



EVALUATING THE SUSTAINABILITY OF VILNIUS CITY RESIDENTIAL AREAS

Milda Viteikienė¹, Edmundas Kazimieras Zavadskas²

*Dept of Construction Technology and Management, Vilnius Gediminas Technical University,
Saulėtekio al. 11, LT-10223 Vilnius, Lithuania*

E-mail: ¹mildav@adm.vtu.lt; ²edmundas.zavadskas@adm.vtu.lt

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Abstract. The objective of this article is to propose a methodology that would enable to rank residential areas according to the indices of sustainable development and to establish the rank of their priorities. The task was framed basing on the survey performed by RAIT (Market analysis and group of survey) for evaluation of the most desirable residential area in Vilnius city. Vilnius residents took part in this survey. Only Vilnius city residential areas and their characteristic indices were sorted out from the survey performed by RAIT. A system of 22 indices defining the sustainability aspects was compiled. Residential areas were evaluated for their facilities, residential and business environment. On the basis of the surveys performed by experts, the significances of indices were determined. Application of multipurpose evaluation method COPRAS (Complex Proportional Assessment) led to establishment of the rank of priorities of residential areas in respect of their sustainability.

Keywords: sustainable development, residential areas of the city, COPRAS, evaluation.

1. Introduction

Sustainable development is one of the major problems all over the world. Probably the utmost problem of sustainability is alterations of social needs. People, business, society and authority can act together in seeking for development of economy, environmental and social welfare.

According to the classical conception, sustainable development consists of social, economical and environmental components. Evaluation of a sustainable city residential area in these aspects shows which residential area is desirable for residents.

Sustainable development is becoming a dominating principle in planning a new and compact format of a city residential area. Conception of impossibility to live in such residential areas as we have now urges us to reconsider our present practice of city planning. Acceptance of new and innovative ideas in the process of city planning is a new challenge for development of sustainable landscape.

Many countries in the world face problems of sustainable development in the city and residential areas.

The contributors make suggestions how to solve water supply problems in cities. Zhang et al [1] analysed sustainable urban development indicators. Diepen and Voogd [2] studied peculiarities of urban transport planning in a sustainable city. The research object chosen by Kountouris et al [3] is sustainable development of urban environment. Henn and Henning [4] analysed the indicators of economic, social and environmental sustainability. Brenheny and Archer [5] concern with urban density researches, influences of local authority on sustainable

development, also with communication problems between residential districts. Banister [6] characterised obstacles that hinder creating sustainability in a city.

Rudlin and Falk [7] described the lifestyle of a sustainable city. To avoid the mistakes made in the Soviet period, the living environment, according to a town – planning specialist Burinskienė [8], should be created in such a way that a dwelling, a garage for a motor car and a recreational space are concentrated, rather than being located in different parts of the city. A residential area should be not too large allowing for the residents to maintain friendly relations with each other and order in a clearly outlined area. A structural core of the residential area should be a group of houses sharing a courtyard and other objects on its territory. A number or group of residential houses with child care institutions, recreational spaces and playgrounds for all groups of inhabitants, as well as green zones, approach roads, parking spaces etc make an urban residential area.

Turskis et al [9] developed a methodology that can help city planners to determine and localise problems of urban fabric density, to enhance motivation and versatility of decisions. Melchert [10] analysed building ecology and urban sustainability planning problems in developing countries. Zavadskas et al [11] develop a model of sustainable urban formation by undertaking a complex analysis of micro, meso and macro environmental factors affecting it and to present recommendations for the increase of its competitive abilities.

West Australian Planning Commission has created the strategic control of the attractive residential area development [12].

Engel-Yan et al [13] emphasise the role of interface in promoting sustainability at the residential area scale.

Priemus [14] introduces us to development of sustainability and stability of the cities in Holand.

In this paper a multipurpose evaluation method COPRAS is used to determine the most sustainable residential area.

Sustainable residential areas can be characterised by social, economical, environmental and cultural indicators.

2. Indices defining a sustainable residential area

A district should meet the requirements of a sustainable development, embracing ecological, social, construction and traffic aspects. Its facilities are coordinated and handy to all residents [15].

Residential areas are defined by economic, ecologic, social, technical, engineering indices. These issues were discussed in a number of publications.

The initiative committee of a sustainable district points out the following indices [15]:

- water;
- land use/agriculture;
- transport;
- buildings/facilities;
- business/industry;
- composting/processing;
- community/education;
- parks/green areas.

The European Academy of the urban environment provides a model of sustainable district development [16]:

- balance between work and leisure time;
- nature preservation;
- priorities for pedestrians, cyclists and public transport;
- economic operation of energy generation and heating systems;
- construction of energy saving houses;
- opening of district supermarkets to satisfy everyday needs;
- opening of elementary schools and day centres;
- opening of public rest places in nature;
- diversity of forms of constructed buildings;
- arable land and agriculture;
- balance between social groups.

In Lithuania the sustainable district projects have not been developed as much as abroad. Development of such projects requires a lot of efforts and means as well as financing by state institutions; nevertheless, establishment of such district is beneficial to all residents in ecological and social aspects. Life in harmony with nature, environment and surrounding people is essential for each individual.

Woodcock emphasises the major aspects of a sustainable urban residential area [17]:

- 1) excellent city development and architecture;
- 2) privileges for the residents;
- 3) considers local needs and characteristics;
- 4) possibilities to acclimatise and change;
- 5) takes care of public space and new houses projects;

- 6) pursues ways to maintain and renovate buildings of historic value;
- 7) takes care of the design of such buildings for the benefit of society and by seeking promotion from a private sector;
- 8) enhances the quality of private territories.

Thus it is essential to develop the spirit of location by enhancing the life quality. This may be achieved by development of an effective public transport network, safe streets, city design, retailing sector, landscaping (open space) network, local employment basis.

Grant et al [18] emphasised the importance of protecting landscape and ecosystems. They urge the architects and designers to revise the priorities in planning the residential areas, taking into account the significant processes and functions associated with landscape preservation. Planning of sustainable districts embraces not only new concepts and ideas, but also new ways of land development. The authors of the present paper believe that communities of sustainable districts should be guided by the following principles/goals:

- to maintain and restore natural processes and functions of the environment;
- to minimise the effect of residential areas on ecosystems;
- to save natural resources for the future generations;
- to reduce waste production by the residential areas;
- to increase the community involvement in developing a sustainable residential areas;
- to support a healthy social environment.

The concept of Kronsberg city development and landscape sustainable development [19] emphasises the following aspects:

- description of large scale social and ecological development concepts;
- overall development of the project and integrated planning process;
- innovatory structure of communications maintaining the process of development;
- education and curricula associated with sustainable development;
- participation planning processes by involving residents and other people.

There is no uniform system of a sustainable city residential area, therefore development of a system of indices of a sustainable city residential area shall consider the needs of the residents as well as social, environmental, technical aspects.

3. Selection of the surveyed object

In order to analyse the sustainability of city residential areas Vilnius was selected as Vilnius is the principal administrative centre of Lithuania with the highest concentrated economic potential, the highest number of inhabitants and the leading political, economical, social and cultural centres.

Evaluation of the sustainability of Vilnius city residential areas was based on RAIT survey of Vilnius city [20].

41 districts and parts of districts were intercompared: Centras I, Centras II, Žvėrynas, Senamiestis, Naujamiestis, Vilkpėdė, Šnipiškės, Žirmūnai, Žirmūnai II, Dvarčionys, Antakalnis, Belmontas, Rasos, Pavilnys, Naujininkai, Lazdynai, Karoliniškės, Viršuliškės, Šeškinė, Baltupiai, Santariškės, Verkiai, Naujoji Vilnia, Žemieji Paneriai, Vaidotai, Kirtimai, Užsienis, Aukštieji Paneriai, Gariūnai, Grigiškės, Justiniškės, Pašilaičiai, Pilaitė II, Valakampiai, Pilaitė I, Medžiakalnis, Fabijoniškės, Gureliai, Trakų Vokė, Kuprijoniškės, Tarandė.

The survey was carried out by direct interviewing using set questionnaire forms where the interviewers recorded the respondents' answers.

In total 2575 permanent residents of Vilnius city, 16 to 74 years of age took part in the survey [20].

To determine the most sustainable Vilnius city residential area, 29 residential areas of Vilnius city were selected from RAIT survey (Fig): Centras I, Centras II, Žvėrynas, Senamiestis, Naujamiestis, Šnipiškės, Žirmūnai, Žirmūnai II (Šiaurės miestelis), Antakalnis, Rasos, Naujininkai, Lazdynai, Karoliniškės, Viršuliškės, Šeškinė, Baltupiai, Santariškės, Verkiai, Naujoji Vilnia, Žemieji Paneriai, Aukštieji Paneriai, Justiniškės, Pašilaičiai, Pilaitė II (Northern part), Valakampiai, Pilaitė I, Fabijoniškės, Vilkpėdė, Grigiškės.



District communities of Vilnius city municipality

RAIT survey evaluates Vilnius city residential area by 22 indices that correspond to sustainability aspects (Table 1): City centre is close (points); Safe (points); Extensive supply of trade services (points); School is close (points); Kindergarten is close (points); Extensive supply of recreation (points); Clean air (points); Nice environment (points); Good transport service with the centre (points); Good transport service with the work place (points); Well attended environment (points); No noise (points); No drug-addicts (points); Policlinics is close (points); Drugstore is close (points); Good facilities for sports (points); Many

cultural institutions (points); No alcohol addicts are in sight (points); No derelicts are in sight (points); Work place is close (points); Nice architecture of buildings (points); Well attended parks (points).

All these indices were taken from RAIT survey [20] where the residents evaluated the desirability of a residential area in points (5 points – excellent, 4 points – very good, 3 points – good, 2 points – bad, 1 point – very bad).

4. Determination of opinion compatibility among the residents

To determine the significances of the criteria, the expert judgement method proposed by Kendall [21] was used. Zavadskas et al [22] discussed the application of this method in the construction field.

Having determined the numerical values of indices, the significance (importance) of the indices is determined. The significances of the indices on sustainability of city residential areas are evaluated in numerical scale from 1 to 22: 1 – insignificant index, 22 – very significant index.

45 residents of Vilnius city residing in these residential areas were interviewed for determining significances of the project indices. These residents have sufficient information about their residential area and are most concerned persons in establishing the value of sustainability of the city residential area.

This expert judgement method was implemented at the following stages [22]:

- Interview;
- Calculation of values t_j ;
- Calculation of weights q_j ;
- Calculation of values S_j ;
- Calculation of values T_k ;
- Calculation of values W_j ;
- Calculation of values χ^2 ;
- Testing the statement $\chi^2 > \chi^2_{tbl}$.

The values t_{jk} for statistical processing were obtained by interviewing the respondents. The average criterion value \bar{t}_j was calculated by the formula:

$$\bar{t}_j = \frac{\sum_{k=1}^r t_{jk}}{r}, \quad (1)$$

where t_{jk} is the ranking of the j criterion by the k respondent and r is number of respondents.

The weights of the criteria were calculated by dividing the sum of the criteria average values by the average value of each criterion:

$$q_j = \frac{\bar{t}_j}{\sum_{j=1}^n \bar{t}_j}. \quad (2)$$

The total weight of the criteria must be equal to one:

$$\sum_{j=1}^n q_j = 1,0. \quad (3)$$

Reliability of the data can be expressed by the coefficient of concordance (agreement) of the respondents' opinions by describing the extent to proximity of individual views. In cases with reiterated ranks for same parameters, as in our case, the coefficient of concordance is:

$$W = \frac{12S}{r^2(n^3 - n)}, \quad (4)$$

where S – the total square deviation of the rankings of each criterion, T_k the index of reiterated ranks in the r rank, r the number of respondents and n the number of evaluation criteria.

The deviation of the criterion ranking:

$$S = \sum_{j=1}^n \left[\sum_{k=1}^r t_{jk} - \frac{1}{n} \sum_{j=1}^n \sum_{k=1}^r t_{jk} \right]^2, \quad (5)$$

where t_{jk} is the rank conferred by the k respondent to the j criterion.

The significance χ^2 of the concordance coefficient is calculated as follows:

$$\chi^2 = \frac{12S}{rn(n+1)}. \quad (6)$$

Kendall [21] has shown that, when $n > 7$, the value $\chi^2 = W \times r \times (n-1)$ has a distribution with degrees of freedom $\nu = n - 1$, where n is the number of criteria considered and r the number of experts. It has been proved that if the calculated value χ^2 is larger than the critical tabular value χ^2_{tbl} for the pre-selected level of significance (eg $\alpha = 0,05$), then the hypothesis about the agreement of independent experts judgements is not rejected. If the $\chi_{a,\nu}^2 > \chi^2_{tbl}$ the significance of concordance coefficient exists on α level, then the agreement of experts' opinions is satisfactory and group opinion is established. Otherwise, when $\chi_{a,\nu}^2 < \chi^2_{tbl}$ is obtained, the respondents' opinions are not in agreement, which implies that they differ substantially and the hypothesis on the rank's correlation cannot be accepted.

The concordance coefficient based on the criteria weights is $\chi^2 = 445,86$ greater than χ^2_{tbl} , the hypothesis on the rank's correlation cannot be accepted. The degrees of freedom ($\nu = n-1 = 22-1 = 21$), and pre-selected level of significance is $\alpha = 0,01$ (or error probability $P = 1\%$); in that case we have the value of χ^2_{tbl} equal to 38,93 [23]. Since $445,86 > 38,93$ $\alpha = 0,01$, and $\nu = 21$, then the assumption is made that the coefficient of concordance is significant and expert rankings are in concordance with 99% probability.

5. Evaluation of city residential areas by using COPRAS method

This method assumes direct and proportional dependence of significance and priority of investigated versions

on a system of criteria adequately describing the alternatives and on values and significances of the criteria.

Application of multipurpose evaluation method COPRAS led to establishment of the rank of priorities of residential areas in respect of their sustainability.

Description of COPRAS methods and possibilities of its application are published in a number of papers [24–29].

The determination of significance and priority of alternatives is carried out in 4 stages [30]:

Stage 1: The weighted normalised decision making matrix D is formed. The purpose of this stage is to receive dimensionless weighted values from the comparative indexes. When the dimensionless values of the indexes are known, all criteria, originally having different dimensions, can be compared. The following formula is used for this purpose:

$$d_{ij} = \frac{x_{ij} \cdot q_j}{\sum_{j=1}^n x_{ij}} \quad i = \overline{1,m}; \quad j = \overline{1,n}, \quad (7)$$

where x_{ij} – the value of the i -th criterion in the j -th alternative of a solution; m – the number of criteria; n – the number of the alternatives compared; q_i – significance of i -th criterion.

The sum of dimensionless weighted index values d_{ij} of each criterion x_i is always equal to the significance q_i of this criterion:

$$q_i = \sum_{j=1}^n d_{ij} \quad i = \overline{1,m}; \quad j = \overline{1,n}. \quad (8)$$

In other words, the value of significance q_i of the investigated criterion is proportionally distributed among all alternative versions a_j according to their values x_{ij} .

Stage 2: The sums of weighted normalised indexes describing the j -th version are calculated. The versions are described by minimising indexes S_{-j} and maximising indexes S_{+j} . The lower value of minimising indexes is better and the greater value of maximising indexes is better. The sums are calculated according to the formula:

$$S_{+j} = \sum_{i=1}^m d_{+ij}; \quad S_{-j} = \sum_{i=1}^m d_{-ij} \quad i = \overline{1,m}; \quad j = \overline{1,n}. \quad (9)$$

In this case, the values S_{+j} [the greater is this value (project 'pluses'), the more satisfied are the interested parties] and S_{-j} [the lower is this value (project 'minuses'), the better is goal attainment by the interested parties] express the degree of goals attained by the interested parties in each alternative residential area. In any case the sums of 'pluses' S_{+j} and 'minuses' S_{-j} of all alternative projects are always respectively equal to all sums of significances of maximising and minimising criteria:

$$S_{+} = \sum_{j=1}^n S_{+j} = \sum_{i=1}^m \sum_{j=1}^n d_{+ij}, \quad (10)$$

$$S_{-} = \sum_{j=1}^n S_{-j} = \sum_{i=1}^m \sum_{j=1}^n d_{-ij}, \quad i = \overline{1,m}; \quad j = \overline{1,n}.$$

In this way, the calculations made may be additionally checked.

A sample sustainability evaluation of a residential district (fragment)

No	Evaluation criteria	Unit of measure	*	Significance	Grigiškės	Centras II	Žvėrynas	Senamiestis	Naujamiestis	Antakalnis	Rasos	Karoliškės	Šnipiškės	Baltupiai	Santariškės	Pašilaičiai	Pilaitė II	Valakampiai	Pilaitė I
1	City centre is close	Points	+	0,042	3,8	5	5	4,9	4,9	4,7	4,5	4,2	4,8	4,3	3,4	3,3	3,5	3,4	3,1
2	Extensive supply of trade services	Points	+	0,03	3,4	4,4	3,3	3,6	4,2	3,6	2,3	4,4	4,6	4	3,7	4,2	2,5	2,2	3,1
3	School is close	Points	+	0,059	4,4	4,8	4,8	4,6	4,5	4,6	3,6	4,8	4,8	4,5	3,8	4,6	3,1	2,7	4
4	Kindergarten is close	Points	+	0,034	4,5	4,9	4,9	4,4	4,4	4,1	3,6	4,9	4,8	4,4	1,9	4,6	2,8	3,1	3,7
5	Extensive supply of recreation	Points	-	0,027	2,4	4,2	2,7	4,1	3,4	2,4	1,7	3,2	4,4	2,6	2,3	2,8	1,7	1,9	2,6
6	Clean air	Points	+	0,071	4	3	3,4	3,2	2,8	3,8	3,5	3,8	3	4,1	4	3,7	4,8	4,6	4,6
7	Nice environment	Points	+	0,061	4,4	4	4,6	4,3	3,4	4,1	3,9	4,2	3,2	4,5	4,2	3,8	4	4,7	4,1
8	Safe	Points	+	0,069	3	3,2	3,9	3,4	2,9	3,4	3,4	2,7	2,9	3,6	3,4	3,3	3,4	3,8	3,8
9	Good transport service with the centre	Points	+	0,064	4,1	5	5	4,7	4,8	4,7	4,1	4,5	4,8	4,4	4,2	4,1	3,9	3,4	3,3
10	Good transport service with the work place	Points	+	0,06	3,6	4,3	4,2	4,3	4,3	3,8	3,8	3,8	4,3	4,1	3,8	4	4,2	3	3,7
11	Well attended environment	Points	+	0,047	3,4	3,6	3,9	3,4	3,4	3,5	2,8	3,7	3,1	3,8	4	3,9	3,9	3,6	3,7
12	No noise	Points	+	0,068	3,8	3,3	4,1	3,7	3,1	3,3	3,8	3,4	3	4	4,7	3,9	4,8	4,4	4,5
13	No drug-addicts	Points	+	0,048	2,8	3,4	2,8	3,1	2,9	2,8	4,1	2,1	2,6	3,4	4	3,4	3,7	3,8	4
14	Policlinics is close	Points	+	0,035	4,4	4,3	3,5	3,9	4,3	4,6	3,8	4,9	3,7	3,7	3,9	4	3,3	3,5	4,1
15	Drugstore is close	Points	+	0,045	4,4	4,8	4,8	4,4	4,7	4,7	3,9	4,9	4,6	4,9	4,7	4,8	4,1	3,4	4,5
16	Good facilities for sports	Points	+	0,023	2,9	3,8	4,6	3,6	3,9	3,8	2,9	4,6	3,6	3,8	4,1	3,5	3,1	4,8	3,6
17	Many cultural institutions	Points	-	0,016	2	4,1	2,6	4	3	2,3	1,6	2,2	3	2	2,1	2,2	1,3	1,3	2,1
18	No alcohol addicts are in sight	Points	+	0,042	2,6	3,2	2,5	2,7	2,6	2,2	3,2	1,8	2	2,7	3,3	3	2,3	3,2	3,4
19	No derelicts are in sight	Points	+	0,026	3	2,9	2,5	2,7	2,5	2,3	3,8	2,1	2,5	2,8	3,2	3,3	2,1	3,4	3,3
20	Work place is close	Points	+	0,075	3,3	4,2	3,7	3,9	3,8	2,9	3,3	3	3,8	3,1	2,9	3,2	3,8	2,6	3,2
21	Nice architecture of buildings	Points	+	0,044	2,9	4,3	3,7	4,5	3,3	2,9	2,7	2,4	3,3	2,8	3,2	2,9	2,5	3,4	2,8
22	Well attended parks	Points	+	0,014	3	3,4	4	3,2	3,3	3,4	2,6	3,3	3,3	3,2	3,3	2,6	3	3,5	3,5

* A sign +(-) indicates that a higher (lower) value of the criteria is better for residents.

Stage 3: The significance (efficiency) of comparative versions is determined on the basis of describing positive ('pluses') and negative ('minuses') characteristics. Relative significance Q_j of each project a_j is found according to the formula:

$$Q_j = S_{+j} + \frac{S_{-\min} \cdot \sum_{j=1}^n S_{-j}}{S_{-j} \cdot \sum_{j=1}^n \frac{S_{-\min}}{S_{-j}}}, \quad j = \overline{1, n}. \quad (11)$$

Stage 4: Priority determination of residential area. The greater is the Q_j , the higher is the efficiency (priority) of the project.

Having made the calculations, we get a sustainable residential area of Vilnius city.

6. Conclusions

The sustainable city development and residential areas have a large number of indices/indices systems in the world. With reference to these indices/indices systems has been made the system of 22 indicators defining the sustainability of residential areas.

Basing on multipurpose evaluation method COPRAS, the most sustainable residential area was determined and evaluated by 22 sustainability development indices. It was established that the multipurpose COPRAS method is suitable for determining the sustainable district.

An analysis was done comparing all areas named above. There we see the most problematic areas in which quality of living must be improved. Improvement of living quality is a target of government and municipality.

Ranking of priorities of city residential areas was compiled: Žvėrynas, Centras II, Baltupiai, Senamiestis, Pilaitė I, Pilaitė II, Santariškės, Naujamiestis, Pašilaičiai, Antakalnis, Valakampiai, Grigiškės, Rasos, Karoliniškės, Šnipiškės, Šeškinė, Fabijoniškės, Centras I, Lazdynai, Naujoji Vilnia, Justiniškės, Žirmūnai II, Viršuliškės, Naujininkai, Verkiiai, Žemieji Paneriai, Žirmūnai, Aukštieji Paneriai, Vilkipėdė.

The most sustainable residential area is Žvėrynas. This area is close to the centre of Vilnius, nice looking architecture, lovely surrounding, a lot of green zones and well – organised infrastructure solutions.

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VILNIAUS MIESTO GYVENAMŲJŲ RAJONŲ DARNOS VERTINIMAS

M. Viteikienė, E. K. Zavadskas

Santrauka

Straipsnio tikslas – pasiūlyti metodiką, kaip surikiuoti gyvenamuosius rajonus pagal darnios plėtros rodiklius ir sudaryti jų prioritetų eilutę.

Suformuluotas uždavinys remiantis Vilniaus miesto RAIT atlikta apklausa patraukliausiam rajonui įvertinti. Šioje apklausoje dalyvavo Vilniaus miesto gyventojai. Iš apklausos buvo atrinkti tik Vilniaus miesto gyvenamieji rajonai (mikrorajonai) ir juos apibūdinantys rodikliai. Buvo sudaryta 22 rodiklių sistema, charakterizuojanti darnos aspektus. Gyvenamieji rajonai vertinami pagal infrastruktūrą, gyvenamąją bei verslo aplinką. Remiantis ekspertų apklausomis, nustatyta rodiklių reikšmė. Taikant daugiatislio vertinimo metodą COPRAS (Complex Proportional Assessment), sudaryta gyvenamųjų rajonų pagal jų darną prioritetų eilutę.

Reikšminiai žodžiai: darnus vystymasis, miesto gyvenamieji rajonai, COPRAS, vertinimas.

Milda VITEIKIENĖ. PhD student and Assistant Professor at the Dept of Construction Technology and Management, Vilnius Gediminas Technical University. MSc degree in construction management and business (2003). Research interests: innovation, economics, marketing, management, the theory of multiple criteria decision-making in practice.

Edmundas Kazimieras ZAVADSKAS. Doctor Habil, Professor, Dr honoris causa of Poznan University of Technology, Vice Rector of Vilnius Gediminas Technical University (Lithuania). Member of Lithuanian Academy of Sciences, President of Lithuanian Operational Research Societies, President of Alliance of Experts of projects and buildings of Lithuania. Editor-in-Chief of the “Journal of Civil Engineering and Management”, “Technological and Economic Development of Economy”; Editor of the “International Journal of Strategic Property Management”. The author of more than 300 scientific papers, 11 books. Research interests: building technology and management, decision-making theory, automation in design, expert systems.