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MULTICRITERIA EVALUATION OF INNER CLIMATE BY USING MOORA METHOD

Darius Kalibatas, Zenonas Turskis

Vilnius Gediminas Technical University
Sauletekio al. 11, LT-10223 Vilnius-40 Lithuania

Abstract. At the time when the demands of customers for quality construction are growing, the problem of evaluating the inner climate in a building and analyzing it from various perspectives becomes particularly important. The article is focussed on the analysis of inner climate, its influence on human beings and problems caused by the parameters of inner climate not meeting the standards. The condition of the spaces is determined by making the required measurements. The factors causing the deviation from the standards are identified and rational dwelling alternatives are offered. By using the method MOORA (Multi Objective Optimization on basis of Ratio Analysis), the best alternative is chosen from the available options. The multicriteria analysis is based on the data obtained in the investigation of inner climate.

Keywords: inner climate, Multi Objective Optimization, MOORA method.

1. Introduction

The development of building construction, embracing new technologies, building materials and the growing demands of customers, raises the problem of evaluating the inner climate of a building as a final product. Most of the people purchasing newly built houses or apartments pay attention only to their price, maintenance costs, living space, location, etc., ignoring such parameters as inner climate, which largely determines how healthy and able-bodied the residents would be, and other important factors [4-11, 15]. A balanced inner climate prevents from spreading of bacteria as well as human immune system and the inner surfaces of a building from vapour condensing and molding [6, 7]. The analysis of inner climate is a time-consuming task. It requires special skills and knowledge as well as special equipment to obtain the data. The data obtained should be properly processed and evaluated. To facilitate the process of evaluation, decision support systems, which can help not only to process the data but to compare the alternatives and to make a rational solution, may be used.

Computer-aided technologies should be used for processing large amounts of the data collected. This makes decisions more effective and increases the amount of data which can be selected and processed per unit time [8]. Given the data, generalized and systemized according to specified criteria, a customer can quickly choose desirable premises.

The information obtained may be also used for identifying the causes of inner climate deviation from the standards specified.

The authors of the present paper made a comparative analysis of premises based on the criteria describing inner climate.

2. Factors influencing inner climate

In this section, factors influencing inner climate are described. They mainly refer to ventilation and air conditioning systems.

2.1. Ventilation and air conditioning systems

The main structural and technical parameters on which inner climate depends refer to windows, doors, wall insulation, acoustic and air conditioning systems and the size of premises [10]. Some measures aimed at changing the inner climate, which consisted in mechanical ventilation, temperature and relative air humidity regulation, had already been taken in the last century.

In this way, the inner climate favourable for the occupants of the rooms was created. The risk for people to get ill increases when the air is saturated with carbon dioxide (CO_2), aerosol or other substances. The effect of the rate of air turnover on the human fitness to work was studied by EUROVEN [13], the European research group. Having analyzed more than hundred papers, they made a conclusion that ventilation directly affects the inner climate. Proper ventilation helps to limit the risk of infection and short-term sickness rate as well as other negative effects. The research group has also determined that the increase of the rate of air turnover largely increases air quality. When the rate of air turnover is lower than 25 l/s ($90m^3/h$) the possibility of a building to acquire "a sick building syndrome" increases [13]. Many viruses and bacteria spread through the air. The more people in the room, the more varied the viruses. The smaller the space of the room per working place, the higher the concentration of viruses. Additional ventilation of the room reduces the concentration of viruses and bacteria in the air, which can penetrate the human body through the respiratory tract.

When an air conditioning system does not operate properly, the sickness rate can also increase [14]. This happens when the room is not properly ventilated and because of it air pollution is increased. It is recommended the temperature difference between the adjacent rooms to be not higher than 5ºC.

It can be stated that the rate of air turnover in the premises ($15m^3/h$) specified by the hygienic norms [3] is not sufficient to provide comfortable thermal conditions, ensuring good health and fitness to work of the occupants.

When air humidity in the premises does not meet the requirements, the sickness rate also increases. At working places where air humidity is much lower than the specified values (40%-60%) illnesses of the respiratory tract are more often [13].

2.2. Building materials

Today, when new buildings are in great demand, they are erected quickly. To save time and get higher profit, cheaper building materials and technologies as well as unqualified labor are used. As a result, a low quality product (building) is obtained. To eliminate the defects, great efforts and large sums of money are required. It may be stated that the best alternative is when low cost is achieved not at the expense of quality [7].

Therefore, choosing the premises, one should know what building materials and elements were used in construction and if the working places in the premises he/she is going to purchase satisfy the requirements of Lithuanian hygienic standards, building codes and other legislative documents. To check it up, the following criteria may be used:

- thermal resistance standards;
- noise level;
- fire protection requirements;
- illumination intensity standards;
- inner climate and air pollution level;
- other criteria of comfort and safety.

Unfortunately, most of the above data are unavailable because real estate enterprises either do not have such information or do not provide it on their websites. It is particularly difficult to get the information about building materials and technologies used in buildings constructed some years ago. Therefore, it is very important that real estate enterprises should provide information about building quality not only to agents selling real property, but to customers as well. Then, they would be able to compare buildings by using intelligent computer-aided systems. A potential owner should be provided with comprehensive information about a particular building, thus allowing him/her to get a "technical passport" of this building, containing all necessary characteristics and parameters of the structure.

To perform multicriteria analysis based on quantitative and qualitative criteria is a complicated problem. The use of expert evaluation is insufficient, therefore, decision support systems should be employed [11]. In expert systems, a comparison of various objects is based on a smaller set of criteria than in decision support systems, giving thereby the answers only in a particular field.

3. The applying of the method MOORA for comparing the inner climate in the premises

To compare the inner climate in various premises, a multicriteria optimization method MOORA [2] was used in the present research. In a short article it is not possible to illustrate why this method is the best or more preferable to use. More details are given in W.K. Brauers book [1] and in Brauers *et al* article [3]. The assessment operations of inner climate variants are performing in the order as is shown in Fig 1.

The most preferable alternative is found according to K from the formula:

$$K = \max_j k_j = \max_j \left(\sum_{i=1}^{g} \bar{x}_{ij} - \sum_{i=g+1}^{i=n} \bar{x}_{ij} \right), \quad (1)$$

$$i = \overline{1,n};\ j = \overline{1,m};$$

where m is the number of alternatives, n is the number of criteria, g is the number of maximizing criteria, $\bar{x}_{ij}$ are normalized non-dimensional values of criteria.

The result of measurements of various dimensions were normalized and turned into non-dimensional values (the square root of the sum of squares of each alternative per criterion) by the formula:

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

$$\bar{x}_{ij} \in [0;1].$$

First, maximizing criteria values (criteria with maximal preferable values) are given in decision making matrix and then they are followed by minimizing criteria (criteria with minimal preferable values) values.

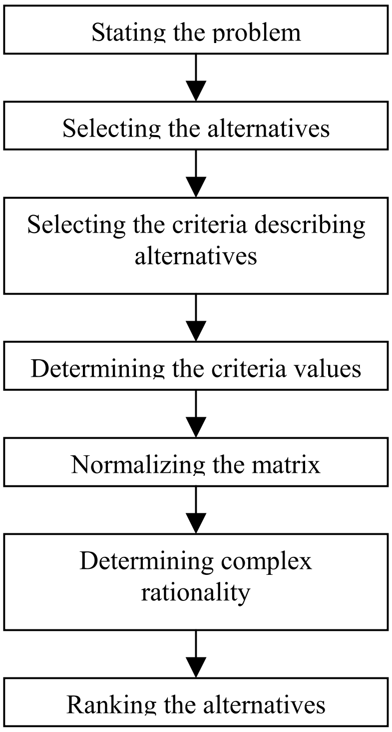

Figure 1. Sequence of operations performed in the framework of multicriteria decision support system MOORA

The ranking of the alternatives follows the principle that the best alternative has the highest k_j value, while the worst alternative has the lowest k_j value.

Then, the criteria for evaluating the inner climate in the premises have to be selected.

4. Selecting a set of criteria for evaluating inner climate

Based on the analysis of the material presented in Sections 2 and 3 of the present paper, we suggest the following criteria for inner climate evaluation:

- Air turnover in the premises - x_1, optimal $x_1 \geq 15$ m^3/h;
- Air humidity - x_2, $x_2 \geq 0$, optimal $x_2 = 50$ %;
- Air temperature - x_3 , $x_3 \geq 0$. As shown in fig. 2, the most comfortable temperature is in the range 24-25 °C. Investigated values are in the range 16-21 °C. On the base of this we can state:
  a) maximal investigated value is the most preferable;
  b) with a small error can be assumed that it is linear function (in graph red line).
- Illumination intensity - x_4;
- Air flow rate - x_5, $x_5 \leq 0.05$ m^3/h;
- Dew point - x_6.

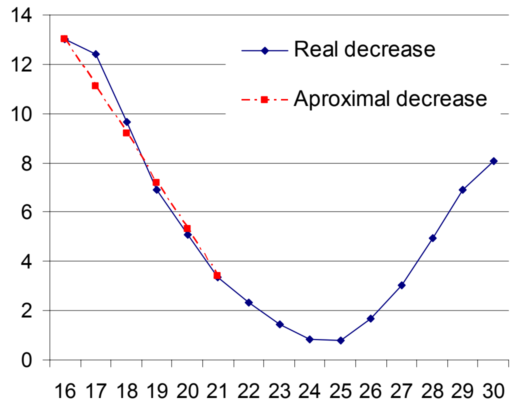

Figure 2. A decrease of work efficiency depending on temperature (our interpretation [12] – square mediocre quadratic values)

5. Evaluating the inner climate in the premises by the method MOORA based on the selected criteria

The study of the inner climate was performed in November 2006 in a five-storied house in Naujoji Vilnia. The house was constructed in 1982. The walls of the building are 51 cm thick. The house has reinforced concrete floor slabs, wooden windows, a basement and bitumen roll prepared roofing.

The required measurements were made by using Metrel equipment MJ6201EU having a calibration certificate. The data obtained are presented in Table 1.

The results obtained in using the method, which was described in Section 3, are given in Table 2. Given the data on the criteria describing the inner climate, rational solutions about its improvement and maintenance cost reduction can be made. The studies performed help to identify the inner climate parameters of the workplace which do not meet specifications. The data obtained can also be used for developing and implementing measures aimed at maintaining favourable inner climate at workplaces. The research aims to determine the inner climate at the premises where people relax and to define measures to be taken to improve their environment.

The calculations made by formula (1) show that the most favourable inner climate is in living room No.7.

The results obtained (quality percentage of living room alternative according to its rank) represent inner climate characteristics with some error.

An ordinary customer making a decision about purchasing or renting a real estate unit cannot get generalized data on the inner climate in premises because he lacks the respective qualification, knowledge and time required to carry out research, formalize and generalize the data, etc.

Table 1. Measurement results

Living room No.	The amount of air changed per head (m^3/h)	Relative air humidity (%)	Air temperature (°C)	Illumination (during work hours) (lx)	Rate of air flow (m/s)	Dew point (°C)
	x_1	x_2	x_3	x_4	x_5	x_6
1	7.5	46	18	400	0.10	11
2	6.7	50	16	250	0.05	10
3	7.1	49	19	280	0.10	12
4	5.2	48	20	300	0.05	11
5	5.3	32	21	300	0.05	11
6	3.9	38	19	260	0.10	8
7	8.1	44	20	400	0.05	6
8	4.5	46	18	300	0.10	7
9	3.8	42	16	250	0.10	5
10	5.4	37	19	200	0.05	9
Optimum	*max*	*max*	*max*	*max*	*min*	*min*

Table 2. Normalized matrix

Living room No.	x_1	x_2	x_3	x_4	x_5	x_6	k	Rank
1	0.40	0.33	0.30	0.42	0.40	0.37	0.68	4
2	0.36	0.36	0.27	0.26	0.20	0.34	0.71	2-3
3	0.38	0.36	0.32	0.29	0.40	0.41	0.54	8
4	0.28	0.35	0.33	0.32	0.20	0.37	0.71	2-3
5	0.28	0.23	0.36	0.32	0.20	0.37	0.62	5
6	0.21	0.28	0.32	0.27	0.40	0.27	0.41	10
7	0.43	0.32	0.34	0.42	0.20	0.20	1.11	1
8	0.24	0.33	0.30	0.32	0.40	0.24	0.55	7
9	0.20	0.30	0.27	0.26	0.40	0.17	0.46	9
10	0.29	0.27	0.32	0.21	0.20	0.31	0.58	6
Optimum	*max*	*max*	*max*	*max*	*min*	*min*		

This is the work of highly qualified specialists. Given the graphs of the inner climate provided with some comments, a customer can make a rational solution about purchasing a real estate unit with much lower losses which he/she could suffer trying to restore it.

6. Discussion of results and conclusions

A survey of literature made by the authors has shown that inner climate is a significant criterion of real estate valuation. Its main parameters are as follows:

- Air turnover in the premises - x_1,
- Air humidity - x_2,
- Air temperature - x_3,
- Illumination intensity - x_4,
- Air flow rate - x_5,
- Dew point - x_6.

Inner climate should be taken into account in real estate valuation because some data obtained in the research reveal significant drawbacks and defects of buildings, thereby helping to avoid the potential expenses in the case of purchasing low quality real property.

The study of the inner climate in the living rooms and a comparative analysis of the obtained data with the values provided by the hygienic norms allowed us to state that most of the investigated parameters do not meet current specifications. Forced ventilation should be installed in these living rooms to ensure the required rate of air turnover.

The evaluation data obtained by using the MOORA method may be used in determining the market value of particular apartments or flats in Lithuania as well as in other countries.

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