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# Multi-performance Review of the Louvre System in Building Design

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**Abstract.**

Louvres are among the architectural elements that serve multiple functions in supporting building performance. Through their adjustable slats, louvres can regulate the entry of natural light, control air circulation, and protect against solar heat and external noise. Beyond their technical roles, louvres also possess strong aesthetic qualities, often enhancing the facade composition and contributing to a building's visual character. In the context of sustainable architectural design, louvre systems have received growing attention for their potential to contribute to passive design strategies. Numerous studies have investigated their performance from various perspectives, including natural ventilation, thermal comfort, energy efficiency, and acoustic and daylight quality. However, most of the studies tend to focus on a single aspect of performance. In practice, these aspects are highly interrelated, and their interaction determines the overall effectiveness of the system. Therefore, a broader and more integrative review is needed to understand the combined roles of louvres in building design. This paper presents a review of 30 studies published over the past 15 years that examine louvre systems with respect to multiple performance criteria. The discussion focuses on aerodynamic, acoustic, energy, and daylighting aspects, as well as their interconnections. Through this approach, the review aims to provide a more comprehensive understanding of louvres as multi-performance components within the framework of sustainable architecture.

**Keywords:** building design, louvre system, multi-performance facade, natural ventilation

## 1. Introduction

This review examines 30 publications from roughly the past 10 years on the performance of the louvre system. In general, studies regard louvres as passive elements that enhance natural ventilation, energy efficiency, daylight control, and noise attenuation. Although each study has a different focus, all depart from the premise that louvres are not merely aesthetic components but performative elements that influence comfort and energy consumption in buildings. Most studies employ numerical simulations, particularly CFD, to observe airflow behavior across various louvre blade configurations (Cao, 2019; M. Iqbal et al., 2023; Kosutova et al., 2015). Several studies validate their findings through experimental tests in wind tunnels or model chambers (Kosutova et al., 2019; Ziarani et al., 2023a), while others assess acoustic performance using sound transmission loss and field measurements (Fausti et al., 2019; Hayne et al., 2019). Research on energy efficiency and daylighting has also expanded, especially in daylight optimization and shading performance (Hernández et al., 2017; Riviere & Malet-Damour, 2023), as well as in studies conducted in temperate and subtropical climates (Ziarani et al., 2023a; Tang, 2017). Over time, research directions have shifted from single-aspect studies toward more integrative approaches. Recent studies have begun to link multiple performance aspects, such as ventilation, acoustics, daylighting, and thermal behavior, and make use of multi-objective optimization models (W. Iqbal et al., 2025; Riviere & Malet-Damour, 2023). Several studies also combine CFD simulations with acoustic analysis or the integration of passive shading strategies (Hayne et al., 2019; Torresin et al., 2019), demonstrating an understanding that louvres have cross-functional interdependencies.

Overall, the literature shows a progression from functional studies toward more performative and integrated approaches, although application in tropical climates and multi-aspect analytical models still requires further development.

## 2. Method

This study employs a narrative literature review approach with an inductive thematic identification method. The literature gathering process was conducted exploratively, allowing for a more flexible and comprehensive mapping of the development of louvre research across various contexts and research methods. Literature searches were conducted using the SciSpace database, combining general terms related to louvres and building ventilation. The keyword inputs included: “louvre performance”, “louvre system, “louvre facade”, “ventilation louvre”, and “louvre window”. As the reading progressed, additional keywords related to specific performance aspects, such as natural ventilation, noise, daylighting, and energy efficiency, were used to refine and expand the search results. The publication range was limited to the 10 years from 2015 to 2025, using SciSpace's built-in filtering features to maintain relevance with current methodological and technological developments.

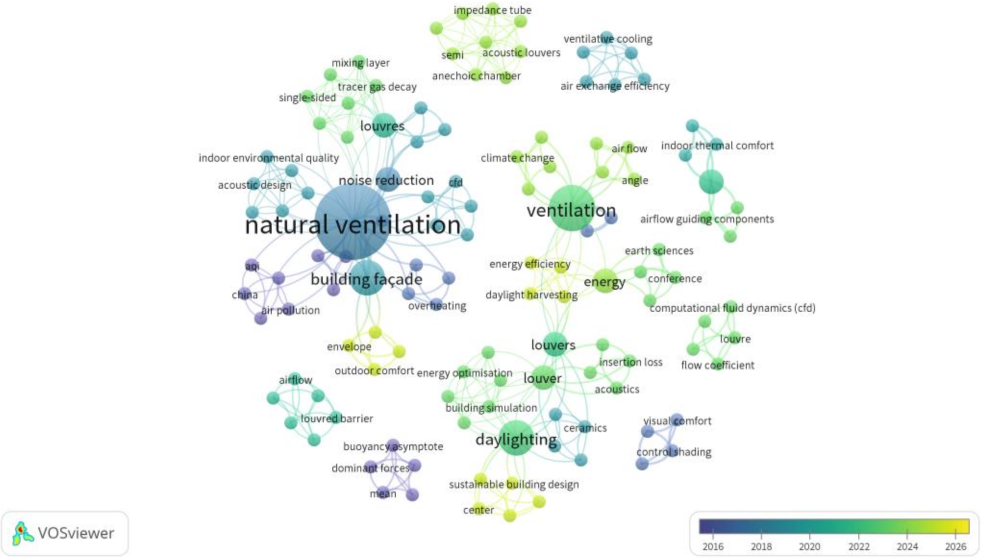


*Figure 1.* Network visualization of keywords related to louvre system performance
Source: Generated by the author using VOSviewer

### 2.1 Literature Criteria

Literature selection was carried out in stages through a review of titles, abstracts, and full texts, including:

- Journal articles or indexed peer-reviewed conference proceedings
- Discussions of louvres as facade or ventilation elements in buildings
- Quantitative or qualitative analyses of louvre performance, either through simulation or experimentation.
- Availability of data, models, or methods that can be interpreted for thematic synthesis

### 2.2 Literature Selection Process

Literature screening was performed using a relevance-ranking filter based on SciSpace search results. Each SciSpace search returns approximately 100 publications, automatically sorted by relevance. The initial evaluation focused on the top 10 articles, as this group typically contains publications most closely aligned with the targeted topic. If any of the first 10 publications were found to be insufficiently relevant or did not meet the criteria, the screening continued to the next-ranked articles up to approximately the top 20. Papers ranked lower generally showed topic deviation or a lack of direct discussion on louvre systems, and were therefore excluded from further selection. Following this pre-selection stage, the shortlisted articles were then examined through abstract and full-text review, resulting in 30 articles that form the primary sources of this study.

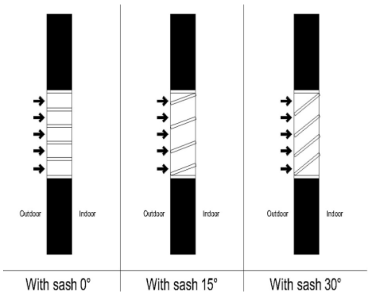
## 3. Result and Discussion

### 3.1 Aerodynamic and Ventilation Performance

Studies on the aerodynamic performance and natural ventilation of louvre systems demonstrate how variations in blade shape, tilt angle, and configuration can influence airflow within a building. The approaches used across various studies generally involve Computational Fluid Dynamics (CFD) simulations as well as experimental testing to identify the relationship between design parameters and ventilation efficiency (Cao, 2019; Kosutova et al., 2019; Ziarani et al., 2023a).

a. Influence of Geometry, Blade Angle, and Density on Airflow

The geometry of the louvre is identified as a fundamental factor in determining airflow patterns and ventilation capacity. Variations in blade angles produce significant changes in the discharge coefficient, where smaller angles create a more open flow path that increases air throughput, while steeper angles intensify turbulence and reduce flow capacity (M. Iqbal et al., 2023). Simulation and experimental results show that increasing the blade opening angle will increase airflow rate up to a certain point, after which it decreases due to rising flow resistance (M. Iqbal et al., 2023; Kosutova et al., 2019). Higher blade density introduces additional resistance to airflow (Amirul et al., 2024), blade density also plays an important role: increasing the number of blades within a panel leads to a decrease in Cd from approximately 0.78 to around 0.27, demonstrating a non-linear response to change in pitch and blocking ratio (Roostaee et al., 2023).



With sash 0° With sash 15° With sash 30°

*Figure 2.* Case of measurement tilt of the louvre
*Source: M. Iqbal et al., 2023*

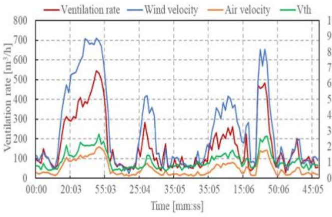


*Figure 3.* Comparison of velocity and ventilation rate with sash 0°
*Source: M. Iqbal et al., 2023*

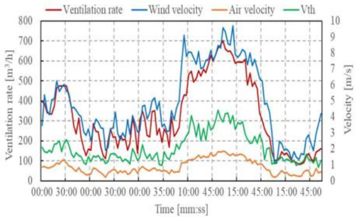


*Figure 4.* Comparison of velocity and ventilation rate with a sash of 15°
*Source: M. Iqbal et al., 2023*

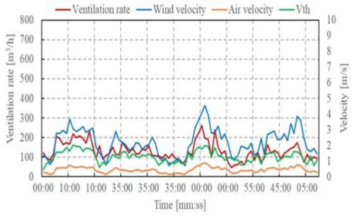


*Figure 5.* Comparison of velocity and ventilation rate with a sash of 30°
*Source: M. Iqbal et al., 2023*

Tilt angles of 30°-45° consistently produce an optimal balance between ventilation rate and pressure loss (Amirul et al., 2024; M. Iqbal et al., 2023). Blade geometry also significantly influences airflow characteristics. Louvres with curved or aerofoil-shaped profiles generate more stable airflow compared to flat blades and reduce turbulence formation behind the opening (Amirul et al., 2024). Blade configurations with narrow spacing tend to generate higher local turbulence, thereby increasing flow resistance at low wind speeds. However, under medium-high wind conditions, specific louvre geometries can function as stabilizers of inflow patterns, as evidenced by full-scale slot louvre studies showing improved inlet consistency and enhanced turbulence structure (O'Sullivan & Kolokotroni, 2016). Field observations show that adjustments to opening geometry, including slot height and the effective area of the louvre, directly affect ventilation rates and the thermal comfort response within indoor spaces (O'Donovan et al., 2017). This pattern indicates that modifying blade geometry can be a practical approach to improving ventilation performance without substantially increasing opening size.

### b. Blade Spacing Ratio and Density

The spacing between blades directly affects airflow resistance and ventilation capacity. Experimental studies show that overly narrow spacing increases pressure drop, although it can reduce turbulence levels inside the space (Ziarani et al., 2023a). A Spacing ratio of 1:5-1:7 is generally considered the most efficient for maintaining a balance between airflow velocity and ventilation stability (Kosutova et al., 2015). In tropical climates with high humidity, configurations with wider blade spacing are considered more effective in maintaining air circulation and preventing heat buildup (Aflaki et al., 2015; Elwan & Dewair, 2019). This indicates that blade density ratios cannot be universally standardized but must be adjusted according to climatic conditions and local wind direction (Aflaki et al., 2015). In single-sided ventilation, blade spacing influences the stability of the incoming jet and the flow distribution pattern inside the room. Inadequate spacing causes jet deflection upward or sideways, reducing ventilation depth and limiting the effective air-exchange zone (Ziarani et al., 2023b). In addition, field studies show that larger opening ratios enhance natural cooling response and reduce overheating under low to moderate heat load conditions, demonstrating a direct relationship between opening area and ventilation effectiveness (O'Donovan et al., 2017).

### c. Louvre Orientation Relative to Wind Direction

The orientation of louvres relative to the incoming wind direction influences dynamic pressure and the distribution of airflow within the space. Simulations indicate that a perpendicular orientation to the wind (0°) produces the highest ventilation. In contrast, angled orientations of 15°-30° provide a more stable balance between incoming airflow and exterior surface pressure (Yang et al., 2020). Orientation settings are also linked to environmental conditions. In areas with high pollution levels, angled orientations have been shown to reduce the amount of contaminated air entering the space (Tong et al., 2016). In tropical contexts, an east-west orientation is recommended to optimize natural cross-ventilation while reducing afternoon heat exposure (Aflaki et al., 2015). In tropical contexts, an east-west orientation is recommended to optimize natural cross-ventilation while reducing afternoon heat exposure (Ziarani et al., 2023b). Ventilation is more effective during frontal winds than during side winds, especially in opening configurations with vertical slots (O'Donovan et al., 2017). These conditions demonstrate that façade orientation and local wind direction are critical factors in evaluating louvre performance.

### d. Interaction Between Louvre Design and Building Pressure

Several studies highlight that the relationship between blade geometry, louvre placement on the facade, and the distribution on the facade surface can lead to differences in airflow velocity between sides of the opening, which ultimately affects cross-ventilation patterns (Kosutova et al., 2019).

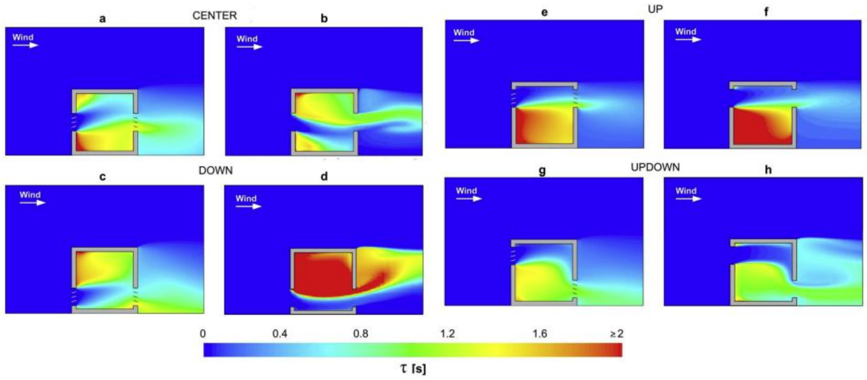


*Figure 6.* Air age contours on the vertical center plan under the cross-ventilation setup
*Source: Kosutova et al., 2019*

Therefore, integrating louvre design with external pressure conditions becomes essential to ensure that the ventilation system operates consistently across all areas of the building (Roostaee et al., 2023). Aerodynamics studies in single-sided ventilation show that adding guiding components to the louvre increases adequate inlet pressure and reduces near-wall eddies that previously hindered incoming flow (Ziarani et al., 2023b). Variations in opening size and configuration lead to differences in interior pressure, which affect natural cooling capacity and thermal comfort performance (O'Donovan et al., 2017). These results show that louvre design functions not merely as a passive opening, but as a pressure-modulating element that shapes indoor airflow dynamics

### e. Simulation Validation and Experimental Approaches

Several studies validate CFD simulation results against experimental data to ensure the accuracy of the airflow model. Comparisons show a high-level agreement between simulations and laboratory tests for blade configurations with moderate tilt angles, with discrepancies below 10% (Hayne et al., 2019; Kosutova et al., 2019). However, differences increase for non-conventional blade geometries or tightly spaced blades due to limitations in turbulence models for predicting complex flow dynamics (Amirul et al., 2024; Ziarani et al., 2023a). Experimental approaches offer advantages in validating actual flow patterns, while numerical simulations remain the primary method for evaluating broader design scenarios without incurring high cost (M. Iqbal et al., 2023; Kosutova et al., 2019). The combination of both methods is therefore essential for producing a more accurate and comprehensive representation of ventilation performance.

### 3.2 Acoustic and Noise Control Performance

In addition to functioning as ventilation and shading elements, louvre systems also play an important role in building noise control. Studies on acoustic performance focus on the system's ability to block, absorb, or redirect sound transmission from the external environment, particularly in areas exposed to traffic noise or industrial activity. Most research employs methods such as Sound Pressure Level (SPL measurement, Transmission Loss (TL), and numerical simulations based on the Finite Element Method (FEM) or Boundary Element Method (BEM) to evaluate acoustic characteristics (Fausti et al., 2019; Hayne et al., 2019).

a. Fundamental Principles of Louvre Acoustic Performance

The acoustic performance of louvres is determined by the mechanisms of sound reflection, absorption, and diffraction that occur between the blades. The pattern of noise reduction strongly depends on the material, blade thickness, and spacing between elements (Hayne et al., 2019). Louvre systems that incorporate blades coated with porous or acoustic-absorbing materials demonstrate higher sound attenuation compared to plain metal blades (Fausti et al., 2019). Configurations with double-layered blades can increase transmission loss by 5-10 dB compared to single-layer systems of similar thickness (Avinash et al., 2023; Lee et al., 2017). In addition to blade shape and material, the cavity depth between blades also influences acoustic performance. Increased cavity depth enhances resonance effects, allowing the system to attenuate a wider frequency range (Fausti et al., 2019; Hayne et al., 2019).

Studies on louvre-based noise barriers show that opening ratio and blade orientation can modify sound-diffraction patterns, thereby influencing noise reduction performance for linear sources such as roadways (Astrauskas et al., 2021). Overall, the fundamental principles of acoustic performance in louvres can be described as a combination of the path-interruption effect and surface-geometry manipulation.

b. Blade Material and Its Influence on Noise Reduction

The selection of blade materials is a key factor in determining sound absorption characteristics. Metal louvres generally exhibit high reflectivity but low absorption of sound waves at mid-range frequencies (Hayne et al., 2019). In contrast, the use of porous material such as mineral wool or foam-based composites can increase the sound absorption coefficient, particularly at frequencies above 500 Hz (Avinash et al., 2023). Recent studies propose alternative materials such as recycled rubber and natural fibers, which offer good sound attenuation while also being environmentally sustainable. This waste-based material approach shows strong potential for use in building noise barriers in high-traffic areas without adding significant structural load (Strazdas & Januševičius, 2024).

(a) (b)

*Figure 7.* Tire rubber as a waste-based material, (a) tilted towards the noise source, (b) tilted away from the noise source
*Source:* Strazdas & Januševičius, 2024

In addition to material composition, blade cross-section geometry also affects attenuation efficiency. Blades with curved profiles have been shown to direct sound waves more effectively toward absorbing surfaces compared to flat blades (Avinash et al., 2023; Lee et al., 2017).

c. Louvre Configuration and Acoustic-Ventilation Performance

The relationship between acoustic performance and natural ventilation is a central consideration in louvre system design. Configurations that are too closed may improve sound insulation values, but simultaneously reduce airflow capacity (Hayne et al., 2019; Torresin et al., 2019). Conversely, systems with open blades and wide spacing offer better ventilation but lower sound attenuation. Several studies indicate that the best compromise is achieved with blade angles of 30º-45º, which maintain a balance between airflow and sound attenuation (Fausti et al., 2019; Lee et al., 2017).

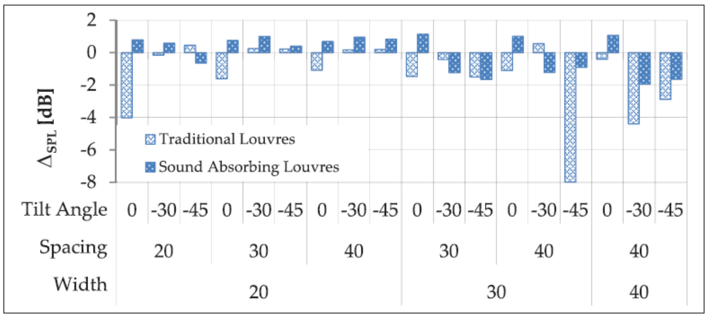


*Figure 8.* Effect of louvre tilt angle
*Source: Fausti et al., 2019*

In an acoustic ventilation louvre system, adding an absorbing layer on the inner side of the blades improves sound attenuation without significantly reducing airflow (Torresin et al., 2019). Other studies show a hybrid louvre system combining reflective and the ventilation rate of a fully open configuration (Hayne et al., 2019). Findings from noise barrier studies indicate that curved or angled blades can enhance diffraction patterns and reduce direct transmission of traffic noise (Astrauskas et al., 2021).

d. Case Studies on Acoustic Louvre Application in Building

Various studies have evaluated the application of acoustic louvre systems in real building contexts. In office buildings located in dense urban areas, the implementation of acoustic louvres has successfully reduced indoor noise levels by 15-20 dB without compromising natural ventilation (Torresin et al., 2019). Meanwhile, research conducted in transportation facilities found that double-layer louvre systems with internal porous layers were able to reduce traffic noise by 8-10 dB at mid-range frequencies (Fausti et al., 2019). In facade design, several studies also highlight the potential for integrating acoustic performance with aesthetic functions (Hayne et al., 2019; Tang, 2017). Increasingly noisy urban contexts also highlight the urgency of facade designs capable of blocking external noise, as discussed in high-rise facade-noise studies (Tang, 2017) and broader evaluations of urban noise pollution (Shirzad et al., 2022).

e. Acoustic validation and Simulation Methods

Experimental validation was carried out through tests in controlled acoustic chambers using a reverberation chamber and impedance tube to measure sound transmission loss and absorption coefficient values (Hayne et al., 2019; Lee et al., 2017). Comparison between experimental and simulation results shows a high level of agreement at mid-range frequencies, with an average deviation of less than 5% (Fausti et al., 2019). Numerical simulations based on Finite Element Analysis (FEA) are used to estimate louvre performances across various configurations, particularly in studies optimizing blade geometry and absorbing materials (Avinash et al., 2023; Strazdas & Januševičius, 2024). This simulation-based approach enables broader design exploration before physical testing, making the process more efficient.

## 3.3 Daylighting and Energy Efficiency

The performance of louvre systems in the context of daylighting and energy efficiency has become a key focus in modern passive façade design. Numerous studies evaluate how blade configurations, surface materials, and louvre orientation influence natural light intensity, visual comfort, and reductions in building energy loads. The approaches used generally rely on daylight simulation tools such as Radiance, DIVA for Rhino, or EnergyPlus, combined with energy consumption and cooling load calculations.

a. Influence of Geometry and Orientation on Daylighting

The geometric configuration of louvre blades plays a crucial role in determining the amount and distribution of natural light entering indoor spaces. Simulation results indicate that blade angles between 25º and 40º can balance light intensity without causing excessive glare (Hernández et al., 2017; Ma et al., 2025). Horizontally oriented blades are effective for controlling direct sunlight from above, while vertically oriented blades are better suited for east- and west-facing facades that receive low-angle solar radiation (Riviere & Malet-Damour, 2023). Other studies show that blade spacing also influences interior daylight distribution. Configurations with narrow spacing increase light diffusion and reduce harsh shadows, whereas wide spacing increases contrast and glare potential (Hernández et al., 2017). Studies on ceramic louvre systems indicate that changes in surface geometry can enhance daylight redirection, particularly during midday when the solar elevation angle is high (Gutiérrez et al., 2019). These surface patterns. This pattern highlights the need to adjust blade angles and spacing according to façade orientation and interior lighting requirements.

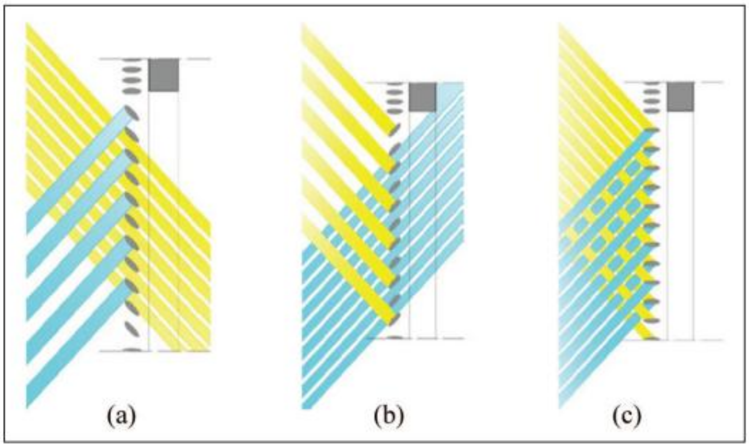


*Figure 9.* Influence of louvre orientation on the propagation of sunlight and street noise: (a) louvres tilted upward, (b) louvres tilted downward, (c) horizontal louvres
*Source: Fausti et al., 2019*

The role of natural ventilation in reducing energy loads is also discussed in studies linking passive ventilation strategies with building energy efficiency, where the use of cross-ventilation and wind-oriented openings plays an important role in reducing dependence on mechanical cooling (Tong et al., 2016). Moreover, facade-design strategies responsive to microclimate and solar exposure, including bladed shading elements, are identified as relevant approaches for improving building energy resilience within hot urban contexts (Khan & Ghiai, 2025).

Overall, louvres can be regarded as passive shading elements with strong potential for solar heat-gain control and reduction of cooling energy consumption, with effectiveness depending on blade geometry, orientation, and operational strategy.

### b. Energy Performance and Solar Heat Control

In addition to their influence on daylighting, louvre systems also play an important role in controlling solar heat gain. Blades designed with optimal tilt angles can reduce solar radiation gain by 30%-40% compared to conditions without shading (Hernández et al., 2017). Thermal efficiency increases significantly in configurations with reflective blades that redirect most direct radiation outward (Ma et al., 2025). Several studies show that using light-colored materials or reflective metal surfaces can reduce cooling loads by up to 15% compared to dark materials with high absorption (Riviere & Malet-Damour, 2023). In buildings located in hot, humid climates, louvre geometries that minimize direct solar exposure have proven effective in maintaining stable indoor temperatures throughout the day (Elwan & Dewair, 2019). The ceramic louvre system also demonstrates stable heat-reduction performance due to the material's thermal properties, which do not readily absorb direct radiation. Thereby limiting surface heat distribution even when light intensity remains high (Gutiérrez et al., 2019).

Annual energy simulations indicate that integrating louvres with natural ventilation strategies can reduce total building energy consumption by 10%-18% depending on climate conditions and façade orientation (Ma et al., 2025; Riviere & Malet-Damour, 2023).

### c. Material and Surface Reflective Properties

The type of blade material affects both daylighting performance and energy efficiency. Materials such as anodized aluminum and stainless steel have high reflectance, which helps reflect natural light deeper into interior spaces without increasing surface heat (Hernández et al., 2017). Meanwhile, materials with matte finishes or dark colors tend to absorb radiation, which can raise blade surface temperatures and increase the thermal load of the space (Riviere & Malet-Damour, 2023). Studies comparing ceramic louvres with conventional shading materials show that ceramic surfaces with microscopic textures have higher light scattering capability, particularly under intense midday radiation (Gutiérrez et al., 2019).

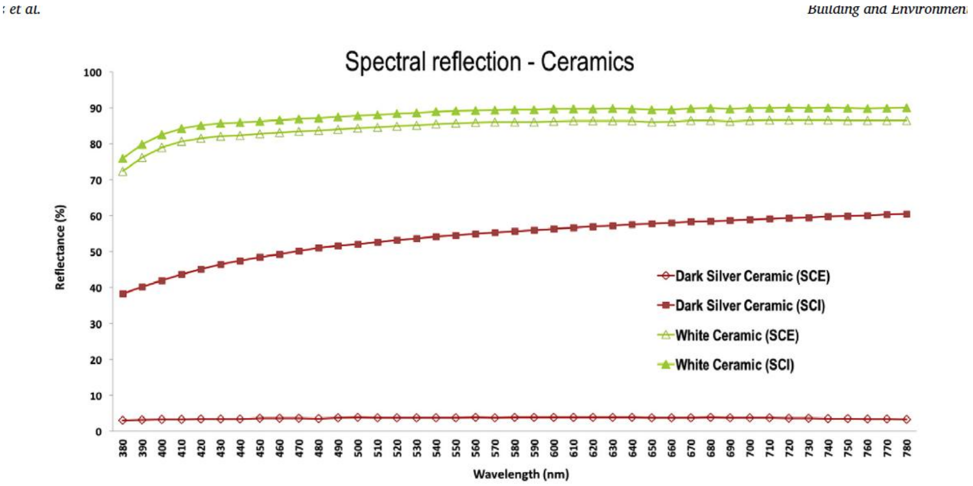


*Figure 10.* Spectral reflection of the ceramic
*Source: Gutiérrez et al., 2019*

More innovative approaches involve the use of dynamic materials or thermochromic coatings, which can adjust their reflectance levels depending on solar intensity (Ma et al., 2025). Research on air quality and urban pressure on passive strategies also suggests that louvres must be designed not only for thermal and lighting performance but also for environmental comfort and stability (Niza et al., 2024). These systems enable higher energy efficiency without compromising user visual comfort.

### d. Integration of Louvres with Passive Building Systems

Several studies evaluate the performance of louvres as part of passive façade systems integrated with natural ventilation and daylight harvesting. This integration serves a dual function: reducing the need for artificial lighting during the day while simultaneously lowering cooling loads by limiting solar heat gain (Ma et al., 2025; Riviere & Malet-Damour, 2023).

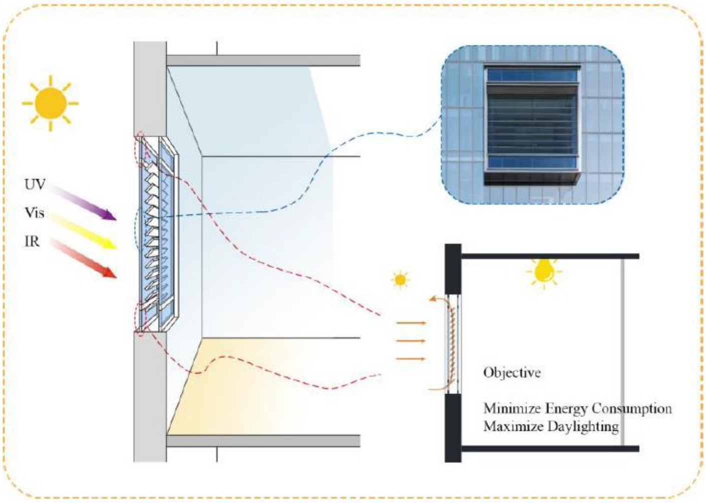


*Figure 11.* Schematic diagram of center-mounted louvre ventilation window
*Source: Ma et al., 2025*

Simulations show that louvre systems optimized with censor-based daylight control can reduce lighting energy use by up to 40%, particularly in multi-story office buildings (Hernández et al., 2017). A similar approach is applied in adaptive systems that automatically adjust blade openings based on outdoor light intensity. The results demonstrate an increase in visual comfort of up to 20% for static systems (Riviere & Malet-Damour, n.d.). Ray-tracing simulation also shows how strong consistency between computational models and the physical light distribution patterns they produce, providing a high level of reliability in performance predictions (Gutiérrez et al., 2019).

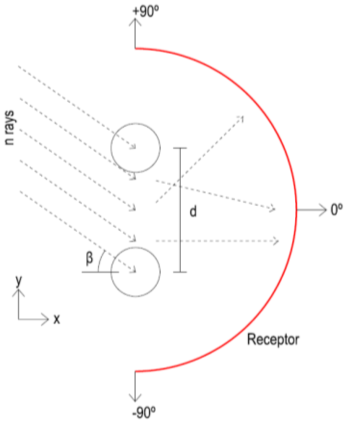


*Figure 12.* Ray-tracing basic simulation setup
*Source: Gutiérrez et al., 2019*

In addition to energy efficiency, integrated systems also contribute to thermal and visual comfort, distributing natural light evenly without increasing heat load (Elwan & Dewair, 2019).

e. Simulation Assessment and Experimental Validation

Most studies use energy and daylighting simulation software to evaluate louvre performance. Comparisons between simulation results and field measurements show a high degree of consistency, with average deviations of less than 10% for illuminance and energy consumption (Hernández et al., 2017; Ma et al., 2025). However, experimental validation is still limited to laboratory-scale testing under controlled environmental conditions. Test results indicate that simulation models tend to overestimate energy-efficiency performance, particularly in buildings exposed to direct solar radiation without additional shading (Riviere & Malet-Damour, 2023). This highlights the need for more field-based testing that reflects real conditions to improve the accuracy of simulation outcomes.

### 3.4 Multi-Performance Integration

a. Relationship between Ventilation and Thermal Comfort

Studies show that improvements in natural ventilation efficiency often directly affect indoor thermal comfort. Increased airflow rates can reduce indoor temperatures by 2º-3ºC in hot conditions, especially in buildings with adequate cross ventilation (Aflaki et al., 2015; Elwan & Dewair, 2019). However, higher ventilation rates also have the potential to introduce outdoor heat if the louvre orientation is not adjusted according to wind direction and solar radiation (Ma et al., 2025). Optimal ventilation performance is typically achieved with louvre configurations at a blade angle of 30º-45º, where airflow can be distributed evenly without generating excessive turbulence (M. Iqbal et al., 2023; Kosutova et al., 2019). This condition not only improves thermal comfort but also helps regulate indoor temperatures without relying on mechanical cooling systems (Ma et al., 2025). In dense urban contexts, environmental pressures related to air temperature and outdoor wind quality also influence ventilation effectiveness, indicating that louvre design must consider microclimatic factors and daily variations in wind direction (Niza et al., 2024). Overall, the linkage between ventilation and thermal comfort in louvre systems is influenced by blade geometry, wind orientation, climatic conditions, and operational strategies

b. Relationship between Ventilation and Acoustics

The integration of natural ventilation and noise control presents a major challenge in louvre system design. Open-blade configurations that support airflow often reduce the system's ability to block sound transmission from outside (Fausti et al., 2019; Hayne et al., 2019). Conversely, increasing blade mass or thickness to enhance sound attenuation tends to reduce natural ventilation rates significantly (Lee et al., 2017). The hybrid acoustic ventilation louvre approach addresses this conflict by adding an acoustic-absorbing layer to the inner side of the blades, allowing air to pass through the gaps without a significant increase in noise (Torresin et al., 2019). Studies show that such a system can reduce noise level by 10-12 dB while maintaining approximately 70%-80% of ventilation capacity (Hayne et al., 2019).

Research on louvred noise barriers indicates that a more closed blade orientation provides higher noise reduction but restricts airflow, especially under low wind-speed conditions (Astrauskas et al., 2021; Strazdas & Januševičius, 2024). Overall, the ventilation-acoustic relationship in louvres is classified as an antagonistic interaction, requiring strategies that balance resistance with noise control.

c. Interaction Between Daylighting and Energy Efficiency

Natural light control through louvres contributes significantly to building energy efficiency, particularly by reducing lighting and cooling loads (Hernández et al., 2017; Riviere & Malet-Damour, 2023). Studies show that optimizing blade tilt angles can increase natural illumination by up to 25% without a meaningful rise in thermal loads (Ma et al., 2025). Light-colored reflective blades have been shown to diffuse light deeper into interior spaces while simultaneously reducing heat from direct solar radiation (Riviere & Malet-Damour, 2023).

However, excessive daylight penetration can also cause glare and increase local temperatures near windows, especially with a glossy blade surface (Hernández et al., 2017). Studies on adaptive facade strategies in urban microclimates also show that blade reflectance and orientation play important roles in reducing heat gain, especially in regions with high solar intensity (Khan & Ghiai, 2025). Balancing daylight availability and solar heat gain becomes a key factor in optimizing energy performance. Overall, the daylighting-energy interaction in louvre systems exhibits a complex and interdependent relationship, necessitating blade-design strategies formulated within a dual-optimization framework.

### d. Conflict and Trade-offs among Performance Aspects

Aerodynamic, acoustic, and daylighting performance do not always align; improving one aspect can degrade another. For example, adding sound-absorbing layers enhances noise attenuation but decreases the ventilation discharge coefficient (Hayne et al., 2019; Kosutova et al., 2019). Meanwhile, blade orientations optimized for natural lighting are not always aligned with the best orientations for cross-ventilation (Aflaki et al., 2015; Riviere & Malet-Damour, 2023). Several studies attempt to identify optimal compromise points through multi-parameter simulations that simultaneously consider ventilation, energy performance, and visual comfort. The results indicate that blade configurations of 35º-40º, with moderate spacing and lightweight reflective materials, provide balanced performance across all three aspects (W. Iqbal et al., 2025; Ma et al., 2025). These conflicts demonstrate that the louvre system requires design approaches that consider inter-performance interactions rather than optimizing a single aspect in isolation.

### e. Integration Approaches in Adaptive Louvre Design

Several recent studies are advancing the development of adaptive louvres that automatically adjust blade positions in response to changing environmental conditions. These systems use censor-based controls to regulate blade openings according to light intensity and wind direction, ensuring balanced performances across multiple aspects (W. Iqbal et al., 2025; Riviere & Malet-Damour, 2023). Simulations show that adaptive systems can improve energy efficiency by up to 155% compared to static systems, without reducing visual comfort or natural ventilation (Ma et al., 2025). In addition, this concept allows dynamic noise control by partially closing the openings when external noise levels rise (Torresin et al., 2019). Such design approaches demonstrate the strong potential of louvre systems as responsive facade elements capable of balancing multiple building performance demands simultaneously (W. Iqbal et al., 2025; Riviere & Malet-Damour, 2023). Additionally, adaptation to urban microclimatic conditions such as dominant wind direction, heat island effects, and noise levels requires a louvre system that responds dynamically to external environmental change (Khan & Ghiai, 2025; Niza et al., 2024). Overall, adaptive design approaches represent the most promising pathway for enhancing multi-performance louvre effectiveness in a manner that is both simultaneous and responsive to environmental dynamics.

## 4. Conclusion

A review of thirty publications over the last decade shows that louvre systems function as multidimensional passive façade elements that regulate natural ventilation, reduce noise, manage daylight, and lower building energy loads. Their performance is influenced by blade geometry, spacing, density, material properties, façade orientation, and environmental conditions. Ventilation effectiveness is determined by airflow behavior and discharge coefficients, while acoustic performance operates through sound-path disruption and absorption, though often at the expense of airflow capacity. In daylighting, louvres shape illuminance levels, glare control, and solar heat gain, which affect cooling-energy demand.

Table 1 summarizes the 30 papers analyzed in this review, grouping their contributions into five performance categories. This mapping is structured to highlight each study's primary focus, the potential for cross-aspect integration, and the research gaps that emerge from the distribution of these themes.

*Table 1.* Performance mapping of the reviewed louvre studies

| No. | Arcticles | AER | ACO | DAY | ENG | MPI |
|---|---|---|---|---|---|---|
| 1 | Aflaki et al., 2015 | ✓ | - | - | - | - |
| 2 | Amirul et al., 2024 | ✓ | - | - | - | - |
| 3 | Astrauskas et al., 2021 | - | ✓ | - | - | - |
| 4 | Avinash et al., 2023 | - | ✓ | - | - | - |
| 5 | Cao, 2019 | ✓ | - | - | - | - |
| 6 | Elwan & Dewair, 2019 | ✓ | - | - | - | - |
| 7 | Fausti et al., 2019 | - | ✓ | - | - | - |
| 8 | Gutiérrez et al., 2019 | - | - | ✓ | ✓ | - |
| 9 | Hayne et al., 2019 | ✓ | ✓ | - | - | - |
| 10 | Hernández et al., 2017 | - | - | ✓ | ✓ | - |
| 11 | M. Iqbal et al., 2023 | ✓ | - | - | - | - |
| 12 | W. Iqbal et al., 2025 | ✓ | - | ✓ | ✓ | ✓ |
| 13 | Khan & Ghiai, 2025 | - | - | - | - | ✓ |
| 14 | Kosutova et al., 2015 | ✓ | - | - | - | - |
| 15 | Kosutova et al., 2019 | ✓ | - | - | - | - |
| 16 | Lee et al., 2017 | ✓ | ✓ | - | - | - |
| 17 | Ma et al., 2025 | ✓ | - | ✓ | ✓ | ✓ |
| 18 | Niza et al., 2024 | - | - | - | - | ✓ |
| 19 | O'Donovan et al., 201 | ✓ | - | - | - | ✓ |
| 20 | O'Sullivan & Kolokotroni, 2016 | ✓ | - | - | - | - |
| 21 | Riviere & Malet-Damour, 2023 | - | - | ✓ | ✓ | ✓ |
| 22 | Roostaee et al., 2023 | ✓ | - | - | - | - |
| 23 | Shirzad et al., 2022 | - | ✓ | - | - | - |
| 24 | Strazdas & Januševičius, 2024 | - | ✓ | - | - | - |
| 25 | Tang, 2017 | ✓ | ✓ | - | - | ✓ |
| 26 | Tong et al., 2016 | ✓ | - | - | ✓ | ✓ |
| 27 | Torresin et al., 2019 | - | ✓ | - | - | ✓ |
| 28 | Yang et al., 2020 | ✓ | - | - | - | - |
| 29 | Ziarani et al., 2023a | ✓ | - | - | - | - |
| 30 | Ziarani et al., 2023b | ✓ | - | - | - | ✓ |

AER: aerodynamic/ventilation
ACO: acoustic
DAY: daylighting
ENG: energy
MPI: multi-performance

*Source: Author's compilation*

Current research remains fragmented, as most studies examine only one or two aspects at a time. There is still no comprehensive multi-performance model integrating ventilation, acoustics, daylighting, and energy, and research in hot–humid tropical climates is notably lacking. Material studies remain limited to standard options such as aluminum, glass, PVC, and recycled components, while advanced surfaces, such as low-E coatings, photovoltaics, and electrochromic systems, remain unexplored. Most findings are also based on simulations or laboratory tests, with minimal full-scale field validation.

Future research directions emphasize the need for holistic, multi-aspect design, the development of integrated optimization frameworks to resolve performance trade-offs, and the exploration of innovative materials and surface technologies. Advancing adaptive louvre systems—equipped with multi-sensor inputs responding to light, heat, wind, and noise—also represents a crucial step toward achieving high-performance façades suitable for tropical climate challenges.

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