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MULTI-ATTRIBUTE MODEL FOR ESTIMATION OF RETAIL CENTRES INFLUENCE ON THE CITY STRUCTURE. KAUNAS CITY CASE STUDY

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Abstract. This paper concerns multi-attribute decision support methodology applied to analyze the impact of retail centres on the city as a complex system. Influence on the city is described as the sum of effects the retail centres give to the quality of life to the neighborhood and other city population, the work of city transportation system, architectural and urban perception of the city. The gamut of impact is estimated and numerical expression is obtained. Using it different alternative objects are compared. The task is described by many attributes. The main attributes are distinguished to measure the influence of retail centres on quality of life, the work of transportation system, on the economics and the architectural – urban perception of the city. On the basis of expert judgment the weights of attributes are estimated. The normalization of the efficiency attributes is done using linear normalization method. The values of different attributes are derived from the rating done by urbanism ground experts. From ideal values the optimal alternative is made. Influence is estimated using Multiplicative Summarized Optimal Criterion method. The strategy of retail centres development is defined by comparison of existing objects to ideal value. The multi-attribute model for estimation of retail centres influence to the city was used in "Kaunas city municipality specialised plan for dislocation of retail centres". The research results determined effectiveness of existing objects and future development strategy.

Keywords: multicriteria analysis, retail centres, influence of retail centres on the city structure, efficiency attributes, ranks, Multiplicative summarized optimal criterion.

1. Introduction

Economical forces mostly drive the problems of development regulation emerging in the cities of today. Such also is the case with retail centres invasion to the east European cities. With the market globalization new investors are coming and often they are not very sensitive to the existing environment. As a result the Lithuanian Ministry of Environment have given an order to the municipalities of bigger cities to make retail centres specialized plans to regulate this kind of development in the cities. Yet there is no experience in post-soviet countries how to keep a curb on economic forces and the problem for the planners is how to strengthen their motivation against inappropriate locations proposed by the investors [1].

When building new super-markets, shopping malls etc. we have to measure the impact it makes on the existing environment. To give a clear answer what kind of development is allowed and what is forbidden the scientific basis is needed [2].

G. Munda in [3] states that sustainable development is a multidimensional concept, including various perspectives. He showed that multi-attribute decision analysis is an adequate approach for dealing with sustainability conflicts at both micro and macro levels of analysis.

Traditional decision support techniques lack the ability to simultaneously take into account these factors and conditions. The opinions are uncertain and preferences appear for possible consequences or outcomes. Utility theory has been developed by Von Neumann and Morgenstern [4], it gives us the elements that we need, so as to make a quantification of preferences in the process of making decision under uncertainty.

Similarly, GIS, while recognized as useful decision support technologies, do not provide the means to handle multiple decision factors. Jun [5] provided a framework for integrating the strengths of GIS, expert systems, and the analytic hierarchy process to incorporate the decision maker's preferences on a range of factors used in finding optimally suitable sites.

Kitsiou et al. [6] presents a study, in which a methodology was developed for the multi-dimensional evaluation and ranking of coastal areas using a set of attributes and based on the combination of multi-attribute choice methods and GIS.

Store and Jokimäki [7] presents a method based on the combined use of empirical evaluation models and models based on expertise in GIS environment. GIS was used to produce the data needed for the models, and as a platform to execute the models and to present the results of the analysis. Furthermore, multi-attribute evaluation methods provide the technical tools for modeling the expertise and for connecting (standardizing, weighting, and combining) the habitat needs of different species.

Lant et al. [8] examines the policy implications of the analysis conducted using this spatial decision support system (SDSS). The structure of SDSS is more in-depth described by Beauleu et al. [9], Sengupta et al. [10], Sengupta and Benett [11], Bennett et al.[12, 13].

2. Types of retail centres. Selecting the objects for research

By the contingent of customers mostly retail centres are of two types. First type provides goods for neighbourhood population and serves people coming on foot and the second type serves people going by car and public transport and is built near the biggest traffic flows.

Size of a retail centre is usually conditioned by the role the retail centre plays in the city, i. e. it is of local, district, city or regional importance.

Some of the newly built retail centres have chosen completely new locations and some were raised-up in the locations where retail centres were planned previously. New locations as a result caused much more bad response in the community.

There were 27 objects of different types, ranks and sizes from different city districts selected. The 28 alternatives were formed from ideal ranking by each attribute to measure the difference of objects from ideal value.

3. Multi-attribute analysis

In order to perform a complete study the complex evaluation of all the aspects is needed. Quantitative descriptions provide this information.

The results of the comparative analysis of objects are presented as a grouped decision making matrix where columns contain n alternative objects, while all quantitative and conceptual information pertaining to them is found in Table 1.

Quantitative information is based on attributes systems and subsystems, units of measure, values and initial weights of the alternatives. Quantitative information is more accurate and reliable than conceptual and allows to use multi-attribute decision making methods.

The values of qualitative attributes must be put into a numerical and comparable form. They must be comparable because a "medium" value for one qualitative attribute must receive approximately the same numerical values as "medium" values of other qualitative attributes.

4. Choosing the attributes, determination of the attributes weights and ranking of objects

The data used for the analysis is characterizing the most substantial fields or how retail centres influence living in the city. To define these attributes the help of experts was needed. The attributes suggested by the experts and urban planners were divided into four main categories:

- Environment changes for the neighbourhood population;
- Changes of architectural and urban perception of the city;
- Communication and transportation changes;
- Economical aspect of necessity of each retail centre.

All these categories can be easily measured in points from –3 to 0 to indicate there were negative changes and from 0 to 3 to indicate positive changes. To disencumber experts from their job researches of population density in the city, traffic flows, problematic transport nodes and retail centres concentration zones were made (Fig 1, 2 and 3).

Then experts gave the ranking of these four attributes. The most substantial attribute was ranked number 1, the next – number 2 and so on. Because there was no agreement the procedure of determining attribute weights was made two times. First time 15 experts from very different fields of practice gave extremely different opinions and the hypothesis about the consent of experts in ranking was not accepted. Second time 30 experts, mostly town planners gave more similar opinions and the hypothesis about the consent of experts in ranking was accepted.

The same experts gave the ratings to each object by each attribute. The average values were taken to make calculations (Table 1). Table 2 shows the algorithm of weights establishment, calculations made and the compatibility of expert judgment.

The ranking showed that mostly the changes of envi-

Table 1. Initial data matrix for the determination of criteria significances

Number.	Environment changes	Changes of architectural and urban perception	Communication and transportation changes	Economical aspect of necessity
	x_1	x_2	x_3	x_4
1	1.7	2.4	–0.1	2.7
2	–1.1	1.3	–0.8	0.3
3	–1	–2.7	0.2	–2.2
4	1.8	0.8	0.4	2
5	2.4	1.6	–0.5	2.6
6	2	0.3	0.1	1.6
7	0.1	0	0.2	0.1
8	0.4	–0.1	0.2	0.2
9	0.3	–0.2	0.2	0.2
10	1.5	0.9	0.5	1.5
11	1.3	0.4	0.7	2.3
12	2.3	1.8	–0.5	2.3
13	1.8	0.1	0	2.1
14	2	–0.1	1	2.3
15	0.5	–1	–0.7	0.2
16	1.7	1	0.4	2.5
17	1.1	1	0.3	1.4
18	1.7	0.5	0.4	2.3
19	-0.8	0.1	–2.4	0.5
20	1.2	–0.1	1	2
21	1.3	–1	–0.3	1.7
22	0.6	–1	1.1	1.5
23	0.8	0	–0.5	0.4
24	0.1	–1.8	–1.5	–0.8
25	0.3	0.3	0.7	0.5
26	0.6	0.7	0	1.3
27	1.3	0.7	0.5	1.1
28	3	3	3	3

ronment were positive except some cases of building in very sensitive locations and replacing the city stadium by the shopping centre.

The changes of architectural and urban perception of the city were not so positive and many experts gave completely different ranking of the same objects.

Communication and transportation changes in the city by the expert judgement were mostly negative and it is natural effect of municipality strategy when the proposed traffic flows are not taken into account.

Necessity aspect shows that almost all of the centres were needed and the success of these centres confirms it.

The complex evaluation was made using Multiplicative Summarized Optimal Criterion method (Table 2). The best variant can be determined by success criterion of the decision made K_i under the formula (1):

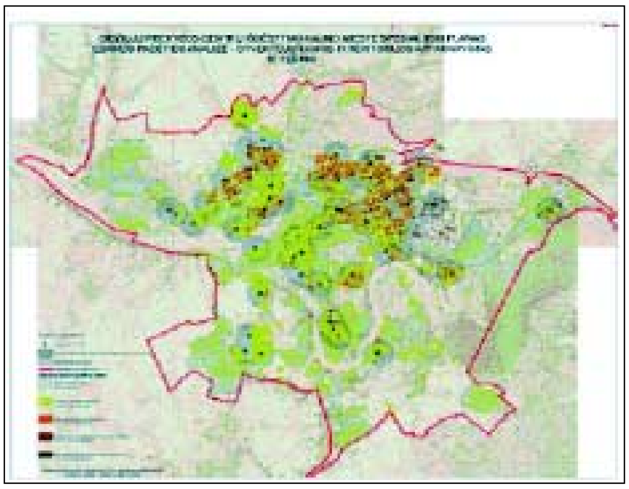

Fig 1. Population density in the city of Kaunas

Fig 2. Traffic flows and the problematic transport nodes in the city of Kaunas

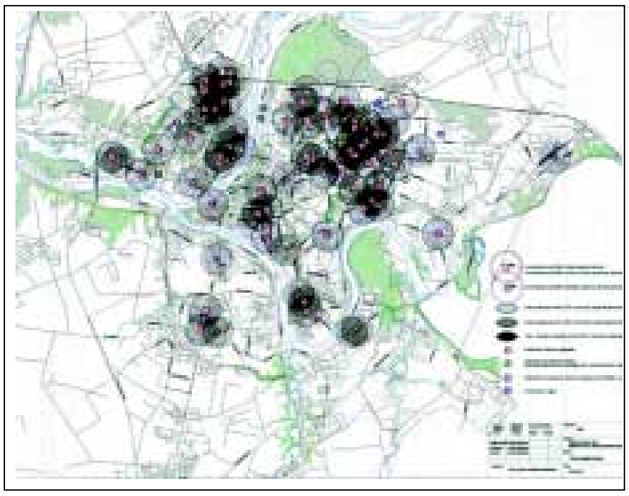

Fig 3. Retail centres concentration zones in the city of Kaunas

$$K_i = \left\{ v_i \middle| \max_i \left(\prod_{j=1}^{n} \bar{x}_{ij}^{q_j} \right) \right\}, \quad (1)$$

where v_i – alternative; $\bar{x}_{ij}$ – normalized attribute values of j-th parameter for i-th variant.

Most often parameters of the importance pay off in such a manner that $\sum_{j=1}^{n} q_j = 1$.

In applying this method [14] the decision matrix elements are normalized according to the formula (2) or (3) (Table 3):

$$b_{ij} = \frac{a_{ij} - \min_i a_{ij}}{\max_i a_{ij} - \min_i a_{ij}} \quad (2)$$

when preferable value $a_{ij} = \min_i a_{ij}$;

$$b_{ij} = \frac{\max_i a_{ij} - a_{ij}}{\max_i a_{ij} - \min_i a_{ij}}, \quad (3)$$

when preferable value $a_{ij} = \max_i a_{ij}$.

Result values vary from 0 to 1 showing the best and worst objects.

Table 2. Algorithm of attributes weights establishment [14]

Process of calculation	Efficiency attributes x_j; $j = 1,...,n$; $n = 4$.			
	x_1	x_2	x_3	x_4
Sum of ranks $t_j = \sum_{k=1}^{r=30} t_{jk}$	49	62	86	101
The average attribute rank value $\bar{t}_j = \frac{\sum_{k=1}^{r=30} t_{jk}}{r}$	1.63	2.07	2.87	3.37
Attribute rank	1	2	3	4
Attribute weight $\bar{q}_j = \frac{t_j}{\sum_{j=1}^{n=4} t_j}$	0.16	0.21	0.29	0.34
Attribute weight *when the best weight is maximal value* $q_j = \frac{1-\bar{q}_j}{n-1}$	**0,28**	**0,26**	**0,24**	**0,22**
$\sum_{k=1}^{r=30} (t_{jk} - \bar{t}_j)^2$	22.967	21.867	19.467	28.967
Dispersion of experts ranking values $\sigma^2 = \frac{1}{r-1} \sum_{k=1}^{r=30} (t_{jk} - \bar{t}_j)^2$	0.792	0.754	0.671	0.999
Variation $\beta_j = \frac{\sigma}{\bar{t}_j}$	0.55	0.42	0.28	0.30
Ranking sum average	$V = \frac{1}{r} \sum_{j=1}^{n=4} \sum_{k=1}^{r=30} t_{jk} = \frac{1}{4}(49 + 62 + 86 + 101) = 74.5$			
The total square ranking deviation	$S = \sum_{j=1}^{n=4} \left(\sum_{k=1}^{r=15} t_{jk} - V \right)^2 = (49-74.5)^2 + (62-74.5)^2 + (86-74.5)^2 + (101-74.5)^2 = 1641$			
The coefficient of concordance	$W = \frac{12S}{r^2(n^3 - n)} = \frac{12 \cdot 1641}{30^2(4^3 - 4)} = 0.365$			
The significance of the concordance coefficient (no related ranks) $\chi^2_{\alpha,v}$	$\chi^2_{\alpha,v} = \frac{12S}{rn(n+1) - \frac{1}{n-1} \sum_{k=1}^{r} T_k} = \frac{12 \cdot 1641}{30 \cdot 4 \cdot (4+1)} = 32.82$, where $\frac{1}{n-1} \sum_{k=1}^{r} T_k = 0$			
Rank of table concordance χ^2_{tbl} when the importance equal to 1 %	The freedom degrees value of a solved problem $v = n - 1 = 4 - 1 = 3$; $\chi^2_{tbl} = 11.34$			
Compatibility of expert judgement [15]	$\chi^2_{\alpha,v} = 32.82 \succ \chi^2_{tbl} = 11.34$ – The hypothesis about the consent of experts in ranking is accepted			

Table 3. Solution results

Number	Normalized decision- making matrix				Result K_i
	x_1	x_2	x_3	x_4	
	0,28	**0,26**	**0,24**	**0,22**	
1	0.34	0.10	0.57	0.06	0.191
2	0.50	0.191	0.70	0.52	0.479
3	1.08	0.479	0.52	1.00	0.873
4	0.32	0.873	0.48	0.19	0.331
5	0.16	0.331	0.65	0.08	0.216
6	0.26	0.216	0.54	0.27	0.364
7	0.76	0.364	0.52	0.56	0.591
8	0.68	0.591	0.52	0.54	0.571
9	0.71	0.571	0.52	0.54	0.583
10	0.39	0.583	0.46	0.29	0.375
11	0.45	0.375	0.42	0.13	0.339
12	0.18	0.339	0.65	0.13	0.237
13	0.32	0.237	0.56	0.17	0.359
14	0.26	0.359	0.37	0.13	0.294
15	0.66	0.294	0.68	0.54	0.646
16	0.34	0.646	0.48	0.10	0.284
17	0.50	0.284	0.50	0.31	0.410
18	0.34	0.410	0.48	0.13	0.320
19	1.00	0.320	1.00	0.48	0.714
20	0.47	0.714	0.37	0.19	0.377
21	0.45	0.377	0.61	0.25	0.477
22	0.63	0.477	0.35	0.29	0.474
23	0.58	0.474	0.65	0.50	0.564
24	0.76	0.564	0.83	0.73	0.790
25	0.71	0.790	0.42	0.48	0.516
26	0.63	0.516	0.56	0.33	0.472
27	0.45	0.472	0.46	0.36	0.418
28	0.00	0.418	0.00	0.00	0.000

5. Conclusions

The described method with little modifications can be used for solving of different tasks. The current example shows implementation of multi-attribute model in the process of city planning. It was very useful to make the decision of prolonging terms of exploitation of existing objects and to define the most significant aspects retail centres made to the city. The research results were used in "Kaunas city specialized plan for retail centres dislocation".

The best results are those of retail centres built by renovation of previously built trading objects. It is mainly because there was positive reaction in the community and the problems of traffic were solved already. These centres are usually of local or district importance only.

The bigger scale objects created more problems and the ranking reflects it. There were also some big objects of a city importance appreciated nicely because of glaring architectural expression but mostly these big centres were ranked low.

The values lower than 0.5 were shown by the centres whose influence on the city was more positive, and values of more than 0.5 were shown by the centres with more negative than positive influence in the eyes of experts. For the objects with negative influence the improvements mainly in communication and transportation, architectural and urban perception must be made.

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PREKYBOS CENTRŲ POVEIKIO MIESTO STRUKTŪRAI ĮVERTINIMO DAUGIAKRITERINIS MODELIS KAUNO MIESTO PAVYZDŽIU

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Santrauka

Aprašomas daugiakriterinio metodo taikymas prekybos centrų poveikiui miestui, kaip sudėtingai sistemai, įvertinti. Poveikis miestui aprašomas kaip prekybos centrų sukeliamų padarinių, pvz., aplinkinių gyventojų ir visų miesto gyventojų aplinkos kokybės pokyčiai, miesto susisiekimo sistemos pokyčiai, architektūrinio ir urbanistinio miesto suvokimo pokyčiai, suma. Padariniai įvertinami skaitinėmis reikšmėmis ir skaičiuojama jų visuma. Taikant šį metodą, lyginami skirtingi alternatyvūs objektai. Uždavinys aprašomas daugeliu kriterijų. Pagrindiniai atributai padeda įvertinti prekybos centrų poveikį gyvenimo kokybei, susisiekimo sistemos darbui, ekonominei naudai ir architektūriniam bei urbanistiniam aplinkos suvokimui. Kriterijų reikšmingumai (svarba) nustatyti ekspertų vertinimo metodu. Jiems normalizuoti taikomas tiesinis normalizavimo metodas. Kriterijų reikšmingumai apskaičiuoti įvertinus miestų planavimo srities specialistų pildytas anketas. Iš idealių įvertinimų suformuota optimali alternatyva, kad galima būtų palyginti su realiai egzistuojančiais objektais. Poveikis skaičiuojamas taikant multiplikatyvinį suminį optimalių kriterijų metodą. Prekybos centrų plėtros strategija siūloma lyginant esamų objektų įvertinimus su optimaliu įvertinimu. Daugiakriterinis prekybos centrų modelis prekybos centrų poveikiui miesto sistemai įvertinti buvo naudojamas Kauno miesto savivaldybės teritorijos didžiųjų prekybos įmonių išdėstymo specialiajame plane. Tyrimų rezultatai padėjo nustatyti egzistuojančių objektų efektyvumą ir prekybos centrų plėtros strategiją ateičiai.

Reikšminiai žodžiai: daugiakriterinė analizė, prekybos centrai, prekybos centrų poveikis miesto struktūrai, efektyvumo kriterijai, rangai, multiplikatyvinis suminis optimalus kriterijus.

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