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Research Paper

A Comprehensive Review on Façade Evaluation Criteria

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Abstract
Any scientific activity or instrumental application involving façades—such as research, design, evaluation, and decision-making—requires a comprehensive set of criteria to cover all expected requirements. This highlights the necessity of a study to explore, gather, and organize a holistic set of criteria for the evaluation, study, design, and decision-making regarding façades. Moreover, establishing a comprehensive list of criteria is essential but insufficient on its own. It is equally important to achieve a mutual understanding of these criteria, providing experts and researchers with a common language and understanding regarding façades. Although various criteria have been mentioned in different façade-related research, a summary study to gather, organize, and reliably define these criteria is needed to improve the logical applications of façades and facilitate mutual understanding. This study aims to take the first step in meeting this requirement by describing each criterion relevant to façade assessment. In this context, a systematic library-based research approach was employed, reviewing 71 related papers. Criteria were then extracted using an exploratory study based on open and axial coding methods. Ultimately, 42 criteria were identified and organized into five primary categories: environmental aspects, social impacts, economic aspects, efficiency and effectiveness, and technical aspects.

Keywords: *Façade, façade criteria, Façade criteria definition, Façade evaluation, Façade decision making.*

INTRODUCTION

Different functions need to be addressed simultaneously when it comes to façades. However, literature reviews predominantly focus on specific aspects or angles of the subject. This trend results in a lack of a comprehensive view of the aspects and criteria a façade should meet to be considered ideal. A few studies have attempted to provide a holistic view of façade aspects, challenging this trend, but their efforts, though valuable, have not been widely extended. Hendriks and Hens (2000) introduced an initial set of façade evaluation criteria based on performance (Hendriks & Hens, 2000). While this was a pioneering attempt to propose a performance-based perspective for façades, it primarily focused on performance and building physics aspects, neglecting other important aspects such as environmental and technical issues necessary for a holistic assessment. This study was also validated by Warren (2003) in Annex 32 of the International Energy Agency (IEA). Annex 32 emphasized that the selection of a façade requires considering all relevant factors, including aesthetic and physical characteristics (Warren, 2003). However, it similarly concentrated mainly on the façade's performance. Later, Z. Chen and Clements-Croome (2007) presented 37 key performance indicators (KPIs) for façades across six clusters: adaptability, affordability, durability, energy, intelligence, and well-being (Z. Chen & Clements-Croome, 2007). Although they aimed to enhance the number, accuracy, and comprehensiveness of indicators, their focus remained solely on the performance aspect of façades. Consequently, their list of criteria can be expanded by incorporating criteria associated with other relevant aspects of façades, which is one of the two primary aims of this research. Moreover, existing categorizations of

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criteria in the literature need to be expanded to cover all dimensions related to façades comprehensively. Importantly, none of the aforementioned studies define the terms and criteria they utilize. This creates a gap, as frequently used terms in the façade field lack consensus among experts when it comes to interpretation or description. Although these terms are defined in various dispersed references such as encyclopedias or architectural dictionaries, publications that compile these terms with their descriptions are scarce. Such an effort would not only improve the logical and technical language used by experts discussing façades but also significantly enhance mutual understanding in façade design and decision-making. The present study aims to address this idea and meet the expectations of technicians who professionally explore façades and their various aspects. To achieve this, façade assessment papers were studied and analyzed to extract relevant criteria for decision-making regarding façades. Additionally, criteria applicable to façades but initially raised for other building components were incorporated to supplement the set. General and specialized resources were then used to find the most relevant definitions and descriptions of these criteria. In instances of differing opinions, all descriptions were presented, and a conclusion was drawn to reach a single, unified meaning. To start, definitions of façades are discussed in the following section.

FAÇADE DEFINITION

At the outset, the definition of a façade must be clear as it forms the basis of this research. The building envelope is the primary interface between a building's exterior and interior environments (Bertagna et al., 2021; Schittich et al., 2006). The façade is the exterior building envelope layer that faces public spaces (Boswell, 2013). According to the Columbia Encyclopedia, a façade is the exterior face or wall of a building. The term "façade" refers to the orderly arrangement of openings and other architectural elements on the exterior of a building. This concept seems inapplicable to a plain, unadorned wall, as a façade requires intentional design. Any standalone structure, however, will have four or more exterior façades, which can be identified by their orientation, such as the south façade (The Columbia Electronic Encyclopedia, 2022). In other words, a façade refers to the primary exterior surface of a building, especially one of its principal sides. Façades typically incorporate an entrance and are distinguished by architectural ornamentation and stylistic detailing (Illustrated Dictionary of Architecture, 2012). Another definition describes the façade as the front or face of a building given special architectural treatment (McGraw-Hill Dictionary of Scientific & Technical Terms, 2003). Additionally, the McGraw-Hill Dictionary of Architecture and Construction denotes the principal exterior surface of a building, typically the architectural front. Façades are occasionally distinguished from other exterior elevations by an elaborate application of architectural embellishments or ornamental details (The McGraw-Hill Dictionary of Architecture and Construction, 2003). The Oxford Dictionary describes a façade as the principal front of a building that faces a street or open space (Oxford Dictionary, 2018). The building façade is the outer surface of the building, which gives the structure its distinctive visual identity (Turkay, 2017). Façade is defined as the front of a building (Britannica, 2023; Merriam-Webster Dictionary, 2023). According to these descriptions, the external surface of the different sides of a single building that faces open space or urban space, and is visible from such spaces, while making use of architectural and specific ornamental details to distinguish it from other buildings, is called a façade in this article. The purpose of a building's façade is to selectively facilitate or obstruct various physical phenomena, such as heat and mass flow, sound transmission, and light passage (Jin & Overend, 2014).

MATERIALS AND METHOD

The focus of this research was on studies within the façade field but was not limited to that. Specifically, 26 papers were found that directly assessed façades using specific criteria. Additionally, criteria mentioned in 45 other references, which assessed other components of buildings, were also utilized. To find the references, the terms “Façade,” “Criteria,” and “Decision-making” were searched using the “or” operator in the Scopus database. After two stages of refinement, 71 papers deemed worthwhile were selected. Next, all criteria were extracted through an exploration of the references and compiled into a single list, ordered alphabetically and coded for the first time. An open coding system (Corbin & Strauss, 2014) was employed at this stage; for example, “Community Disturbance” was coded as X22. The method for extracting criteria involved either copying the criteria verbatim when they were directly mentioned in the studies or listing the criteria based on the research objectives or materials. In the next phase, the criteria were coded again and categorized based on their meanings into different groups. In other words, criteria that conveyed the same meaning were grouped together. An axial coding system (Corbin & Strauss, 2014) was used for this process. For example, “Resource Sustainability,” “Natural Resource Depletion,” and “Resource Consumption” were categorized in the same group, and their codes were replaced by EC41, EC42, and EC43, respectively. In this coding system, "E" represents the theme of the cluster (Environment), "C" stands for the cluster, the first index number denotes the cluster number, and the second index signifies the criteria number. For instance, EC43 represents the third criterion of the fourth cluster associated with the Environment field. Afterward, the groups were named based on the meanings they conveyed, ensuring the names semantically covered the criteria within each group. The name of the group accounts for the criteria it contains, and this group of criteria is known by the group name. For instance, “Thermal Properties,” “Thermal Insulation,” “Thermal Transmittance,” and “Thermal Comfort” were grouped under "Thermal Performance," all placed in a cluster with a "Performance" theme. Thus, their new codes were PC19-1, PC19-2, PC19-3, and PC19-4, respectively. Subsequently, the analysis was conducted based on the group names. Those with the same themes and scopes were clustered together to organize all criteria into categories that clearly represent the aspects they address. The findings of this research are detailed below.

FINDINGS

In the initial phase, a review of 71 papers resulted in gathering 195 criteria, which were compiled into a single list ordered alphabetically. Subsequent stages of analysis and categorization revealed five major categories: environmental aspects, social impacts, economic aspects, efficiency and effectiveness, and technical aspects. Ultimately, 42 criteria were identified and categorized within these broader categories. Table 1 presents the results as follows: Environmental aspects encompassed 10 criteria, social impacts included 6 criteria, and economic aspects comprised 2 criteria. Efficiency and effectiveness had 18 criteria, while technical aspects included 6 criteria. These clusters and their respective criteria are defined and described in Section 3.

Table 1. Comprehensive and categorized set of criteria based on literature review

No.	Category	Final criteria	References
1	Environmental aspects	Suitability to Location conditions	(Al-Hammad & Hassanain, 1996; Granadeiro et al., 2013; Hendriks & Hens, 2000; Martinez, 2005; Moussavi Nadoushani et al., 2017; Warren, 2003)
		Embodied energy	(Z. Chen & Clements-Croome, 2007; Hendriks & Hens, 2000; Martabid & Mourgues, 2015; Moussavi Nadoushani et al., 2017; W. Wang et al., 2006; Warren, 2003)
		Carbon dioxide emission	(Ahmadian et al., 2017; L. Chen & Pan, 2016; Z. Chen & Clements-Croome, 2007; Hendriks & Hens, 2000; Martabid & Mourgues, 2015; Moussavi Nadoushani et al., 2017; Shin & Cho, 2015; W. Wang et al., 2006; Warren, 2003)
		Natural resource depletion	(Ahmadian et al., 2017; Y. Chen et al., 2010; Z. Chen & Clements-Croome, 2007; Hendriks & Hens, 2000; Kibert, 2022; Kim & Rigdon, 1998; Martabid & Mourgues, 2015; Moussavi Nadoushani et al., 2017; Singhaputtangkul et al., 2014, 2016; Tsai et al., 2011; W. Wang et al., 2006; Warren, 2003b)
		Water use	(Ahmadian et al., 2017; Z. Chen & Clements-Croome, 2007; Hendriks & Hens, 2000; Martabid & Mourgues, 2015; Noh et al., 2014; W. Wang et al., 2006; Warren, 2003)
		Energy consumption	(Ahmadian et al., 2017; Bank et al., 2011; Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Hendriks & Hens, 2000; Horvat & Fazio, 2020; Jalilzadehazhari et al., 2019; Kaklauskas et al., 2006; Kibert, 2022; Martabid & Mourgues, 2015a; Martinez, 2005; Singhaputtangkul et al., 2014, 2016; W. Wang et al., 2006; Warren, 2003; J. Yu et al., 2008; Zavadskas et al., 2008)
		Waste generation	(Ahmadian et al., 2017; Z. Chen & Clements-Croome, 2007; Hendriks & Hens, 2000; Jaillon & Poon, 2008; Martabid & Mourgues, 2015; Singhaputtangkul et al., 2014, 2016; Spiegel, R. and Meadows, 2010; Tsai et al., 2011; W. Wang et al., 2006; Warren, 2003)
		Recycle and reuse	(Ahmadian et al., 2017; Asokan et al., 2009; Z. Chen & Clements-Croome, 2007; Hendriks & Hens, 2000; W. Wang et al., 2006; Warren, 2003)

No.	Category	Final criteria	References
		Renewable energy use	(Z. Chen & Clements-Croome, 2007; Hendriks & Hens, 2000; Moussavi Nadoushani et al., 2017; W. Wang et al., 2006; Warren, 2003; Zavadskas et al., 2008)
		Environmental impacts	(Hendriks & Hens, 2000; Martabid & Mourgues, 2015; W. Wang et al., 2006; Warren, 2003)
2	Social impacts	Aesthetics	(Ahmadian et al., 2017; Al-Hammad & Hassanain, 1996; Ashby & Johnson, 2014; Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Granadeiro et al., 2013; Kaklauskas et al., 2006; Martabid & Mourgues, 2015; Moussavi Nadoushani et al., 2017; Passe & Nelson, 2013; Singhaputtangkul et al., 2014, 2016; W. Wang et al., 2006; Yang et al., 2003; Zavadskas et al., 2005, 2008)
		Clients' preferences in façade design	(Karan et al., 2021; Karan & Asadi, 2019)
		User's involvement in façade design	(Martinez, 2005)
		Compatibility to the context	(Al-Hammad & Hassanain, 1996; Hendriks & Hens, 2000; Martinez, 2005; Moussavi Nadoushani et al., 2017; Warren, 2003)
		Health, safety, and security of occupants and society	(Ahmadian et al., 2017; Al-Hammad & Hassanain, 1996; Brock, 2005; Z. Chen & Clements-Croome, 2007; Chew, 2017; Horvat & Fazio, 2020; Martabid & Mourgues, 2015; Singhaputtangkul et al., 2014, 2016; Spiegel, R. and Meadows, 2010; C. W. F. Yu & Kim, 2010; Zavadskas et al., 2008)
		Social impacts	(Z. Chen & Clements-Croome, 2007)
3	Economic aspects	Costs	(Ahmadian et al., 2017; Al-Hammad & Hassanain, 1996; Asokan et al., 2009; L. Chen & Pan, 2016; Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Das et al., 2010; Emmit & Yeomans, 2008; Ginevičius et al., 2008; Hendriks & Hens, 2000; Irizarry et al., 2013; Jalilzadehazhari et al., 2019; Kaklauskas et al., 2006; Lacasse et al., 1997; Martabid & Mourgues, 2015; Martinez, 2005; Moussavi Nadoushani et al., 2017; Passe & Nelson, 2013; Said & El-Rayes, 2011; Shin & Cho, 2015; Singhaputtangkul et al., 2014, 2016; W. Wang et al., 2006; Warren, 2003; J. K. W. Wong & Li, 2008; Zavadskas et al., 2005, 2008)
		Time	(Ahmadian et al., 2016, 2017; Al-Hammad & Hassanain, 1996; Dissanayaka & Kumaraswamy, 2001; Ginevičius et al., 2008; Kaklauskas et al., 2006; Martabid & Mourgues, 2015; Tommelein et al., 2008; Zavadskas et al., 2005, 2008)
4	Efficiency and effectiveness	Thermal performance	(Ahmadian et al., 2017; Al-Hammad & Hassanain, 1996; Babaeian Jelodar et al., 2021; Bryan, 2014; Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Ginevičius et al., 2008; Granadeiro et al., 2013; Hendriks & Hens, 2000; Horvat & Fazio, 2020; Jalilzadehazhari et al., 2019; Kaklauskas et al., 2006; Kibert, 2022; Martabid & Mourgues, 2015; Martinez, 2005; Moussavi Nadoushani et al., 2017; Passe & Nelson, 2013; Scheuer et al., 2003; Singhaputtangkul et al., 2014, 2016; Warren, 2003; You et al., 2011; J. Yu et al., 2008; Zavadskas et al., 2005, 2008; Zhou et al., 2009)
		Acoustic performance	(Al-Hammad & Hassanain, 1996; Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Hendriks & Hens, 2000; Horvat & Fazio, 2020; Kaklauskas et al., 2006; Low, Liu, & Oh, 2008; Martabid & Mourgues, 2015; Moussavi Nadoushani et al., 2017; Singhaputtangkul et al., 2014, 2016; Warren, 2003; Yang et al., 2003; Zavadskas et al., 2008)
		Indoor visual environment	(Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Hendriks & Hens, 2000; Jalilzadehazhari et al., 2019; Kaklauskas et al., 2006; Low, Liu, & Wong, 2008; Nielsen, 2003; Singhaputtangkul et al., 2014, 2016; Warren, 2003)
		Moisture resistance	(Al-Hammad & Hassanain, 1996; Ginevičius et al., 2008; Horvat & Fazio, 2020; Kaklauskas et al., 2006; Martabid & Mourgues, 2015; Zavadskas et al., 2008)
		Air-tightness	(Hendriks & Hens, 2000; Horvat & Fazio, 2020; Kaklauskas et al., 2006; Warren, 2003; Zavadskas et al., 2008)

No.	Category	Final criteria	References
		Weather protection performance	(Bryan, 2014; Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Martabid & Mourgues, 2015; Singhaputtangkul et al., 2014, 2016; Yang et al., 2003; Zavadskas et al., 2008)
		Orientation	(Z. Chen & Clements-Croome, 2007; Granadeiro et al., 2013; Martinez, 2005; W. Wang et al., 2006)
		Fire resistance	(Ahmadian et al., 2017; Al-Hammad & Hassanain, 1996; Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Hendriks & Hens, 2000; Horvat & Fazio, 2020; Lo et al., 2008; Martabid & Mourgues, 2015; Warren, 2003; Zavadskas et al., 2008)
		Light-weightiness	(Ginevičius et al., 2008; Moussavi Nadoushani et al., 2017; Zavadskas et al., 2008)
		Durability	(Ahmadian et al., 2017; Al-Hammad & Hassanain, 1996; Bryan, 2014; Z. Chen & Clements-Croome, 2007; Ginevičius et al., 2008; Hendriks & Hens, 2000; Kaklauskas et al., 2006; Kneifel, 2010; Martabid & Mourgues, 2015; Martinez, 2005; Moussavi Nadoushani et al., 2017; Passe & Nelson, 2013; Singhaputtangkul et al., 2014, 2016; Warren, 2003; Zavadskas et al., 2005, 2008; Zhou et al., 2009)
		Resistance to decay	(Z. Chen & Clements-Croome, 2007; Hendriks & Hens, 2000; Moussavi Nadoushani et al., 2017; Warren, 2003)
		Maintainability	(Ahmadian et al., 2017; Al-Hammad & Hassanain, 1996; L. Chen & Pan, 2016; Z. Chen & Clements-Croome, 2007; Das et al., 2010; Lacasse et al., 1997; Martabid & Mourgues, 2015; Martinez, 2005; Singhaputtangkul et al., 2014, 2016; Sirisalee et al., 2004; Zavadskas et al., 2005, 2008)
		Constructability	(Ahmadian et al., 2017; Kibert, 2022; Martabid & Mourgues, 2015; Passe & Nelson, 2013)
		Indoor air quality	(Ahmadian et al., 2017; Z. Chen & Clements-Croome, 2007; Kaklauskas et al., 2006; Nematchoua et al., 2015; Zavadskas et al., 2008)
		Buildability	(Bryan, 2014; Y. Chen et al., 2010; Chew, 2017; F. E. Gould, 2010; Hinze et al., 2006; Kibert, 2022; Low, Liu, & Oh, 2008; Ofori, 2000; Singhaputtangkul et al., 2014, 2016; Vrijhoef & Koskela, 2000; Yang et al., 2003)
		Refurbishment flexibility	(Al-Hammad & Hassanain, 1996; Z. Chen & Clements-Croome, 2007)
		Availability of materials and façade systems	(Al-Hammad & Hassanain, 1996)
		Intelligence	(Z. Chen & Clements-Croome, 2007)
5	Technical aspects	Complexity of construction	(Bryan, 2014; Y. Chen et al., 2010; Low, Liu, & Oh, 2008; Martabid & Mourgues, 2015; Singhaputtangkul et al., 2014, 2016; Yang et al., 2003)
		Quality of material	(Z. Chen & Clements-Croome, 2007; Ginevičius et al., 2008; Granadeiro et al., 2013; Kaklauskas et al., 2006; Martinez, 2005; Zavadskas et al., 2005, 2008)
		Quality of construction	(Z. Chen & Clements-Croome, 2007; Ginevičius et al., 2008; Kaklauskas et al., 2006; Zavadskas et al., 2008)
		Structural performance	(Ahmadian et al., 2017; Al-Hammad & Hassanain, 1996; L. Chen & Pan, 2016; Z. Chen & Clements-Croome, 2007; Chua & Chou, 2010; Ginevičius et al., 2008; Horvat & Fazio, 2020; Kaklauskas et al., 2006; Lo et al., 2008; Martabid & Mourgues, 2015; Zavadskas et al., 2008)
		Window's area	(Granadeiro et al., 2013; Kaklauskas et al., 2006)
		Compliance with codes, regulations, and technical conditions	(Chua & Chou, 2010; Karan & Asadi, 2019; Tan et al., 2007, 2010)

CRITERIA AND DEFINITION

This study categorizes its findings into five main groups. The first category focuses on environmental aspects, encompassing criteria related to the environmental impact across the lifecycle of facades. Predominant concerns in the literature include energy consumption, depletion of natural resources, and generation of waste. The second category addresses social impacts, highlighting trends such as aesthetics, occupant health, safety, and security. The third category examines economic aspects, emphasizing cost and time as primary criteria, with cost being the most frequently cited. The fourth category, efficiency and effectiveness, includes criteria such as thermal performance, durability, acoustic performance, and maintainability. The fifth category, technical aspects, complements the others by covering structural performance, construction complexity, material quality, and compliance with codes and regulations relevant to facade engineering.

To begin with, environmental aspects consist of 10 criteria that are discussed in the following:

Location suitability implies that a building's facade should harmonize with its surroundings without disrupting the neighborhood's identity, style, shape, and ambiance (Moussavi Nadoushani et al., 2017). This criterion also encompasses the potential energy efficiency benefits of a facade that adapts to local climate conditions. Additionally, it considers how climate impacts the appearance of facade materials, potentially causing issues like stains, efflorescence, and cracks over prolonged exposure (Moussavi Nadoushani et al., 2017).

Embodied energy refers to the energy consumed during the manufacturing or construction of a product or the provision of services. This encompasses energy used in extracting and processing raw materials, manufacturing construction materials, transportation, distribution, and the assembly of facades. The cradle-to-grave approach in calculating embodied energy also considers energy required for refurbishment, maintenance during the facade's service life, and for demolition and waste management at the end of its life cycle (Tuladhar & Yin, 2019). This criterion is crucial in evaluating facades across their life cycle.

Carbon dioxide (CO_2) emissions arise primarily from the combustion of fossil fuels such as oil, coal, and natural gas, as well as from the incineration of waste materials for energy generation. Deforestation and specific industrial processes, notably cement manufacturing, also contribute to atmospheric CO_2 levels (OECD, 2016). These emissions result from the combustion of solid, liquid, and gaseous fuels, including gas flaring (The World Bank, 2023). This paper focuses on CO_2 emissions throughout the life cycle of facades.

Natural resource depletion refers to the consumption of non-renewable energy resources at a rate faster than they can naturally replenish (Park, 2007). This process, described as depletion, occurs when resources are utilized more quickly than they can renew themselves (Höök et al., 2010).

Buildings typically involve both direct and indirect water consumption throughout their life cycle. Direct water use includes water consumed for facade cleaning, aggregate washing, concrete production and curing, dust suppression, and equipment and surface washing. Indirect water use refers to the embodied water utilized in the manufacture of facade materials. During building operation, water is required for purposes such as drinking, landscaping, cleaning, and recreational or cooling activities. Measures to minimize water consumption should be integrated into the planning phase (Rahman et al., 2019). This criterion is referred to as the water use criterion in this study.

Energy consumption, as shown in Table 1, refers to the total electricity or equivalent energy used annually by a building (Hasanuzzaman et al., 2020). The building's facade significantly influences energy requirements for cooling, heating, lighting, and other purposes. If renewable energy sources are available, should be subtracted from the total energy consumption (Hasanuzzaman et al., 2020). Facade waste generation encompasses any inefficiencies or losses directly or indirectly associated with the facade across its life cycle stages: procurement, development, manufacturing, construction, maintenance during occupancy, and demolition. These stages generate both direct and indirect materials and costs that do not contribute value to the completed building project (Tongo et al., 2021). Facade waste includes various materials such as concrete, bricks, wood, glass, metals, and plastics (Deloitte, 2017).

Recycling is the process of extracting resources from waste and adding value to materials for reuse (Burden, 2012). This includes various methods such as extraction, reprocessing, conversion, and reuse of building waste materials. Common recyclable materials include metals, wood, masonry, glass, plastics, paper, appliances, asphalt, paints, and landscaping products. While much building waste is non-hazardous, stringent regulations in many countries govern its transportation, storage, and disposal (Burden, 2012).

The use of renewable energy involves the utilization of resources like solar, wind, geothermal, and biomass, which can be replenished at a rate equal to or greater than their rate of depletion (Burden, 2012).

Environmental impact refers to any change in the environment, whether positive or negative, resulting from human activities, industries, or natural disasters. It encompasses the social and physical consequences of development or governmental policies on both natural and built environments (Burden, 2012). In this study, the construction and operation of facades as human activities can potentially harm the environment.

The second cluster focuses on the social impacts of the facade and includes six factors, with aesthetics being the most frequently cited. Explanations of these criteria are provided below.

User involvement in facade design aims to ensure that the design effectively meets the needs and preferences of users (Lind & Rittgen, 2009). Various approaches to user involvement exist, with participatory design and user-centered design being the most prominent (Fischer et al., 2020; Gould & Lewis, 1985; Norman & Draper, 1986; Schuler & Namioka, 1993; Spinuzzi, 2005).

The Oxford English Dictionary defines 'aesthetic' as "concerned with beauty or the appreciation of beauty," and more specifically, as "giving or designed to give pleasure through beauty" (Oxford Dictionary, 2018). In contrast to this beauty-centric definition, the scientific study of aesthetics, known as empirical aesthetics, primarily explores the perception and evaluation of art. It takes a quantitative approach and acknowledges the significance of beauty while expanding its scope to include factors like interest, emotional impact, and even repulsion (Brielmann & Pelli, 2018). The field of empirical aesthetics has not yet settled on a single definitive definition. Neuroscientist Anjan Chatterjee offers a comprehensive definition, stating that aesthetics broadly encompasses the perception, creation, and response to art, as well as interactions with objects and scenes that evoke strong feelings, often associated with pleasure (Chatterjee, 2015).

Preferences in facade design refer to factors that clients express a desire for (Swift & Callahan, 2009). Compatibility with the context implies that a building's facade should harmonize with its surroundings, preserving the identity, style, shape, and ambiance of its neighborhood (Moussavi Nadoushani et al., 2017).

Health, safety, and security constitute a multidisciplinary criterion focused on the well-being of occupants and society. According to the World Health Organization (WHO), health is defined as "a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity" (Jain et al., 2018; World Health Organization, 1946). Safety, as per the Oxford Dictionary, refers to the condition of being protected from danger, risk, or injury (Jain et al., 2018; Oxford Dictionary, 2023). It involves managing known hazards to achieve an acceptable level of risk (Jain et al., 2018), encompassing the mitigation of both fatal and non-fatal occupational injuries resulting from construction or operational activities. Furthermore, safety entails safeguarding occupants during operations by selecting appropriate materials and structural systems that ensure their protection (Hamida & Alshibani, 2020). Security is defined as the state of being free from danger and threat (Oxford Dictionary, 2023). In the context of designing and constructing a facade, security involves a set of provisions, principles, and regulations that ensure safety and protection (Cambridge Dictionary, 2023). It pertains to the physical and mental well-being of individuals who seek to reside securely in their buildings and neighborhoods, free from the risk of harm to life or property (Cambridge Dictionary, 2023). The criterion of health, safety, and security for occupants and society encompasses provisions, schemes, laws, rules, and principles aimed at ensuring the physical and mental well-being of individuals, and creating conditions where people feel safe from injury or disease at home, work, and public places, and where they are protected from the risk of harm to life or property (Cambridge Dictionary, 2023).

Social impact refers to the consequences of activities, projects, programs, or policies (including facade design) that result in changes in the knowledge and behaviors of individuals, groups, or organizations (Bozaykut-Buk & Titiz, 2020). Essentially, social impact involves significant and beneficial changes that contribute to addressing or resolving social challenges (Mitchell, 2023). This criterion specifically addresses the social effects of the facade.

The next category concerns economic aspects, which primarily include two factors: cost and time.

Cost refers to the monetary value of goods and services purchased by producers and consumers. To consumers, cost typically equates to the price of a good or service. For manufacturers or service providers, cost represents the expenditure incurred in producing, manufacturing, or constructing something (Britannica, 2023). In the context of facade design, cost refers to the amount of money required throughout the facade's life cycle (Cambridge Dictionary, 2023). Construction cost, a significant component of life cycle costs, includes expenses for materials, transportation, equipment, and labor during construction (Alshamrani et al., 2017; Chen et al., 2010; Hamida & Alshibani, 2020; Singhaputtangkul et al., 2014, 2016).

Time encompasses the indefinite progress of existence and events unfolding in an irreversible sequence from the past through the present and into the future, viewed as a unified whole (Oxford Dictionary, 2018). It also refers to the measurable period during which an action, process, or condition persists (Merriam-Webster Dictionary, 2023). In the context of facade construction in this study, time includes the duration encompassing transportation and manufacturing of materials, as well as the completion of facade operations.

To identify and categorize the factors influencing facade performance, a fourth group was established, named "Efficiency and Effectiveness." This group comprises 18 criteria, encompassing all functions of a facade, even those that may not align perfectly. Below is the description of these criteria.

Thermal performance is a crucial facade characteristic that significantly influences the operational energy requirements of buildings (Moussavi Nadoushani et al., 2017). It generally refers to how efficiently a facade retains or prevents the passage of heat, often involving the thermal conductivity of materials or assemblies used in the facade (Thermal Performance of Buildings, 2021). According to The Gold Standard Foundation, thermal performance in buildings is measured by the total energy needed (per unit of indoor floor area) to maintain a minimum level of thermal comfort through heating or cooling (The Gold Standard Foundation, 2023). The role of the facade is to minimize heat transfer through the walls (Martabid & Mourgues, 2015).

Acoustic performance refers to the ability of the building envelope to mitigate sound disturbances during its occupancy phase (Singhaputtangkul et al., 2014, 2016). Effective design and construction of facade systems should ensure adequate insulation of the interior from external noise (Hamida & Alshibani, 2020), as noise pollution can significantly diminish indoor environmental comfort and adversely affect residents' health (Moussavi Nadoushani et al., 2017; Osada, 1988).

The indoor visual environment refers to the ability of the building envelope to provide visual comfort for occupants. This includes factors such as the transmission properties of windows and external walls, the size and shape of shading devices, and the color of window and wall materials, all of which impact the amount of natural light entering the space (Singhaputtangkul et al., 2014, 2016). It encompasses the overall characteristics of the building's exterior, including facade properties, design of openings, and window-to-wall ratio. These factors influence the visually guided behaviors and actions of occupants within the indoor space (C. Wang & Leung, 2023).

Moisture resistance refers to the property of a material or object, such as a facade, that is impermeable to water. It is crucial in building envelopes and other applications to prevent moisture from entering and thereby avoid condensation issues (Burden, 2012).

Air-tightness is a term used to describe the resistance of the building envelope to infiltration, which is the unintended entry of air through cracks, joints, or other openings in the building structure (Thermal Performance of Buildings, 2021; Burden, 2012). Achieving air-tightness helps prevent air leakage into and out of the building.

One of the key expectations of occupants is the ability of facade materials and designs to mitigate weather impacts during the building's occupancy phase (Bryan, 2014; Das et al., 2010; Singhaputtangkul et al., 2016). The facade serves as a crucial layer in modifying the natural environment to create a stable, comfortable, and safe indoor environment. This aspect is referred to as weather protection performance, which includes managing temperature fluctuations, optimizing sun exposure for heating and cooling requirements, and mitigating unpleasant odors and air pollution (Bryan, 2014).

Orientation in architecture refers to the placement of a structure on a site, considering local conditions such as sunlight, wind patterns, drainage, and desirable views (Burden, 2012).

Fire resistance of the facade refers to the capability of materials or construction to withstand fire or provide protection from it. This is characterized by their ability to confine fire or maintain their structural function during a fire event (Burden, 2012).

Light-weightiness refers to the quality or condition of being lightweight or weighing less than average (Cambridge Dictionary, 2023). In the context of building materials, the weight is a performance metric (Hamida & Alshibani, 2020).

Durability refers to the resistance of geomaterials to deterioration caused by physical, chemical, and biological factors in a specific environment. Materials that are durable maintain their original properties and appearance over time (Pinho & Santarém Andrade, 2018). In broader terms, durability also denotes the capacity of a product to perform as intended for an extended period under normal use, without requiring excessive maintenance or incurring high repair costs (Cooper, 1994).

Resistance to decay refers to a quality of facade materials that prevents or slows down their gradual deterioration over time due to natural processes such as decomposition (Britannica, 2023).

Maintainability refers to the capability of a facade to undergo restoration, repairs, and modifications (Kazman et al., 2020). It also denotes the capacity of an item to be preserved or restored to a condition where it can fulfill its intended functions under normal conditions, provided that maintenance is carried out following prescribed procedures (Gaonkar & Verlekar, 2021).

Constructability, as defined by the Construction Industry Institute (CII), is the optimal utilization of construction knowledge and experience across planning, design, procurement, and field operations to achieve project objectives (The Construction Industry Institute, 1986). It involves designing facades that facilitate construction by considering factors such as worker qualifications, capabilities, safety, environmental conditions, and equipment-worker interfaces (Bea, 2005). Constructability serves as a project management approach to assess the entire construction process. It is a relative concept rather than an absolute one, aiming to optimize resources including workforce, time, cost, quality, and working environment conditions (Ding et al., 2019; Jadidoleslami et al., 2021; Wimalaratne et al., 2021).

Buildability entails integrating construction expertise across project stages to achieve overall goals. It enhances construction performance by optimizing cost, quality, productivity, safety, and ensuring timely completion (Wimalaratne et al., 2021). Buildability also assesses how easily a design can be constructed; designs that are impractical receive lower scores on this scale (Gorse et al., 2012). The concept underscores the importance of designers being cognizant of construction methods (Hyde, 1995). Widely defined, buildability gauges how effectively a building's design facilitates ease of construction while meeting all final requirements (Wong et al., 2006).

Indoor air quality (IAQ) is defined as air that is free of harmful contaminants at levels considered safe by relevant authorities, where a significant majority of occupants (80% or more) express satisfaction (ANSI/ASHRAE Standard 62.1: Ventilation and Acceptable Indoor Air Quality, 2022). According to the U.S. Environmental Protection Agency and the National Institute for Occupational Safety and Health, good indoor air quality involves adequate ventilation, control of airborne contaminants, and maintenance of acceptable temperature and humidity levels (Burden, 2012).

The intelligence of a building facade refers to its capability to go beyond traditional envelopes by utilizing advanced materials and components. An intelligent facade can dynamically adjust its thermal, physical, visual (transparency), and color properties to achieve high performance through adaptive behavior (Al-Qaraghuli & Alawsey, 2016; Wigginton & Harris, 2002).

Refurbishment is the process of bringing an existing building up to standard or adapting it for a new use through renovation or the installation of new equipment, fixtures, furnishings, and finishes (Burden, 2012). Flexibility refers to the ability to easily change or adapt to different situations (Cambridge Dictionary, 2023; Oxford Dictionary, 2023). Refurbishment flexibility, in the context of this research, pertains to the capability of the facade to be easily renovated or adapted.

Material availability refers to a company's ability to procure and access the materials, components, and resources necessary for their manufacturing, production, or construction activities. It represents the likelihood that materials will be available for use at a specific time according to the schedule (Gunnarsdottir & Valdimarsdottir, 2012). This definition is relevant to facade systems, where the technology, knowledge, skills, and infrastructure required for constructing facade systems are also essential factors.

The final segment of categorization focused on engineering aspects and technical issues related to facades, encompassing six criteria: complexity of construction, quality of materials, quality of construction, structural performance, window area, and code compliance. Each criterion is detailed below.

Gidado (1996) defines construction project complexity as the level of difficulty involved in executing a complex production process, which includes integrating multiple intricate components into a sophisticated operational network. This must be completed within specified constraints of time, cost, and quality, while effectively managing the various stakeholders involved (Gidado, 1996; Wood & Gidado, 2008). Alternatively, complexity can also be understood as the challenge in implementing a plan to achieve specific measurable objectives (Wood & Gidado, 2008), with the focus here being on facade construction. The Construction Industry Institute characterizes project complexity as "the degree of interrelatedness between project attributes and interfaces, and their consequential impact on predictability and functionality" (Kermanshachi et al., 2020).

Quality refers to the extent to which an object, process, product, or service meets a specified set of attributes or requirements. When discussing materials, quality pertains to the degree to which the inherent characteristics of the materials satisfy the specific demands of a given application, such as a building facade (Diaz, 2014).

Quality can also denote a measure of excellence or the state of being free from defects, deficiencies, and significant variations. Regarding construction, quality of construction refers to achieving excellence through rigorous adherence to specific standards, ensuring that the completed building conforms to design specifications and meets the expectations of the users (Diaz, 2014).

Structural performance refers to the ability of buildings to withstand different forces while maintaining safety, functionality, and occupant comfort. Key criteria for structural performance include safety, ensuring the protection of human life; reparability, which safeguards property; and serviceability, aimed at preserving building functions and maintaining occupant comfort (Akiyama et al., 1999).

Window area is the total area of windows on each front of a façade.

Code compliance ensures that the plans and specifications of a building or facade meet the minimum standards prescribed by local building codes. Building codes comprise regulations set by authorities to govern the design, construction, materials, use, and safety of buildings. They specify architectural, structural, mechanical, and sanitation requirements to ensure public health, safety, and welfare, including provisions for adequate light and air (Burden, 2012).

DISCUSSION AND CONCLUSION

The motivation behind this research was to provide a comprehensive overview and framework for researching, designing, evaluating, and making decisions about facades. There was a recognized need in the literature to develop this area, leading to the identification and description of a set of criteria for scientific and practical applications in facade design. It was crucial to establish a clear understanding of these criteria and terms within the facade field, which was a significant incentive for completing this study. The research categorized 42 identified criteria into five clusters: environmental aspects, social impacts, economic aspects, efficiency and effectiveness, and technical aspects, detailing the components of each cluster. This research aimed to consolidate and define criteria that are often generalized and applicable across various parts of buildings or related industries, but which are crucial for the facade sector. By synthesizing dispersed references, this study provided a focused and professional viewpoint within the construction industry in a single paper. The outcomes are particularly valuable for researchers, designers, evaluators, and decision-makers in the facade field, as they clarify the criteria that experts must consider. This study sought to expand on previous research efforts. Previous studies by Hendriks and Hens (2000), Warren (2003), and Z. Chen and Clements-Croome (2007) primarily focused on the performance and physical aspects of facades. In contrast, this paper comprehensively addressed all relevant facets of facades, including environmental, technical, economic, and social aspects. Furthermore, Z. Chen and Clements-Croome (2007) introduced 37 key performance indicators, which conceptually align with 19 criteria from the final list in this study. This illustrates that the current study contributes an additional 23 criteria to the existing literature on holistic facade evaluation. The additional criteria introduced in this study include suitability to location conditions, carbon dioxide emission, natural resource depletion, water use, waste generation, recycling & reuse, clients' preferences, users' involvement, compatibility to the context, health, safety, and security of occupants and society, time of construction, moisture resistance, air-tightness, light-weightiness, constructability, indoor air quality, buildability, availability of materials and facade systems, complexity of construction, quality of construction, windows' area, and code compliance. Comparing the final list of criteria from this study with those found in similar studies by Hendriks and Hens (2000) and Warren (2003) reveals that these earlier studies typically covered a total of seven criteria. Building on the foundations laid by Hendriks and Hens (2000) and Warren (2003), this study aimed to expand upon and develop a comprehensive list of criteria for facade evaluation.

Therefore, significant efforts were dedicated to providing comprehensive findings and materials for future research in the field of facades. These accomplishments pave the way for researchers focusing on specific aspects of facades, clearly specifying the criteria to concentrate on for each facade component. While this set of criteria is applicable to any facade type or system, it has been tailored specifically for facades. Future research can delve deeper into criteria that are particularly relevant to specific facade systems or types, such as intelligent facades, adaptive facades, or double-skin facades. Furthermore, this set of criteria serves as a foundation for researchers to explore the intricacies of each aspect and criterion in detail. For instance, criteria like aesthetics have indicators that facilitate clearer expression and understanding. Overall, this study aims to foster a comprehensive approach to facades that allows for expansion and refinement in future research endeavors.

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