Architecture tred	Deconstruction
Project name	Cultural center Chengdu
Architect's name	Zaha deed
Year	2013

leaving the observer somewhat bewildered as they tried to fathom the structural intricacies and comprehend the forces at play beneath the surface (Convertino et al., 2021), (Afshari, 2020).

6 Stability and formal balance

Balance denotes the state of stability where all elements reside in their rightful positions, and balanced architecture addresses the diverse human needs across various times and locations. Achieving balance can take various forms, whether it's static, dynamic, or asymmetrical. When we examine mass and facades, along with their intricate details, we discern the influence of gravity. It involves preserving constants and variables while emphasizing the inherent lines within the form's design to achieve visual equilibrium (Soycan and Soycan, 2019). One method of achieving balance is by maintaining the fundamental structure's alignment in relation to gravity and considering the surroundings and natural context (Morvan and Thibert, 2002), (Charlier et al., 2015). Modern architecture can be viewed as a manifestation of equilibrium stemming from labor and proficiency. Therefore, it exhibits a seemingly static visual balance that arises from the well-structured construction, which relies on technology, construction expertise, mechanical capabilities, and the materials employed in its design. Various architectural forms emerge within different environments, each offering distinct facets of equilibrium (Hartwell et al., 2021). Architecture engages with multiple senses, leading many architects to define architectural design as a perceptual impression of its components. Regardless of the complexity of construction techniques, architecture must inherently encompass the capacity to provide delight (Adeeb Fahmy Hanna, 2020).

Architecture is often regarded as the most conspicuous form of art, as it encompasses our surroundings and environment wherever our gaze falls. Le Corbusier assures us that the perception of a building is achieved through a holistic interpretation of its elements and relationships. This perception is observed by the viewer, resulting in the final impression of the ever-changing physical qualities and characteristics of the structure. The human mind deciphers the alterations in these architectural facades, discerns their deviations, and identifies the sensory aspects, not solely the physical or structural aspects. It seeks to comprehend the transformations that have occurred throughout the entirety of the architecture, encompassing its functional and sensory intricacies represented by its form, its facets, its proportions, its texture, and its contextual circumstances. The tridimensional shape and its attributes are intricately linked with the characteristics of construction materials such as wood, brick, stone, steel, and glass, as well as the methods of joining these elements together. This synergy between materials and assembly techniques is what provides the eye with a sense of stability, strength, and harmony. It is through the amalgamation of design elements, material properties, and the principles of gravity that the structure is conceived. Within these interconnections among architectural components, we find the elements that give rise to space, movement, form, ornamentation, and functionality, as depicted in illustration Figure 9 (Convertino et al., 2021), (Xiang et al., 2021). Nature's guiding principle is self-organization, which can be defined as the efficient attainment of a goal with minimal effort. The fundamental concept underlying studies of form and structure involves mathematically representing abstracted natural phenomena while considering essential architectural parameters.

Finally, The Theoretical Section focuses on examining the dynamic elements in modern architectural facades, analyzing their impact on the advanced structural aesthetics. The main objective is to gain a theoretical understanding of how these dynamic elements contribute to the overall visual appeal and functionality of a building's facade.

7 The analytically study

The authors conducted an analytical study on (6) different buildings to discover the detailed mechanisms of form facades this comparison of the architectural facades between the modernist and deconstructivism streams. The following factors are analyzed to determine the differences between these two architectural styles (Degree of balance, Harmony of surfaces with the environment, Systemic structural relationship and Presence of directionality) their effect on structural relations. Tables (Table 1, Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, Table 11 and Table 12) illustrates the nature of the architectural facades and the structural relationships, and how they affect formal balance and stability and Figure 10 illustrates a comparison of the architectural facades between the modernist and deconstructivism streams. The following factors are analyzed to determine the differences between these two architectural styles:

- **Degree of balance:** This refers to how balanced the building's facade appears, both in terms of symmetry and proportion. A higher degree of balance implies a more stable and harmonious appearance.
- **Harmony of surfaces with the environment:** This considers how well the building's facade integrates with its surroundings, both visually and functionally. A higher harmony suggests a more cohesive relationship between the building and its context.
- **Systemic structural relationship:** This examines the interplay between the building's structural elements and its overall design. A coherent and efficient systemic structural relationship contributes to the building's stability and visual appeal.
- **Presence of directionality:** This relates to how well the building's facade conveys a sense of direction and orientation. A strong presence of directionality can enhance the building's visual impact and functionality.
- **Surface compatibility with gravity:** This factor assesses how well the building's facade design responds to the force of

TABLE 10 Analytical Examination of Dynamic Elements Case Study—Cultural center chengdu.

<table>
<tr><th colspan="6">Stability and formal balance</th><th rowspan="2">Structural relationships under which architectural surfaces are organized</th><th colspan="6" rowspan="2"></th></tr>
<tr><th colspan="3">Degree of balance</th><th colspan="3">Balance type</th></tr>
<tr><td>Low</td><td>Med</td><td>Big</td><td>Unbalanced</td><td>Balance</td><td>Steady</td><td>Harmony surface mod. mechanisms and regular structure</td><td colspan="6">Systemic structural relationship</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">V_L-V_L</td><td>V_L-H_Z</td><td colspan="2">V_L-H_Z (Roof)</td></tr>
<tr><td>--</td><td>√</td><td>--</td><td>--</td><td>√</td><td>--</td><td>√</td><td colspan="6">Right angle link</td></tr>
<tr><td rowspan="3">  </td><td rowspan="3">  </td><td rowspan="3">  </td><td colspan="3">The directivity of Architectural surfaces</td><td colspan="3">The nature of architectural surfaces</td></tr>
<tr><td rowspan="2">Lake of directivity</td><td colspan="2">Presence of direction</td><td rowspan="2">Surface texture/ color corresponds</td><td rowspan="2">Surface to gravity</td><td rowspan="2">The shape of (H_Z) surface</td><td rowspan="2">The shape of (VL) surface</td></tr>
<tr><td>Focus on the VL dir</td><td>Focus on the HZ dir</td></tr>
<tr><td></td><td></td><td>The merging of vertical and horizontal facades</td><td colspan="3">Focus on the vertical and horizontal Direction</td><td colspan="2">√</td><td>expansive and wavelike</td><td>expansive and wavelike</td></tr>
</table>

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TABLE 11 Deconstructivism Architecture - Denver Museum of Art.

Architecture treed	Deconstruction
Project name	Denver Museum of Art
Architect's name	Daniel Libeskind
Year	2006

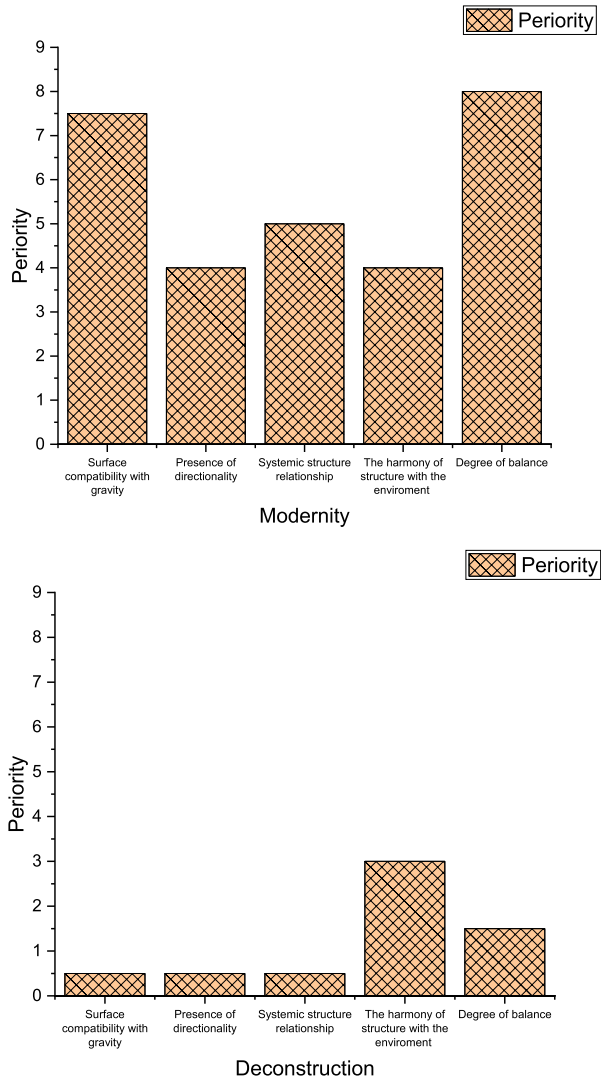

FIGURE 10
A comparison of the architectural facades of the modernist and deconstructivism streams.

gravity, both in terms of structural integrity and aesthetics. A higher compatibility suggests a more efficient and visually pleasing facade design.

By analyzing these factors, Figure 10 provides insights into the distinguishing characteristics between modernist and deconstructivism architectural styles and their impact on the building's overall appearance and functionality. The categories and metrics used by the authors to analyze the building were defined through an examination of the dynamic elements in modern architectural facades for advanced structural.

7.1 Office building—building description

The design philosophy is rooted in "structuralism," which focuses on the construction arrangement in the design process. The structure consists of individual units repeated to form the entire building. The basic project structure extends from the smallest unit to be assembled continuously to accommodate multiple uses in one building space. The construction was based on a system of columns, floor beams, and floor elements. The units used were multiples of 92 cm, leading to the unification of parts and the development of a structural architecture. The insurance company project resulted in a deep spatial matrix building.

7.2 Rothfield house- building description

The Schröder House, designed according to the principles of the De Stijl architectural movement, showcases the use of dynamic elements. The external link to the interior through large glass windows and the utilization of the same colors and abstract shapes as artist Mondrian (a founder of De Stijl) used in his paintings are key features of this design. The emphasis on horizontal and vertical elements adds to the building's modern aesthetic.

7.3 Pompidou center—building description

The Pompidou Center, designed by architect John Portzman, is a prime example of modern architecture, characterized by its tree-like structure. As part of the modern architecture movement, this building showcases a new era of design and innovation.

7.4 The dancing building—building description

This work of architecture is part of the deconstruction trend, generating unusual images. The design is an irregular assembly of shapes, contrasting titanium-covered metal blocks with stone blocks and glass walls. The building uses unconventional forms, creating an unusual language to engage the user and stimulate the senses through unfamiliar symbols and illogical relationships. It challenges existing cognitive structures and redefines architecture through new formal combinations. Titanium is used to clad the main mass, expressing the future and its connection to the ocean, as the building is located inside the sea in Bilbao, a city known for its shipbuilding industry. This reflects on the process of formation, metaphor, and spatial influence.

7.5 Cultural center chengdu—building description

The building's behavior features wavy and airy geometry that forms a long, flowing shape. This unique design responds to the water and site shape, and contrasts the surrounding tall buildings.

TABLE 12 Analytical Examination of Dynamic Elements Case Study Denver Museum of Art.

<table>
<tr><th colspan="6">Stability and formal balance</th><th rowspan="2">Structural relationships under which architectural surfaces are organized</th><th colspan="6"></th></tr>
<tr><th colspan="3">Degree of balance</th><th colspan="3">Balance type</th><th colspan="6"></th></tr>
<tr><td>Low</td><td>Med</td><td>Big</td><td>Unbalanced</td><td>Balance</td><td>Steady</td><td>Harmony surface mod. mechanisms and regular structure</td><td colspan="6">Systemic structural relationship</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">V_L-V_L</td><td>V_L-H_Z</td><td>V_L-H_Z (Roof)</td></tr>
<tr><td>--</td><td>√</td><td>--</td><td>--</td><td>√</td><td>--</td><td>√</td><td colspan="6">Right angle link</td></tr>
<tr><td colspan="3" rowspan="2">  </td><td colspan="3" rowspan="2">  </td><td rowspan="4">Lack of clear modulation mechanism that can plotted</td><td colspan="3">The directivity of Architectural surfaces</td><td colspan="3">The nature of architectural surfaces</td></tr>
<tr><td rowspan="2">Lake of directivity</td><td colspan="2">Presence of direction</td><td rowspan="2">Surface texture/ color corresponds</td><td rowspan="2">Surface to gravity</td><td rowspan="2">The shape of (H_Z) surface</td><td rowspan="2">The shape of (VL) surface</td></tr>
<tr><td colspan="3">The Denver Art Museum, designed by architect Daniel Libeskind in 2006, exhibits a unique deconstructivism style that sets it apart from conventional museum architecture. The building's unusual angles and geometric shapes create a visually stunning and thought-provoking experience for visitors</td><td colspan="3">Irregular Reflection of Segmentation and Overlapping Blocks</td><td>Focus on the VL dir</td><td>Focus on the HZ dir</td></tr>
<tr><td colspan="3">Lake of directivity</td><td>√</td><td>√</td><td>√</td><td>segmented</td></tr>
</table>

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Pedestrian paths are woven throughout, creating an organic architectural language. The building is highly flexible, with multipurpose halls that can transform for various functions.

7.6 Denver museum of art—building description

The Denver Museum of Art, designed by architect Daniel Libeskind, is an example of the deconstructivism architecture movement. This movement is characterized by its unconventional and complex approach, which challenges established architectural ideas. The building employs a unique architectural language, using unfamiliar and abstract forms, yet it remains structurally sound. It defies expectations by employing pure forms to create its language, similar to modernism, while breaking composition rules to create reflections of instability and lack of harmony. The building's appearance resembles a huge rock, emphasizing the distinctiveness of the local nature.

8 Discussion

The analytical examination of dynamic elements in modern architectural facades for advanced structural aesthetics reveals insights into the key factors that influence the appearance and functionality of architectural facades. These factors include the degree of balance, harmony with the environment, systemic structural relationship, presence of directionality, and surface compatibility with gravity. In modern architecture, the fundamental box shapes serve as the defining design elements of architectural facades. These regular forms contribute to achieving a heightened level of stability and formal equilibrium. They are easily grasped and comprehended by the human mind, creating a sense of harmony and balance in the building's facade.

On the other hand, deconstructive architecture departs significantly from the conventional box shape, vertical facades, and typical structural alignments characterized by right angles. Instead, it embraces complex and non-linear shapes that defy simplification or straightforward depiction. Observers are compelled to rotate the building and view it from different perspectives in order to fully grasp its form and perception. However, these geometric configurations introduce formal deviations that disregard established principles of stability and formal balance, departing from the established norms of load-bearing in relation to gravitational forces. During the creation of architectural facades, designers often incorporate structural materials, texture characteristics, and color attributes into their designs. In modernist architecture, a consistent texture and color scheme that spans the entire building is frequently employed. This approach plays a crucial role in achieving structural stability, even in instances of facade fragmentation. The works of Zaha Hadid exemplify this approach, where a unified texture and color scheme counterbalance the potential fragmentation and disintegration of facades.

Conversely, deconstructivity architecture, such as the works of Frank Gehry, introduces design elements that disrupt solid masses and facades. For example, the use of reflective titanium introduces multiple reflections and surface segmentation. While this may compromise both stability and morphological balance, it adds visual interest and complexity to the facade. These design choices challenge traditional notions of stability and aesthetics, pushing the boundaries of architectural expression. By analyzing these factors, Figure 10 provides insights into the distinguishing characteristics between modernist and deconstructivity architectural styles. It highlights how these styles impact the building's overall appearance and functionality, shedding light on the interplay between architectural elements and their effects on structural aesthetics.

9 Findings

The results of this study shed light on the dynamic elements in modern architectural facades and their impact on advanced structural aesthetics. The analysis focused on the degree of balance, harmony with the environment, systemic structural relationship, presence of directionality, and surface compatibility with gravity in both modernist and deconstructivism architectural styles.

In terms of balance, it was found that modernist architecture relies on fundamental box shapes to achieve a heightened level of stability and formal equilibrium. These regular forms are easily comprehensible and provide a sense of visual harmony. On the other hand, deconstructivism architecture deviates from the conventional box shape and introduces complex and non-linear shapes that challenge traditional notions of balance. This departure can lead to formal deviations and a reduction in stability.

Regarding the harmony with the environment, both modernist and deconstructivism architecture aim to integrate the building's facade with its surroundings. In modernist architecture, techniques such as breaking down horizontal and vertical surfaces, shifting them both horizontally and vertically, and interconnecting them at right angles are employed to achieve this harmony. Deconstructivism architecture, however, often disrupts the harmony by introducing unconventional shapes and forms that may not align with the architectural context.

The systemic structural relationship between the building's structural elements and its overall design was also examined. In modernist architecture, there is a coherent and efficient interplay between the structural elements and the facade design. This contributes to the building's stability and visual appeal. In contrast, deconstructivism architecture challenges these established relationships by introducing unconventional structural alignments and right angles, potentially compromising both stability and aesthetics. The presence of directionality in architectural facades was found to be significant for both modernist and deconstructivism styles. Modernist architecture often employs a clear sense of directionality, utilizing vertical and horizontal alignments to establish a sense of stability and visual impact. Deconstructivism architecture, however, embraces multiple and variable directions in various facades, departing from the conventional approach. This departure can result in a reduction of stability and formal balance, making the architectural structures less stable.

Surface compatibility with gravity was assessed to understand how well the building's facade design responds to the force of gravity in terms of structural integrity and aesthetics. In modernist architecture, the use

of fundamental box shapes ensures a high level of compatibility with gravity, contributing to both stability and visual appeal. In contrast, deconstructivism architecture challenges these principles by introducing shapes that deviate from established norms, potentially compromising both stability and morphological balance.

In summary, the results of this study demonstrate the contrasting characteristics of modernist and deconstructivism architectural facades in terms of balance, harmony with the environment, systemic structural relationship, presence of directionality, and surface compatibility with gravity. These findings provide valuable insights for architects and designers in creating aesthetically pleasing and structurally sound architectural facades.

10 Conclusion and recommendations

This study has provided valuable insights into the dynamic elements of modern architectural facades and their impact on advanced structural aesthetics. Through the analysis of balance, harmony with the environment, systemic structural relationship, directionality, and surface compatibility with gravity, we have gained a deeper understanding of the contrasting characteristics between modernist and deconstructivism architectural styles.

The findings of this study provide architects and designers with valuable insights for creating aesthetically pleasing and structurally sound architectural facades. By understanding the interplay of these dynamic elements, practitioners can make informed design decisions that balance visual aesthetics with structural integrity.

To further enhance the understanding of dynamic elements in architectural facades, future research could explore the integration of energy-efficient and sustainable design strategies. Additionally, a larger sample size of case studies could provide a more comprehensive analysis of modernist and deconstructivism architectural styles. The impact of these styles on factors like indoor comfort, environmental impact, and user experience could also be investigated.

The attributes of architectural facades and the underlying structural connections are fundamental in understanding the formal composition and evaluating the facades' ability to generate shapes. Moreover, the research recommends the utilization of digital software for crafting unique architectural elements, as they have proven effective in generating design blueprints and generating innovative and adaptable solutions for architectural facades based on diverse relationships.

The study on the analytical examination of dynamic elements in modern architectural facades for advanced structural aesthetics extracted valuable research recommendations. By analyzing the complex mechanisms of shape surfaces in modernist and deconstructive architecture and their influence on structural relationships, the study highlights the need to integrate technological advancements, especially in construction materials and building systems, into the design process. Utilizing these developments in architectural surfaces with diverse structural relationships is crucial for establishing a fresh morphological characteristic of buildings and their impact on formal stability from various perspectives. These recommendations provide insightful guidance on the integration of technology and design, leading to improved architectural aesthetics and stability.

11 Limitations

It should be noted that this study focused on analyzing architectural facades from a visual, architectural and structural perspective. Other aspects, such as energy efficiency and sustainability, have not been widely explored.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ME: Investigation, Supervision, Visualization, Writing–original draft, Writing–review and editing. EO: Investigation, Project administration, Writing–review and editing. SB: Methodology, Validation, Writing–original draft. AA-A: Investigation, Supervision, Visualization, Writing–original draft, Writing–review and editing. DS: Conceptualization, Project administration, Writing–original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Adeeb Fahmy Hanna, H. (2020). Definition of the building envelope: towards a new perspective. *Eng. Res. J.* 165 (0), 33–56. doi:10.21608/erj.2020.131803

Afshari, N. K. N. A. (2020). A qualitative analysis of public buildings on ContemporaryIranian architecture in the second pahlavi era based on theArchitectural tectonic approach. *Bagh-e Nazar* 17 (90), 101–122. doi:10.22034/bagh.2020.191552.4187

Agirbas, A. (2018). Façade form-finding with swarm intelligence. *Autom. Constr.* 99, 140–151. doi:10.1016/j.autcon.2018.12.003

Approach, C. G. (2016). 済無*No title No title No title*, 1–23.

Bedon, C., Zhang, X., Santos, F., Honfi, D., Kozłowski, M., Arrigoni, M., et al. (2018). Performance of structural glass facades under extreme loads – design methods, existing research, current issues and trends. *Constr. Build. Mat.* 163, 921–937. doi:10.1016/j.conbuildmat.2017.12.153

Biddulph, M. (2014). Drawing and thinking: representing place in the practice of place-making. *J. Urban Des.* 19 (3), 278–297. doi:10.1080/13574809.2014.890045

Brzezicki, M. (2019). The architectural design of light-permeable facades – a summary of recent trends and observations. *Czas. Tech.* 12, 5–30. doi:10.4467/2353737xct.19.120.11445

Charlier, B., Nardi, G., and Trouvé, A. (2015). The matching problem between functional shapes via a BV-penalty term: a Γ-convergence result. Available at: http://arxiv.org/abs/1503.07685.

Chatzikonstantinou, I., and Sariyildiz, I. S. (2017). Addressing design preferences via auto-associative connectionist models: application in sustainable architectural Façade design. *Autom. Constr.* 83, 108–120. doi:10.1016/j.autcon.2017.08.007

Ching, F. D. K. (2007). *Architecture: form, space, and order*. Available at: http://www.amazon.co.uk/Architecture-Francis-D-K-Ching/dp/0471752169.

Convertino, F., Vox, G., and Schettini, E. (2021). Evaluation of the cooling effect provided by a green façade as nature-based system for buildings. *Build. Environ.* 203, 108099. doi:10.1016/j.buildenv.2021.108099

Durmus, S., and Gur, S. O. (2011). Methodology of deconstruction in architectural education. *Procedia - Soc. Behav. Sci.* 15, 1586–1594. doi:10.1016/j.sbspro.2011.03.335

Elmoghazy, Z. A. A. E., and Afify, H. M. N. (2023). Reflective façades: revisiting a neglected trait of modernism in contemporary architecture with new implications and significance. *Buildings* 13 (11), 2740. doi:10.3390/buildings13112740

Hartwell, R., Macmillan, S., and Overend, M. (2021). Circular economy of façades: real-world challenges and opportunities. *Resour. Conserv. Recycl.* 175, 105827. doi:10.1016/j.resconrec.2021.105827

High-rise, D. A. O. F. (2014). *Politecnico di Torino sandro cammarano static and dynamic analysis of high-rise buildings dottorato di Ricerca in ingegneria delle strutture*. doi:10.6092/polito/porto/2565549

Jabłońska, J., Telesińska, M., Adamska, A., and Gronostajska, J. (2022). The architectural typology of contemporary façades for public buildings in the European context. *Arts* 11 (1), 11. doi:10.3390/arts11010011

Kasperski, M. (2022). *How advancements in manufacturing processes and design workflows could inform a new circular tectonic language of contemporary timber architecture?*

Köhler, M. (2008). Green facades-a view back and some visions. *Urban Ecosyst.* 11 (4), 423–436. doi:10.1007/s11252-008-0063-x

Lim, Y. W., Kandar, M. Z., Ahmad, M. H., Ossen, D. R., and Abdullah, A. M. (2012). Building façade design for daylighting quality in typical government office building. *Build. Environ.* 57, 194–204. doi:10.1016/j.buildenv.2012.04.015

Lin, C. H., and Tsay, Y. S. (2021). A metamodel based on intermediary features for daylight performance prediction of façade design. *Build. Environ.* 206, 108371. doi:10.1016/j.buildenv.2021.108371

Mao, Y., Qi, J., and He, B. J. (2020). Impact of the heritage building façade in small-scale public spaces on human activity: based on spatial analysis. *Environ. Impact Assess. Rev.* 85, 106457. doi:10.1016/j.eiar.2020.106457

Morvan, J. M., and Thibert, B. (2002). Smooth surface and triangular mesh: comparison of the area, the normals and the unfolding. *Proc. Symp. Solid Model. Appl.*, 147–158. doi:10.1145/566282.566306

Paech, C. (2016). Structural membranes used in modern building facades. *Procedia Eng.* 155, 61–70. doi:10.1016/j.proeng.2016.08.007

Paleologos, E. K., Caratelli, P., and El Amrousi, M. (2016). Waste-to-energy: an opportunity for a new industrial typology in Abu Dhabi. *Renew. Sustain. Energy Rev.* 55, 1260–1266. doi:10.1016/j.rser.2015.07.098

Perricone, V., Santulli, C., Rendina, F., and Langella, C. (2021). Organismal design and biomimetics: a problem of scale. *Biomimetics* 6 (4), 56. doi:10.3390/biomimetics6040056

Radić, J., Kušter, M., and Kincl, B. (2010). Structural - architectural approach to bridge design. *Large Struct. Infrastructures Environ. Constrained Urban. Areas*, 416–417. doi:10.2749/222137810796025203

Riccobono, A. (2014). Architectural design in the Digital Era - identifying computer influences and new expressive trends in current architecture. *Tese Doutorado*, 1–315.

Sadeqi, S., Ekhlassi, A., and Norouzian-Maleki, S. (2019). An analysis of structural aesthetics in architecture case study: taj-Ol-Molk Dome, Jāmeh Mosque of Isfahan, Iran. *SN Appl. Sci.* 1 (6), 570–580. doi:10.1007/s42452-019-0558-5

Sayed, M. A. A. E. D. A., and Fikry, M. A. (2019). Impact of glass facades on internal environment of buildings in hot arid zone. *Alex. Eng. J.* 58 (3), 1063–1075. doi:10.1016/j.aej.2019.09.009

Sayed El Falafli, M. (2021). The impact of the use of smart materials on the environment. *Int. J. Adv. Eng. Civ. Res.* 1 (2), 41–54. doi:10.21608/ijaecr.2023.214440.1010

Sekularac, J. I., Sekularac, N., and Tovarovic, J. C. (2012). Wood as element of façade cladding in modern architecture. *Tech. Technol. Educ. Manag.* 7 (3), 1304–1310.

Sharma, A., and Mishra, K. B. (2021). Experimental investigations on the influence of 'chimney-effect' on fire response of rainscreen façades in high-rise buildings. *J. Build. Eng.* 44, 103257. doi:10.1016/j.jobe.2021.103257

Soycan, A., and Soycan, M. (2019). Perspective correction of building facade images for architectural applications. *Eng. Sci. Technol. Int. J.* 22 (3), 697–705. doi:10.1016/j.jestch.2018.12.012

Sung, D. (2016). A new look at building facades as infrastructure. *Engineering* 2 (1), 63–68. doi:10.1016/J.ENG.2016.01.008

Tomiku, R., Otsuru, T., Azuma, D., and Takahashi, Y. (2005). Use of finite element method for comparison of sound field diffuseness in reverberation rooms with and without absorption materials. *Acoust. Sci. Technol.* 26 (2), 225–228. doi:10.1250/ast.26.225

Węgrzyński, W., Antosiewicz, P., Burdzy, T., Tofiło, P., and Papis, B. K. (2020). Experimental investigation into fire behaviour of glazed façades with pendant type sprinklers. *Fire Saf. J.* 115, 103159. doi:10.1016/j.firesaf.2020.103159

Xiang, C., Matusiak, B. S., Røyset, A., and Kolås, T. (2021). Pixelization approach for façade integrated coloured photovoltaics-with architectural proposals in city context of Trondheim, Norway. *Sol. Energy* 224, 1222–1246. doi:10.1016/j.solener.2021.06.079