LETTERS IN BIOMATHEMATICS
An International Journal

RESEARCH ARTICLE

OPEN ACCESS

A New Approach for The Assessment of Building Performance of Adaptive Façade Systems to Achieve High-Performance Façades

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ABSTRACT

Background: Building facades play an important part in lowering energy use without compromising indoor environmental quality. Nonetheless, traditional facade evaluation has been primarily focused on using static indicators that might not be suitable for adaptive facades.

Aim: The objective of this research is to provide a comprehensive multi-criteria framework for evaluating the performance of the façade and its appropriateness for adaptive systems like kinetic shading, switchable glazing, and responsive façades.

Methodology: The proposed framework combines energy performance, thermal comfort, visual comfort, materials aspects, and occupant's feedback within one assessment model during early stages of architectural design. The proposed approach will encompass comparative analysis of LEED-certified projects recognized worldwide, expert review of assessment criteria, formulation of quantitative assessment equation, and application to selected cases of buildings in Egypt.

Expected Results: The concept is anticipated to offer a structured and quantifiable method of assessment of adaptive facades through various criteria while considering both the environment and occupant-based factors.

Conclusion: Through the combination of design principles with performance assessments, the framework will provide guidance for informed architectural decision making and facilitate high-performance, climate-responsive, energy-efficient, and occupant-centric building envelopes.

ARTICLE HISTORY
Received October 13, 2026
Accepted November 16, 2026

KEYWORDS
Sustainable Architecture; High-Performance Facade; Adaptive Façade Systems; The Building Performance Assessment; Thermal Comfort; Leed; Energy Efficiency

1. Introduction

Buildings are among the biggest consumers of global energy, so the way the building envelope performs becomes, sort of, a crucial point when people try to cut energy demand and reduce environmental impacts. Inside the envelope, the façade is especially influential because it manages the exchange of heat, daylight and air between the interior side and the outside environment (Favoino et al., 2015). Still, façade performance should not be read only as the ability to lower energy use. It is more like a tangle of trade-offs, there is a balance between energy efficiency and thermal comfort, but also visual comfort, indoor environmental quality, and even how well occupants feel day to day. Some traditional façade approaches can boost one part of performance and, at the same time, weaken another part. That makes clear why methods that focus on energy reduction alone have their obvious limits.

Because of climate change, higher energy demand, and more strict energy rules, there is a growing need to revisit façade design, not like an isolated architectural skin, but as a fully integrated environmental system. High-performance façades then must react, in an adaptive way, to shifting climate conditions and changing occupancy patterns. The goal is to keep energy use down, keep environmental impacts lower, while still delivering acceptable indoor comfort levels (Attia, 2018). In other words, this trend underlines why façade strategies should be judged with a critical eye, based on how well they can bring together the competing aims related to environment, energy, and occupant performance, instead of checking "efficiency" just by looking at energy consumption.

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In response to these challenges, adaptive façade systems have become an important design strategy. Unlike conventional façades that operate in a fixed way, adaptive façades can adjust their behaviour according to changes in weather conditions, building occupancy, and user comfort requirements (Kim et al., 2018; Loonen et al., 2013; Tabadkani et al., 2021). Examples include kinetic shading systems, switchable glazing, and responsive multi-layer façade systems. By adapting to changing conditions, these technologies have the potential to perform more efficiently than traditional static façades in different climates (Attia et al., 2018; CEN, 2019; Loonen et al., 2013). The role of an adaptive façade system in mediating environmental and occupancy-related conditions is illustrated in **Fig. 1**.



Fig.1 The role of adaptive façade system

Even though adaptive façades could improve building performance, by adjusting themselves to changing environmental conditions, their evaluation is still boxed in by assessment methods that were mostly created for static façade systems. Conventional indicators, like U-value, solar heat gain coefficient (SHGC), and shading coefficient are indeed useful when you want to describe fixed envelope parts; however, they only map out a limited picture for façades where thermal and optical properties shift with climate, occupant demands, and the way controls are set. If façade properties are handled as "almost constant," then these metrics can miss the time related and mutually influenced behaviour that is central to adaptive systems (Attia et al., 2018; Loonen et al., 2017; Voigt et al., 2024). So, there is a methodological mismatch, between the dynamic performance of adaptive façades and the tools, that during architectural design are mostly static. This is especially noticeable early in the process, since choices about façade configuration, orientation, materiality, and control strategies tend to steer, the performance that follows later (Mohtashami et al., 2022; Zhang et al., 2022).

To address this problem, the present research intends to develop a design-stage framework to evaluate adaptive façade performance, using an integrated set of environmental and material criteria. Instead of treating energy efficiency, thermal comfort, visual comfort, and material feature as separate items, the framework tries to look at how they connect and where the trade-offs can show up inside one consistent assessment process. The framework will be shaped through a comparative review of well-known adaptive façade case studies and backed up with expert judgement.

The performance of a façade is tied to how well it can mediate the bond between the outdoor climate and the indoor space. So, a high-performance façade is not only about reducing energy use, it is more about balancing heat movement, solar exposure, daylight availability, and air motion in a sensible way, while also keeping indoor conditions within acceptable comfort bounds (Attia, 2018). That balance is, in practice, shaped a lot by local weather patterns. Take hot-arid or hot-humid settings for instance: there, cutting down solar heat gain and avoiding overheating is usually the big deal, meanwhile in temperate or cold climates the priorities can shift toward admitting solar radiation in a controlled manner, plus getting better thermal insulation, which can end up bringing more meaningful gains (International Energy Agency [IEA], 2019). Because of this, climate should be treated not only as a background factor but as a core driver of what façade performance really means, and how much weight each criterion gets.

Looking back at earlier work, researchers have made substantial progress on single components of façade performance, especially energy efficiency, daylighting, and thermal comfort. Even so, the fact that many studies stay quite separated from each other means they often cannot support a full, connected evaluation of adaptive façade systems. If you judge each indicator on its own, you might miss the way performance criteria interact; for example, pushing daylight deeper inside can also raise solar heat gains, whereas adding more shading may lower cooling demands but at the same time hurt visual comfort. And with adaptive façades, these compromises can get even messier, since the system can reconfigure itself as environmental conditions change.

1.1 Research Gap

The current literature has increased knowledge about adaptive facades in terms of energy efficiency, daylighting performance, thermal comfort, and types of façades. Yet, these studies analyse the performance aspects separately or using simulations but do not provide an integrative model for architectural design. In addition, the current assessment methods target post-design phase analysis and

cannot assist in façade selection at the design stage. An integrated model that combines energy performance, thermal comfort, visual comfort, acoustic performance, material properties, occupants' satisfaction, and architectural integration is yet to be developed. Thus, this paper introduces a conceptual multi-criteria framework to fill these research gaps.

2. Methods

The following section aims at operationalizing the objective identified in Section 1 by highlighting the methodology that was employed in the creation of the suggested design-stage assessment framework. The technology of adaptive façades is discussed in Section 2.1 whereas Section 2.2 highlights existing building performance assessment techniques. Section 2.3 highlights the process undertaken in developing the framework, consisting of four stages comparative case studies analysis, multi-criteria framework creation, questionnaire validation by experts, and application to Egypt.

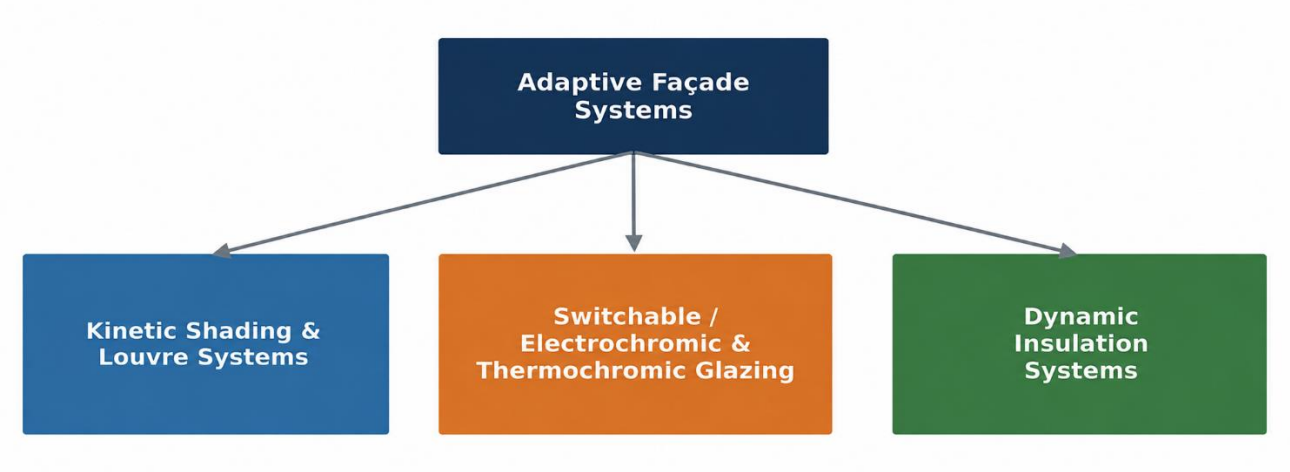


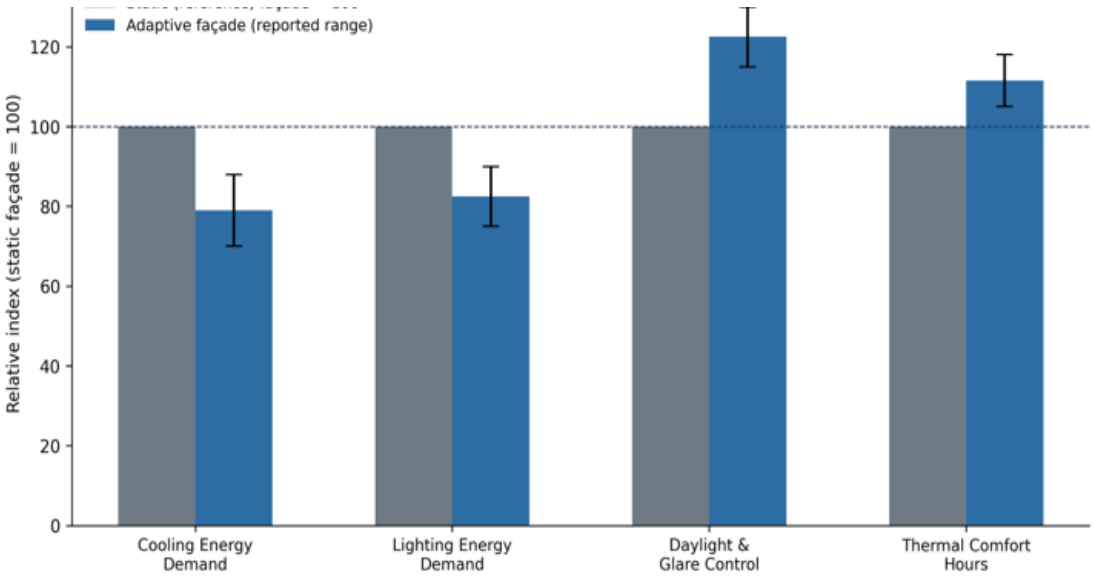
Fig 2. Principal categories of adaptive façade systems reviewed in this paper, (Kim et al., 2018; Niazy et al., 2023).

2.1 Adaptive Façade Systems

Adaptive, also known as responsive, façades can change their properties over time to respond to weather conditions and occupants' needs. Unlike conventional façades, these systems do not operate in a fixed way. Instead, they continuously adjust their performance to improve building efficiency and indoor comfort (Kim et al., 2018; Niazy et al., 2023). Common examples include kinetic shading devices, louvre systems, electrochromic and thermochromic glazing, and dynamic insulation technologies (Fig. 2). Previous studies have shown that these systems can reduce cooling and lighting energy demand while improving daylight availability and reducing glare compared with conventional façades, as illustrated by the comparative performance trends in Fig. 3. However, their actual performance depends on several factors, including the control strategy, occupants' interactions with the system, and the surrounding climate.

2.1.1 Theoretical Foundation

The presented approach is based on the fundamental concepts of building performance assessment and sustainable architecture design. Adaptive façades theory is used as one of the key references that view building envelopes as complex systems able to adapt to environment and occupancy changes. Multi-criteria decision making is used as another theoretical base of the suggested approach as façade performance cannot be measured with the use of a single performance criterion. Instead, the range of technical, environmental, and occupant factors must be considered at once to make well-balanced architectural decisions.



2.2 N, 2019; Kim et al., 2018).

2.1.2 Building Performance Assessment Methods

Several methods are commonly used to evaluate façade performance. These include steady-state calculations, dynamic energy simulation using software such as Energy Plus, daylight and glare analysis with tools such as Radiance and Daysim, and thermal comfort evaluation based on PMV/PPD or adaptive comfort models (ASHRAE, 2020; Chen & Tang, 2024). These assessment methods work well for conventional static façades. However, evaluating adaptive façades is more challenging because their performance changes over time. To represent this behavior accurately, the façade must be modeled in different operating states and linked to a control strategy, which makes the simulation process more complex (Lin et al., 2025) (Fig. 4).

2.2 Justification for the Proposed Framework

The existing façade evaluation systems normally consider the following factors individually: thermal transmittance, daylighting potential, or energy use. These indicators give significant insight; however, they cannot consider the interaction among environment performance, comfort, materiality, and architectural qualities. This calls for the development of an appropriate evaluation system that would combine different fields to facilitate the decision-making process. This research proposes a new system where different indicators can be combined into one conceptual evaluation system applicable for architecture design.

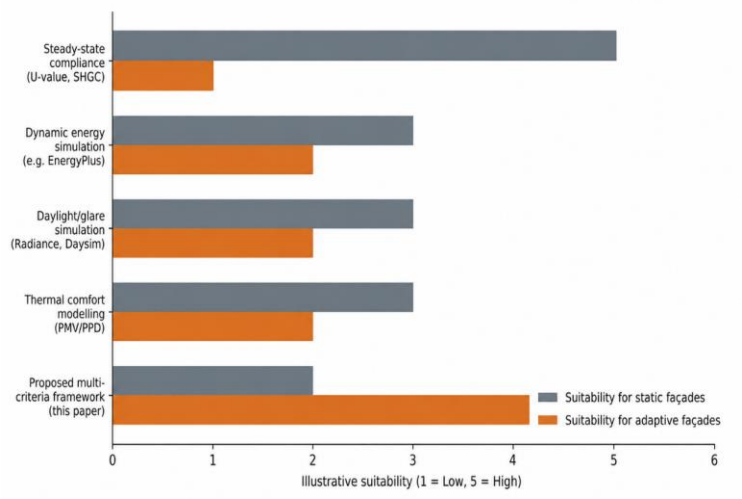


Fig 4. Illustrative suitability of existing building-performance assessment methods for static versus adaptive façade systems, (ASHRAE, 2020; Chen & Tang, 2024; Lin et al., 2025).

2.3 Proposed Assessment Framework and Methodology

This study proposes a four-stage methodology to evaluate adaptive façade systems and translate performance assessment into a practical guideline that can support architectural design decisions, as summarized in Fig. 5. The main stages of the proposed methodology are described below.



Fig 5. The four-stage methodology proposed in this paper, Author.

2.3.1 Stage One: Comparative Case Study Analysis

The first stage focuses on analysing a minimum of twelve internationally recognized LEED-certified buildings that are known for their successful use of high-performance and adaptive façade systems. The selected projects represent different climate zones and urban environments to provide a broad range of design approaches. Each case study is examined individually by reviewing its façade type, climatic conditions, and reported performance. The findings from all case studies are then compared to identify common design features and performance criteria that contribute to successful façade design.

2.3.2 Stage Two: Multi-Criteria Framework Development

The second stage develops a multi-criteria assessment framework based on the findings from the comparative analysis. The framework brings together the main factors that influence adaptive façade performance, including energy efficiency, thermal comfort, visual comfort, material and envelope characteristics, and occupant satisfaction. The proposed assessment categories and their representative indicators are presented in Table 1 and illustrated in Fig. 6.

Table 1. Proposed multi-criteria performance framework for adaptive façade assessment.

Performance Domain	Representative Indicators	Typical Assessment Method
Energy Performance	Annual primary energy use, heating/cooling loads	Dynamic energy simulation (e.g., EnergyPlus)
Thermal Comfort	PMV/PPD, operative temperature exceedance hours	Thermal comfort modeling
Visual Comfort	Useful Daylight Illuminance (UDI), Daylight Glare Probability (DGP)	Daylight/glare simulation (Radiance, Daysim)
Acoustic Performance	Sound transmission class, indoor noise levels	Acoustic modeling / field measurement
Material & Envelope Properties	U-value, SHGC, thermal mass, embodied energy	Material property analysis
Occupant Satisfaction	Perceived comfort, override frequency, satisfaction surveys	Post-occupancy questionnaire
Architectural Integration	Adaptability, aesthetic responsiveness, buildability	Expert/designer questionnaire evaluation

2.3.3 Stage Three: Expert Questionnaire and Criteria Validation

The third stage involves conducting a structured questionnaire with architects and façade design specialists. The aim is to evaluate the proposed assessment criteria, determine their relative importance, and identify the design stages where each criterion is most useful (Voigt et al., 2023). The collected responses will be analyzed to establish a weighted or ranked set of criteria. These results will then be used to develop both the final design guideline and a quantitative assessment equation for evaluating high-performance adaptive façades.

2.3.4 Conceptual Model of the Proposed Framework

The proposed conceptual model depicts the relationship between adaptive façade attributes, performance assessment areas, and

architectural decisions. The environmental factors, the façade technologies and the human needs are all responsible for influencing the seven performance areas. These performance areas are all interconnected within an assessment process framework that allows the selection and optimization of adaptive façades that provide high-performance building envelopes.



Fig 6. Seven performance domains of the proposed multi-criteria assessment framework, Author.

2.3.5 Stage Four: Application and Validation in the Egyptian Context

The final stage applies the proposed guideline and assessment equation to selected buildings in Egypt. This application will evaluate how well the framework performs under local climatic conditions and within the Egyptian building context. In addition, two Egyptian case studies will be examined to demonstrate how the framework can support façade design decisions and guide future retrofit projects.

3. Results and Discussion

This segment begins by describing the main finding of the methodology presented in Section 2 and ends by considering its importance, uniqueness, and limitations in comparison to traditional façade evaluation practices.

3.1 Summary of the Proposed Framework

The main finding of the methodology is the multi-criteria, seven domain assessment framework which is described in Table 1 and Fig. 6. It includes energy performance, thermal comfort, visual comfort, acoustic performance, material and envelope characteristics, occupant satisfaction, and architecture. Together with the four-stage methodology presented in Fig. 5, the above-described framework presents the conceptual result of the research performed thus far.

Table 2. Comparison with Existing Assessment Frameworks

The suggested framework is superior to the traditional approaches in terms of providing a more thorough assessment through incorporating seven performance areas into one theoretical model. Contrary to the conventional approaches that assess each indicator separately, the suggested framework facilitates holistic decision making at the initial stage of architectural design.

Assessment Feature	Conventional Methods	Proposed Framework
Energy Assessment	✓	✓
Thermal Comfort	✓	✓
Visual Comfort	✓	✓
Acoustic Performance	Limited	✓
Occupant Satisfaction	Rare	✓

Material Performance	Limited	✓
Integrated Assessment	✗	✓
Design-Stage Decision Support	✗	✓
Adaptive Façade Evaluation	Partial	✓

The proposed framework represents deviation from the usual façade assessment toward something more integrated and, well, more design-oriented too. In conventional methods, people tend to lean on individual indicators, like U-value or the solar heat gain coefficient which are quite helpful for static façade elements, but they usually cannot really capture how adaptive systems behave when conditions change. Since adaptive façades respond in a dynamic way to solar radiation, temperature, daylight and occupancy, their performance is more clearly understood through the relationship among multiple criteria rather than through one single performance metric.

So, the framework fills a methodological gap, in that it treats façade performance as multidimensional and strongly context dependent process. And there are trade-offs, because if one part improves it can easily bring issues elsewhere. For instance, boosting daylight might raise visual comfort yet at the same time it may elevate solar heat gain, while stronger shading could lower cooling demand but also limit daylight. This kind of situation makes it obvious you need an assessment approach that can spot and explain those interrelationships during the design process, not only evaluate outcomes one by one.

Furthermore, the framework is meant to help with decision making at the early design stage, when architects must think through alternative strategies before any detailed modelling is properly started. It is not really intended to stand in for simulation or post-occupancy evaluation, but more so to give a structured, first pass platform for comparison. How well it works will rely on the right criteria, the weighting choices, and validation across different climatic settings. There are three key characteristics that set the proposed approach apart: it has a multi criteria structure, it is applied to those early-stage design decisions, and it blends case study evidence with expert judgement, in a single view.

3.2 A Multi-Criteria Alternative to Single-Indicator Assessment

In contrast to traditional methods of evaluation that use only one indicator of performance, such as U-values or solar heat gain coefficient, the new proposed framework considers façade performance through seven distinct yet interlinked categories. It is important to understand that energy performance, comfort, and architectural value cannot usually be ensured by only one decision; rather, they are based on several conflicting goals of design. Consequently, by identifying such conflicts, the new framework provides a much clearer view of façade performance compared to the traditional approaches.

3.2.1 Supporting Early-Stage Design Decisions

The second differentiating aspect of the framework is that the latter is meant to aid in decision-making at the initial stages of architecture design rather than in evaluating its performance once the design is completed. The fact that seven performance domains and their corresponding indicators are known from the very beginning of a project gives an architect an opportunity to compare different design options, choose an appropriate adaptive façade system, and make decisions concerning material and control strategy selection at the earliest stage of the design process.

3.2.2 Integrating Case Study Evidence with Expert Knowledge

Another advantage of the suggested validation strategy is the ability to link case study evidence with expert judgement from practicing architects and façade engineers. While simulations and performance data collected through monitoring can be used to provide insight into the behavior of adaptive façades under actual conditions, there are cases when the information may not reflect critical issues like constructability and architectural integration. In view of this, the combination of case study evidence with expert judgement in the suggested validation process will help make sure that the final product will be practical.

3.3 Practical Implications

The suggested framework is applicable in practice and offers recommendations for architects, façade consultants, sustainability experts, and decision-makers at the conceptual design phase. Thanks to the combination of various aspects of performance into one evaluation system, the framework makes façade selection easier, facilitates multidisciplinary cooperation, and promotes designing climate-resilient façades (Yitmen et al., 2022). In addition, the suggested framework can serve as a basis for future decision-making tools and

sustainability certification processes.

3.4 Limitations and Scope for Validation

Even though the proposed framework provides a structured and design-stage based alternative approach to the traditional façade performance assessment approaches, there are several limitations that should be pointed out regarding the research at this stage. The first limitation consists in the fact that the framework is still conceptual. Neither the criteria, nor the quantitative assessment equation were verified through comparative case study analysis and an expert questionnaire, as mentioned in Sections 2.3.1 and 2.3.3, respectively. Second, the weights of the seven performance categories are yet to be determined; as a result, different weight schemes might lead to different assessment results depending on the climate type, building types and project-specific priorities of the design process. Finally, the limitations of the proposed generalization of the framework are related to the fact that it was built on a sample of LEED-certified buildings; thus, this approach may not provide the generalization of the diverse set of adaptive façade applications, especially in terms of hot-arid and hot-humid climates like Egypt.

4. Conclusion

This study proposes an integrated, sort of framework for evaluating the performance of adaptive façade systems, and it recognizes that their shifting, environmental reactions can't really be caught well with ordinary, static appraisal methods. The methodology itself blends comparative case study analysis, a multi-criteria assessment framework, expert validation, and then contextual use in Egypt. When you put these pieces together, the framework tries to offer a more orderly and comprehensive way to judge adaptive façades with respect to energy performance, thermal and visual comfort, environmental responsiveness, and architectural considerations. This is especially important now, because adaptive façade technologies keep becoming more complex, and there is a real need to check performance across multiple, sometimes conflicting, criteria.

One main contribution of the proposed framework is that it attempts to close the gap between the dynamic behaviour of adaptive façades and the mostly static evaluation approaches that tend to be used during architectural design. Instead of judging façade performance via separated, isolated indicators, the framework treats performance as a multidimensional result shaped by climatic conditions, the façade's responsiveness, occupant needs, and building-specific features. Even so, the framework is still conceptual in this stage, and it still needs systematic validation before its reliability, and real applicability, can be confidently confirmed. The next research phases will therefore move toward comparative analysis of known international adaptive façade projects, validation using expert questionnaires, development of a quantitative assessment equation, and applying the framework to a set of chosen projects within the Egyptian context.

The recommendations coming out of this study are following:

First validate the framework by using international case studies: you should look at a varied set of well recognised adaptive façade projects, and check if the assessment criteria they propose are broad enough, and still usable across different climatic situations technological setups, and architectural contexts.

Second strengthen expert validation: involve architects, façade specialists, environmental engineers, and building-performance researchers through structured questionnaires and interviews. This kind of input can help adjust the assessment criteria, spot what might be missing as parameters, and help decide more balanced weighting for the various performance indicators.

Third develop a quantitative assessment equation: the framework should be turned into a measurable assessment model, so the relative performance of adaptive façade systems can be compared in a more objective way. The weighting for each criterion should be supported by expert evidence and, as much as possible, backed with empirical performance data.

Fourth take the Egyptian climatic context seriously: the framework needs to be modified to reflect Egypt's own climate solar exposure cooling needs and regional differences. This matters because criteria crafted from other places might not match the environmental priorities, or the daily operational realities of Egyptian buildings.

Fifth integrate performance assessment into early design stages: the framework should really support architects and designers during conceptual work and preliminary design. The idea is that façade performance can be checked before big design choices get locked in. If done properly, this could increase the probability that adaptive façade strategies contribute in a meaningful way, to energy efficiency.

Overall, the proposed framework gives a sort of basis for moving, toward something more evidence based and context sensitive when you evaluate adaptive façades. But how well it works really depends on having rigorous validation, doing the right quantitative weighting, and then managing a proper adaptation to local climatic and architectural conditions. So, the next phase of research, well it becomes critical for seeing if this framework can do more than just sit there as an analytical research tool, it should also work as a practical decision support way for the design and evaluation of adaptive façade systems in Egypt.

References

ASHRAE. (2020). *ANSI/ASHRAE Standard 55-2020: Thermal environmental conditions for human occupancy*. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Attia, S. (2018). *Net zero energy buildings (NZEB): Concepts, frameworks and roadmap for project analysis and implementation*. Butterworth-Heinemann.

Attia, S., Bilir, S., Safy, T., Struck, C., Loonen, R. C. G. M., & Goia, F. (2018). Current trends and future challenges in the performance assessment of adaptive façade systems. *Energy and Buildings, 179*, 165–182.

Chen, P., & Tang, H. (2024). A framework for adaptive façade optimization design based on building envelope performance characteristics. *Buildings, 14*(9), 2646.

CEN. (2019). *EN 17037: Daylight in buildings*. European Committee for Standardization.

Favoino, F., Overend, M., & Jin, Q. (2015). The optimal thermo-optical properties and energy saving potential of adaptive glazing technologies. *Applied Energy, 156*, 1–15.

International Energy Agency. (2019). *2019 global status report for buildings and construction*. IEA/UNEP.

Kim, D., Cox, S. J., Cho, H., & Yoon, J. (2018). Comparative investigation on building energy performance of double skin façade (DSF) with interior or exterior slat blinds. *Journal of Building Engineering, 20*, 411–423.

Lin, Y., Xu, L., Yang, W., Tian, L., & Chan, M. (2025). A systematic review on the research and development of adaptive buildings. *Buildings, 15*(10), 1593.

Loonen, R. C. G. M., Favoino, F., Hensen, J. L. M., & Overend, M. (2017). Review of current status, requirements and opportunities for building performance simulation of adaptive façades. *Journal of Building Performance Simulation, 10*(2), 205–223.

Loonen, R. C. G. M., Trčka, M., Cóstola, D., & Hensen, J. L. M. (2013). Climate adaptive building shells: State-of-the-art and future challenges. *Renewable and Sustainable Energy Reviews, 25*, 483–493.

Mohtashami, N., Fuchs, N., Fotopoulou, M., Drosatos, P., Streblow, R., Osterhage, T., & Müller, D. (2022). State of the art of technologies in adaptive dynamic building envelopes (ADBEs). *Energies, 15*(3), 829.

Niazy, D., Metwally, E. A., Rifat, M., Awad, M. I., & Elsabbagh, A. (2023). A conceptual design of circular adaptive façade module for reuse. *Scientific Reports, 13*(1), 20552.

Shan, R., & Junghans, L. (2023). Multi-objective optimization for high-performance building façade design: A systematic literature review. *Sustainability, 15*(21), 15596.

Tabadkani, A., Roetzel, A., Li, H. X., & Tsangrassoulis, A. (2021). Design approaches and typologies of adaptive façades: A review. *Automation in Construction, 121*, 103450.

Voigt, M. P., Roth, D., Blandini, L., & Kreimeyer, M. (2024). An integrated design methodology for extrinsic adaptive façades: Process model, standards, and case study. *Journal of Building Engineering, 94*, 109810.

Voigt, M. P., Roth, D., & Kreimeyer, M. (2023). Decision support for defining adaptive façade design goals in the early design phase. *Energies, 16*(8), 3411.

Yitmen, I., Al-Musaed, A., & Yücelgazi, F. (2022). ANP model for evaluating the performance of adaptive façade systems in complex commercial buildings. *Engineering, Construction and Architectural Management, 29*(1), 431–455.

Zhang, X., Zhang, H., Wang, Y., & Shi, X. (2022). Adaptive façades: Review of designs, performance evaluation, and control systems. *Buildings, 12*(12), 2112.

نهج جديد لتقييم الأداء البنائي لأنظمة الواجهات التكيفية لتحقيق واجهات عالية الأداء

الملخص

تُعد واجهة المبنى من أهم العوامل المؤثرة في استهلاك الطاقة بالمبنى وفي مستوى الراحة التي يشعر بها شاغلوه. ويُتوقع من الواجهات عالية الأداء أن تحد من التأثيرات البيئية الخارجية الضارة مع الحفاظ على الراحة الحرارية والبصرية والصوتية الداخلية بأقل استهلاك ممكن للطاقة. وتُوسّع أنظمة الواجهات التكيفية — مثل أنظمة التظليل الحركي، والزجاج القابل للتحويل، وتقنيات الغلاف المستجيب — هذا المفهوم من خلال إعادة تشكيل خصائصها الفيزيائية استجابةً للظروف المناخية ومعدلات الإشغال.

ومع ذلك، فإن الطرق الحالية لتقييم أداء المباني لا تزال تعتمد بشكل كبير على معايير ثابتة أحادية الحالة، وبالتالي تفشل في التعبير بشكل كافٍ عن السلوك الديناميكي متعدد الحالات الذي تتحكم فيه أنظمة التحكم في الأنظمة التكيفية. تستعرض هذه الورقة البحثية بشكل نقدي أساليب تقييم أداء الواجهات الحالية، وتحدد أوجه القصور فيها فيما يتعلق بالأنظمة التكيفية، وتقترح إطار عمل مفاهيميًا متعدد المعايير يدمج الأداء الطاقي والراحة الحرارية والراحة البصرية وخصائص المواد وتغذية راجعة من الشاغلين في بنية تقييمية واحدة قابلة للتطبيق أثناء مرحلة التصميم المعماري.

ويُراد تفعيل هذا الإطار المقترح من خلال منهجية منظمة تجمع بين التحليل المقارن لدراسات حالة معتمدة دوليًا وحاصلة على شهادة LEED، واستبيان للخبراء للتحقق من صحة المعايير، وصياغة معادلة تقييم كمية، مع تطبيق لاحق على مبانٍ ممثلة في مصر.

الكلمات المفتاحية: الواجهات عالية الأداء؛ أنظمة الواجهات التكيفية؛ كفاءة الطاقة؛ تقييم أداء المباني؛ الراحة الحرارية؛ الإضاءة الطبيعية؛ شهادة LEED؛ العمارة المستدامة.