International Journal of Architecture and Urban Development
Vol. 14, No. 2, P .Spring 2024

E-ISSN 2345-2331
Applied Research Article

A Review on the Recent Façade Evaluation Approaches and Criteria

[1] Amirhossein Zekri, [2] Ahmad Ekhlassi, [3]Abbas Tarkashvand*

[1]*Ph.D. Candidate, Department of Architecture, School of Architecture and Environmental Design, Iran University of Science and Technology, Tehran, Iran.*

[2]*Associate Professor, Department of Architecture, School of Architecture and Environmental Design, Iran University of Science and Technology, Tehran, Iran.*

[3*]*Assistant Professor, Department of Architecture, School of Architecture and Environmental Design, Iran University of Science and Technology, Tehran, Iran.*

Recieved 2024.03.05 ; Accepted 2024.08.23

ABSTRACT: Novel viewpoints see the façade as a multi-functional component that should simultaneously meet functional and aesthetic requirements. These requirements need to be evaluated using a state-of-the-art approach. Although façade performance assessments are seen in the literature, studies that investigate the aesthetics and performance of façades rarely can be found together. Reviewing the approaches, methodologies, and criteria utilized to assess façades can draw a vision of the background for those who intend to develop a method for façade evaluation based on a novel perspective. This study aims to investigate recent research to discover approaches to façades. An exploratory case study methodology was applied to implement this aim, while the data collection method was library-based. Content analysis was employed via logical reasoning to determine the approaches, methods, and criteria of façade evaluations. Also, open and axial coding was used to organize the criteria extracted.

The found approaches were "sustainability," "buildability," "life cycle assessment," "competing objectives," "performance," and "general," while the most frequent ones were "performance" and "sustainability" after "general." Previous façade-focused research methodologies were concentrated on five methodologies: multicriteria decision-making (MCDM), simulation, optimization, library-based, and hybrid. The most popular method was MCDM. Extraction of criteria demonstrated that "Costs," "Thermal performance," "Environmental impacts," and "Durability" are respectively the trend ones with the highest frequency of presentation. To conclude, the façade as a multi-functional element needs to be assessed with state-of-the-art methods that consider all the required functions of a façade, including aesthetics. In contrast, Conventional methods cannot provide such a service.

Keywords: *Façade, Evaluation, Trends, Approaches, Criteria, Performance.*

INTRODUCTION

Even though numerous studies on façade are in the literature, hardly any studies review the approaches, methodologies, and trends in façade evaluation. While most papers focus on a single approach, no efforts have been made to organize approaches on a façade. This study strived to explore façade literature differently and express its content in three primary categories: approaches, research methodologies, and criteria. The results will provide a vision for professionals who intend to develop new methods for façade evaluation based on its novel definition, which has multiple functions and aesthetics (Moghtadernejad et al., 2019). As any flawless assessment necessitates a systematic approach with specified criteria, conducting a review study focusing on façade assessment approaches and criteria is imperative. Particularly when conventional methods are ineffective. There is a new interpretation of the term "façade" that goes beyond its aesthetic appeal and requires it to serve multiple functions in the building. The problem is the lack of a convenient methodical approach for façade assessment based on novel viewpoints, while traditional methods like intuitive assessment are no longer responsive. Using outdated approaches will hinder the consideration of significant aspects, namely aesthetics, and performance, to the extent that they are worth it.

Theoretical Framework

Initially, the façade definition needs to be clear as the basis of the research. The building envelope is the primary interface between the exterior and interior environments of a building (Bertagna et al., 2021; Schittich et al., 2006). The façade is the exterior building envelope layer that faces the public space (Boswell, 2013). The term "façade"

*Corresponding Author Email: *tarkashvand@iust.ac.ir*

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 façad(The Columbia Electronic Encyclopedia, 2022). Harris (2006) also denotes the principal exterior surface of a building, which is typically the architectural front. Façades are occasionally distinguished from other exterior elevations by elaborating on architectural embellishments or ornamental details (Harris, 2006). The building façade is the outer surface of the building that gives the building its unique visual expression (Turkay, 2017). According to the descriptions above, the external surface of the different sides of a single building that faces the open space or urban space and is also visible from open space or urban space which makes use of architectural and specific ornamental details to be distinguished from other buildings is called 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). The role of the façades has been expanded despite advancements in building technology. Formerly, the primary function of façades as a part of the building envelope was to serve as an interface between the interior and outside environment and shield the building structure from harsh environmental conditions. Additionally, they were designed to fulfill the aesthetic standards of the building (McFarquhar, 2012; Moghtadernejad, 2013; Moghtadernejad et al., 2019). In addition to the former roles, the façades provide major performance attributes, including structural integrity, safety, sustainability, human comfort, durability, and cost efficiency (Moghtadernejad et al., 2018).

A question arises to develop an approach for systematic façade evaluation based on a novel viewpoint: "What are the recent approaches, methods, and criteria for façade evaluation?". The following looks after the response to this question. However, a few studies have attempted to address this issue. Hendriks and Hens (2000) established criteria for evaluating façades, primarily focused on the façade's performance (Hendriks & Hens, 2000). The International Energy Agency (IEA) has confirmed this work. These studies emphasized the significance of using a systematic approach when selecting a façade, considering all essential factors. These factors encompass all aesthetic and physical attributes that are incorporated into the overall functionality of a building (Warren, 2003). While proposing a performance-oriented perspective for façades was a pioneering step, several aspects of this study seemed to require further research and development: 1- Some of the criteria presented were extremely vague, such as introducing sustainability as a criterion. 2- The categories lacked semantic consistency; sustainability was mentioned within the performance aspect of the façade. 3- This study focused solely on the performance and physical characteristics of buildings, neglecting the environmental, social, and static approaches of the façade. Chen and Clements-Croome (2007) presented an MCDM model for façade assessment that considers ecological innovation and environmental sustainability (Chen & Clements-Croome, 2007). Thirty-seven key performance indicators (KPIs) for façade were categorized into 6 clusters (Chen & Clements-Croome, 2007): adaptability, affordability, durability, energy, intelligence, and well-being. Nevertheless, certain points appear to demand greater consideration. 1- the research only concentrated on the performance aspect of the façade, neglecting the aesthetics aspect. 2- the KPIs were not accurate regarding semantic and categorization levels. For instance, the accuracy of environmental and social impacts and indoor sound reverberation differed. 3- Static and buildability approach deserved attention.

This study extends prior research, aiming to review and develop what they discover while addressing their limitations. Resources are explored and classified from three perspectives: Approaches toward façade evaluation, research methodologies for assessing façade, and criteria of façade assessment. Given that these three are the basic principles of evaluating façade, the present research concentrated on them to clarify the effective dimension of façade assessment for those interested in pursuing this area of research.

MATERIALS AND METHODS

An exploratory case study methodology is used to answer the research question(Priya, 2021). The method of data collection was library-based (Priya, 2021). The Scopus database was searched via the "Decision-making," "Approach," "Façade," and "Criteria" keywords with the "or" operator. The found papers were refined twice at first. Afterward, an exploration was made through the citations of the remaining studies to complete the library. As cases should be bound by time and activity (Creswell & Creswell, 2022), the case study was limited to either assessing the façade merely or analyzing it as a case study. It was also restricted to publications between 1996 to 2024. An in-depth content analysis was conducted using logical reasoning to investigate the selected resources. This was continued by open and axial coding (Corbin & Strauss, 2014) when it comes to criteria extraction. To the author's best knowledge, no efforts have been made to gather this sort of information in the literature with a coherent category regarding façade. Last, five groups of approaches, 5 clusters of methods, and 20 criteria were recognized as the findings. The detailed results are discussed below. Figure 1 demonstrates the stages of the research methodology.

RESULTS AND DISCUSSIONS

Findings are categorized into three primary categories. These categories are the approaches around which studies assessed façades, the research methods, and the criteria based on which the papers consider façade-related objectives.

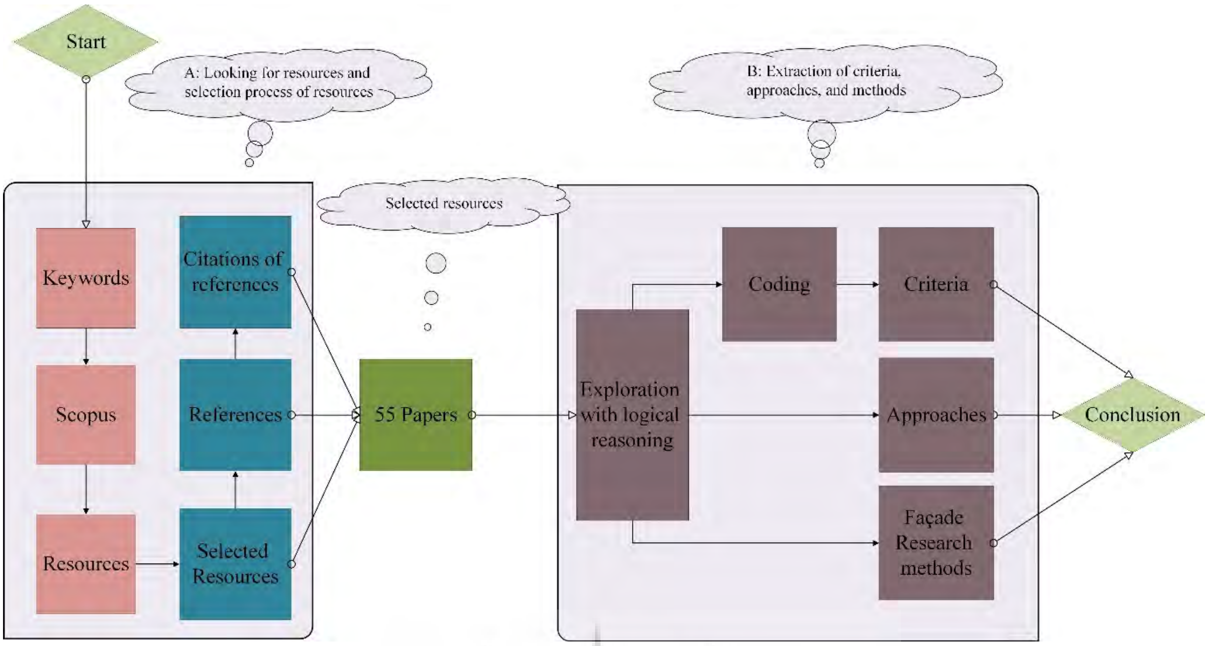

Fig. 1: Stages of research methodology

Approach

The found research can be organized based on whether their research objectives pursue a specific or general approach. The approach is the overall viewpoint to assess a façade. Those with a specific approach followed popular trends such as sustainability or life cycle assessment. Studies with specific approaches categorized the criteria in contrast to those with a general approach. For instance, sustainability has three main criteria: environmental, social, and economic. On the other hand, those with a general approach only discussed research objectives that could not be organized under a single and consistent approach. For example, Passe and Nelson (2013) took aesthetics, cost, thermal performance, durability, and buildability as criteria for evaluating a façade, where they did not consider an approach that could cover the criteria they opted for (Passe & Nelson, 2013).

The following studies that exclusively evaluated façades with a specific approach are discussed. Afterward, studies with a general approach are fully introduced. In the general approach, papers follow the objectives they set specifically in the research to investigate the variables. There were three times as many studies with a general approach as those with a specific approach. Studies with a general approach lacked criteria organization, resulting in projects that merely evaluated the disparate objectives.

Six primary approaches found in the literature are:

- Sustainability
- Buildability
- Building life cycle assessment
- Competing objectives
- Performance
- General

Sustainability

Recent research on façades indicates that sustainability is a widespread trend. There are three main categories of sustainability: economic, social, and environmental. Ahmadian et al. (2017) examine the sustainability assessment of curtain wall supply decisions in terms of cost, time, quality, and social and environmental factors in Australia (Ahmadian et al., 2017). In another endeavor, Moussavi Nadoushani (2017) added "performance" to the three categories above (Moussavi Nadoushani et al., 2017). Iwaro et al. (2014) determined that façade assessment and façade design should consider sustainable performance criteria (Iwaro et al., 2014). Gilani et al. (2017) explained that attention to comprehensive sustainability assessment of façades needed more effort. They presented an MCDM model concentrating on social, environmental, and economic pillars to assess the sustainability of building façades based on stakeholder satisfaction (Gilani et al., 2017). Furthermore, Moghtadernejad et al. (2018) defined five principal categories for designing criteria for sustainable façades (Moghtadernejad et al., 2018): Structural integrity and safety, human comfort, environmental footprint, durability, and cost efficiency. Later, Elkhayat et al. (2020) assessed the glazing systems of an office building employing four criteria of sustainability: energy, environmental impacts, costs, and occupant comfort (Elkhayat et al., 2020). Moreover, Habibi et al. (2020) attempted to tackle the lack of comprehensive assessments on intelligent façades. They introduce a model based on economic, environmental, and social indexes that quantitatively explores the sustainability of intelligent façades (Habibi et al., 2020). Table 1 details the characteristics of these two studies.

Table 1: Research with a sustainability approach

Approach	Purpose	Title	Country of research	Date	Categorization	Categories	Authors
		Multicriteria selection of façade systems based on sustainability criteria	Australia (Sydney)	2017	Yes	1. Economic 2. Social 3. Environmental	(Moussavi Nadoushani et al., 2017)
		BIM-enabled sustainability assessment of material supply decisions (Case study: Curtain wall)	Australia	2017	Yes	1. Cost 2. Time 3. Quality 4. Social and environmental sustainability	(Ahmadian et al., 2017)
		An integrated criteria weighting Framework for the sustainable performance assessment and design of building envelope	Trinidad and Tobago	2014	Yes	1. Energy efficiency 2. External benefit 3. Economic Efficiency 4. Material efficiency 5. Environmental impact 6. Regulation efficiency	(Iwaro et al., 2014)
Sustainability	Sustainability	A new sustainability assessment approach based on stakeholder satisfaction for building façade	Spain	2017	Yes	1. Environmental 2. Economic 3. Social	(Gilani et al., 2017)
		Multicriteria decision-making methods for preliminary design of sustainable façades	Canada	2018	Yes	1. Structural integrity & safety 2. Human comfort 3. Environmental footprint 4. Durability 5. Cost efficiency	(Moghtadernejad et al.,2018)
		New sustainability assessment model for Intelligent Façade Layers when applied to refurbished school buildings skins	Spain	2020	Yes	1. Economic 2. Environmental 3. Social	(Habibi et al., 2020)
		Multicriteria selection of high-performance glazing systems A case study of an office building in new Cairo, Egypt	Egypt	2020	Yes	1. Energy 2. Environmental impacts 3. Costs 4. Occupant comfort	(Elkhayat et al., 2020)

SUSTAINABILITY AND BUILDABILITY

Buildability is one of the substantial priorities in façade architectural design, followed by sustainability. These two trends are the foremost objectives of a study conducted in Singapore, in which professionals are asked about the most important evaluation criteria for a façade. The criteria are listed below in four sections. The first three are the subcategories of sustainability.

a) Economic aspect
b) Social aspect
c) Environmental aspect
d) Buildability

Table 2 displays this study.

Table 2: Research with sustainability and buildability approach

Approach	Purpose	Title	Country of research	Date	Categorization	Categories	Authors
Sustainability & Buildability	Sustainability & Buildability	Criteria for Architects and Engineers to Achieve Sustainability and Buildability in Building Envelope Designs	Singapore	2013, 2014, and 2016	Yes	1.Economic aspects 2. Social aspects 3. Environmental aspects 4. Buildability	(Singhaputtangkul et al., 2013, 2014, 2016)

Building life cycle assessment

Some recent façade research focuses on building life cycles. They strive to consider all main phases of a façade, including construction, operation, and demolition. To exemplify, Shin and Cho (2015) developed a model to analyze the façade of a real building in South Korea and pick one of the proposed alternatives (Shin & Cho, 2015). The features are shown in Table 3.

Table 3: Research with building life cycle approach

Approach	Purpose	Title	Country of research	Date	Categorization	Categories	Authors
Sustainability	Building's life cycle assessment	BIM Application to Select Appropriate Design Alternative with Consideration of LCA and LCC	South Korea	2015	Yes	1.Construction 2. Operation 3. Disposal	(Shin & Cho, 2015)

Competing objectives

This group pursues a multi-objective strategy in which researchers seek various objectives that may even be conflicting. Table 4 illustrates an example study conducted in Sweden to improve energy efficiency and indoor air quality. Using the analytical hierarchy process (AHP), different types of exterior walls and windows were selected.

Table 4: Research with a multi-objective approach

Approach	Purpose	Title	Country of research	Date	Categorization	Categories	Authors
Multi-objective	1.Energy consumption reduction 2.Improving indoor air quality	Achieving a Trade-off Construction Solution Using BIM, an Optimization Algorithm, and a Multicriteria Decision-Making Method	Sweden	2019	No	-	(Jalilzadehazhari et al., 2019)

Performance

This category seems to be the most sophisticated, as it attempts to take a holistic approach when evaluating the façade. Hendriks and Hens (2000) introduced a façade evaluation criteria based on the façade's performance. This perspective was also validated in Annex 32 of the International Energy Agency (IEA), which provided various façade performance dimensions. These studies declared that the performance of a façade comprises all aesthetic and physical properties integrated into the building's function. Table 5 illustrates building façade performance aspects presented by Hendriks & Hens (2000) and Warren (2003) (annex 32 of IEA report) (Hendriks & Hens, 2000; Warren, 2003).

Table 5:Building façade performance aspects (Hendriks & Hens, 2000; Warren, 2003)

Topic	Aspects of Performance
Heat and mass	1. Airtightness 2. Thermal insulation 3. Transient response 4. Moisture response 5. Thermal bridging
Acoustics	6. Whole envelope insulation against external noise 7. Lateral sound transmission 8. Sound absorption
Light	9. Light transmittance for the transparent elements 10. Fenestration to whole wall elevation area ratio
Fire	11. Fire resistance 12. Reaction to fire of internal finishes and components 13. Flame spread along the envelope
Service life	14. Physical attack 15. Chemical attack 16. Biological attack
Costs	17. Net present value and optimization investments, operational cost, maintenance costs
Sustainability	18. Sustainability profile

Chen and Clements-Croome (2007) also investigated façade evaluation. They proposed 37 Key Performance Indicators (KPIs). Some are quantitative (such as energy and cost), while others are qualitative (e.g., well-being and aesthetics). These KPIs are introduced in Table 6 (Chen & Clements-Croome, 2007). Al-Hammad et al. (2014) presented a systematic approach for assessing curtain wall systems of medium-high-rise structures using performance criteria and aesthetics (Al-Hammad et al., 2014), a revolutionary movement. Later, to overcome the shortcomings of the previous study, Hamida and Alshibani (2020) developed a relatively comprehensive MCDM model that facilitated the evaluation and selection of curtain wall systems in office buildings. They also demonstrate a conceptual framework of façade evaluation, categorizing criteria into three main groups: technical, economic, and socio-environmental(Hamida & Alshibani, 2020). Still, the criteria are defined as performance-oriented. Moghtadernejad et al. (2020) proposed design strategies to enhance the performance of building façades, considering aesthetics as a performance criterion (Moghtadernejad et al., 2020). It is rare to emphasize the aesthetic qualities of a façade as a measure of performance. Recently, Bianchi et al. (2024) stated that the façade has multiple functions in the building and needs to fulfill performance requirements. They divide performance criteria into three primary categories (Bianchi et al., 2024): Functional, environmental, and financial. Table 7 compiles this research, taking performance into account.

The studies in Table 7 have a different perspective on façade as they revolved around a novel viewpoint regarding façade based on performance.

Table 6: Key performance indicators (KPIs) (Chen & Clements-Croome, 2007)

Clusters of KPIs	KPIs to evaluate building façade systems
Adaptability	1. Maintenance flexibility 2. Refurbishment flexibility 3. Environmental impacts 4. Social impacts
Affordability	5. Design cost 6. Construction cost 7. Maintenance cost 8. Refurbishment cost 9. Demolition cost 10. Recycling cost
Durability	11. Lifespan 12. Fire protection pattern 13. Fire endurance 14. Material density 15. Structural reliability 16. Decay resistance 17. Quality
Energy	18. Embodied energy 19. Energy performance 20. Renewable energy 21. Building orientation
Intelligence	22. Control strategy 23. System Integration 24. Emergency response 25. Automation
Well-being	26. Aesthetics 27. Daylight absorbability 28. Indoor daylight comfort 29. Outdoor daylight comfort 30. Indoor sound reverberation 31. Outdoor sound reverberation 32. Indoor sound absorption 33. Outdoor sound absorption 34. Indoor temperature 35. Indoor relative humidity 36. Indoor ventilation 37. Toxicity hazards

Table 7: Research considered performance

Approach	Purpose	Title	Country of research	Date	Categorization	Categories	Authors
Performance	-	Building envelopes infrom a holistic perspective	-	2000	Yes	1. Heat and mass 2. Acoustics 3. Light 4. Fire 5. Service life 6. Costs 7. Sustainability	(Hendriks & Hens, 2000)
	-	Integral Building Envelope Performance Assessment	-	2003	Yes	1. Heat and mass 2. Acoustics 3. Light 4. Fire 5. Service life 6. Costs 7. Sustainability	(Warren, 2003)

continue of Table 7: Research considered performance

Approach	Purpose	Title	Country of research	Date	Categorization	Categories	Authors
	-	An ANP approach to the assessment of Buildings Façade Systems	-	2007	Yes	1. Adaptability 2. Affordability 3. Durability 4. Energy 5. Intelligence 6. Well-being	(Chen & Clements-Croome, 2007)
	-	Evaluation and selection of curtain wall systems for medium-high rise building	Saudi Arabia	2014	No	-	(Al-Hammad et al., 2014)
	-	A multicriteria decision-making model for selecting curtain wall systems in office buildings	Saudi Arabia	2020	Yes	1. Technical 2. Economic 3. Socio-environmental	(Hamida & Alshibani, 2020)
	-	Design strategies using multicriteria decision-making tools to enhance the performance of building façades	Canada	2020	No	-	(Moghtadernejad et al., 2020)
	-	Multicriteria design methods in façade engineering: State-of-the-art and future trends	-	2024	Yes	1. Functional 2. Environmental 3. Financial	(Bianchi et al., 2024)

General Approach

In this section, papers with a general approach are analyzed. These studies investigate façades without any specific approach or organization of criteria. They defined the evaluation criteria incoherently and only based on the objectives they pursued throughout the research. Consequently, no one considers a comprehensive approach and a list of all required criteria. Table 8 provides a list of these studies. This research group has allocated 65 percent share, the most among the categories. The key research of this group is generally reviewed in the following.

Table 8: Façade assessment with a general approach

Approach	Purpose	Title	Country of research	Date	Categorization	Categories	Authors
General Approach	-	Value Engineering in the Assessment of Exterior Building Wall Systems	Saudi Arabia	1996	No	-	(Al-Hammad & Hassanain, 1996)
	-	Estimation of external walls decisions of multistorey residential buildings applying methods of multicriteria analysis	Lithuania	2005	No	-	(Zavadskas et al., 2005)
	-	Thermal-energetic behavior of the exterior housing envelope in San Miguel de Tucumán concerning climatic suitability	Argentina	2005	No	-	(Martinez, 2005)
	-	Selection of Low-E windows in a retrofit of public buildings by applying multiple criteria method COPRAS: A Lithuanian case (Case study: Selection of windows).	Lithuania	2006	No	-	(Kaklauskas et al., 2006)
	-	Floor shape optimization for green building design (Along with translucent components of the façade)	Canada (Montreal)	2006	No	-	(Wang et al., 2006)
	-	Selection of the effective dwelling house walls by applying attribute values determined at intervals	Lithuania	2008	No	-	(Zavadskas et al., 2008)
	-	Evaluating the alternative solutions of wall insulation by multicriteria methods	Lithuania	2008	No	-	(Ginevičius et al., 2008)
	-	Evaluating the performance of shading devices and glazing types to promote energy efficiency of residential buildings (Shading and windows assessment)	Singapore	2010	No	-	(Chua & Chou, 2010)
	-	Automated Code Compliance Checking for Building Envelope Design	Canada (Montreal)	2010	No	-	(Tan et al., 2010)
	-	Envelope-related energy demand: A design indicator of energy performance for residential buildings in early design stages	Portugal (Lisbon)	2013	No	-	(Granadeiro et al., 2013)
	-	Constructing Energy Efficiency: Rethinking and Redesigning the Architectural Detail	-	2013	No	-	(Passe & Nelson, 2013)
	-	Criteria used for selecting envelope wall systems in Chilean residential projects	Chile	2015	No	-	(Martabid & Mourgues, 2015)
	-	BIM-aided Variable Fuzzy Multicriteria Decision Making of Low-carbon Building Measures Selection (Windows)	Hong kong	2016	Yes	1. Economic aspects 2. Technical aspects 3. Environmental aspects	(L. Chen & Pan, 2016)
	-	Intelligent designer : A computational approach to automating the design of windows in buildings	-	2019	No	-	(Karan & Asadi, 2019)
	-	BEPAT – Building envelope performance assessment tool: Validation	-	2020	No	-	(Horvat & Fazio, 2020)

The restricted viewpoint that governs these projects needs an overarching strategy. The main reason may be specificity and narrowing the subject to a single objective, leading to ignoring the other influential criteria on the results. This elimination of influential criteria overshadows the holistic evaluation of façades, identified as a literature review gap. Based on the new definition that sees the façade as a multi-functional component in a building, all required functions shall be met. This needs a comprehensive set of criteria and a holistic approach that facilitates the façade evaluation to address all requirements.

Analysis of Methodologies

This study also considers façade research methodologies. Findings have shown that research methodologies for façade studies typically fall into five major categories: MCDM, Simulation, Optimization, Library-based, and Hybrid methods. In MCDM methods, the criteria weights were obtained primarily for evaluating alternatives. For instance, Chen and Clements-Croome (2007) evaluated building façade systems employing the analytic network process (ANP) method (Chen & Clements-Croome, 2007). Simulation, typically, models the façade to evaluate thermal performance, acoustic performance, visual performance, fire resistance, durability, and light-weightiness of façades. Optimization is one of the more recent types of research methods. This method optimizes a façade object for a particular purpose. Typically, algorithms and machine learning are used to perform these optimizations. To illustrate, Karan et al. (2021) have attempted a machine learning algorithm to optimize the position, size, and number of windows on a building's façade (Karan et al., 2021). The library-based research normally analyzes a particular scope of façade evaluation. Passe and Nelson (2013) compared energy-efficient façade construction methods (Passe & Nelson, 2013). The hybrid method usually occurs when a researcher employs two or more of the abovementioned methods. Jalilzadehazari et al. (2019), for instance, utilized an optimization algorithm and simulation technique via BIM along with an analytical hierarchy process (AHP) to accomplish a construction solution that balances visual comfort, thermal comfort, energy demands, life cycle costs, and indoor environment quality (Jalilzadehazhari et al., 2019) Table 9 details the methodologies employed in these studies.

As is evident, MCDM is the most prevalent trend among façade researchers, followed by the simulation approach. As façade functions differently in buildings and the decisions should be made in the early design phase, the MCDM methods and simulation are very helpful. MCDM methods have been utilized in almost 55 percent of studies that directly evaluated façades based on Table 9, mainly because a façade is required to tackle multiple objectives.

Criteria

An open and axial coding method was used in an exploratory study to extract the criteria. Table 10 shows the results. In addition to displaying the number of criteria in each study, Table 10 also depicts the frequency of each criterion in all studies. The number of criteria in each study varies and is unrelated to its recency. Al-Hammad & Hassanain (1996) conducted research based on 14 criteria in 1996, whereas Passe & Nelson (2013) identified five criteria in 2013, and Singhaputtangkul et al. (2016) investigated 11 criteria in 2016.

Additionally, it does not imply that, as time goes by, researchers endeavor to specialize in a particular field. For example, Shin & Cho (2015) evaluated two criteria, whereas later, Ahmadian et al. (2017) evaluated 11. Cost and thermal performance are the primary concerns of researchers during this time frame, with 19 and 17 studies,

Table 9: Research methods for façade assessment in the literature review

No.	Methods	No. of references (out of 26)	References that used this method
1	MCDM	14	(Ahmadian et al., 2017; A. Al-Hammad & Hassanain, 1996; Z. Chen & Clements-Croome, 2007; Ginevičius et al., 2008; Hendriks & Hens, 2000; Horvat & Fazio, 2020; Kaklauskas et al., 2006; Martabid & Mourgues, 2015; Moussavi Nadoushani et al., 2017; Singhaputtangkul et al., 2014, 2016; Warren, 2003; Zavadskas et al., 2005, 2008)
2	Simulation	6	(Chua & Chou, 2010; Granadeiro et al., 2013; Martinez, 2005; Shin & Cho, 2015; Tan et al., 2007, 2010)
3	Optimization	3	(Karan et al., 2021; Karan & Asadi, 2019; Wang et al., 2006)
4	Library-based	1	(Passe & Nelson, 2013)
5	Hybrid	2	(L. Chen & Pan, 2016; Jalilzadehazhari et al., 2019)

respectively. Environmental impacts and durability have been the concern of 15 and 14 studies, placing them after cost and thermal performance. Environmental impacts have been the subject of eight studies since 2015, while cost and thermal performance have been the subject of seven and six studies. This demonstrates that environmental impacts are becoming a trend in research, whereas researchers have consistently concentrated on cost and thermal performance throughout the time frame. As of 2017, eleven studies have examined aesthetics as a criterion for evaluating façades, which ranks fifth after durability. Durability has been the subject of 14 studies between 1996 and 2017. The intelligence of the façade is brought up just once, which is a relatively new concentration in the façade. User involvement is the least-mentioned criterion with just one occurrence.

Moreover, "compatibility to the context" is neglected, primarily because it was only researched twice during these years. "The client's preferences and expectations" is the most recent criterion that has drawn attention twice from 2019 to the present. "Refurbishment flexibility" was also examined twice. Future attention must be paid to the aforementioned areas due to their importance and function within the buildings.

Table 10: Criteria identified in the literature review

No	Research / Final Criteria	Suitability to location and climate	Compatibility to the context	Environmental impacts	Aesthetics	Clients' expectations and preferences	Users' involvement in façade design	Health, safety, and security	Costs	Duration of Construction	Thermal performance	Acoustic performance	Visual performance	Moisture resistance	Fire resistance	Structural performance	Durability	Maintainability	Buildability	Refurbishment flexibility	Intelligence	Total (out of 20)
1	(Al-Hammad & Hassanain, 1996)	✓	✓		✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓		14
2	(Hendriks & Hens, 2000)	✓		✓					✓		✓	✓	✓		✓		✓					8
3	(Warren, 2003)	✓		✓					✓		✓	✓	✓		✓		✓					8
4	(Zavadskas et al., 2005)				✓				✓	✓	✓						✓	✓				6
5	(Martinez, 2005)	✓		✓			✓		✓		✓						✓	✓				7
6	(Kaklauskas et al., 2006)			✓	✓				✓	✓	✓	✓	✓	✓		✓	✓					10
7	(Wang et al., 2006)			✓					✓													2
8	(Chen & Clements-Croome, 2007)			✓	✓			✓	✓		✓	✓	✓		✓	✓	✓	✓		✓	✓	13
9	(Zavadskas et al., 2008)			✓	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓				12
10	(Ginevičius et al., 2008)								✓	✓	✓			✓		✓	✓					6
11	(Chua & Chou, 2010)				✓				✓		✓	✓	✓		✓	✓						7
12	(Passe & Nelson, 2013)				✓				✓		✓						✓		✓			5
13	(Martabid & Mourgues, 2015)			✓	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓			13
14	(Shin & Cho, 2015)			✓					✓													2
15	(Singhaputtangkul et al., 2014, 2016)			✓	✓			✓	✓	✓	✓	✓	✓				✓	✓	✓			11
16	(Chen & Pan, 2016)			✓					✓							✓		✓				4
17	(Moussavi Nadoushani et al., 2017)	✓	✓	✓	✓				✓		✓	✓				✓	✓					9
18	(Ahmadian et al., 2017)			✓	✓			✓	✓	✓	✓				✓	✓	✓	✓	✓			11
19	(Karan & Asadi, 2019)					✓																1
20	(Jalilzadehazhari et al., 2019)			✓					✓		✓		✓									4
21	(Horvat & Fazio, 2020)			✓							✓	✓		✓	✓	✓						6
22	(Karan et al., 2021)					✓																1
	Total	5	2	15	11	2	1	6	19	8	17	11	7	6	9	11	14	9	4	2	1	

Figure 2 is a schematic derived from this study's findings and key concepts. This strives to summarize the found data in a coherent organization that leads to a conclusion. This illustration concisely states that the requirement of a new method to assess a façade based on a novel viewpoint that sees the façade as multi-functional is obvious. MCDM methods can fit since they facilitate considering all required criteria.

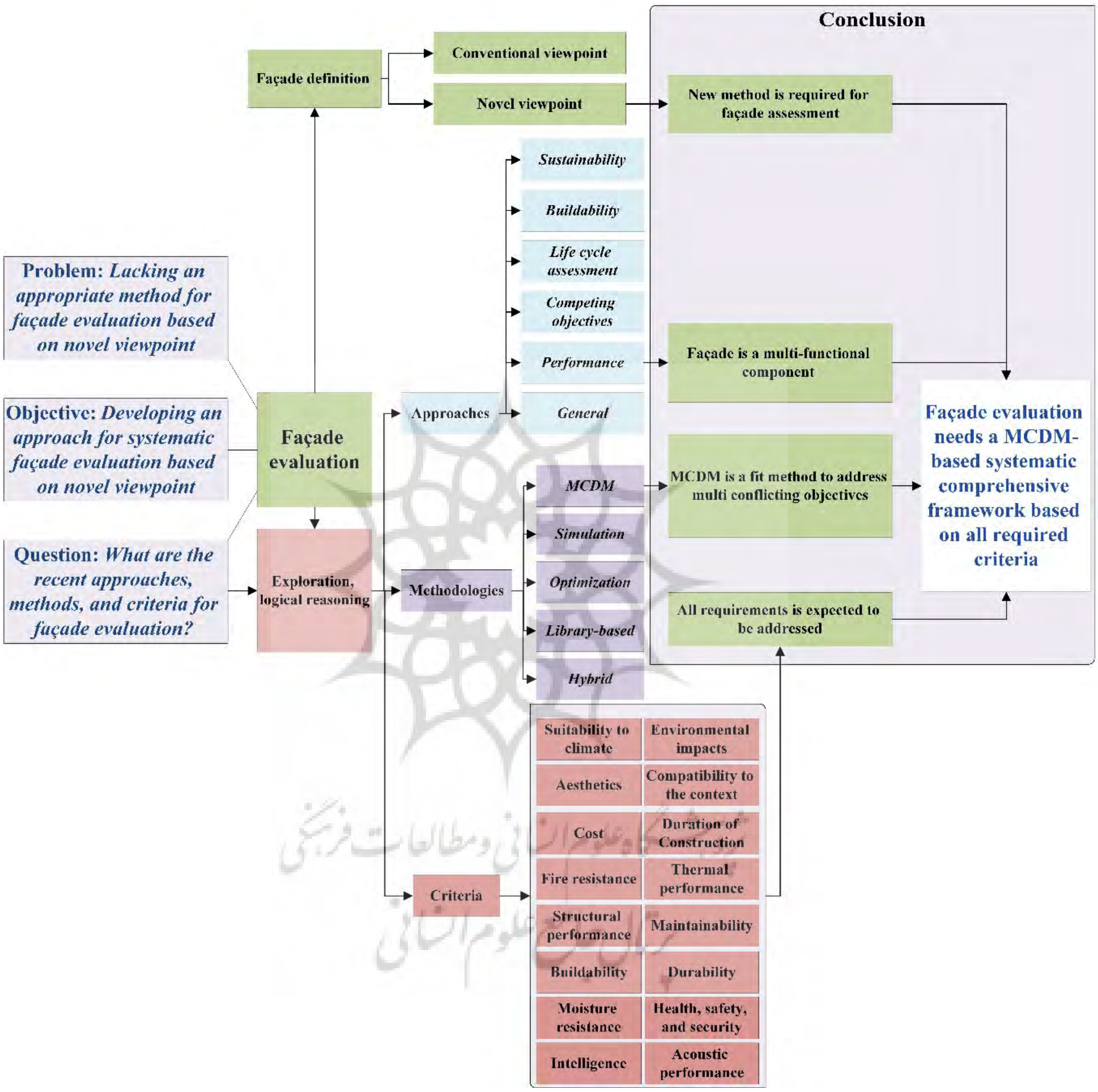

Fig. 2: Organization of key concepts and findings

CONCLUSION

A need to review façade studies trends is evident since façades face a paradigm shift in which performance aspects are highlighted (Moghtadernejad et al., 2019). Hence, new evaluation methods are required to fit the novel definition and function of the façade. Although systematic reviews have been done on the related scopes of this research, like MCDMs, there was room to carry out review research that was concentrated on façade to clarify the background knowledge of this field in an organized and simple way. Clarifying the approaches and frequency of concentrations on façade studies can shed light on the areas of great importance but have not received enough attention and show the trends and shifts in paradigms. This study strived to review a specific period of the literature to identify approaches, methodologies, and criteria background in the façade.

To begin with, the first found approaches toward façade were "sustainability," "buildability," "life cycle assessment," "competing objectives," "performance," and "general." Among these, "sustainability" and "performance" were the concerns of many studies. Second, several methodologies were found to apply to façade, including MCDM, simulation, optimization, library-based, and hybrid methods. MCDM is the most frequently employed in almost half of the research. This implicitly shows the multi-functional nature of the façade in the building since MCDM methods were designed to handle various conflicting criteria.

Third, 20 criteria were extracted from the references via an exploratory study using open and axial coding. These criteria are displayed in Table 10. The top 4 frequently used criteria are "Costs," "Thermal performance," "Environmental impacts," and "Durability," whereas the most recent ones are "Environmental impacts," "Costs," "Thermal performance," and "Structural performance." This result demonstrates that the façade has been considered an affordable and environmentally friendly item that should meet multiple functions in the building. Meanwhile, "Intelligence" of the façade and "User's involvement in façade design" are at the bottom of the popular list. "Intelligence" is a new paradigm in façade that seems to attract more attention in the coming years.

Overall, this research tried to broaden the horizon of professionals who intend to conduct research in façade by introducing the approaches employed in the three decades of academic efforts. Studies that investigate the façade with this perspective can hardly be found. The findings can propose new paths for future research. The dispersed nature found in the criteria suggests a requirement for a study that can gather all the criteria together with the organization. This will help researchers systematically evaluate the façade where all required functions can be addressed.

AUTHOR CONTRIBUTIONS

A. Zekri performed the literature review and compiled, analyzed, and interpreted the data. He conceptualized the article and prepared the original draft. A. Ekhlassi contributed to the conceptualization and edition of the manuscript. A. Tarkashvand contributed to the conceptualization and assisted in manuscript preparation.

ACKNOWLEDGEMENT

This article is derived from a PhD thesis done by the first author under the supervision of the co-authors.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the authors have witnessed ethical issues, including plagiarism, informed consent, misconduct, data fabrication or falsification, double publication and/or submission, and complete redundancy.

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