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TOPSIS-BASED PERFORMANCE ASSESSMENT OF EXTERNAL WALL MASONRY BLOCKS FOR A NET-ZERO ENERGY RESIDENTIAL BUILDING

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Abstract. This article investigates the use of the *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS) method for evaluating the performance of external wall masonry blocks in a net-zero energy residential building. Four alternative masonry blocks (autoclaved aerated concrete block *"Bauroc 200 mm Classic'* (B1)*;* silicate block *"ARKO 180 mm M-18"* (B2)*;* ceramsite block *"5 MPa FIBO 200 mm"* (B3) and ceramic block *"Porotherm" 188 mm 18,8 P+W"*(B4)) were assessed based on six criteria: the design value of the thermal conductivity coefficient (W/(m·K)); the price of the blocks and insulation EPS70N (€/m²); the resistance to freezing/heating (cycles); the compressive strength (MPa); the weight of the wall blocks (kg/m²) and the sound reduction index (dB). The results of the empirical research indicate that the ceramic block "*Porotherm 188 mm 18.8 P+W"* is the most effective wall masonry block for a net-zero energy residential building. This block achieved the highest relative performance score (0.8529). In contrast, the ceramsite block "*5 MPa FIBO 200 mm"* (0.4326 points) and the silicate block "*ARKO 180 mm M-18"* (0.4331 points) were the least effective alternatives among the four tested block types.
Keywords: external wall; masonry block; net-zero energy residential building; TOPSIS method

INTRODUCTION

Buildings account for 40% of final energy consumption in the European Union (EU) and 36% of its energy-related greenhouse gas emissions, while 75% of EU buildings remain energy-inefficient. Regulation (EU) 2021/1119 of the European Parliament enshrines the target of economy-wide climate neutrality by 2050 into EU law and establishes a binding EU domestic reduction commitment to lower net greenhouse gas emissions by at least 55% below 1990 levels by 2030 (Regulation (EU) 2024/1275).

The new Directive (EU) 2024/1275 defines two concepts of buildings: "nearly zero-energy" and "zero-emission" buildings. In Lithuania, net-zero energy (or "nearly zero-energy") buildings are required to meet the standards of A++ class buildings, as specified in the technical construction regulation STR 2.01.02:2016 (Aviža, 2023).

Extensive scientific research on nearly zero-energy buildings is available in the literature (Lu, et al. 2024; Bliūdžius, et al. 2024; Makhloufi, et al. 2024; Wu, et al. 2021 and others). Despite the availability of data on various aspects of nearly zero-energy buildings, there is a lack of information regarding their external wall masonry blocks performance assessment across multiple criteria for residential buildings. As a result, this paper will examine typical exterior wall blocks for a net-zero energy (A++ class) residential building in more detail. After conducting a TOPSIS empirical analysis, the most effective external wall masonry block alternative will be determined.

The goal of this paper is: to assess the TOPSIS-based performance of external wall masonry blocks for net-zero energy residential buildings in Lithuania.

The objectives of this study are:

1. to investigate the application of the TOPSIS method in Multi-Criteria Decision-Making context.
2. to construct a research model based on a typical exterior wall detail (*Rendered Façade*) for a net-zero energy (A++ class) residential building in Lithuania.
3. to conduct a multi-criteria assessment of the effectiveness of four different external wall masonry blocks based on six criteria.

Research methods: review of technical and scientific literature; empirical analysis; TOPSIS application.

THE TOPSIS METHOD

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), created by Yoon and Hwang in 1981, operates by determining the relative proximity of each alternative option to the optimal solution using Euclidean distance. TOPSIS is a popular method for multi-criteria decision-making (MCDM) applications due to its simplicity and computational efficiency (Jong et al. 2024). Other researchers (Kraujalienė, 2019, A. Podviezko & V. Podvezko, 2014) have examined the advantages and disadvantages of the TOPSIS application (Table 1).

Table 1

Advantages and disadvantages of the TOPSIS method (Kraujalienė, 2019)

No	Advantages	Disadvantages
1	This absolute evaluation tool, which is not requiring transformation to minimize the variables; the data transformation is not perverted.	The application of Euclidean Distance does not look to the correlation of the attributes.
2	The TOPSIS method is allowing to interpret the absolute evaluation of certain alternative, its deviation magnitude assessing the results starting from the best and the worst average alternatives.	In this tool is quite difficult to weight and also keep the consistency of judgment, particularly with additional attributes.
3	This tool is providing the possibility of the most stable performance results in case the input data is varying.	
4	The research of developing hypothetical worst and best objects is suitable for certain tasks are worth to be started in many areas, where quantitative evaluation is needed.	
5	The TOPSIS is based on the simple process; it is programmable and easy to apply.	
6	The TOPSIS method is easy in terms of maintaining the same number of steps in regard to the size of the problem.	
7	The TOPSIS tool is widely in use for areas like logistics, manufacturing systems and engineering, environmental management, marketing management, design, business, water and human resources management.	

The seven-step process of TOPSIS is well-defined and easy to comprehend, making it a widely used tool in decision-making (Jong et al. 2024). The core concept of this technique is that the chosen alternative should have the smallest geometrical distance from the positive solution (PIS) and the largest geometrical distance from the negative ideal solution (NIS). Nowadays this technique used in different fields of life such as energy, medicine engineering and manufacturing systems, safety and environmental fields, chemical engineering and water resources studies (Zulqarnain et al. 2020).

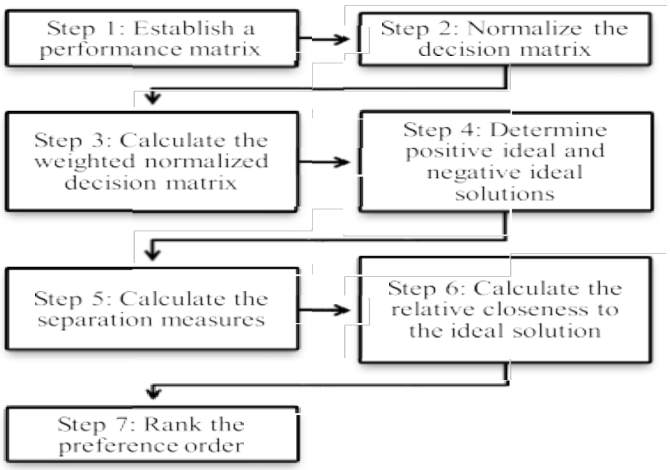

Figure 1. **The TOPSIS algorithm (Jong et al. 2024)**

The TOPSIS algorithm follows the seven steps illustrated in Fig. 1 (Jong et al. 2024).

THE RESEARCH MODEL

The research model was created by using a typical external wall (*Rendered Facade* (ETICs)) detail of an A++ class residential building in Lithuania. The tested layer – no 1 (Figure 2).

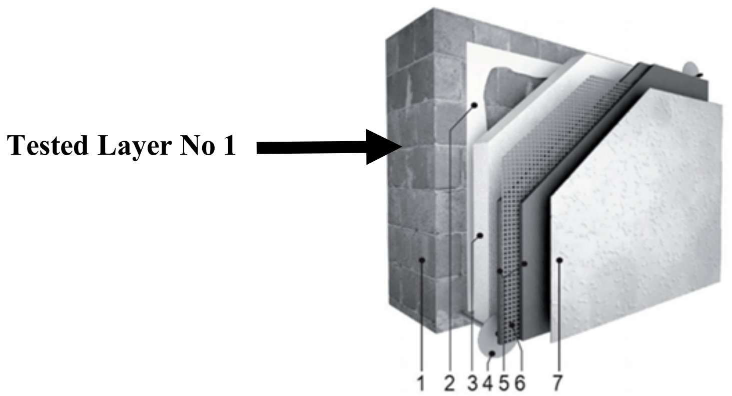

Figure 2. **The research model – external wall detail of an A++ class residential building (for the explanation of layers, see Table 2). Source: ST 2124555837.01:2021**

Following the Technical Regulations of Construction STR 2.01.02:2016, were calculated: a) the required heat transfer coefficient of an A++ class residential wall, U=0.11 W/m²K and b) the thickness of EPS70N thermal insulation material.

Table 2

The External Wall Layers

No	Name of the layer	Thickness, mm
1-2	Wall Masonry Blocks + Adhesive mortar (5 mm)	180-200
3	Expanded polystyrene (EPS70N) foam λ_{dec}=0,032; 64,89 €/m³	270-300
4	Anchor with plastic nail	-
5	Adhesive mortar coated with masonry sealer	5
6	Reinforcing mesh	
7	Decorative coat	

In this study, four different wall masonry blocks were tested: autoclaved aerated concrete block "*Bauroc 200 mm Classic*" (B1), silicate block "*ARKO 180 mm M-18*" (B2), ceramsite block "*5 MPa FIBO 200 mm*" (B3), and ceramic block "*Porotherm 188 mm 18.8 P+W*" (B4).

The TOPSIS (*Technique for Order Preference by Similarity to Ideal Solution*) method was selected for the multi-criteria assessment of the effectiveness of these four masonry blocks based on six criteria.

THE RESEARCH METHODOLOGY AND OUTCOMES

In the first TOPSIS-based performance evaluation step, a primary decision-making matrix (Table 3) is compiled, and four different wall masonry blocks – autoclaved aerated concrete block (B1), silicate block (B2), ceramsite block (B3), and ceramic block (B4) – are evaluated against six criteria extracted from the technical specifications: resistance to freezing/heating (cycles), compressive strength (MPa), weight of wall blocks (kg/m²), sound reduction index (dB), the price of the blocks and EPS70N insulation (€/m²) (Q4 2024). The design value of thermal conductivity coefficient (W/(m·K)) has been taken from the technical construction regulation (STR 2.01.02:2016), as some manufacturers declare inappropriate coefficient values for the energy performance assessment. The significance of all attributes is assumed to be equal (0.17).

Table 3

Primary Decision-making Matrix

Tested alternatives/ Significances	Attributes					
	The design value of thermal conductivity coefficient (A1), W/(m·K)	*The price (Q4 2024) of the blocks and insulation EPS70N (A2), €/m²*	*The resistance to freezing/ heating (A3), cycles*	*The compressive strength (A4), MPa*	*The weight of wall blocks (A5), kg/m²*	*The sound reduction index (A6), Db*
Autoclaved aerated concrete block (B1)	0.23	27.23	35	3	93.50	43
Silicate block (B2)	0.90	27.14	50	15	252.84	53
Ceramsite block (B3)	0.60	25.89	50	5	150.00	49

Tested alternatives/ Significances	Attributes					
	The design value of thermal conductivity coefficient (A1), W/(m·K)	*The price (Q4 2024) of the blocks and insulation EPS70N (A2), €/m²*	*The resistance to freezing/ heating (A3), cycles*	*The compressive strength (A4), MPa*	*The weight of wall blocks (A5), kg/m²*	*The sound reduction index (A6), Db*
Ceramic block (B4)	0.25	24.14	50	15	144.00	51
Significance	0.17	0.17	0.17	0.17	0.17	0.17

In the next step, the primary decision-making matrix is normalized (Table 4).

Table 4

Normalized decision-making matrix

Tested alternatives	Attributes					
	A1	*A2*	*A3*	*A4*	*A5*	*A6*
Autoclaved aerated concrete block (B1)	0.203	0.521	0.375	0.136	0.275	0.438
Silicate block (B2)	0.794	0.519	0.535	0.682	0.743	0.539
Ceramsite block (B3)	0.529	0.495	0.535	0.227	0.441	0.499
Ceramic block (B4)	0.221	0.462	0.535	0.682	0.423	0.519

The weighted normalized decision matrix is computed in the next step (Table 5).

Table 5

Weighted normalized decision matrix

Tested alternatives	Attributes					
	A1	*A2*	*A3*	*A4*	*A5*	*A6*
Autoclaved aerated concrete block (B1)	0.084	0.147	0.149	0.167	0.162	0.023
Silicate block (B2)	0.084	0.167	0.167	0.124	0.167	0.039
Ceramsite block (B3)	0.167	0.158	0.158	0.086	0.139	0.167
Ceramic block (B4)	0.017	0.134	0.135	0.099	0.083	0.039
Min./Max.	Min.	Min.	Max.	Max.	Min.	Max.

In the final steps, the PIS and NIS were determined and calculated: Separation Distance from PIS and NIS for each alternative, Relative Closeness to the Ideal Solution, and Ranking of Preference Order (Table 6).

Table 6

Ranking alternatives

Tested alternatives	Relative Closeness to the Ideal Solution, in scores	Ranking of Preference Order
Autoclaved aerated concrete block (B1)	0.5649	2
Silicate block (B2)	0.4331	3
Ceramsite block (B3)	0.4326	4
Ceramic block (B4)	0.8529	1

After completing the multi-criteria TOPSIS-based evaluation, the efficiency scores were calculated for each wall masonry block (Figure 2).

The empirical analysis unveils that, for a net-zero energy (A++ class) residential building, the most effective external wall masonry block is the Ceramic block (B4), while the least effective is the Ceramsite block (B3), with a relative efficiency score of 0.4326 points.

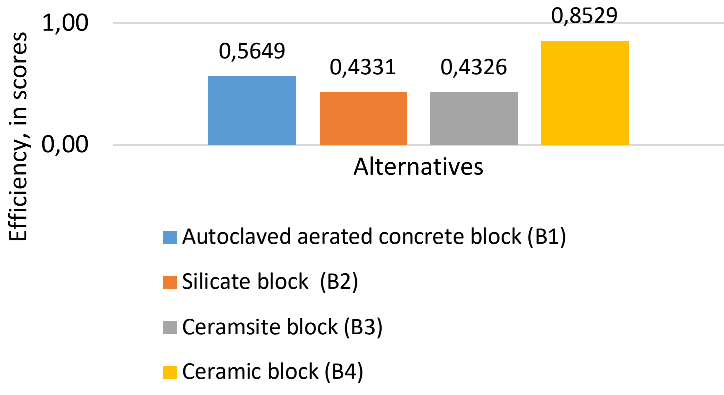

Figure 2. **The assessment of the efficiency of the wall masonry blocks**

CONCLUSIONS

1. It was revealed by using the TOPSIS method that the most effective external wall masonry block for a net-zero energy (A++ class) residential building (considering four block alternatives and six criteria) is the Ceramic block "*Porotherm 188 18.8 P+W*" (B4). This alternative achieved the highest relative efficiency score of 0.8529 points.
2. The second most effective option is the autoclaved aerated concrete block "*Bauroc 200 Classic*" (B2), which scored 0.5649 relative efficiency points.
3. The least effective alternatives (out of the four tested) are the Ceramsite block "*5 MPa FIBO 200*" (0.4326 points) and the Silicate block "*ARKO 180 M-18*" (0.4331 points). The relative difference in efficiency between the best and worst alternatives is 49.28%.
4. If ceramic blocks are selected for future projects (A++ class), a total savings of 11.35% could be achieved on the cost of the blocks and their insulating materials.

REFERENCES

Aviža, D. (2023). Evaluation of the thermal insulation performance of the ground floor of an A++ class public building using the SAW method. Taikomieji tyrimai studijose ir praktikoje - Applied Research in Studies and Practice, 19(1), 39-44. https://ojs.panko.lt/index.php/ARSP/article/view/202.

Bliūdžius, R. et al. (2024). Analysis of Improvement in the Energy Efficiency of Office Buildings Based on Energy Performance Certificates. Buildings, 14, 2791. DOI: https://doi.org/10.3390/buildings14092791.

Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings. European Parliament, 2024.

Jong, F. C. et al. (2024). Multi-Criteria Decision-Making Solutions for Optimal Solar Energy Sites Identification: A Systematic Review and Analysis. IEEE Access, 12(99). DIO: https:// 10.1109/ACCESS.2024.3461948.

Kraujalienė, L. (2019). Comparative analysis of multicriteria decision-making methods evaluating the efficiency of technology transfer. Business, Management and Education, 17, 72-93. DOI: https://doi.org/10.3846/bme.2019.11014.

Lu, M. et al. (2024). Multi-objective design optimization of multiple energy systems in net/ nearly zero energy buildings under uncertainty correlations. Applied Energy, 370, 123620. DOI: https://doi.org/10.1016/j.apenergy.2024.123620.

Makhloufi, A. W. et al. (2024). Optimising building performance for a resilient Future: A Multi-Objective approach to Net Zero energy strategies. Energy & Buildings, 324, 114869. DOI: https://doi.org/10.1016/j.enbuild.2024.114869.

Podviezko, A., & Podvezko, V. (2014). Absolute and relative evaluation of socio-economic objects based on multiple criteria decision making methods. Engineering Economics, 25(5), 522-529. https://doi.org/10.5755/j01.ee.25.5.6624.

ST 2124555837.01:2021 – Insulation of buildings with EPS. Construction regulation. Vilnius, 2021.

Technical construction regulation STR 2.01.02:2016. Design and certification of energy performance of buildings. Vilnius: Ministry of Environment of the Republic of Lithuania, 2024.

Wu, W. et al. (2021). Residential net-zero energy buildings: Review and perspective. Renewable and Sustainable Energy Reviews, 142, 110859. DOI: https://doi.org/10.1016/j.rser.2021.110859.

Zulqarnain, R. M. et al. (2020). Application of TOPSIS Method for Decision Making. International Journal of Scientific Research in Mathematical and Statistical Sciences, 7(2), 76–81. https://www.researchgate.net/publication/342347772.