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A MODEL FOR EVALUATING THE INVESTMENT IN THE CONSTRUCTION OF DWELLING HOUSES BASED ON MULTIPLE CRITERIA DECISION SYNTHESIS METHODS

INTRODUCTION

The aim of the present investigation is to answer the question whether it is more advisable to invest in individual dwelling-houses construction in Vilnius or in the construction of apartment houses.

The analysis of the market of individual dwelling-houses in Lithuania has revealed that the construction of many houses is not completed.

In the period from 1998 to 2003 there was a boom in the construction of new dwelling-housing in Lithuania (Figure 1) [12].

In order to achieve the specified objective, an analysis of works of foreign and Lithuanian authors was performed and a decision model based on financial and economical indicators for evaluating dwelling-house construction in Vilnius and profitability of investment in this area compared to that of apartment houses was developed.
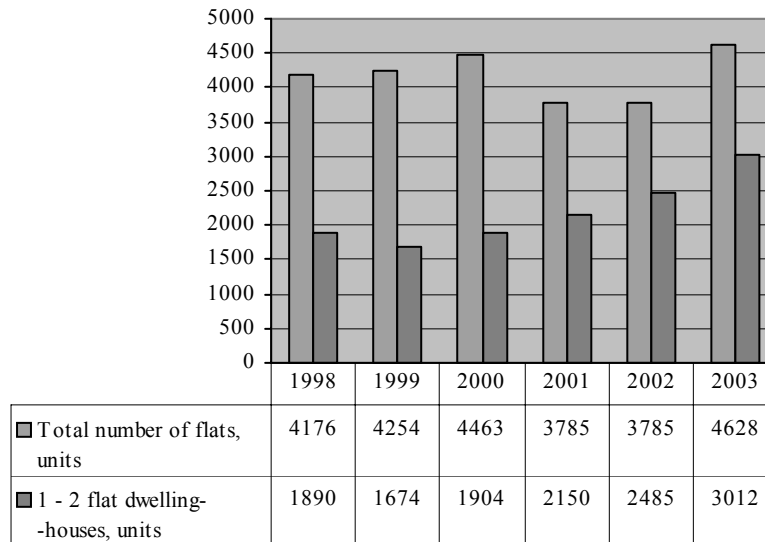
	1998	1999	2000	2001	2002	2003
☐ Total number of flats, units	4176	4254	4463	3785	3785	4628
☐ 1 - 2 flat dwelling--houses, units	1890	1674	1904	2150	2485	3012

Fig. 1. Statistical data on the construction of new dwelling-houses in Lithuania [12]

1. A SURVEY OF DECISION SUPPORT SYSTEMS AND EVALUATION REQUIREMENTS

The authors carried out an analysis of the decision support systems developed by Lithuanian and foreign researchers, and suggested a decision making model for the analysis of the planning stage of individual house construction. This problem is rather complicated; therefore, at this stage, the authors suggest to analyze the problems of site selection and financial and investment evaluation.

The significant problems of housing construction relating to design, construction, finance and maintenance were considered by many authors [2; 15; 16; 20; 21]. The tools proposed by Park [10] and Piramuthu [11] use information technology to support decision making as well as evaluation methods and data managing in construction.

According to the expert system developed by Christian, preliminary building cost and construction time may be determined at the pre-design stage. Using the data from earlier projects (project price) and referring to experts' knowledge, the system may predict the cost of forthcoming developments [3].

Mohan described the expert systems created in various countries and intended for calendar planning – PLATFORM, site preparation – SI-TEPLAN, analysis of industrial safety – HOWSAFE (Stanford University, USA), as well as a system for determining preliminary cost and time of construction, for making construction plans – PLANEX, analysis of building site – DSCAS (Colorado State University, USA), strategic planning of construction projects – ELSIE (University of Salford, UK), and analysis of construction process and risk analysis (University of Texas, USA and Georgia Institute of Technology, USA) [7].

Ozdoganm and Birgonul (Middle East Technical University, Turkey) developed a model on the basis of which multiple decisions in BOT (Build--operate-transfer) type projects were made in municipal projects with private capital investment. The model was developed to evaluate the selection of contractors and the risks involved. The model was intended to help select a municipality where a private company is allowed to finance, build and operate a project for some time before it is transferred to municipality [9]. This model could be used for municipality housing program development.

Multicriteria analysis of project selection problems was also performed by Nowak [8].

A new multiple criteria decision methodology developed by Zavadskas and Kaklauskas was proposed for solving various multi-objective problems [4; 16; 17; 19].

Realization of a model for complex analysis of a single-family house life cycle was proposed by Kvederyte [5]. Complex analysis model of rational Lithuanian housing was developed by Banaitis [1].

When solving technological and economic problems in construction to find optimal solutions, it is advisable to use decision support systems based on game theory and the normalisation methods proposed and described by Migilinskas and Ustinovichius [6].

2. A MODEL OF ECONOMIC EVALUATION OF DWELLING-HOUSES CONSTRUCTION BASED ON MULTIPLE CRITERIA DECISION SYNTHESIS METHODS

A two-stage model for evaluating the profitability of investment in the construction of dwelling-houses is selected.

At the first stage, the land plot for individual dwelling-houses is evaluated, while at the second stage, a comparative analysis of the possible construction variants of individual dwelling-houses and apartment houses from economical perspective is made.

For decision-making, the authors selected a modern method of multiple criteria project synthesis DSS1 [13; 14]. The method consists in the synthesis of a number of interrelated engineering solutions by selecting the best decisions at any stage of analysis.

Synthesis is a solution incorporating various problems (stage solutions) into a general project based on the relationship matrices [13].

The underlying principle of the two main structural elements of decision support systems is based on the data (DB and their control system) and the major elements of economic evaluation of the construction model of dwelling--houses (the structure of the expert methods, integrated solutions and multiple criteria assessment methods) which are shown in Figure 2.

The first stage of decision-making is intended for stating the problem and selecting a database structure (DBS). At this stage, the data are being collected for a database (i.e. the criteria to be used, the data on the variants, the relationship matrices needed etc.). Sets of closely interrelated criteria to be used at both stages are defined. The criteria referring to the variants under consideration are subdivided into qualitative and quantitative. For calculating the criteria values, descriptions or particular formulas will be used in the model.

For evaluating the qualitative criteria, the descriptions for expert assessment in decision making or integrated pre-assessed qualitative criteria are provided.

Based on the approach described, a decision tree related to the economic evaluation model to be used in the construction of dwelling-houses has been created (Figure 3).
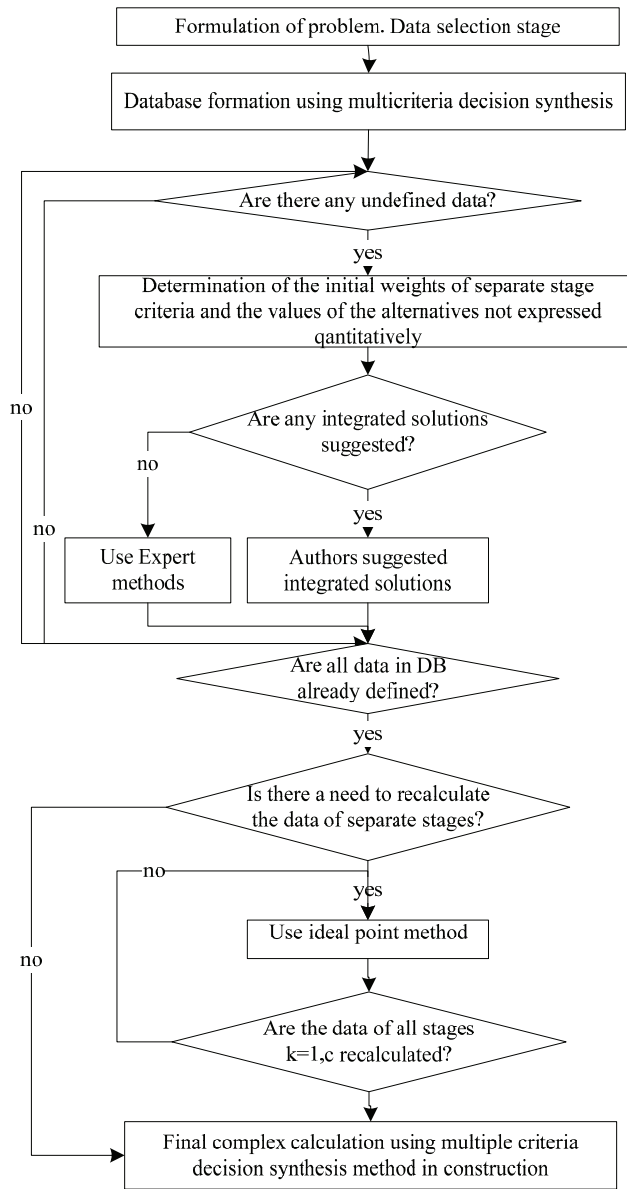

Fig. 2. Economic evaluation of the construction of dwelling-houses based on multiple criteria decision synthesis methods

STAGE 1 $m_1=3, z_1=n$	STAGE 2 $m_2=2, z_2=2$	GENERALIZED CRITERION $K_s, s=Z_k$

Plot g_{11}	Investition g_{21}	K_1
	Investition g_{22}	K_2

Plot g_{12}	Investition g_{21}	K_3
	Investition g_{22}	K_4

...	...	...
	...	...

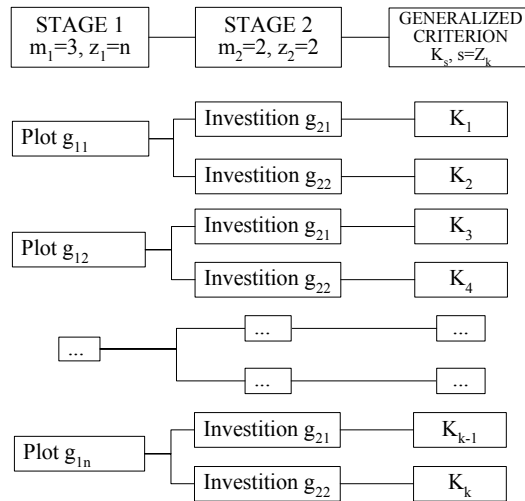| Plot g_{1n}	Investition g_{21}	K_{k-1}
	Investition g_{22}	K_k

Fig. 3. Fragment of a decision tree (DT) structure created by multiple criteria decision synthesis methods

A set of criteria to be used in selecting a rational investment alternative in the construction of dwelling houses was defined (Figure 4).
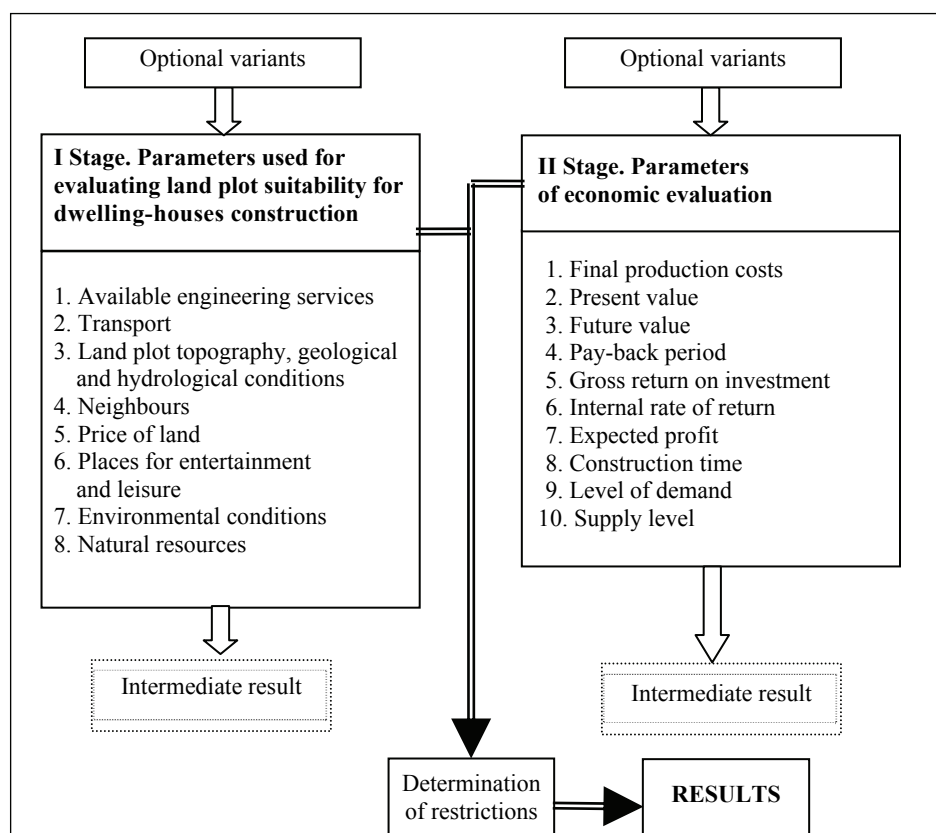
Fig. 4. Major criteria used for evaluating the construction of dwelling-houses

2.1. The criteria describing the land plot

For siting (plot) evaluation the authors have developed a set of integrated criteria. To increase the evaluation reliability and to decrease the influence of subjective factors on the expected result, internal parameters were determined for each criterion. According to the determined internal parameters, possible variants of the criteria were developed and evaluated by the experts. A description of the criteria is presented together with the particular values. If in the process of evaluation the selection is made from the alternatives to which the integrated criterion values cannot be applied, it is recommended to apply the interpolation method and to recalculate the value for a new variant of the newly created criteria.

The criteria describing the land plot are as follows:

Engineering services. According to the existing project, it is necessary to join the water-supply system, sewage, heating and electricity networks. Each of these connections may be assigned points from 1 to 5, depending on the distance to the connection points, because the highest costs are associated with the need to cutting, uplifting or going around the existing systems.

The connections are evaluated in the following way:

- Connection to the existing systems at 50 m distance – 5 points.
- New filiations to existing systems (in suburbs), when there are no more networks requiring uplifting or going around – 4 points.
- Connection to existing systems at 50-100 m distance – 3 points.
- Connection to existing systems over 100 m distance – 2 points.
- Connection to existing systems requiring performing the renovation of the main line or meeting other special requirements – 1 point.

Experts helped to determine the economic effect of the available engineering services and their connections on the project.

Table 1

	P1	P2	...	Pn
E1	xp11	xp21	...	xpn1
E2	xp12	xp22	...	xpn2
...	...	...	...	...
Em	xp1m	xp2m	...	xpnm

Experts with experience of more than 10 years in construction and engineering were selected. The experts were asked to assess the economic effect of each connection by ranking the alternatives (the most significant is No 1, the less significant is No X). By collecting the estimates of the experts, the significance of each connection was determined, with the maximum significance equal to 5 points (Table 1).

Here, E is an expert, P – a connection and x − an estimate.

The expert's estimate of each connection P is obtained from the sum:

$$A_n = \sum_{n=1}^{m} xp_{nm} \tag{1}$$

The average estimate value of each expert is calculated as X:

$$Xpn_{vid} = A_n / m \tag{2}$$

It is assumed that the least value Xpn_{vid} is the best (in other words, this will be the factor with the highest influence on the project) – 5 points (i.e. 100%), thus every other Xp_{vid} is calculated as the deviation from the best

result, because it also indicates that in the process of assessment the experts expressed their opinions that the costs of the works of the smallest and the largest assessed Pmn will differ proportionally. Therefore, the significance may be determined for each P:

$$Kpn = 5 / Xpn_{vid} \qquad (3)$$

Transport. Laying of roads requires additional costs and is associated with the restrictions of traffic. Therefore, roads and streets and their condition influence the evaluation of land plot. This, however, depends on land usage and its intensity.

As the road network in Vilnius is sufficiently developed, the main factor for transport evaluation is the time needed to get from the land plot to shops and institutions most often visited by people. Each value is assigned points from 1 to 0.1 (Table 2). The maximum estimate is 1 point if the land plot is 5 min. away from the object, 0.1 points if 90 min. or more are needed to reach it. The maximum allowable value of the criteria could be 5 points.

Table 2

	<5 min.	<15 min.	<30 min.	<45 min.	<60 min.	><90 min.
City centre	1	0.8	0.6	0.4	0.2	0.1
School	1	0.8	0.6	0.4	0.2	0.1
Shopping centre	1	0.8	0.6	0.4	02	0.1
Hospital	1	0.8	0.6	0.4	0.2	0.1
Eating house	1	0.8	0.6	0.4	0.2	0.1

The total estimate of each Transport value T is obtained from the sum:

$$T_n = \sum_{n=1}^{m} xp_{nm} \qquad (4)$$

Land plot topography, geological and hydrological conditions may restrict decisions on construction and the total price of the building. Soil properties are the decisive factors in design and laying of foundations. The following criteria values are recommended to be used for the evaluation:
−   3 points ─ good conditions (natural cohesive soil, no remains of demolished buildings, low groundwater level),
−   2 points ─ average conditions (cohesive soil, remains of demolished buildings, high level of groundwater),
−   1 point ─ satisfactory conditions (unstable, bulk soil, remains of former demolished buildings, high level of groundwater).

Neighbouring areas. The evaluation is made according to the district and the purposes of nearby buildings. The smaller the built-up area or the farther the neighbouring areas from the project area, the smaller the required investments. The estimates offered are as follows:

- The areas close to the land plot are not built-up (no restrictions for constructions) – 4 points.
- Neighbouring land plots are industrial areas (minimum restrictions) – 3 points.
- Neighbouring land plots are commercial or cultural heritage areas, partially restricted access (many minor restrictions) – 2 points.
- Neighbouring land plots are residential or secured areas (many particular and strictly defined restrictions) – 1 point.

Price of land. Price is one of the most important criteria in siting evaluation. It includes not only the technical and qualitative data of the land plot, but also the prestige of location, traditions, as well as possibilities for expansion and growth. It is recommended to use the average district price for the area.

Places for leisure and entertainment. When evaluating the place with respect to this criterion it is necessary to take into account the location of the recreational centres, i.e. the accessibility (preferably on foot) of cafes, bars, night clubs, shops, museums and theatres. The estimate shows the concentration of these centres in a particular neighbourhood within 1 km^2. The following evaluation criteria for Vilnius were proposed (Table 3):

Table 3

Vilnius district	Value
Old town	8.4
New city	22.4
Zverynas	2.8
Zujūnai	2.8
Valakampiai	3.3
Naujininkai	5.1
Riešė	2.0
Antakalnis	3.9
Antaviliai	0.5

Environmental conditions. Ecologically clean accommodation environment should be one of the most important criteria in evaluation of the land plot in order to ensure the most favourable conditions for the inhabitants

of dwelling-houses. The criterion is affected by many factors: traffic flow, overall air and soil pollution in the area, development of manufacture, noise and radiation level.

– Good environmental conditions (not including any aforementioned factors) – 3 points.
– Satisfactory (1-2 factors) – 2 points.
– Poor (3-4 factors) – 1 point.

Natural resources. For each of the described natural resources close to the potential land plot 0.20 points are added to the initial 0.20 points: park/forest, natural water body, ornamental water (basins, ponds), spectacular landscape.

2.2. Economic evaluation

Economic evaluation is made at all stages including activity preparation, the process itself and selling of the product in the past, present and future (formation and usage of labour, material resources, economic and financial indicators of activity).

Economic and financial evaluation of the investment projects is a rational way to make a decision.

A brief description of the economic criteria is presented below.

Final production costs include all the costs necessary for the item production, including land plot.

Economic evaluation of an engineering project is based on the planned cash flow. The flow shows the future investments, incomes and expenses. One of the most significant and complicated issues in evaluation is the forecasting of the future cash flow for the period of 5 years. In this way, the worth of the future money at present is determined.

Pay-back period represents the amount of time needed for the project to recover the investments made.

Gross return on investment is the total profit, received from the project during its lifetime, divided by the amount of investments and expressed in percentage.

Internal rate of return is the rate of return of the project when the present value of all cash flows received from the project is equal to zero. Thus, this rate is a certain profitability measure, while the external economic factors, capable to affect the planned investment flows, are not taken into account.

In the evaluation process, the project with the highest positive internal rate of return is selected.

Expected profit is the calculated weighted average profit based on probabilities. It describes the average or the main trend in probabilistic profit distribution.

The expected profit is the mathematical average of the different possible profit rates. In mathematical statistics the expected magnitude is referred to as the first moment of stochastic distribution. The second moment of stochastic distribution (around the mean) is called the average square deviation.

Construction time. The duration of construction is calculated from the beginning of the pre-design stage to the planned date of the project commissioning.

Level of demand. The year 2003 was one of the most successful for the developers of all types of real estate. Particularly high demand for all types of real estate determined the increase in sales price by 10-40%, depending on the type of real estate. Although quite a high demand was for the rent of premises as well, there was no price increase in this sector of real estate market – prices for rent (especially those for old flats, luxury apartments and houses) are constantly decreasing as the supply of new apartments and houses is increasing.

Under these market conditions, when sales prices are increasing and rent prices are decreasing or remain constant, the profitability of investment in real estate purchasing and the subsequent renting fell to 6-12% in the sector of residential premises. Depending on the market sector, the profit of real estate developers is about 15-30%. However, the increasing building costs and price of land plots as well as growing competition are likely to reduce the profit of real estate valuators in the nearest future.

Determination of supply level. The supply of construction products is evaluated by experts according to the following factors [2]:
− Costs.
− Technologies. With the advances in technology, the price of the products decreases and the quality increases.
− Prices of complementary goods. Manufactured products may complement or substitute each other. For example, cheaper alternative windows decrease the cost of building renovation.
− Other factors: political crises, wars, strikes, interest rate variation etc.

Table 4

Criterion	Arbitrary notation of the criterion	Integrated value of the criterion
Demand level increases	A11	10.0
Demand level is constant	A12	8.0
Demand level decreases	A13	4.0

Table 5

Criterion	Arbitrary notation of the criterion	Integrated value of the criterion
Supply level is lower than demand level (shortage)	A21	10.0
Supply is equal to demand	A22	6.7
Supply level is higher than demand (market surplus)	A23	3

3. EVALUATION OF THE CONSTRUCTION OF DWELLING-HOUSES IN VILNIUS

3.1. Selection of location

Following the description presented in section 2, possible location alternatives for dwelling-houses were selected. For each variant the initial data were generated (presented in Table 6). When the model for evaluating the construction of dwelling-houses based on multiple criteria decision synthesis methods is used, the integrated solutions are available, and the decision maker does not need to ask an expert to evaluate the situation (except for the case when there is a recommended alternative). This saves time of the decision maker. At the first stage of research based on the application of multiple criteria synthesis method (DSS1), the intermediate result was obtained.

As shown in the table, the most suitable land plot for housing construction from economical perspective is in Riese. The land plot suitable for the construction of dwelling-houses in Zujunai was the second, and the third was a plot in New City.

Table 6

Criteria	Expressed or not expressed in monetary units	Units of measure	Min or Max	Weight	New City	Riese	Zujunai
Engineering services	-	points	+	0.17	5	2.5	1.5
Transport	-	points	+	0.14	5	3.6	3.6
Topography of land plot	-	points	+	0.09	2	3	2
Neighbours	-	points	+	0.09	3	4	4
Price of land	+	1000 Lt.	-	0.18	100.00	10.00	15.00
Places for entertainment and leisure	-	%	+	0.07	22.4	2	2.8
Environmental conditions	-	points	+	0.17	2	3	3
Natural resources	-	points	+	0.9	0.20	0.80	0.60

3.2. Economic evaluation

In order to determine the more economical engineering project at the second stage, as a variant of housing construction, the possibility to build an apartment house was selected out of all the criteria described in the methodological part of the paper. The indicators whose values are not the same were used for calculations. For example, only the gross return on investment was selected from the profitability indices because the values of other criteria are identical. When selecting the criteria, it is important to group together related criteria, e.g. costs, pay-back period, profitability indices and so on.

Table 7

Criteria	Units of measurement	Min or Max	Initial significance	Dwelling house (2 units*160m²)	Apartment (8flat*100m²)
Costs:					
Final production costs	Thousand Lt	-	0.10	1009.00	2005.00
Money time value:					
Present value	Lt	-	0.10	0.95	0.95
Future value	Lt	+	0.10	1.34	1.39
Pay-back period	Years	-	0.11	2.5	3.5
Profitability indices:					
Gross return on investment	Percent	+	0.10	111.28	119.70
Internal rate of return	Percent	+	0.10	11.33	9.12
Risk:					
Expected profit	Percent of 1 Lt	+	0.11	0.11	0.14
Construction time	months	-	0.90	10.00	12.00
Level of demand	points	+	0.50	8.00	10.00
Supply level	points	-	0.50	10.00	8.00

The significance of the criteria is determined by expert methods, i.e. by interviewing the experts [14]. The initial data are presented in Tables 6 and 7.

By performing the calculations, the restrictions for dwelling-house siting were determined. The restrictions for the location of an apartment house were not established.

Table 8

Priority of alternatives	Alterna-tive №	K_{bita} value	Variant composition		Value of K_{bit} alternatives
1	3	1.00			
			6	Riese	1.000
			3	Dwelling-house	1.000
2	4	0.99			
			6	Riese	1.000
			4	Apartment	0.989
3	5	0.76			
			10	Zujunai	0.758
			3	Dwelling-house	1.000
4	6	0.75			
			10	Zujunai	0.758
			4	Apartment	0.989

The calculations performed by the SPS_DS system applying multiple criteria synthesis methods yielded a final result. According to it, the construction of a dwelling-house in Riese or Zujunai is most promising from economic perspective.

In general, project alternatives (options) have been made using the initial data, expert methods and multi-stage multiple criteria decision synthesis DSS1 approach. Next, the most efficient siting alternative for dwelling house construction and economic evaluation were calculated by DSS1 method (Table 8). The results were:

− Riese.
− Dwelling-house.

It should be noted that the above system does not provide precise data. A model is based on generalized criteria giving a possibility to choose among a number of the available decisions.

The authors believe that the model suggested may help harmonize the needs of various interested parties at minimum expenses at the initial stage of investment, thereby allowing for contracting and further development and implementation of other steps in project execution.

CONCLUSIONS AND RECOMMENDATIONS

1. A model for evaluating the construction of dwelling-houses has been developed. The model is designed for complex evaluation of their location and for a comparative analysis of profitability of investment in the construction of dwelling-houses and apartment buildings.
2. The model is designed for the construction in Vilnius. In order to apply the model in other localities, some of the criteria should be revised.
3. The model was applied to the real problem solution. The result obtained shows that the construction of dwelling-houses is more economically promising in 2004.
4. The system of integrated indicators presented in the model allows for the reduction of the amount of expert evaluation work as well as for saving his time.

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