



Darius KALIBATAS

**THE MULTI-ATTRIBUTE ASSESSMENT
OF ENVIRONMENTAL FACTORS
INFLUENCING ON DWELLING-HOUSES**

**Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)**

1630-M

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Darius KALIBATAS

**THE MULTI-ATTRIBUTE ASSESSMENT
OF ENVIRONMENTAL FACTORS
INFLUENCING ON DWELLING-HOUSES**

Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)

Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2005–2009.

Scientific Supervisor

Prof Dr Habil Edmundas Kazimieras ZAVADSKAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T).

The dissertation is being defended at the Council of Scientific Field of Civil Engineering at Vilnius Gediminas Technical University:

Chairman

Prof Dr Habil Leonas USTINOVIČIUS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T).

Members:

Assoc Prof Dr Rasa APANAVIČIENĖ (Kaunas University of Technology, Technological Sciences, Civil Engineering – 02T),

Prof Dr Habil Pranas BALTRĖNAS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T),

Prof Dr Habil Gintaris KAKLAUSKAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T),

Prof Dr Vitalija RUDZKIENĖ (Mykolas Romeris University, Technological Sciences, Informatics Engineering – 07T).

Opponents:

Prof Dr Marija BURINSKIENĖ (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T),

Prof Dr Dalė DZEMYDIENĖ (Mykolas Romeris University, Technological Sciences, Informatics Engineering – 07T).

The dissertation will be defended at the public meeting of the Council of Scientific Field of Civil Engineering in the Senate Hall of Vilnius Gediminas Technical University at 2 p. m. on 10 June 2009.

Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.

Tel.: +370 5 274 4952, +370 5 274 4956; fax +370 5 270 0112;

e-mail: doktor@adm.vgtu.lt

The summary of the doctoral dissertation was distributed on 8 May 2009.

A copy of the doctoral dissertation is available for review at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, LT-10223 Vilnius, Lithuania).

© Darius Kalibatas, 2009

VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Darius KALIBATAS

**APLINKOS VEIKSNIŲ ĮTAKOS
GYVENAMOSIOMS PATALPOMS
DAUGIATIKSLIS VERTINIMAS**

Daktaro disertacijos santrauka
Technologijos mokslai, statybos inžinerija (02T)

Disertacija rengta 2005–2009 metais Vilniaus Gedimino technikos universitete.
Mokslinis vadovas

prof. habil. dr. Edmundas Kazimieras ZAVADSKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T).

Disertacija ginama Vilniaus Gedimino technikos universiteto Statybos inžinerijos mokslo krypties taryboje:

Pirmininkas

prof. habil. dr. Leonas USTINOVIČIUS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T).

Nariai:

doc. dr. Rasa APANAVIČIENĖ (Kauno technologijos universitetas, technologijos mokslai, statybos inžinerija – 02T),

prof. habil. dr. Pranas BALTRĖNAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovaizdis – 04T),

prof. habil. dr. Gintaris KAKLAUSKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T),

prof. dr. Vitalija RUDZKIENĖ (Mykolo Romerio universitetas, technologijos mokslai, informatikos inžinerija – 07T).

Oponentai:

prof. dr. Marija BURINSKIENĖ (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T),

prof. dr. Dalė DZEMYDIENĖ (Mykolo Romerio universitetas, technologijos mokslai, informatikos inžinerija – 07T).

Disertacija bus ginama viešame Statybos inžinerijos mokslo krypties tarybos posėdyje 2009 m. birželio 10 d. 14 val. Vilniaus Gedimino technikos universiteto senato posėdžių salėje.

Adresas: Saulėtekio al. 11, LT-10223 Vilnius, Lietuva.

Tel.: (8 5) 274 4952, (8 5) 274 4956; faksas (8 5) 270 0112;

el. paštas doktor@adm.vgtu.lt

Disertacijos santrauka išsiuntinėta 2009 m. gegužės 8 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, LT-10223 Vilnius, Lietuva).

VGTU leidyklos „Technika“ 1630-M mokslo literatūros knyga.

© Darius Kalibatas, 2009

Introduction

An overview of the problem

The microclimate of buildings, where people live, work, have rest and spend time in other ways may be divided into the following categories: 1) complying with the Lithuanian Hygiene Norm (HN 42:2004) or 2) non-complying with the Lithuanian Hygiene Norm.

The majority of Lithuanian buildings were built in 1960–1990. Then, although fuel costs for heating were high, it did not cost much in comparison with the present. Therefore, the energy performance category of the houses built is low.

The *energy performance* of a building is the amount of energy estimated according to the requirements of the Regulation, which is expressed by a building energy performance class and required when using a building according to the purpose.

A building or part of a building energy performance class is a building energy performance class, determined according to the value of a qualifying indicator, and the requirements of this Regulation.

However, the situation has changed nowadays. On the one hand, due to the increase of fuel prices the problem of reducing fuel costs has become one of the most painful ones. On the other hand, as the time spent in the buildings is getting longer, their indoor environment has become a matter of concern.

The indoor environment of the majority of buildings does not comply with the Lithuanian Hygiene Norm, i. e. it does not meet thermal comfort parameters and people's needs. The buildings of this kind must be renovated so that their indoor environment complies with the Lithuanian Hygiene Norm and meets the people's needs as much as possible. However, before renovation works, it is necessary to perform an analysis and identify what environmental factors influence the indoor environment of buildings and how they influence an indoor environment of buildings. Moreover, it is important to determine how to process the data obtained during the examination of buildings.

In the dissertation, the impact of environmental factors on dwelling-houses and workplaces is analysed and the multi-objective assessment method is proposed.

Object of the research

The object of the research is indoor environment and its compliance with the Lithuanian Hygiene Norm and the people's needs; determining efficiency of indoor renovation.

Aim and objectives of the work

People have been spending increasingly more time indoors. Therefore, it is important to identify the environment of dwelling-houses that influences the people's health and being.

The aim of the dissertation is to expand quality assessment methods of comfortable environment by proposing the multi-attribute assessment of environmental factors influencing on dwelling-houses. To achieve the aim, it is necessary to solve these objectives:

1. To perform analysis of indoor environment and microclimate research methods and modes and define their advantages and disadvantages according to the results obtained while determining the indoor environment of buildings.
2. On the basis of the performed analysis, to determine the main attributes, on the basis of which it is purposeful to evaluate the indoor environment of dwellings and workplaces. Also, to determine the importance level of the selected attributes, while performing expert analysis.
3. To develop multi-attribute assessment method enabling to determine the compliance of dwellings and workplaces with the Lithuanian Hygiene Norm and people's needs according to the established attributes of indoor climate assessment.
4. To perform analyses of indoor environment and microclimate of buildings and apply the proposed multi-attribute assessment method to determine the quality of comfortable environment of the dwellings and workplaces. To select rational living and working environment by means of multi-attribute aggregation method.
5. To compare one-apartment dwelling houses before the renovation and after it and determine the renovation efficiency (S_i).

Methodology of the research

In the analytical part of the work, in performing analysis of attributes and methods of indoor environment and microclimate of buildings reference was made to the Lithuanian and foreign scientists' works performed in this field. Methods of logical induction, generalization of concepts and conceptual modelling are used to generalize methods and develop multi-attribute aggregation method for the assessment of indoor environment. For the practical realisation of the proposed theory of the work, experimental research methods are used.

Scientific novelty

A new multi-attribute assessment method of indoor environment is presented in the dissertation. New results are obtained in this work:

1. A new assessment method is proposed, which, according to the selected attributes, allows assessment of indoor environment by means of several multi-attribute methods and to process their results by means of multi-attribute aggregation method.
2. The proposed multi-attribute assessment method of indoor environment is applied in practice in assessing apartment houses and one-apartment dwelling houses as well as workplaces.
3. The renovation efficiency of dwelling houses is compared by means of multi-attribute aggregation method.
4. The existing situation of indoor environment is determined and its compliance with the Lithuanian Hygiene Norm is compared.

Practical value

The results of the research should be used by designers in preparing a design and selecting construction materials, constructors – in performing construction works, and operators – in supervising buildings.

The developed method may be applied to assess alternatives of various funds and make a rational decision.

It is purposeful to apply the developed method in assessing real estate and determining its state as it allows determining the indoor environment of real estate and highlighting its shortcomings and defects. It protects against expenses that might occur after acquisition of poor-quality real estate.

Defended propositions

1. The main attributes describing the indoor comfort are the following: temperature, humidity, illumination, sound insulation, speed of air movement and exchange, the price of 1 square metre, heating costs.
2. It is purposeful to apply multi-attribute assessment methods in determining the environment of rational living place and workplace.
3. It is purposeful to apply multi-attribute aggregation method in determining the renovation efficiency of a building (S_i).

The scope of the dissertation

The dissertation consists of the introduction, three chapters, general conclusions, references, list of author's publications on the topic of dissertation and three annexes. The total scope of the dissertation is 110 pages, 48 pictures and 26 tables.

1. Indoor environment of dwellings and indoor environment assessment methods

In the first chapter, the concepts of indoor environment and microclimate are analysed; an impact of indoor environment and microclimate on a workplace and dwelling place is reviewed; how renovation influences on indoor environment and microclimate and how it is suggested to assess indoor environment and microclimate in compliance with the Lithuanian Hygiene Norm are analysed; factors forming the quality of indoor environment, a description of the importance of microclimate to a man's being and working quality are reviewed. There is also an analysis of the influence of construction and exploitation of a building on microclimate and energy consumption. Particular ways proposed to explore the environment and to improve it are also presented here.

After the analysis, performed at this chapter, it is determined that a system of attributes is needed for the assessment of indoor environment and microclimate. On the basis of the review of the related works, which is presented in the first chapter, assessment attributes of indoor environment and microclimate of offices and dwelling-houses are determined.

There are the following main assessment attributes of the indoor environment of dwelling houses:

- exchange of indoor air (m^3/h),
- air humidity (%),
- air temperature ($^{\circ}\text{C}$),
- price of 1 m^2 (thousands of LTL),
- sound insulation (in points),
- annual heating costs (t/year).

The main assessment attributes of the microclimate in offices are the following:

- air movement speed (m/s),
- air exchange volume per employee (m^3/h),
- air humidity (%),
- air temperature ($^{\circ}\text{C}$),
- dew point ($^{\circ}\text{C}$),
- illumination (lx).

As it may be noticed, assessment attributes for indoor environment of offices and dwelling-houses differ. This is due to the different activity: in offices people work and in dwelling-houses they have rest and spend time in other ways. It is important to organise favourable conditions for work in a workplace. Therefore, illumination (lux), air exchange volume per employee

(%) and dew point (°C) are important. The price of 1 sq. m. (thousands of LTL), sound insulation (in points) and annual heating costs (t/ year) play an important role in selecting a dwelling house. Air exchanges in the premises (m³/h), air humidity (%) and air temperature (°C) are important both in offices and dwelling-houses.

2. Multi-attribute decision making methods

The results of the first chapter showed that there is no common indoor environment assessment method. Many authors suggest assessment attributes for indoor environment of dwelling-houses and / or workplaces; however, they perform indoor environment assessment in a certain aspect. For example, they analyse noise, air pollution or other things. Therefore, they often assess indoor environment according to one or several attributes, which do not constitute a general view. Besides, many authors only review attributes without indicating their importance levels and do not presenting any indoor environment assessment method or approach.

Therefore, in the second chapter, the analysis of the concept of multi-attribute decision-making, examination of multi-attribute decision-making methods, their classification and evolution are presented. For the more detailed analysis TOPSIS, COPRAS and MOORA multi-attribute decision-making methods are selected.

The results of the analysis of multi-attribute decision-making methods showed that methods differ according to: 1) the number of potential alternatives and attributes being evaluated, 2) evaluation of importance levels of attributes (importance level is being evaluated or not), 3) the credibility of the results obtained, 4) the possibility of method improvement, 5) method sensitivity, 6) data submission form.

According to the results obtained during the analysis of TOPSIS, COPRAS and MOORA, it was determined that it is purposeful to process the data obtained by these methods by means of the multi-attribute aggregation method in order to get a more precise distribution according to the grade.

3. The multi-attribute assessment of dwellings and evaluating the efficiency of renovation of dwellings

In the third chapter, the importance levels of attributes for dwelling houses and offices is determined, the multi-attribute assessment method is proposed and the research methodology of indoor environment and thermovision is described.

The multi-attribute assessment method is presented in Fig. 1. The beginning of the assessment starts from the selection of alternatives (dwellings or workplaces), which are going to be evaluated by means of the selected methods. In our case, these methods are MOORA, COPRAS and TOPSIS. Then, attributes are selected according to which the alternatives are compared. The attributes that best reflect the requirements are presented in the first chapter. I. e. offices are evaluated according to the air exchange speed and volume, temperature, relative humidity, illumination and dew point, and dwellings are assessed according to the air exchange speed, temperature, relative humidity, price of 1 m², sound insulation and heating costs.

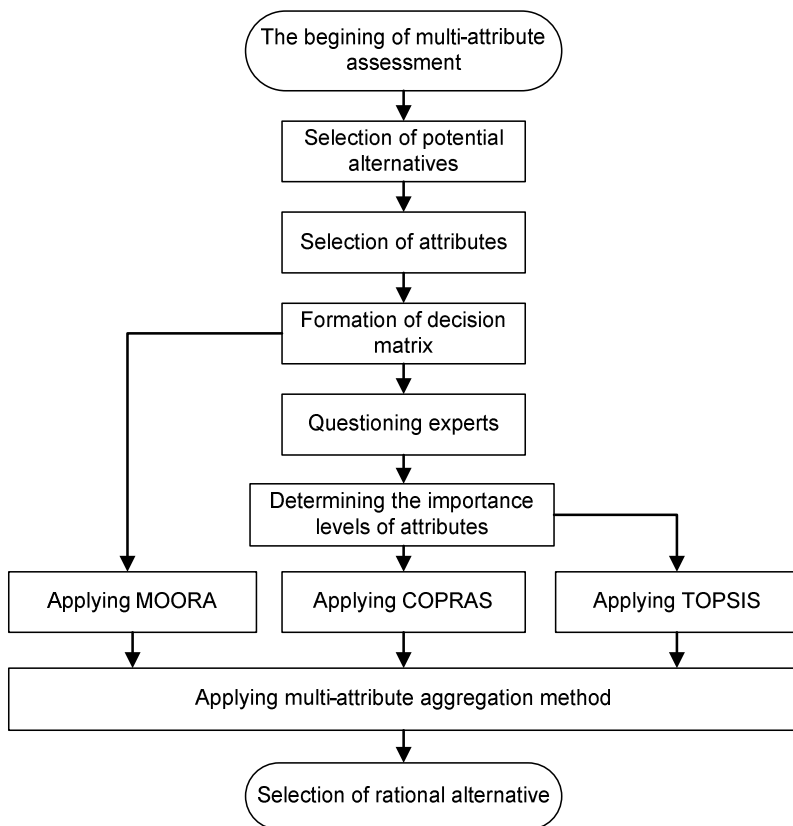


Fig. 1. The schema of the multi-attribute assessment of dwellings

Having the alternatives j and attributes i we form a decision matrix, which will be processed by means of methods MOORA, TOPSIS and COPRAS. In the cases of COPRAS and TOPSIS, importance levels are attached to the attributes. Experts (specialists in construction field when dwelling-houses is being evaluated, and office staff when offices are being assessed) are questionnaire to determine the importance levels of attributes.

Having conducted expert survey, the results obtained showed that the importance levels of attributes are: air exchange in the premises (0.094), air humidity (0.074), air temperature (0.137), price of 1 m² (0.261), sound insulation (0.190), annual heating costs (0.244) in assessing indoor environment of dwelling-houses, and speed of air movement (0.14), air exchange volume per employee (0.24), air humidity (0.20), air temperature (0.26), dew drop (0.07), illumination (during working time) (0.09) – in assessing microclimate of offices.

In the case of MOORA, the importance levels are not applied. The obtained assessment data of MOORA, TOPSIS and COPRAS methods are combined by means of the multi-attribute aggregation method and the alternative most satisfying the Lithuanian Hygiene Norm is selected – dwelling-house or workplace.

The proposed multi-attribute assessment method of indoor environment and microclimate is applied in order to conduct researches on indoor environment of dwelling-houses (5 one-apartment houses and 10 apartment houses) and 10 offices. The research results of dwelling-houses and offices obtained are processed by means of COPRAS, TOPSIS and MOORA methods, and assessment results are processed by means of the multi-attribute aggregation method. For renovated dwelling-houses multi-attribute utility function is calculated and renovation efficiency of indoor environment of dwelling houses is determined.

In Table 1, normalised values of multi-attribute assessment attributes of one apartment dwellings are presented, which are calculated by means of multi-attribute aggregation method, combining MOORA, TOPSIS and COPRAS.

Table 2 presents the comparison of one-apartment dwellings by multi-attribute aggregation method.

The ratio R_i^K of multi-objective optimality criterion of indoor environment of one-apartment dwelling houses before the renovation and after it and the price ratio R_i^P of indoor environment of one-apartment dwelling houses before the renovation and after it are calculated in order to determine the renovation efficiency of indoor environment of one-apartment dwelling houses S_i .

The ratio R_i^K of multi-attribute optimality criterion of indoor environment of one-apartment dwelling houses before the renovation and after it is calculated according to the formula (1).

Table 1. Normalised values of multi-attribute assessment attributes, where q_j – the importance level of attributes, x_j^{opt} – optimal value of an attribute

One-apartment dwelling house No	Period	Multi-attribute assessment attributes					
		Air exchange in the premises	Air humidity	Air temperature	Price of 1 m ²	Sound insulation	Annual heating costs
q_j		0.094	0.074	0.137	0.261	0.190	0.244
1	Before the renovation	0.636	0.769	0.727	0.519	0.667	0.664
2		0.667	0.725	0.773	0.590	0.778	0.603
3		0.879	0.735	0.773	1.000	0.667	0.649
4		0.667	0.909	0.818	0.514	0.778	0.604
5		1.000	0.685	0.727	0.535	0.667	0.709
1	After the renovation	0.485	0.900	1.000	0.467	0.889	0.985
2		0.515	0.960	0.957	0.538	1.000	0.885
3		0.545	0.960	1.000	0.919	0.889	0.864
4		0.576	0.962	0.955	0.464	1.000	0.910
5		0.545	0.860	0.955	0.487	1.000	1.000
x_j^{opt}		1.000	1.000	1.000	1.000	1.000	1.000

$$R_i^K = K_j^+ / K_j^-, \quad (1)$$

where K_j^+ – stands for the multi-objective optimality criterion of one-apartment dwelling house after the renovation of indoor environment; K_j^- – stands for the multi-objective optimality criterion of one-apartment dwelling house before the renovation of indoor environment.

The price ratio R_i^P of indoor environment of one-apartment dwelling houses before the renovation and after it is calculated according to the formula (2).

$$R_i^P = P_i^- / P_i^+, \quad (2)$$

where P_j^+ – stands for the price of indoor environment of one-apartment dwelling house after the renovation; P_j^- – stands for the price of indoor environment of one-apartment dwelling house before the renovation.

The renovation efficiency (S_i) of indoor environment of one-apartment dwelling houses is calculated according to the formula (3).

$$S_i = R_i^K \cdot R_i^P. \quad (3)$$

Table 2. Comparison of one apartment dwellings by multi-attribute aggregation method, where S_{MTC} – multi-attribute aggregation method

Method Dwelling		MOORA	TOPSIS	COPRAS	S_{MTC}	Priority of the alternative
1	Before the renovation	0.411	0.277	0.730	0.473	10
2		0.443	0.414	0.763	0.540	8
3		0.638	0.791	0.872	0.767	2
4		0.475	0.290	0.756	0.507	9
5		0.517	0.476	0.786	0.593	7
1	After the renovation	0.609	0.585	0.846	0.680	6
2		0.718	0.666	0.886	0.757	3
3		1.000	1.000	1.000	1.000	1
4		0.689	0.585	0.860	0.711	5
5		0.691	0.644	0.879	0.738	4

Table 3. Determining efficiency of indoor renovation of one-apartment dwellings in Naujoji Vilnia

One-apartment dwelling No	K_j		Price, $\times 10^3$ LTL		Ratio		Efficiency (S_i)
	K_j^-	K_j^+	P_i^-	P_i^+	R_i^K	R_i^P	
1	0.374	0.561	420	466	1.500	0.901	1.664
2	0.435	0.617	560	614	1.418	0.912	1.555
3	0.626	0.769	370	403	1.228	0.918	1.338
4	0.417	0.583	600	665	1.398	0.902	1.550
5	0.488	0.604	590	649	1.238	0.909	1.361

In Table 3, the meanings of the multi-objective optimality criterion (K_j) of indoor environment of one-apartment dwellings before the renovation and after it, which are calculated combining MOORA, TOPSIS and COPRAS methods, the meanings of the ratio of optimality criterion (R_i^K), the meanings of price ratio (R_i^P), the meanings of renovation efficiency (S_i) of indoor environment of one-apartment dwelling houses are presented. Fig. 2 presents the efficiency (S_i) of renovation of one-apartment dwellings in Naujoji Vilnia

According to the attributes set, renovation efficiency measurements showed that the renovation best served the purpose in the first one-apartment dwelling.

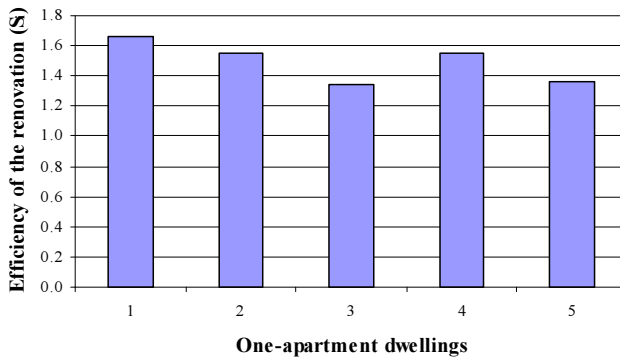


Fig. 2. Determining the efficiency (S_i) of renovation of one-apartment dwellings in Naujoji Vilnia

While performing indoor environment assessment of 10 apartment dwellings and 5 one-apartment dwellings as well as 10 offices according to the proposed method, the layout of buildings by grade is determined: the indoor environment of the seventh apartment dwelling, the third one-apartment dwelling and office room No. 612b is the best.

General conclusions

1. The analysis of the related works on environment of buildings shows that the authors exploring the indoor environment of dwellings and workplaces suggest assessing it according to such attributes as noise, air pollution and others; however, they perform assessment of indoor environment of buildings

according to one or several attributes, which do not constitute a general view. Besides, the authors do not indicate the importance levels of attributes and do not present assessment method or approach of indoor environment of buildings.

2. Having performed the analysis of the existing environmental researches of dwellings and offices, it is concluded that the main attributes influencing the microclimate of dwelling-houses are: air exchange in the premises, air humidity, air temperature, the price of 1 sq. m., sound insulation and annual heating costs; the main indicators influencing the microclimate of offices are: speed of air movement, air exchange volume per employee, air humidity, air temperature, dew point and illumination.

3. The research results obtained by evaluating the indoor air of dwelling-houses and offices showed that living and working environment is not acceptable for living and working according to the with the Lithuanian Hygiene Norm and the external enclosing constructions do not meet the effectual technical regulations for construction.

4. The research results obtained by evaluating the indoor environment of 5 one-apartment houses allow drawing a conclusion that after the renovation, the living environment improved from 1,36 till 1,66 and satisfy the regulatory requirements.

5. The researches conducted by evaluating the indoor environment of dwelling-houses and offices using the proposed multi-attribute aggregation method shows that it helps to assess and choose a rational living and working place reasonably.

6. When there are research results of dwellings or workplaces, it is possible to select the most acceptable option of living environment. Besides, having performed measurements and determined the shortcomings of indoor environment, it is possible to take measures for improvement of indoor environment.

7. Although there are a number of multi-attribute assessment methods, it is still not clear which of the methods in which case is the best. The new method developed allows to assess alternatives by means of several methods at the same time and to process the results obtained by means of the multi-attribute aggregation method. The developed method may be applied in various fields in order to assess alternatives and make a rational solution.

List of published works on the topic of the dissertation

In the reviewed scientific periodical publications

1. Kalibatas, D.; Krutinis, M.; Vileikienė, M. 2007. Multi-criteria analysis of microclimate in dwelling, *Technological and Economic Development of Economy* XIII(1): 24–31 (IRBdirect, ICONDA).
2. Zavadskas, E. K.; Kaklauskas, A.; Šaparauskas, J.; Kalibatas, D. 2007. Evaluation of Vilnius Urban Sustainability with Special emphasis on Pollution, *Ekologija* 53: 64–72 (ISI Master Journal List).
3. Kalibatas, D.; Turskis, Z. 2008. Multicriteria evaluation of inner climate by using MOORA method, *Information Technology and Control* 37(1): 79–83 (ISI Web of Science).
4. Zavadskas, E. K.; Kaklauskas, A.; Turskis, Z.; Kalibatas, D. 2009. An approach on multi-attribute assessment of indoor environment before and after refurbishment of dwellings, *Journal of Environmental Engineering and Landscape Management* 17(1): 5–11 (ISI Web of Science).

In the other editions

1. Zavadskas, E. K.; Kalibatas, D. 2007. Dwelling's microclimate compare using iterative multi-attribute method, in *Vainiūnas, P. (Ed.), Proc. of the 9th International Conference „Modern Building Materials, Structures and Techniques 2007“, Vilnius, Lithuania, 2007*. Vilnius: Technika, 282–286 (ISI Proceedings).
2. Zavadskas, E. K.; Kaklauskas, A.; Turskis, Z.; Kalibatas, D. 2008a. Multi attribute assessment of dwelling houses renovation, in *Cygas, D. Froehner K. D. (Eds.). The 7th International Conference „Environmental engineering“, Vilnius, Lithuania, 2008*. Vilnius: Technika, 902–906 (ISI Proceedings).
3. Zavadskas, E. K.; Kaklauskas, A.; Turskis, Z.; Tamosaitiene, J.; Kalibatas, D. 2008b. Assessment of indoor environment applying COPRAS method with attributes determined in intervals, in *Cygas, D. Froehner, K. D. (Eds.). The 7th International Conference „Environmental Engineering“, Vilnius, Lithuania, 2008*. Vilnius: Technika, 907–912 (ISI Proceedings).
4. Kaklauskas, A.; Bagdonavičius, A.; Sliogerienė, J.; Kalibatas, D.; Povilaityte, J. 2006. Development of market-based land mass appraisal online system for land taxation, in *The First Symposium of the World's Best Practices in Mass Appraisal for Asia, Bangkok, Thailand, 2006*, 297–307.
5. Kalibatas, D. 2007. Gyvenamo būsto mikroklimato daugiataisė analizė taikant COPRAS metodą, iš *10-osios Lietuvos jaunujų mokslininkų*

konferencijos „Mokslas – Lietuvos ateitis“ pranešimų rinkinys.
Vilnius: Technika, 342–347.

About the author

Darius Kalibatas was born in Vilnius, on 1st March 1978. Darius Kalibatas started studying in the Faculty of Civil Engineering of Vilnius Gediminas Technical University in 1996 and in 2001 he defended bachelor's thesis. In 2003 Darius Kalibatas finished master's studies and defended thesis. He started doctoral studies in 2005 in the Department of Construction Technology and Management.

Darius Kalibatas was PhD student of Vilnius Gediminas Technical University in 2005–2009.

Acknowledgements

I would like to thank the scientific supervisor Prof. Dr. Habil. Edmundas Kazimieras Zavadskas, Principal Vice-Rector and Head of the Department of Construction Technology and Management, Faculty of Civil Engineering of Vilnius Gediminas Technical University in Lithuania, for ideas and for encouraging me to develop the dissertation.

I would like to express my gratitude to Prof. Dr. Habil. Arturas Kaklauskas, Head of the Department of Construction Economics and Property Management, Faculty of Civil Engineering, and Dr. Zenonas Turskis, the Department of Construction Technology and Management, Faculty of Civil Engineering, for valuable comments.

Finally, I gratefully acknowledge the support, encouragement and patience of my family.

APLINKOS VEIKSNIŲ ĮTAKOS GYVENAMOSIOMS PATALPOMS DAUGIATIKSLIS VERTINIMAS

Mokslų problemų aktualumas

Patalpų, kuriuose žmonės gyvena, dirba, poilsiauja ir kitaip leidžia laiką, mikroklimatą galima būtų skirstyti į tokias dvi kategorijas: 1) tenkinantis Lietuvos higienos normą arba 2) netenkinantis Lietuvos higienos normos.

Dauguma dabartinių pastatų Lietuvoje pastatyta 1960–1990 metais. Tada nors kuro išlaidos šildymui buvo didelės, bet kainavo tai palyginus su dabartimi nedaug. Todėl buvo statomi namai, kurių energinio naudingumo kategorija yra žema.

Pastato energinis naudingumas – pagal Reglamento reikalavimus apskaičiuotas energijos kiekis, išreikštas pastato energinio naudingumo klase, reikalingas naudojant pastatą pagal paskirtį.

Pastato ar pastato dalies energinio naudingumo klasė – pagal kvalifikacinio rodiklio vertę ir šio Reglamento reikalavimus nustatyta pastato energinio naudingumo klasė.

Tačiau šiais laikais situacija pasikeitė. Iš vienos pusės, dėl kuro kainų didėjimo kuro sąnaudų mažinimo problema tapo viena iš opiausių. Iš kitos pusės, ilgėjant praleidžiamam laikui patalpose, susirūpinta patalpų mikroklimatu.

Daugumos patalpų mikroklimatas netenka Lietuvos higienos normą, t.y. netenka šiluminio komforto parametrų ir gyventojų poreikių. Tokio tipo patalpos turi būti renovuotos, kad jų mikroklimatas atitiktų Lietuvos higienos normą ir kiek galima maksimaliai tenkintų gyventojų poreikius. Tačiau prieš atliekant renovavimo darbus, būtina atlikti tyrimus ir nustatyti kokie aplinkos veiksniai ir kaip įtakoja patalpų mikroklimatą. Be to svarbu nustatyti kaip apdoroti gautus duomenis.

Disertacijoje nagrinėjama aplinkos veiksnių įtaka gyvenamosioms patalpoms ir siūlomas daugiatis vertinimo metodas.

Tyrimo objektas

Pastatų mikroklimatas ir jo atitiktis Lietuvos higienos normoms bei gyventojų poreikiams. Pastatų renovavimo efektyvumo vertinimas daugiatis liugavimo metodu.

Darbo tikslas ir uždaviniai

Pastaruoju metu žmonės vis daugiau laiko praleidžia patalpose, todėl svarbu nustatyti gyvenamųjų patalpų aplinką, kuri įtakoja gyventojų sveikatą ir savijautą.

Disertacijos tikslas – praplėsti aplinkos kokybės vertinimo metodus, siūlant metodą, leisiantį pagal esančius patalpų vidaus aplinkos vertinimo rodiklius nustatyti patalpų atitiktį Lietuvos higienos normoms ir gyventojų poreikiams. Tikslui pasiekti būtina išspręsti šiuos uždavinius:

1. Atlikti patalpų aplinkos veiksnų įtakos tyrimų metodų ir būdų analizę ir remiantis gautais rezultatais apibrėžti jų privalumus ir trūkumus.
2. Atliktos analizės pagrindu nustatyti pagrindinius rodiklius, remiantis kuriais tikslinga vertinti patalpų aplinką. Taip pat, atliekant ekspertinį alternatyvų rodiklių reikšmingumo tyrimą, nustatyti pasirinktų rodiklių reikšmingumą.
3. Sukurti daugiatislį vertinimo metodą, leisiantį pagal esančius patalpų vidaus aplinkos vertinimo rodiklius nustatyti patalpų atitiktį Lietuvos higienos normoms ir gyventojų poreikiams.
4. Atlikti pastatų aplinkos ir mikroklimato tyrimus ir pritaikyti pasiūlytą daugiatislį vertinimo metodą patalpų komfortiškos aplinkos kokybei nustatyti. Remiantis daugiatisliu agregavimo metodu parinkti racionalią gyvenamąją aplinką.
5. Palyginti tarpusavyje vienbučius gyvenamuosius namus prieš renovaciją ir po jos bei nustatyti renovacijos efektyvumą.

Tyrimų metodika

Analitinėje darbo dalyje, atliekant patalpų mikroklimato rodiklių ir metodų analizę remtasi Lietuvos ir užsienio šalių mokslininkų šioje srityje atliktais darbais. Metodams apibendrinti ir patalpų mikroklimato daugiatislio vertinimo metodui sukurti naudojami loginės indukcijos, sąvokų apibendrinimo ir koncepcinio modeliavimo metodai. Darbe pasiūlytos teorijos praktinei realizacijai naudojami eksperimentiniai tyrimo metodai.

Mokslinis naujumas

Disertacijoje pateikiamas naujas patalpų vidaus aplinkos daugiatislio vertinimo metodas. Šiame darbe gauti nauji rezultatai:

1. Pasiūlytas naujas vertinimo metodas, kuris pagal pasirinktus rodiklius leidžia įvertinti patalpų vidaus aplinką keliais daugiatisliais metodais ir jų rezultatus apdoroti daugiatisliu agregavimo metodu.
2. Pasiūlytas daugiatislis patalpų vidaus aplinkos vertinimo metodas pritaikytas praktikoje vertinant daugiabučius ir vienbučius gyvenamuosius namus ir darbo patalpas.
3. Daugiatisliu agregavimo metodu palygintas gyvenamųjų namų renovacijos efektyvumas.

4. Nustatyta patalpų vidaus aplinkos esama situacija ir palygintas jos atitikimas Lietuvos higienos normai.

Praktinė vertė

Tyrimų rezultatais turėtų naudotis projektuotojai rengdami projektą ir parinkdami statybinės medžiagas, statybininkai – atlikdami statybos darbus ir eksploatuotojai – prižiūrėdami pastatus.

Sukurtą metodą galima taikyti įvairios srities alternatyvoms vertinti ir racionaliam sprendimui priimti.

Sukurtą metodą tikslinga taikyti vertinant nekilnojamąjį turtą ir nustatant jo būklę, kadangi jis leidžia nustatyti nekilnojamojo turto vidaus aplinką ir išryškinti jo trūkumus ir defektus. Tai apsaugo nuo išlaidų, galinčių atsirasti įsigijus nekokybišką nekilnojamąjį turtą.

Ginamieji teiginiai

1. Pagrindiniai vidaus patalpų komfortą apibūdinantys rodikliai yra šie: temperatūra, drėgmė, apšvietumas, garso izoliacija, oro judėjimo ir apsikeitimo greitis, garso izoliacija, 1 m² kaina, išlaidos už šildymą.
2. Nustatant racionalios gyvenamosios ir darbo vietos aplinką tikslinga taikyti daugiatakslius vertinimo metodus.
3. Nustatant pastatų renovacijos efektyvumą (S_i) tikslinga taikyti daugiatakslį agregavimo metodą.

Disertacijos struktūra

Disertaciją sudaro įvadas, trys skyriai, rezultatų apibendrinimas, naudotos literatūros bei autoriaus publikacijų disertacijos tema sąrašai ir trys priedai.

Darbo apimtis yra 110 puslapių, tekste panaudotos 39 numeruotos formulės, 48 paveikslai ir 26 lentelės. Rašant disertaciją buvo panaudoti 141 literatūros šaltiniai.

Įvadiniame skyriuje nagrinėjamas problemos aktualumas, formuluojamas darbo tikslas bei uždaviniai, aprašomas mokslinis darbo naujumas, pristatomi autoriaus pranešimai ir publikacijos, disertacijos struktūra.

Pirmame skyriuje pateiktas mikroklimato sąvokos apibrėžimas, analizuojami Lietuvos ir užsienio mokslininkų vidaus aplinkos tyrimų metodai, pateikiamos Lietuvos higienos normos ir teisinė dokumentacija, reglamentuojanti vidaus mikroklimatą. Antrame skyriuje analizuojami ir pateikiami daugiataksliai sprendimo metodai, kuriais galima būtų parinkti racionalią gyvenamąją aplinką. Trečiame skyriuje pateikiamas daugiatakslis vidaus aplinkos ir mikroklimato vertinimo prieš ir po renovacijos metodas ir jo

pritaikymas 5 vienbučiams, 10 daugiabučių namų ir 10 biurų vertinti, atliekant termovizinius ir vidaus aplinkos tyrimus.

Bendrosios išvados

1. Atlikus patalpų aplinkos tyrimų metodų ir būdų analizę nustatyta, kad autoriai, nagrinėjantys patalpų vidaus aplinką, siūlo ją vertinti pagal atskirus rodiklius, kurie nesudaro bendro patalpų vidaus aplinkos vaizdo. Autoriai taip pat nenurodo rodiklių reikšmingumą ir nepateikia patalpų vidaus aplinkos vertinimo metodo arba būdo.
2. Išnagrinėjus esamus patalpų aplinkos tyrimus nustatyta, kad pagrindiniai rodikliai, darantys įtaką gyvenamųjų patalpų aplinkai yra oro apsikeitimas patalpoje, oro drėgmė, oro temperatūra, 1 kv. m kaina, garso izoliacija ir metinės išlaidos šildymui; biuro patalpoms – oro judėjimo greitis, oro apsikeitimo kiekis, tenkantis vienam darbuotojui, oro drėgmė, oro temperatūra, rasos taškas ir apšviestumas.
3. Įvertinus vienbučių, daugiabučių namų ir biurų aplinką, nustatyta, kad dabartinė daugelio patalpų būklė neatitinka Lietuvos higienos normų, o išorinės atitvarinės konstrukcijos netenkina galiojančių statybos techninių reglamentų.
4. Tyrimų rezultatai, gauti vertinant 5 vienbučių namų vidaus aplinką prieš renovavimą ir po jo, leidžia daryti išvadą, kad renovavimo efektyvumo koeficientas siekė nuo 1,36 iki 1,66, o gyvenamoji aplinka pagerėjo ir atitiko norminius reikalavimus.
5. Atlikus gyvenamųjų namų vidaus aplinkos ir biurų mikroklimato vertinimus siūlomu daugiatiksliu agregavimo metodu nustatyta, kad jis padeda pagrįstai (remiantis matavimais ir skaičiavimais) įvertinti ir parinkti racionalią darbo ir poilsio aplinką pagal keliamus reikalavimus.
6. Atlikus vidaus patalpų tyrimus, galima pasirinkti labiausiai poreikius atitinkančią gyvenamąją aplinką. Be to, atlikus patalpų vidaus aplinkos matavimus ir pagal juos nustatčius aplinkos trūkumus, galima imtis vidaus aplinkos gerinimo priemonių.
7. Nors sukurta nemažai daugiatikslių vertinimo metodų, iki šiol lieka neišku, kuris metodas koku atveju geriausias. Sukurtas naujas metodas vienu metu įgalina alternatyvas vertinti keliais metodais ir gautus rezultatus apdoroti daugiatiksliu agregavimo metodu. Jį

galima taikyti projektavimo, statybos ir kt. srityse alternatyvoms vertinti ir racionaliam sprendimui priimti.

Trumpos žinios apie autorių

Darius Kalibatas gimė 1978 m. kovo 1 d. Vilniuje.

2001 m. įgijo statybos inžinerijos bakalauro laipsnį Vilniaus Gedimino technikos universiteto Statybos inžinerijos fakultete. 2003 m. įgijo statybos inžinerijos mokslo magistro laipsnį Vilniaus Gedimino technikos universiteto Statybos inžinerijos fakultete. 2005–2009 m. studijavo Vilniaus Gedimino technikos universiteto doktorantūroje. Šiuo metu dirba kapitalinės statybos direkcijoje. Skaito paskaitas statybos technologijos ir vadybos katedroje.

Padėka

Dėkoju darbo vadovui, Vilniaus Gedimino technikos universiteto pirmajam prorektoriui ir Statybos inžinerijos fakulteto Statybos technologijos ir vadybos katedros vedėjui prof. habil. dr. Edmundui Kazimierui Zavadskui už idėjas ir paskatinimą rašant šį darbą. Nuoširdžiai esu dėkingas Statybos ekonomikos ir nekilnojamojo turto vadybos katedros vedėjui prof. habil. dr. Artūriui Kaklauskui ir Statybos technologijos ir vadybos katedros dr. Zenonui Turskiui už vertingas pastabas.

Taip pat dėkoju savo artimiesiems už kantrybę ir supratimą.

Darius Kalibatas

**THE MULTI-ATTRIBUTE ASSESSMENT OF ENVIRONMENTAL
FACTORS INFLUENCING ON DWELLING-HOUSES**

**Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)**

Darius Kalibatas

**APLINKOS VEIKSNIŲ ĮTAKOS GYVENAMOSIOMS PATALPOMS
DAUGIATIKSLIS VERTINIMAS**

**Daktaro disertacijos santrauka
Technologijos mokslai, statybos inžinerija (02T)**

2009 05 08. 1,5 sp. l. Tiražas 60 egz.
Vilniaus Gedimino technikos universiteto
leidykla „Technika“, Saulėtekio al. 11, LT-10223 Vilnius
<http://leidykla.vgtu.lt>
Spausdino UAB „Biznio mašinų kompanija“,
J. Jasinskio g. 16A, 01112 Vilnius