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MULTIFACTOR ANALYSIS AND OPTIMIZATION OF FACADE RECONSTRUCTION IN THE CLIMATIC CONDITIONS OF ASTANA

КӨПФАКТОРЛЫ ТАЛДАУ ЖӘНЕ АСТАНА ҚАЛАСЫНЫҢ КЛИМАТТЫҚ ЖАҒДАЙЫНДА ҚАСБЕТТЕРДІ ҚАЙТА ҚҰРЫЛЫМДАУДЫ ОҢТАЙЛАНДЫРУ

МНОГОФАКТОРНЫЙ АНАЛИЗ И ОПТИМИЗАЦИЯ РЕКОНСТРУКЦИИ ФАСАДОВ В КЛИМАТИЧЕСКИХ УСЛОВИЯХ ГОРОДА АСТАНА

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Keywords:
multifactor analysis, reconstruction methods, optimisation of solutions, energy efficiency, architectural appearance.

ABSTRACT
The article is devoted to a multifactor analysis of the efficiency of facade reconstruction in the established residential buildings of Astana city. Given the sharply continental climate of Kazakhstan's capital, facade renovation plays a crucial role in improving energy efficiency, enhancing the architectural appearance, and extending the service life of buildings. The study examines contemporary approaches to assessing the technical and aesthetic condition of facades, considering factors such as material degradation, thermal insulation performance, and compliance with modern regulatory standards. Various reconstruction methods are analyzed, with a focus on their adaptability to Astana's climatic conditions and their contribution to sustainable urban development. The research identifies key factors influencing the durability and resilience of building facades, including environmental impact, construction materials, and technological advancements in facade engineering. Based on the findings, the study provides recommendations for optimizing design solutions to ensure long-term performance and sustainability. The proposed approaches aim to balance economic feasibility with architectural integrity while addressing urban planning challenges. The results of this work will be useful for professionals in architecture, urban planning, and construction, as well as for policymakers and organizations involved in the development and modernization of urban infrastructure in regions with extreme climate conditions.

Түйінді сөздер:
көп айнымалы талдау, қайта құру әдістері, шешімдерді оңтайландыру, энергия тиімділігі, сәулеттік келбеті.

ТҮЙІНДЕМЕ
Бұл мақала Астана қаласындағы қалыптасқан тұрғын үй ғимараттарының қасбеттерін қайта құру тиімділігін көпфакторлы талдауға арналған. Қазақстан астанасының күрт континенттік климаты жағдайында қасбеттерді жаңарту энергия тиімділігін арттыруда, сәулеттік келбетті жақсартуда және ғимараттардың пайдалану мерзімін ұзартуда маңызды рөл атқарады. Зерттеуде қасбеттердің техникалық және эстетикалық жағдайын бағалаудың заманауи тәсілдері қарастырылады, оның ішінде құрылыс материалдарының

тозуы, жылу оқшаулау көрсеткіштері және заманауи нормативтік талаптарға сәйкестігі ескеріледі. Қайта құру әдістері талданып, олардың Астана климатына бейімділігі және қаланың тұрақты дамуына қосатын үлесі зерттеледі. Ғимарат қасбеттерінің беріктігі мен төзімділігіне әсер ететін негізгі факторлар анықталып, қоршаған орта факторлары, құрылыс материалдары және қасбеттік инженериядағы технологиялық жетістіктер ескерілді. Зерттеу нәтижелері негізінде ұзақ мерзімді тиімділікті және тұрақтылықты қамтамасыз етуге бағытталған жобалық шешімдерді оңтайландыру бойынша ұсыныстар жасалды. Ұсынылған тәсілдер экономикалық тиімділік пен сәулеттік тұтастықты сақтауды көздейді және экстремалды климаттық жағдайлардағы қалалық инфрақұрылымды дамыту мен жаңғыртуға қатысатын сәулет, қала құрылысы және құрылыс саласындағы мамандарға, сондай-ақ мемлекеттік ұйымдарға пайдалы болуы мүмкін.

Ключевые слова:
многофакторный анализ, методы реконструкции, оптимизация решений, энергоэффективность, архитектурный облик.

АННОТАЦИЯ

Статья посвящена многофакторному анализу эффективности реконструкции фасадов сложившейся жилой застройки города Астаны. В условиях резко континентального климата столицы Казахстана реконструкция фасадов играет важнейшую роль в повышении энергоэффективности, улучшении архитектурного облика и продлении срока службы зданий. В исследовании рассматриваются современные подходы к оценке технического и эстетического состояния фасадов с учетом таких факторов, как деградация материалов, теплоизоляционные характеристики и соответствие современным нормативным требованиям. Анализируются различные методы реконструкции с акцентом на их адаптированность к климатическим условиям Астаны и вклад в устойчивое развитие города. В исследовании определены ключевые факторы, влияющие на долговечность и устойчивость фасадов зданий, включая воздействие окружающей среды, строительные материалы и технологические достижения в области фасадной инженерии. На основе полученных данных в исследовании даны рекомендации по оптимизации проектных решений для обеспечения долгосрочных эксплуатационных характеристик и устойчивости. Предлагаемые подходы направлены на достижение баланса между экономической целесообразностью и архитектурной целостностью, а также на решение градостроительных задач. Результаты данной работы будут полезны для специалистов в области архитектуры, градостроительства и строительства, а также для политиков и организаций, занимающихся развитием и модернизацией городской инфраструктуры в регионах с экстремальными климатическими условиями.

INTRODUCTION

The issue of residential building facade reconstruction is becoming increasingly relevant for Astana, where climatic conditions significantly accelerate the deterioration of construction materials and reduce the operational performance of buildings. During winter, temperatures can drop to -30-35°C, while in summer, they can rise to +30-35°C, creating extreme conditions for facade structures. Additionally, strong wind loads (gusts reaching 20–25 m/s) and high levels of solar radiation contribute to facade degradation, material cracking, and the deterioration of thermal insulation properties. Consequently, facade reconstruction requires a comprehensive analysis that considers not only the technical condition of buildings but also economic feasibility, energy efficiency, and architectural expressiveness.

The aim of this study is to conduct an analysis to identify key factors influencing the successful reconstruction of facades, aimed at improving durability, energy efficiency, and the aesthetic appearance of residential buildings.

To achieve this goal, an analysis of existing approaches to facade reconstruction was conducted, and a multifactor analysis methodology was developed, including:

- Examination of modern reconstruction technologies and identification of the most effective solutions for the city of Astana.
- Development of a criteria system for evaluating facade systems, incorporating parameters such as material thermal conductivity, mechanical strength, UV resistance, and impact on the architectural appearance of buildings.
- Assessment of the impact of individual factors (e.g., cladding type, insulation thickness, joint sealing) on the overall energy efficiency and operational characteristics of facades.
- Formulation of recommendations for implementing the identified reconstruction methodologies within urban planning programs and construction standards of the Republic of Kazakhstan.

The research hypothesis suggests that the application of multifactor analysis, taking into account the climatic and architectural features of Astana, will enhance the accuracy and justification of design decisions, ensuring durability, energy efficiency, and improved visual characteristics of residential facades.

The relevance of this study is driven by the need to improve urban environmental quality, enhance the energy efficiency of residential buildings, and modernize outdated facades in accordance with contemporary standards. The research is based on an analysis of existing reconstruction practices in countries with similar climatic conditions, including Russia and the northern regions of Europe, with adaptations to the regulatory and technical requirements of Kazakhstan. The obtained results can be utilized for developing facade reconstruction standards aimed at improving the operational characteristics of buildings under the conditions of a sharply continental climate.

LITERATURE REVIEW

The analysis of domestic and international research reveals a significant variety of approaches to facade reconstruction. European publications primarily focus on environmental sustainability and the use of intelligent facade systems that regulate heat exchange and building illumination. Studies conducted in Germany, the United Kingdom, and the Netherlands demonstrate that the use of dynamic facade panels, which adapt to changing weather conditions, can reduce building energy consumption by 20-30% (Soltani, Atashi, 2023).

In countries with cold climates, such as Canada and Finland, the primary emphasis is placed on using facade materials with high thermal resistance, including multilayer insulation systems with a thermal conductivity coefficient of less than 0.035 W/(m·K) (Radić, Dodig, Auer, 2019).

Increasing attention has been paid to the use of structured evaluation frameworks in building renovation studies, particularly in the context of energy-efficient modernization of residential buildings (Radić, Dodig, Auer, 2019; Soltani, Atashi, 2023). Researchers note that facade reconstruction decisions are inherently multi-dimensional, as facade systems simultaneously influence thermal performance, durability, economic efficiency, architectural quality, and indoor comfort conditions.

In this context, multi-criteria decision-making approaches are increasingly applied to support such complex evaluations (Radić, Dodig, Auer, 2019).

For residential buildings located in cold and sharply continental climates, the relevance of integrated evaluation approaches is particularly pronounced (Soltani, Atashi, 2023). Climatic factors such as prolonged heating periods, frequent freeze-thaw cycles, and moisture-related impacts impose increased demands on facade systems, making it necessary to assess reconstruction alternatives from a comprehensive perspective rather than through single-criterion assessments.

These considerations indicate that the application of multifactor evaluation frameworks represents a promising direction for facade reconstruction research. Such approaches complement traditional regulatory and energy-focused studies by providing a structured basis for the comparative analysis of alternative facade systems under severe climatic conditions.

MATERIALS AND METHODS

Multifactor analysis is a comprehensive method for assessing the effectiveness of facade reconstruction, based on a quantitative and qualitative evaluation of multiple influencing factors. The primary objective of this analysis is to determine the prioritization of technical, economic, architectural, and operational characteristics that ensure the durability and energy efficiency of facade systems in the sharply continental climate of Astana.

The study relies on the following methodological principles:

- Systematic approach. Facade reconstruction is considered a multi-level process that includes evaluating the thermal performance of materials, their resistance to climatic factors (frost resistance, water absorption, thermal conductivity), and their impact on building operational costs.

- Hierarchical structure of factors (Figure 1). Key indicators such as energy efficiency levels, the lifespan of cladding materials, resistance to pollution, installation and maintenance costs are identified. For example, ceramic granite cladding has an operational lifespan of over 50 years (GOST R 70573-2022), whereas composite panels may require replacement within 25–30 years under high wind loads.

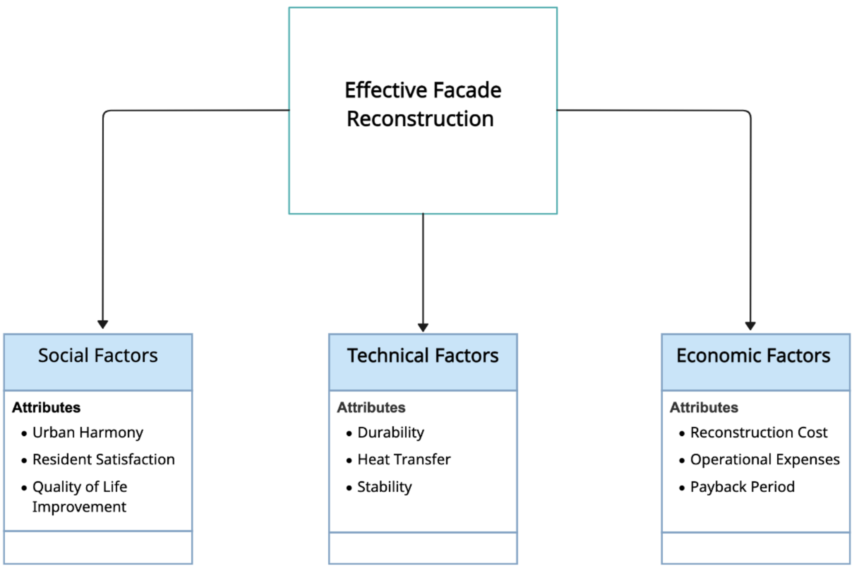

Figure 1. Relationship of factors affecting reconstruction efficiency

Note – compiled by the authors (Baktybayev, 2025)

- Mathematical data processing. To quantitatively assess the impact of various factors, multicriteria analysis methods are applied, including the Analytic Hierarchy Process (AHP) to determine weighting coefficients and establish relationships between selected parameters (Saaty, 1993).

The applied methodology follows a consistent sequence of criteria selection, weighting, and aggregation, which ensures the transparency and reproducibility of the evaluation results for similar residential buildings.

To assess the effectiveness of facade reconstruction, a system of evaluation criteria was developed within a multifactor framework that integrates technical, economic, architectural, and social aspects. Each group of criteria contributes to the overall assessment of reconstruction alternatives.

Technical criteria include material durability, thermal resistance, moisture sensitivity, and resistance to freeze-thaw cycles, which are critical under Astana's sharply continental climate. Material thermal conductivity and frost resistance were considered to reflect the influence of environmental conditions on facade performance.

Economic criteria account for initial reconstruction costs, expected service life of facade systems, and long-term operational efficiency. Architectural criteria address visual quality and the integration of renovated facades into the surrounding urban environment.

The application of this criteria system enables a structured and consistent comparison of alternative facade solutions within the proposed multifactor framework and provides the methodological basis for subsequent analytical evaluation of reconstruction effectiveness.

The decision-making process is formalized using the Analytic Hierarchy Process (AHP). This method decomposes the problem into a hierarchical structure, allowing for the quantification of qualitative criteria through pairwise comparisons.

The model is organized into three levels:

- Goal: Selection of the most effective facade reconstruction strategy.
- Criteria (C_n): The four groups identified (Technical, Economic, Architectural, Social).
- Sub-criteria (S_n): Specific indicators (e.g., $S_{1.1}$ - thermal resistance, $S_{2.1}$ - initial cost).
- Alternatives (A_n): Specific facade systems (e.g., Ventilated facade vs. EIFS).

Pairwise comparisons and weight calculations were performed independently at each hierarchical level of the model.

For each level, a pairwise comparison matrix A is constructed using Saaty's 1-9 scale:

$$A=[a_{ij}]=\begin{pmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{pmatrix}$$

where a_{ij} represents the relative importance of criterion i over criterion j. The local priority weights are derived by calculating the principal eigenvector of the matrix.

To ensure the reliability of expert judgments, the Consistency Ratio (CR) is calculated:

$$CR=\frac{CI}{RI}$$

where $CI=\frac{\lambda_{max}-n}{n-1}$ is the Consistency Index and RI is the Random Index for a matrix of order n. Only results with CR <= 0.10 are considered acceptable for the final synthesis.

The final score for each reconstruction alternative (V_{alt}) is determined by the additive synthesis of local weights:

$$V_{alt}=\sum w_i \times s_i$$

where w_i is the weight of the i-th criterion and s_i is the score of the alternative relative to that criterion.

Pairwise comparisons were performed using Saaty's fundamental 1–9 scale, where higher values indicate stronger relative importance between criteria. Intermediate even values were used when compromise judgments were required. Standard Random Index (RI) values proposed by Saaty were applied for consistency verification.

The selection of evaluation criteria within the proposed multifactor framework was guided by the climatic, regulatory, and operational specificities of residential buildings located in regions with sharply continental climates. Under such conditions, facade systems are exposed to significant thermal gradients, repeated freeze-thaw cycles, and moisture-related impacts, which directly affect their durability and energy performance. Therefore, technical criteria were defined to reflect the ability of facade systems to ensure long-term structural reliability and effective thermal protection. Particular attention was given to thermal resistance, moisture sensitivity, and resistance to freeze-thaw cycles, as these parameters largely determine heat loss levels and the rate of material degradation in cold climates. The prioritization of technical criteria within the model is consistent with national building regulations of the Republic of Kazakhstan (SNiP RK), which emphasize thermal insulation performance and frost resistance as key requirements for building envelopes.

Economic criteria were incorporated to account for practical constraints associated with facade reconstruction projects, including initial investment costs, expected service life, and long-term operational efficiency. In the context of large-scale residential modernization programs, economic feasibility plays a critical role in decision-making, as technically effective solutions must also remain financially justifiable over the building life cycle. Therefore, economic criteria were assigned a significant, though subordinate, weight relative to technical factors.

Architectural criteria address the visual quality and urban integration of reconstructed facades. In dense urban environments, facade modernization influences not only individual buildings but also the overall perception of residential districts. The inclusion of architectural criteria allows the model to capture aspects related to facade composition, material appearance, and compatibility with the existing urban context, which are particularly relevant for renovation projects in established residential areas.

Social criteria were included to reflect the impact of facade reconstruction on indoor comfort and environmental conditions affecting occupants. Improved thermal comfort, reduced air infiltration, and mitigation of moisture-related issues contribute to enhanced living conditions and occupant well-being. Although social factors do not directly determine structural performance, their inclusion ensures a comprehensive evaluation that extends beyond purely technical and economic considerations.

Overall, the selected set of criteria provides a balanced representation of the key factors influencing facade reconstruction effectiveness under Astana's climatic conditions. The adopted classification is consistent with regulatory requirements and ensures practical applicability within the AHP-based decision-making framework.

RESULTS AND DISCUSSION

To demonstrate the application of the proposed multifactor model, quantitative optimization results were obtained through an illustrative evaluation of a typical multi-storey residential building representative of Astana's housing stock and operating under sharply continental climatic conditions. The purpose of this illustrative evaluation is to demonstrate the logical sequence and transparency of the proposed assessment procedure rather than to provide a detailed project-specific solution, thereby facilitating the potential adaptation of the methodology to similar residential buildings.

The weighting procedure reflects the prioritization of criteria that are most influential for facade performance in cold climates, including thermal resistance, material durability, moisture resistance, and long-term operational efficiency. Economic considerations, such as initial investment costs and expected operational savings, were incorporated to ensure practical relevance, while architectural and social criteria were included to account for urban integration and indoor comfort.

By explicitly presenting the weighting structure and final synthesis results, the proposed approach ensures transparency and reproducibility of the decision-making process and enables a consistent comparison of alternative facade reconstruction strategies under Astana's climatic conditions.

Table 1. Pairwise Comparison Matrix for Facade Reconstruction Criteria

Category	Technical	Economic	Architectural	Social	Weight (w_i)
Technical	1	2	3	3	0.45
Economic	1/2	1	2	2	0.25
Architectural	1/3	1/2	1	1	0.15
Social	1/3	1/2	1	1	0.15
Note – compiled by the authors (Baktybayev, 2025)					

The pairwise comparison matrix of the main facade reconstruction evaluation criteria was developed using the Analytic Hierarchy Process (AHP) (Table 1). The relative importance of the criteria was assessed based on expert judgment using Saaty's fundamental 1–9 scale, taking into account the climatic, technical, and operational conditions typical for residential buildings in Astana.

The comparison results indicate the dominant role of technical criteria, which were evaluated as moderately to strongly more important than economic, architectural, and social criteria. This prioritization reflects the critical influence of thermal resistance, durability, and frost resistance on facade performance under sharply continental climatic conditions. Economic criteria were assigned moderate importance, while architectural and social criteria received equal but lower weights, as their impact is primarily indirect in terms of operational efficiency.

The priority vector (w_i) was derived from the normalized principal eigenvector of the comparison matrix, resulting in final weights of 0.45 for technical, 0.25 for economic, and 0.15 for both architectural and social criteria. The consistency of expert judgments was verified, and the consistency ratio satisfied the acceptable threshold (CR ≤ 0.10), confirming the reliability of the weighting procedure.

The obtained weighting structure ensures that the evaluation framework is sensitive to the most critical performance-related parameters of facade systems operating in cold climates and enhances the transparency and reproducibility of the decision-making process.

Table 2. Local and global weights of facade reconstruction evaluation criteria

Category	Weight (w_i)	Sub-criteria	Local weight (s_i)	Global weight ($w_i \cdot s_i$)
Technical	0.45	Thermal resistance (R_0)	0.60	0.27
		Durability and frost resistance	0.40	0.18
Economic	0.25	Initial capital investments	0.70	0.175
		Long-term operational savings	0.30	0.075
Architectural	0.15	Visual quality & urban integration	1.00	0.150
Social	0.15	Indoor thermal comfort	1.00	0.150
Total	1.00		1	1.000
Note – compiled by the authors (Baktybayev, 2025)				

For the Architectural and Social categories, a single representative sub-criterion was considered; therefore, their local weights were set equal to 1.00.

The weighting structure (Table 2) reflects the relative importance of evaluation criteria under the climatic and operational conditions of Astana. The dominant weight assigned to technical criteria (0.45) highlights the critical role of thermal resistance, durability, and frost resistance in facade performance for residential buildings exposed to severe temperature fluctuations. These parameters directly influence heat loss, moisture accumulation, and long-term material degradation, which are key challenges in sharply continental climates.

Economic criteria, assigned a weight of 0.25, represent the necessity to balance technical effectiveness with financial feasibility. While initial investment costs and long-term operational savings are important for decision-making, their influence remains secondary to technical reliability in cold-climate regions. Architectural and social criteria were assigned equal weights (0.15 each), reflecting their complementary role in facade reconstruction projects, where visual integration into the urban environment and improvement of indoor comfort contribute to overall building performance but do not dominate the decision-making process.

This weighting distribution ensures that the proposed multifactor model prioritizes facade solutions capable of delivering long-term thermal reliability and durability, while still accounting for economic constraints and user-oriented considerations. Such an approach reflects the realities of facade reconstruction in cold-climate regions, where insufficient thermal performance can lead to increased operational costs, accelerated material degradation, and reduced service life of building envelopes.

Overall, the adopted weighting structure supports the selection of facade reconstruction solutions that combine technical reliability with acceptable economic performance and qualitative benefits, which is essential for sustainable residential building modernization under Astana’s climatic conditions.

To improve the interpretability of the obtained weighting structure, the relative influence of the main groups of evaluation criteria is illustrated (Figure 2).

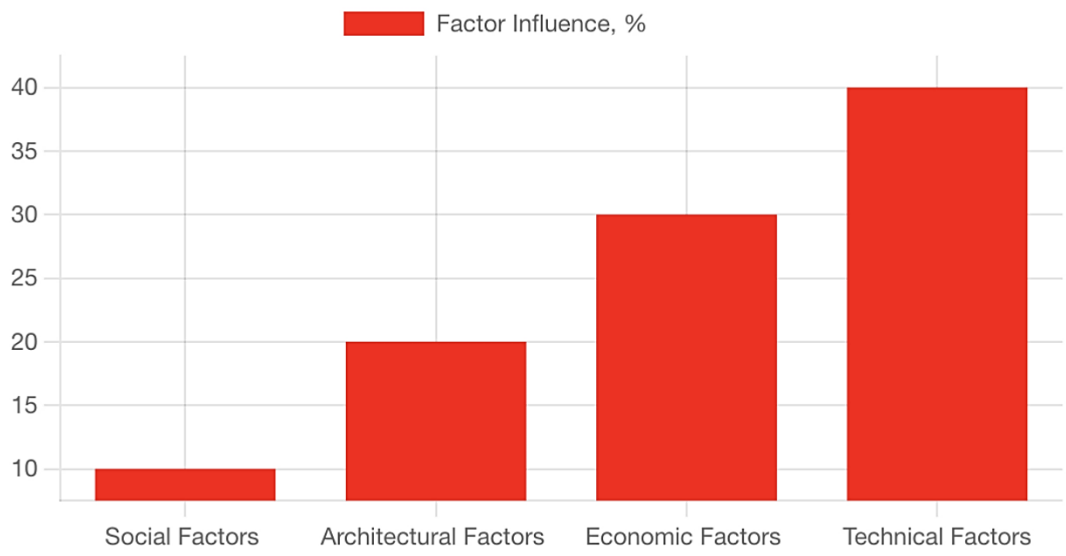

Figure 2. Relative influence of evaluation criteria groups in the multifactor model
Note – compiled by the authors (Baktybayev, 2025)

The distribution of influence among the main evaluation criteria groups within the proposed multifactor framework (Figure 2). The visualization highlights the relative contribution of technical, economic, architectural, and social factors to the overall decision-making process in facade reconstruction projects.

Technical criteria exert the strongest influence on the evaluation outcome. This dominance reflects the critical importance of thermal resistance, durability, and resistance to freeze-thaw cycles for facade systems operating under Astana's sharply continental climate. Economic criteria represent the second most influential group, indicating the necessity of balancing technical effectiveness with financial feasibility, particularly in large-scale residential renovation programs.

Architectural and social criteria demonstrate a lower but complementary influence within the weighting structure. While these factors do not directly determine the physical performance of facade systems, they contribute to the visual integration of reconstructed buildings into the urban environment and to improvements in indoor comfort conditions for occupants.

The weighting structure (Figure 2) confirms the rationality of the adopted multifactor model and supports a balanced decision-making approach that combines technical reliability, economic feasibility, and qualitative performance aspects. The clear distribution of criterion influence enhances the transparency and interpretability of the quantitative results obtained through the AHP-based synthesis.

To further demonstrate the applicability of the proposed model, a comparative evaluation was performed for two common facade reconstruction alternatives:

- Alternative 1 (A1): Ventilated Facade System (Mineral wool insulation).
- Alternative 2 (A2): External Insulation Finishing System (EIFS / "Wet facade")

Table 3. Final Synthesis of Priorities and Ranking of Alternatives

Category	Global Weight	Score A1 (s_{i1})	Score A2 (s_{i2})	Weighted Score A1 ($w_i \times s_{i1}$)	Weighted Score A2 ($w_i \times s_{i2}$)
Technical	0.45	0.90	0.70	0.405	0.315
Economic	0.25	0.60	0.85	0.150	0.212
Architectural	0.15	0.80	0.75	0.120	0.112
Social	0.15	0.85	0.80	0.127	0.120
Final priority	1.00			0.802	0.759
Note – compiled by the authors (Baktybayev, 2025)					

The results of the final synthesis (Table 3) indicate that Alternative A1 (ventilated facade system with mineral wool insulation) achieves a higher integral priority value (0.802) compared to Alternative A2 (EIFS), which scored 0.759. The leading position of A1 is primarily driven by its superior performance in technical criteria, which have the highest global weight in the overall evaluation. Although Alternative A2 demonstrates stronger economic performance, this advantage is insufficient to offset its lower technical effectiveness under Astana's sharply continental climate.

The obtained ranking remains stable under moderate variations of individual criterion weights, indicating the robustness of the proposed multifactor evaluation. This confirms that the preference for Alternative A1 is not driven by a single criterion but results from the combined influence of multiple factors.

The application of the AHP-based multifactor model demonstrates its effectiveness for the quantitative comparison of facade reconstruction alternatives and provides transparent decision support applicable to residential buildings operating under comparable climatic conditions.

The obtained weighting structure reflects compliance with national Building Codes of the Republic of Kazakhstan (SNiP RK) and indicative regional market conditions, reinforcing the practical relevance of the evaluation results.

Despite the demonstrated effectiveness of the proposed AHP-based multifactor framework, several limitations of the study should be acknowledged. First, the evaluation was conducted in an illustrative manner for a typical residential building; therefore, the obtained results reflect generalized performance trends rather than site-specific conditions. Variations in building geometry, construction quality, and operational regimes may affect the relative performance of facade systems in practice.

Second, the weighting structure of the evaluation criteria is inherently dependent on expert judgment. Although the Analytic Hierarchy Process includes consistency verification to ensure logical coherence, the resulting weights may vary when alternative expert groups or decision-makers are involved. This characteristic reflects the contextual nature of facade reconstruction decisions influenced by regional priorities, regulatory requirements, and stakeholder preferences.

Third, the assessment does not explicitly incorporate long-term degradation processes such as material aging, prolonged moisture exposure, or changes in thermal properties over time. While durability and frost resistance were considered within the technical criteria, a more detailed life-cycle-oriented modeling could further enhance the robustness of the evaluation.

The analysis focuses on a limited set of commonly used facade reconstruction alternatives. The inclusion of additional facade technologies, such as hybrid or adaptive systems, could influence the final ranking and provide a broader basis for comparison. These limitations highlight opportunities for further refinement and expansion of the proposed framework rather than undermining its applicability.

CONCLUSION

This study developed and applied a multifactor evaluation framework based on the Analytic Hierarchy Process to assess facade reconstruction alternatives for residential buildings operating under the sharply continental climatic conditions of Astana. The proposed methodology enables a transparent and structured comparison of reconstruction solutions by integrating technical, economic, architectural, and social criteria into a unified decision-making model. Such an approach allows for the systematic consideration of multiple, often competing, factors that influence the long-term performance and feasibility of facade modernization projects.

The results of the final synthesis demonstrate that the ventilated facade system with mineral wool insulation achieved a higher integral priority compared to the External Insulation Finishing System (EIFS). This outcome is primarily driven by the dominant influence of technical criteria, particularly thermal resistance and durability under repeated freeze–thaw cycles, which are critical for facade performance in cold-climate regions. Although the EIFS alternative exhibits advantages in terms of lower initial investment costs, these economic benefits are insufficient to compensate for its comparatively lower technical effectiveness and long-term reliability under severe climatic conditions.

The obtained results confirm that facade reconstruction strategies in Astana should prioritize solutions that combine high thermal reliability, resistance to climatic impacts, and adequate economic performance over the building life cycle. The emphasis on technical robustness is especially important given the long heating season, significant temperature fluctuations, and moisture-related challenges characteristic of the region. At the same time, the inclusion of architectural and social criteria ensures that facade reconstruction decisions contribute not only to energy efficiency but also to improved urban aesthetics and indoor comfort.

The proposed AHP-based multifactor framework demonstrates practical applicability for housing modernization programs and can support informed decision-making at both the design and planning stages. Its flexible structure allows adaptation to local regulatory requirements, material availability, and market conditions, making it suitable for broader application in residential building renovation projects across regions with similar climatic characteristics. By providing a transparent basis for comparing alternative facade solutions, the framework can help reduce the risk of suboptimal technical choices driven solely by short-term economic considerations.

Despite the demonstrated effectiveness of the proposed approach, several limitations should be acknowledged. The evaluation was conducted in an illustrative manner for a typical residential building, which implies that the results reflect generalized performance trends rather than site-specific conditions. In addition, the weighting structure of the criteria depends on expert judgment, which may vary depending on stakeholder priorities and regional contexts. Future research may focus on expanding the set of considered facade systems, incorporating life-cycle assessment indicators related to embodied energy and environmental impact, and integrating digital tools such as Building Information Modeling to enhance the predictive and analytical capabilities of the proposed framework.

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