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Ranking Heating Losses in a Building by Applying the MULTIMOORA

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Nowadays everyone likes a nation or a company until it tries to reduce energy losses in heating. This paper proposes the project to study energy losses in heating a building. Investigations and heating losses calculations were made and methods selected to optimize the results. These methods concern MOORA (Multi-Objective Optimization by Ratio analysis) and MULTIMOORA (MOORA plus Full Multiplicative Form). Starting with a matrix of alternative responses on the objectives, three approaches come to an unambiguous result.

Keywords: *windows, walls, objectives, alternatives, MOORA method, MULTIMOORA method.*

Introduction

Heating energy consumption in a building depends on climate, energy resources acquisition price, environmental requirements and construction design traditions. Investigations and calculations about heating energy losses in a building presented the results with different significance values and dimensions. To select an optimal alternative having different objectives and attributes with difference values and dimensions the multi-objective optimization methods: MOORA (Multi-Objective Optimization by Ratio analysis) and MULTIMOORA (MOORA plus Full Multiplicative Form) were used.

Using multi-objective optimization methods all usable objectives must be measurable, even if the measurement is performed only at the nominal scale (present/absent; yes/no) and their outcomes must be measured for every decision alternative. Objective outcomes provide the basis for a comparison of the alternatives and consequently facilitate the selection. Therefore, multi-objective techniques seem to be an appropriate tool for ranking or selecting one or more alternatives from a set of the available options based on multiple, sometimes conflicting, objectives. A large number of methods have been developed for solving multi-objective problems (Kaplinski and Tamosaitiene 2010; Peldschus *et al.* 2010; Peldschus 2008; Zavadskas *et al.* 2010; Jakimavicius and Burinskiene 2009a, b; Hui *et al.* 2009; Liaudanskiene *et al.* 2009; Liu 2009; Plebankiewicz. 2009; Ulubeyli and Kazaz. 2009; Turskis *et al.* 2009; Selih *et al.* 2008; Zavadskas and Vaidogas 2008). Multi-objective optimization frameworks vary from simple approaches, requiring very little information, to the methods based on mathematical programming techniques, requiring extensive information on each objective and the preferences of stakeholders.

Multi-objective optimization by ratio analysis (MOORA) composed of two methods: ratio analysis and reference point theory, starting from the previous found ratios responds to the seven conditions from Brauers and Zavadskas in 2010. If MOORA is joined with a full multiplicative form for multiple objectives, a total of three methods are joined under the name of MULTIMOORA. In addition, if MULTIMOORA is associated with the Ameliorated Nominal Group Technique and with Delphi, the most robust approach exists for multi-objective optimization up to now (Brauers and Zavadskas. 2010).

MOORA method

MOORA was launched by Brauers and Zavadskas for the first time in 2006. The method starts with a matrix of responses of different alternatives on different objectives:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

where: x_{ij} - the response of alternative *j* on objective or attribute *i*; *i= 1, 2,… , n* - is the number of objectives; *j= 1, 2,… , m* - is the number of alternatives.

With internal normalization, MOORA method does not use weights of objective or attribute (*i)*. The MOORA method consists of two components: the ratio system and the reference point approach (Brauers and Zavadskas 2009).

The ratio System part of MOORA

In the ratio system, initial data of an alternative on an objective are internally normalized. Each response of an alternative on an objective is compared to a denominator which is a representative for all alternatives concerning that objective. The denominator consists of the square root of the sum of squares of each alternative per objective (Van Delft and Nijkamp 1977).

$$\bar{x}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^{2}}} \quad (2)$$

with: x_{ij} - response of alternative *j* on objective *i; j = 1, 2, ..., m; m* the number of alternatives; *i = 1, 2, ..., n; n* - is the number of objectives; $\overline{x}_{ij}$ - a dimensionless number representing the normalized response of alternative *j* on objective *i*.

The ratio system gets dimensionless numbers and in this way has no specific unit of measurement. The normalized response of the alternatives on the objectives belongs to the interval [0; 1]. However, sometimes the interval could be [-1; 1] indeed, for instance, in the case of productivity the growth of some sector, regions or countries may show decrease instead of increase in productivity i.e. a negative dimensionless number (Brauers *et al.* 2008).

For optimization, these responses are added in the case of maximization and subtracted in case of minimization:

$$\overline{y}_j = \sum_{i=1}^{i=g} \overline{x}_{ij} - \sum_{i=g+1}^{i=n} \overline{x}_{ij}, \tag{3}$$

where: *i=1, 2, ..., g* as the objectives to be maximized; *i= g + 1, g + 2, ..., n* as the objectives to be minimized; $\overline{y}_j$ as the normalized assessment of alternative *j* with respect to all objectives.

An ordinal ranking of $\overline{y}_j$ shows the final preference.

The reference point part of MOORA

Reference point theory is based on the ratios found in formula (2) whereby a maximal objective reference point is also deduced. The maximal objective reference point approach is called as realistic and non-subjective when the coordinates (r_i) selected for the reference point are realized in one of the candidate alternatives.

Given the dimensionless number representing the normalized response of alternative *j* on objective *i*, i.e. $\overline{x}_{ij}$ in formula (2), we come to the matrix:

$$\left(r_i - \overline{x}_{ij}\right) \tag{4}$$

where: *i = 1, 2, ..., n* as the attributes; *j = 1, 2, ..., m* as the alternatives; r_i - the i^{th} coordinate of the reference point; $\overline{x}_{ij}$ - the normalized attribute *i* of alternative *j;*

This matrix is subject to the min- max metric of Tchebycheff (Karlin & Studden, 1966):

$$\min_{(j)} \left\{ \max_{(i)} \left| r_i - \overline{x_{ij}} \right|_{(i)} \right\} \tag{5}$$

with: $\left| r_i - \overline{x_{ij}} \right|$ the absolute value if $\overline{x}_{ij}$ is larger than r_i for instance by minimization. The min-max metric is the best choice between all the possible metrics of reference point theory (Brauers & Zavadskas 2006).

The Full Multiplicative Form for Multi-Objectives

Besides additive utilities, a utility function may also include a multiplication of the attributes. The two dimensional *u(y,z)* can then be expressed as a multi-linear utility function (Keeney and Raiffa 1993):

$$u(y,z)= k_y u_y(y)+ k_z u_z(z)+ k_{yz} u_y(y) u_z(z). \tag{6}$$

If $k_{yz} = 0,$ we return to the additive form. For Keeney the additive form is rather a limiting case of the multiplicative utility function (Keeney and Raiffa 1993).

If $k_{yz} \neq 0,$ then the utility function possess a multiplicative part:

If $k_{yz} > 0,$ then mutual influence is positive,

If $k_{yz} < 0,$ then the mutual influence has a negative effect on the utility function.

This representation mixes additive and multiplicative parts. It is not related to a multiplicative utility function nor to a product form, but to a bilinear representation of the form: $\sum_r \sum_s a_{rs} x_r y_s$. Indeed this representation is bilinear and not purely multiplicative: "since two sets of variables are involved and each appears in a linear way… and constant coefficients can be added to make the forms completely general" (Allen 1957).

The danger exists that the multiplicative part becomes explosive. The multiplicative part of the equation would then dominate over the additive part and finally would bias the results. It could happen if the factors are larger than 1, unless the weights for the multiplicative part are extremely low.

The Multiplicative form for multi-objectives was introduced by Miller and Star in 1969. It is nonlinear, non-additive and does not use weights.

The following n- power form for multi-objectives since now is called Miller and Star full- multiplicative form in order to distinguish it from the mixed forms:

$$U_j = \prod_{i-1}^{n} x_{ij}, \tag{7}$$

where: *j = 1, 2, ...,m; m* the number of alternatives; *i = 1, 2, ...,n; n* the number of objectives; x_{ij} - the response of alternative *j* on objective *i*; U_j – the overall utility of alternative *j*.

The overall utilities (U_j), obtained by multiplication of difference units of measurement, become dimensionless.

Stressing the importance of an objective can be done by adding an *α* - term or by allocating an exponent (a Significance Coefficient) on condition that this is done with unanimity or at least with a strong convergence in opinion of all the stakeholders concerned.

How is it possible to combine a minimization problem with the maximization of other objectives? Therefore, the objectives to be minimized are denominators in the formula:

$$U'_j = \frac{A_j}{B_j}, \tag{8}$$

With: $A_j = \prod_{g=1}^{i} x_{gi},$ *j = 1, 2... m; m* the number of alternatives; *i* - the number of objectives to be maximized;

With: $B_j = \prod_{k=i+1}^{n} x_{kj}$, *n-i* - the number of objectives to be minimized;

With: U'_j : the utility of alternative *j* with objectives to be maximized and objectives to be minimized. Following mathematical logic in the Full Multiplicative Form multiplication and division are harmoniously linked to each other, like addition and subtraction in the ratio system (see formula 3).

MULTIMOORA

MULTIMOORA is the further sequence of the MOORA method and of the full multiplicative form of multiple-objectives. MULTIMOORA was introduced by Brauers and Zavadskas for the first time at the beginning of 2010. MULTIMOORA becomes the most robust system of multiple optimizations under condition of support from the ameliorated nominal group technique and Delphi (Brauers and Zavadskas 2010).

Selection of the effective building windows and external walls design alternatives using multi-objective decision-making methods

The main building purpose is to create good living conditions, which means better life quality. One of the most qualitative aspects of living in a building is having it warm. In order to have it warm, the basic building design must comply with certain requirements (Juodis *et al.* 2009; Pasanisi & Ojalvo 2008). Basic building design such as external walls, roof, ground level floor and windows have a special role in the building construction. These elements can involve the construction of heating and cooling systems for different seasons. Their design requires much special scientific knowledge (Wang *et al.* 2009; Sobotka & Rolak 2009; Jurelionis and Isevicius 2008; Chen *et al.* 2008). Nearly half of all heating losses in a building is caused by external walls and windows (Pupeikis *et al.* 2010; Zukowski & Gajda 2009; Ekici and Aksoy 2008; Zavadskas *et al.* 2008; Ginevicius *et al.* 2008). Therefore, it is very important to select and adapt external walls and windows in a building. However external walls and window selections do not guarantee the reduction of the total building heat losses reduction. There are more other elements which affect heat losses (Samarin *et al.* 2007, 2009; Seduikyte & Paukstys 2008). Only comprehensive assessment of the responsible elements can greatly reduce heat loss, particularly in buildings refurbishments (Mickaityte *et al.* 2008; Martinaitis *et al.* 2007).

The aim of this investigation is to create a technique for the choice and selection of external walls and windows for a building by the use of multi-objective decision-making methods like MOORA and MULTIMOORA.

Alternatives for external walls and windows are being formed by using various windows measurements but with the same heat transfer coefficient. Heating energy losses and inflows were calculated using formulas from technical construction regulation (STR.2.05.01:2005).

A case study considers six possible alternatives of external walls and windows ratio in Table 1.

Table 1

External walls and windows quantity (m²) in the building according to the point of compass

	Alternatives (m²)											
	A₁		***A₂***		***A₃***		***A₄***		***A₅***		***A₆***	
	walls	windows	walls	windows	walls	windows	walls	windows	walls	windows	walls	windows
South	119.36	31.35	149.51	1.20	144.11	6.60	106.31	44.40	136.46	14.25	145.31	5.40
West	54.88	6.72	58.60	3.00	57.88	3.72	50.63	10.97	54.88	6.72	55.60	6.00
North	82.01	6.00	86.21	1.80	83.21	4.80	74.76	13.25	82.01	6.00	83.81	4.20
East	52.40	10.68	59.48	3.60	56.66	6.42	45.15	17.93	56.00	7.08	59.00	4.08
Total:	308.65	54.75	353.80	9.60	341.86	21.54	276.85	86.55	329.35	34.05	343.72	19.68

Each alternative provided in table 2, is described by seven objectives:

1) Heat losses through the building external walls- x_1 [kWh/m²*year];
2) Heat losses through the building windows- x_2 [kWh/m² per year];
3) Heat losses through the bearer thermal bridges- x_3 [kWh/m² per year];
4) Heat losses through above the rated air infiltration- x_4 [kWh/m² per year];
5) External heat inflows in the building- x_5 [kWh/m² per year];
6) Total heat consumption – x_6 [kWh/m² per year];
7) External walls and windows price ratio- x_7 [10³ LTL].

Objectives witch define heat losses in a building are minimizes, heat inflows and price ratio in a building are maximize. Whereas the relative window square meter is more expensive than the wall square meters, the cost is maximized, to reduce the cost of building construction.

Final evaluations are shown in tables, accordingly: table 2c represents the results of the ratio system, table 2e represents the results of reference point, and table 3 represents the results of the MULTIMOORA method.

Table 2

The ratio system (2a until 2c) and the reference point (2d until 2e) approach as a part of MOORA

2a. Matrix of responses of alternatives on objectives: (x_{ij})

	x_1	x_2	x_3	x_4	x_5	x_6	x_7
	min	min	min	min	max	Min	max
A_1	33.95	23.78	11.45	39.97	29.44	167.1	3.852
A_2	38.9	4.17	6.32	0.01	4.29	132.52	25.184
A_3	37.59	9.36	8.23	4.35	10.22	136.71	10.845
A_4	30.44	37.59	13.91	74.08	45.1	198.34	2.186
A_5	36.21	14.79	9.17	17.77	17.06	148.3	6.610
A_6	37.8	8.55	7.97	2.35	9.25	134.83	11.935

2b. Sum of squares and their square roots

	x_1	x_2	x_3	x_4	x_5	x_6	x_7
A_1	1152.603	565.488	131.103	1597.601	866.714	27922.410	14.840
A_2	1513.210	17.389	39.942	0.0001	18.404	17561.550	634.218
A_3	1413.008	87.610	67.733	18.923	104.448	18689.624	117.617
A_4	926.594	1413.008	193.488	5487.846	2034.010	39338.756	4.778
A_5	1311.164	218.744	84.089	315.773	291.044	21992.890	43.686
A_6	1428.840	73.103	63.521	5.523	85.563	18179.129	142.438
Sum of squares.	7745.418	2375.342	579.876	7425.665	3400.182	143684.36	957.576
Square roots	88.008	48.737	24.081	86.172	58.311	379.057	30.945

2c. Objectives divided by their square roots and MOORA

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	total	rank
A_1	0.3858	0.4879	0.4755	0.4638	0.5049	0.4408	0.1245	-1.6245	**5**
A_2	0.4420	0.0856	0.2625	0.0001	0.0736	0.3496	0.8138	-0.2522	**1**
A_3	0.4271	0.1920	0.3418	0.0505	0.1753	0.3607	0.3505	-0.8463	**3**
A_4	0.3459	0.7713	0.5776	0.8597	0.7734	0.5232	0.0706	-2.2336	**6**
A_5	0.4114	0.3035	0.3808	0.2062	0.2926	0.3912	0.2136	-1.1870	**4**
A_6	0.4295	0.1754	0.3310	0.0273	0.1586	0.3557	0.3857	-0.7746	**2**

2d. Reference point theory with ratios: coordinates of the reference point equal to the maximal objective values

	x_1	x_2	x_3	x_4	x_5	x_6	x_7
r_i	0.3459	0.0856	0.2625	0.0001	0.7734	0.3496	0.8138

2e. Reference point theory: deviations from the reference point

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	max	Rank min
A_1	0.0399	0.4024	0.2130	0.4638	0.2686	0.0912	0.6893	0.6893	**4**
A_2	0.0961	0.0000	0.0000	0.0001	0.6999	0.0000	0.0000	0.6999	**5**
A_3	0.0812	0.1065	0.0793	0.0505	0.5982	0.0111	0.4634	0.5982	**1**
A_4	0.0000	0.6857	0.3152	0.8597	0.0000	0.1736	0.7432	0.8597	**6**
A_5	0.0656	0.2179	0.1184	0.2062	0.4809	0.0416	0.6002	0.6002	**2**
A_6	0.0836	0.0899	0.0685	0.0273	0.6148	0.0061	0.4281	0.6148	**3**

Table 3

The full Multiplicative Form

	1	2	2.1	3	3.1	4	4.1	5	5.1
	min	min	2.1=1:2	min	3.1=2.1:3	min	4.1=3.1:4	max	5.1=4.1·5
A_1	33.95	23.78	1.42767	11.45	0.124687	39.97	0.0031195	29.44	0.091839
A_2	38.9	4.17	9.328537	6.32	1.476034	0.001	1476.0344	4.29	6332.187
A_3	37.59	9.36	4.016026	8.23	0.487974	4.35	0.1121779	10.22	1.146458
A_4	30.44	37.59	0.80979	13.91	0.058216	74.08	0.0007859	45.1	0.035442
A_5	36.21	14.79	2.448276	9.17	0.266988	17.77	0.0150246	17.06	0.25632
A_6	37.8	8.55	4.421053	7.97	0.554712	2.35	0.2360476	9.25	2.18344

6	6.1	7	7.1	8	9
min	6.1=5.1:6	max	7.1=6.1·7	Result	Project
167.1	0.00055	3.852	0.002117	**5**	A_1
132.52	47.78288	25.184	1203.364	**1**	A_2
136.71	0.008386	10.845	0.090947	**3**	A_3
198.34	0.000179	2.186	0.000391	**6**	A_4
148.3	0.001728	6.610	0.011425	**4**	A_5
134.83	0.016194	11.935	0.193276	**2**	A_6

Calculation results

MOORA and MULTIMOORA optimization technique with discrete alternatives was used for ranking alternatives in the case study. Three results were totally got: MOORA ratio system, MOORA reference point and MULTIMOORA. Final calculation results are shown in Table 4.

Table 4

MULTIMOORA as a consequence of the MOORA method and of the Full Multiplicative Form

	MOORA Ratio system	MOORA Reference point Tchebycheff	**Full Multiplicative Form**	**MULTIMOORA**
A_1	5	4	**5**	**5**
A_2	1	5	**1**	**1**
A_3	3	1	**3**	**3**
A_4	6	6	**6**	**6**
A_5	4	2	**4**	**4**
A_6	2	3	**2**	**2**

The ratio system calculation results concerned best scores A_2, A_6, and A_3. The reference point calculation results concerned best scores A_3, A_5, and A_6. MULTIMOORA calculation results concerned best scores A_2, A_6, and A_3. The ultimate preference using the thirst MOORA component, the ratio system, and MULTIMOORA is well pronounced and is variant A_2. (Building external walls total area is 353.80 m^2; building windows total area is 9.60 m^2). The study proposes second best scores under the form of either variant A_6 (Building external wall total area: 343.72 m^2, building windows total area: 19.68 m^2) or A_3 (Building external wall total area: 341.86 m^2, building windows total area: 21.54 m^2). Value deviations of A_1, A_4 and A_5 are considered too big for the decision makers these alternatives have been rejected.

Conclusions

For Multi-Objective Optimization MULTIMOORA is a Synthesis of three Approaches: ratio system, reference point method based on the obtained ratios and the full multiplicative method. The methods bring cardinal utilities implying a final ordinal preference.

The case study using Multi-Objective Optimization methods concerned an effective selection between six walls and windows ratios for a building

Applying above mentioned methods proved that the best alternative was external wall total area is 353.80 m^2 and windows total area 9.60 m^2. The worst solution is constructing dwelling house with windows measurements (total area: 86.55 m^2).

It can be concluded that multi-objective analysis in construction is necessary. The selection of the best alternative cannot be based on a single objective. The case study using MOORA and MULTIMOORA methods proved that the proposed theoretical model was effective in a real life situation and could be successfully applied to solving similar utility problems and not only in construction.

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Pastato šilumos nuostolių skaičiavimas taikant daugiakriterį MULTIMOORA metodą

Santrauka

Šildymo energijos vartojimas pastate priklauso nuo klimato sąlygų, energijos išteklių ir jų galimybių įsigijimo kainos, aplinkosaugos reikalavimų ir statybos projektavimo tradicijų. Kriterijai: lauko klimato sąlygos, energijos išteklių kaina ar aplinkosaugos reikalavimai, negali daryti įtakos greitos ar apskritai įtakos. Tačiau statybos projektavimo kriterijus gali daryti įtaką projektuojant, net nekeičiant statybos techninių reikalavimų ar direktyvų. Atliekant šiluminės energijos nuostolių tyrinėjimus ir skaičiavimus pastate, buvo gauti skirtingų reikšmių ir matavimo vienetų rezultatai. Išrinkti optimalų rezultatą turint skirtingus rodiklius ir septynis skirtingus kriterijus, pakankamai sunku. Taigi tolesniam skaičiavimui pasirinkti daugiakriteriai sprendimo priėmimo metodai MOORA ir MULTIMOORA.

Daugiatikslis sprendimo priėmimas yra apibrėžiamas kaip procesas, leidžiantis pagal tam tikrą taisyklę išdėstyti galimų sprendimų aibės elementus į eilę, tai yra pagal tam tikrą optimalumo principą išdėstyti aibės elementus. Daugiakriteriai metodai klasifikuojami pagal pirmų raidžių inicialus arba pagal sprendimo priėmimo skaičių.

Daugiakriteriuose sprendimų priėmimo metoduose visi naudojami kriterijai turi matavimo vienetus, net jei kriterijus apibrėžiamas nominalia matavimo vieneto skale (taip ne; esantis nesantis) ir rezultatai turi būti matuojami kiekvieno rodiklio sprendimu. Daugiakriterinės sprendimų paramos sistemos nagrinėja problemas, kurių sprendimų erdvė yra diskreti. Ją sudaro aibė galimų alternatyvų (rodiklių).

Pagrindiniai daugiakriterio sprendimo priėmimo sistemos etapai:

- Kriterijų parinkimas ir įvertinimas;
- Alternatyvų sistemos sukūrimas užsibrėžtiems tikslams pasiekti;
- Rodiklių normalizavimas;
- Daugiakriterio metodo pritaikymas sprendimo priėmimo sistemai įvertinti;
- Gautų rezultatų įvertinimas ir optimalaus varianto priėmimas;
- Jei galutinis sprendimas nėra priimamas, renkama nauja informacija sprendimo priėmimo sistemai įvertinti.

Tyrimo uždavinys. Parinkti optimalų išorinių sienų ir langų kiekį pastate, taikant daugiakriterius sprendimų priėmimo metodus MOORA ir MILTIMOORA, gautus rezultatus palyginti.

Tyrimo naujumas. Teorinių metodų pritaikymas realiems pastatų projektavimo atvejams statybose. Pasiūlytas naujas būdas, parenkant išorinių sienų ir langų kiekius pastate.

Tyrimo objektas. Minimaliai sumažinti šilumos nuostolius pastate parenkant išorinių sienų ir langų kiekius, atsižvelgiant į pasaulio šalis.

Šio tyrimo tikslas. Pasiūlyti optimalų išorinių sienų ir langų santykio parinkimą, kai turimi skirtingi šilumos nuostolių kriterijai.

Tyrimo metodas. Analitinis tyrimas, grįstas tiriamuoju uždaviniu.

Tyrimo pavyzdys. Pavyzdyje pateikiama sudaryta uždavinio sprendimo priėmimo matrica. Atsižvelgiant į šilumos nuostolius pastate, priklausomai nuo langų ir išorinių sienų santykio, buvo pateiktos šešios skirtingos alternatyvos. A_1 (sienų 308,65 m^2, langų 54,75 m^2), A_2 (sienų 353,80 m^2, langų 9.60 m^2), A_3 (sienų 341,86 m^2, langų 21,54 m^2), A_4 (sienų 276,85 m^2, langų 86,55 m^2), A_5 (sienų 329,35 m^2, langų 34,05 m^2), A_6 (sienų 343,72 m^2, langų 19,68 m^2). Iš pateiktų šešių alternatyvų reikia išrinkti geriausią.

Alternatyvoms aprašyti buvo parinkti septyni reikšmingi kriterijai, kurie daro įtaką šilumos nuostoliams pastate, keičiant langų ir sienos santykį:

x_1– šilumos nuostoliai per pastato išorines sienas;
x_2– šilumos nuostoliai per langus;
x_3– šilumos nuostoliai per šiluminius tiltelius;
x_4– šilumos nuostoliai dėl išorinės oro infiltracijos;
x_5– šilumos pritekėjimas į pastatą iš išorės;
x_6– pastato suminės energijos sąnaudos;
x_7– išorinių sienų ir langų kainos santykis.

Išvados. Atliekant tyrimą, taikant daugiakriterius metodus, buvo apskaičiuotas ir išrinktas optimalus variantas iš pateiktų šešių langų ir išorinių sienų skirtingų dydžių variantų. MOORA ir MULTIMOORA metoduose rodikliai yra nedimensiniai dydžiai, kurie neturi svorio, todėl skaičiavimo eiga ir rezultatas pateikiami greičiau. Galima teigti, kad statyboje naudojama daugiakriterė analizė padeda išspręsti problemas greičiau ir naudingiau. Geriausios alternatyvos išrinkimas negali būti grindžiamas vienu kriterijumi. Minėti metodai leidžia kriterijų skaičių išplėsti iki begalybės. Tyrimo atvejis, taikant MOORA ir MULTIMOORA metodus, parodė, kad siūlomas teorinis modelis buvo veiksmingas realiame gyvenime ir galėtų būti sėkmingai taikomas sprendžiant panašias problemas ir ne statybos srityje.

Raktažodžiai: *langai, sienos, kriterijai, alternatyvos, MOORA metodas, MULTIMOORA metodas.*

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