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ENVIRONMENTAL OBJECTIVE ANALYSIS, RANKING AND CLUSTERING OF HUNGARIAN CITIES

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Abstract. The aim of the study is to rank and classify Hungarian cities according to environmental and social elements. To reach this goal, a 'Green City Index' was calculated, which is used to rank cities into different categories of 19 environmental and social elements. Furthermore, our aim is to classify cities using geographic clustering. After performing factor analysis, the retained factors received the so-called collective nouns on the relation of the individual factor loadings to the original variables. According to the factor scores map of the retained factors it can be established that the region around Budapest indicates favourable supply with water and sewerage public utilities, with waste management and with settlement amenities. Transdanubia shows favourable position in waste management, climate, air quality and settlement amenities. The Hungarian Great Plain indicates low energy consumption, friendly waste management and low dust levels. However, the northern mountainous region does not show favourable properties in any component. The Lake Balaton region, the first recreational area of Hungary, is favourable in all components, except for waste management. Cluster analysis resulted in 6 most homogenous groups of cities, which did not form comprehensive spatial patterns. Environmentally friendly and adverse cities form separate clusters. However, the clusters are not compact. Each of them involves cities far from the region, where they condense.

Keywords: green index, ranking, factor analysis, geographic clustering.

AIMS AND BACKGROUND

In Hungary, 236 cities accounting for 65.7% of the country's population were registered on January 1, 2001. Environmental elements in cities such as housing, transportation, air quality and public green space, etc., are important to the quality of life[1]. However, which cities have cleaner air, more urban parkland, or more pleasant climate? Which do a better job at organising traffic systems, waste management or public sanitation? Which cities are wasteful in their use of water or energy? To

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answer these questions, at least at a preliminary level, the so-called 'Green City Index', which ranks cities on several environmental criteria, was developed[2].

Ranking cities according to their environmental quality is not a simple task. Over the years, several papers have appeared on the urban quality of life[3–5]. Some of them modelled the priorities, expectations and needs of the inhabitants[6]. Other group of papers ranked or analysed cities in terms of various aspects of quality of life, such as public health criteria[7–9], or focused on the influence of popular 'best places to live' rankings on urban policy[10], or classified cities on the basis of given considerations, e.g. on the basis of the local prevalence of specific types of restaurants[11]. Others analysed quality of life with urban size[12], or developed a subjective wellbeing index to measure the quality of life[13], or used objective and subjective elements for this aim[14,15], or developed an area-based index of locational access to community services, facilities and amenities[16], or explained social geographical approach of quality of life and urban environmental quality[17]. Recently, more and more papers have focused on different environmental criteria[15,18–21]. Sustainability of current urban regeneration, as an aspect of urban environmental load, has recently become increasingly recognised[22].

The aim of the study is to rank and classify Hungarian cities according to their environmental quality. Besides, after using cluster analysis, spatial distribution of the clusters received is also compared.

The data basis for the study is drawn partly from the Statistical yearbook of Hungary[23] comprising data of the environmental and social elements of year 2000 analysed for the cities, partly from the Statistical yearbook of Hungary[24] consisting of preliminary results of the comprehensive census of January 2001 and partly from the air quality data of the National Health Institute, concerning the non-heating half-year (April 1 – September 30, 2000) and the heating half-year (October 1, 2000 – March 31, 2001) of the cities[25–27].

EXPERIMENTAL

Environmental and social elements and the Green City Index. Seven different categories of environmental and social elements ranging from water consumption to air quality were included in the Green City Index. Specific measures within each category were selected on the basis of data availability. Some related measures were combined to yield new, composite measures. Altogether nineteen elements that were shared by all the Hungarian cities studied were considered (Table 1).

Table 1. Categories and elements used for compiling the Green City Index

Categories	Serial No	Elements	Units
Water consumption	1	Water use	m^3/capita/year
Energy consumption	2	Gas consumption	m^3/household/year
	3	Electric energy consumption	kWh/household/year
	4	[1]Degree days	sum of heating and cooling degree days
Public utilities supply	5	Ratio of households connected to gas conduit network	%
	6	Ratio of dwellings connected to drinking water conduit network	%
	7	Ratio of dwellings connected to public sewerage system	%
	8	Public sewerage system	m/km drinking water conduit
Traffic	9	Supply with passenger car	inhabitants per passenger car
Waste management	10	Drained-off waste water total	m^3/capita/year
	11	Total waste removed	m^3/capita/year
	12	Ratio of dwellings connected to regular waste removal system	%
Settlement amenities elements	13	Public green area	m^2/capita
	14	Ratio of constructed inner roads	%
	15	Ratio of constructed public surfaces cleaned regularly	%
	16	Housing	occupants/dwelling
[2]Air quality	17	Average concentration of particulates deposited	g/m^2/30 days
	18	Average concentration of sulphur-dioxide	$\mu g/m^3$
	19	Average concentration of nitrogen-dioxide	$\mu g/m^3$

[1]Heating (cooling) degree-days are defined as the number of days when the mean temperature is above (below) 18°C, with each day weighted by the number of degrees above (below) 18°C. This parameter can be used as a measure of energy use for space heating (cooling). 18°C is considered the optimum temperature; [2]Based on average of non-heating half-year (April 1, 2000 – September 30, 2000) and average of heating half-year (October 1, 2000 – March 31, 2001).

Data on all 19 parameters are available for only 88 of the 236 cities in the data base. Hence, further analyses are based on those 88 cities. Though these elements are neither ideal nor exhaustive, they enable an overall comparison among the relevant cities.

The Green City Index is derived as follows:

(a) The values of each element for each city were compiled from the Year books.

(b) Each element is represented with a serial number (1–19). See column 2 of Table 1.

(c) For each element, cities were ranked from the most environmentally friendly (1) to least friendly (88) based on their element values as determined in step (a). These ranks represent city scores on each element.

(d) The rank scores achieved for each city over the 19 elements were averaged. The resulting figure is the City Green Index (column 3, Table 2).

(e) Finally, the Green City Indices were ranked to yield the Final Sequence (column 2, Table 2). The Final sequence (FS) places the cities in rank order from the best (1) to the most adverse (88) based on step (d). FS is a rank of ranks.

Table 2. Average of rankings of the environmental and social elements; namely, the Green City Index, and the final sequence of the cities (1 = best, 88 = weakest)

City	Final sequence	Green City Index
1	2	3
Nagykanizsa	1	29.89
Balatonföldvár	2	30.58
Balatonboglár	3	30.68
Balatonlelle	4	32.11
Szombathely	5	32.89
Tiszaújváros	6	33.00
Zalaegerszeg	7	33.16
Kaposvár	8	33.32
Siófok	9	34.32
Százhalombatta	10	34.63
Fonyód	11	34.74
Bonyhád	12	34.79
Tapolca	13	35.95
Tatabánya	14	36.26
Miskolc	15	36.84
Komló	16	37.16
Oroszlány	17	37.21
Lenti	18	37.68
Szolnok	19	38.26
Győr	20	38.58
Sopron	21	39.05
Kazincbarcika	22	39.37
Budapest	23	39.74
Székesfehérvár	24	39.89

to be continued

Continuation of Table 2

1	2	3
Szekszárd	25	39.91
Pécs	26	40.00
Keszthely	27	40.32
Eger	28	40.74
Dunaújváros	29	41.21
Pilisvörösvár	30	41.63
Siklós	31	42.26
Szeged	32	42.32
Vác	33	42.47
Dorog	34	42.74
Debrecen	35	42.84
Szigetvár	36	42.88
Bátonyterenye	37	43.00
Baja	38	43.26
Tata	39	43.32
Mohács	40	43.95
Gyöngyös	41	44.05
Békéscsaba	42	44.21
Kőszeg	43	44.37
Ózd	44	44.53
Gyula	45	44.63
Balatonfüred	46	44.79
Salgótarján	47	44.89
Jászberény	48	45.00
Hajdúszoboszló	49	45.05
Dunakeszi	50	45.47
Hatvan	51	45.63
Veresegyház	52	46.00
Balatonalmádi	53	46.21
Kalocsa	54	46.27
Várpalota	55	46.58
Kecskemét	56	46.74
Nyíregyháza	57	46.95
Gárdony	58	47.21
Csongrád	59	47.26
Veszprém	60	47.42
Esztergom	61	47.74
Göd	62	47.78
Dombóvár	63	48.16
Békés	64	48.37

to be continued

Continuation of Table 2

1	2	3
Lőrinci	65	48.84
Nagymaros	66	50.00
Cegléd	67	50.74
Hajdúnánás	68	50.84
Pápa	69	51.05
Szentendre	70	51.14
Sümeg	71	51.32
Szécsény	72	51.42
Komárom	73	51.47
Ajka	74	51.58
Pásztó	75	51.63
Mátészalka	76	51.74
Budaörs	77	52.00
Záhony	78	52.11
Szentlőrinc	79	52.37
Orosháza	80	53.16
Kisvárda	81	53.26
Zirc	82	54.16
Kistelek	83	54.26
Tiszavasvári	84	55.89
Sajószentpéter	85	56.79
Balassagyarmat	86	58.05
Mór	87	58.68
Mosonmagyaróvár	88	59.21

Because environmental regulations in many cities have become increasingly more stringent, part of the data used in this study may be obsolete by publication date. Consequently, Green City Index rankings should be viewed as a measure of environmental quality and concern at a given point in time.

It is noted that the elements considered were not weighted to reflect their relative importance to environmental quality or overall contribution to making a city liveable. Rather, they illustrate how each city fared when compared to others.

Human activities are the greatest source of contaminants in the environment. Thus, population and population density might be important environmental elements. But their implications to environmental quality are frequently contradictory since increases in the size of either variables or both, do not automatically indicate a tendency towards poorer environmental quality. For example, compact and highly centralised cities with high population densities have the advantage of decreasing passenger car traffic between city centre and the suburbs thus contributing to lower air pollution loads. However, such advantage may be mitigated by more concentrated sources of pollution and waste, and more congestion. On the other hand, cities that sprawl and are dispersed, resulting in lower population densities, may have a harder time providing mass transit, but they may have more open space. On balance, large centralised cities tend to have greater difficulty achieving the same level of environmental quality than smaller cities.

Factor analysis. Factor analysis reduces the dimensionality of a large data set of p correlated variables, expressing them in terms of m ($m < p$) new uncorrelated ones: the factors[28,29]. One important stage of this method is the decision for the number (m) of the retained factors. On this matter, many criteria have been proposed. In this study, the Guttmann criterion is used, which determines to keep the factors with eigenvalues > 1 and neglect those ones that do not account for at least the variance of one standardised variable X_i. Factor analysis was applied on the tables of the initial data consisting of 19 columns (environmental and social elements) and 88 rows for cities.

Cluster analysis. Cluster analysis is the most commonly used technique for searching natural structure among observations. This procedure classifies a series of n observations into different, characteristic homogeneous groups: the clusters. The aim is to maximise the homogeneity of objects within the clusters and also to maximise their heterogeneity between the clusters. Hence, the resulting clusters show then high internal (within cluster) homogeneity and, at the same time, high external (between cluster) heterogeneity[30,31].

All statistical computations were performed with SPSS (Statistical Package for the Social Sciences) (version 15.0)[32,33]. SPSS is a widely used program for statistical analysis, data management and data documentation in social science.

RESULTS AND DISCUSSION

RANKING

The final sequence of the cities shows some surprising results (Table 2). Nagykanizsa, near the Hungarian-Croatian border, is the highest-ranked city. Though ranks achieved in concentration of deposited particulates (79), water consumption (60), ratio of cleaned public area total (54) and waste water drainage (50) are relatively poor, the city high rank placing in gas and electric energy consumption (ranked 7, and 2, respectively), development of the public sewerage system (5) and waste removal total, enables it to win its coveted position as the most environmentally friendly city in the country. Nagykanizsa is followed by settlements around lake Balaton: Balatonföldvár (2), Balatonboglár (3) and Balatonlelle (4). Among the major cities, Szombathely (5), Zalaegerszeg (7) and Kaposvár (8) are stand out (Table 2).

Mosonmagyaróvár (88), Mór (87) and Balassagyarmat (86) are the most adversely ranked cities (Table 2) in spite of their relatively good rank in a number of factors. Mosonmagyaróvár is 19th ranked in development of public sewerage system and 33rd in the ratio of dwellings connected to regular waste removal system. Mór is ranked 1st in both the ratio of households connected to the public water conduit network and its per capita water consumption. Balassagyarmat is 9th in per capita water consumption and 13th in waste removal total. Summing up, no city is found consistently either at the top or the bottom half of the rankings on all environmental and social elements. All cities in Hungary are characterised by a mixture of favourable and less favourable environmental quality.

Environmental quality of Hungarian cities is best in the western and southern parts of Transdanubia, where Green City Index values are smallest. There are no clear regional patterns in the rest of the country (Fig. 1).

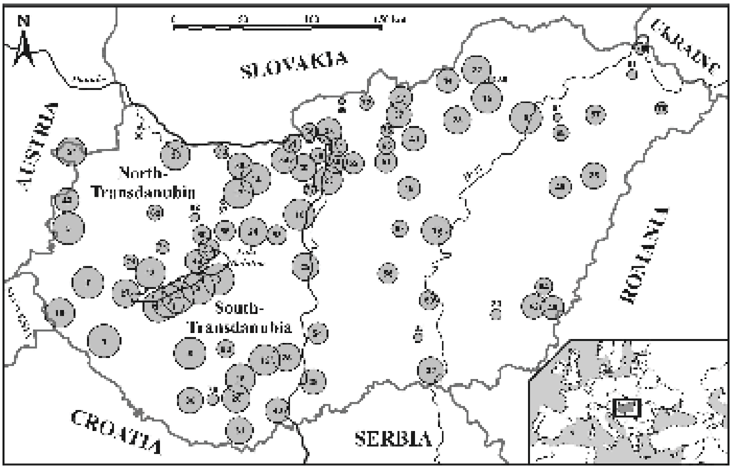

Fig. 1. Environmental quality of cities according to their Green City Index (high values (circles with large area) = favourable; low values (circles with small area) = adverse). The numbers indicate the final sequence of the cities (1 = best, 88 = weakest; see Table 2)

Potential impact of population on the Green City Index. The possible consequence of including population and population density in the Green Index was examined by comparing the rankings obtained with the inclusion of the two variables (modified Final Sequence) and those calculated without them (original Final Sequence). The Spearman rank correlation coefficient, which was utilised for this purpose, yielded a value of 0.94 significant at the 99.9% confidence level. This means that there is a significant relationship between the original and modified groups of elements. Hence, the original final sequence is not substantially influenced by not considering population and population density. This result indicates that, although not perfect, the Green City Index, as calculated, is a reasonably fair method for providing an environmental rating for cities in Hungary.

FACTOR ANALYSIS

When performing factor analysis, according to the Guttmann criterion, 7 factors were retained, which explained 70.82% of the total variance of the original variables (Table 3).

Matrix of the rotated factor loadings comprising the coefficients of the rotated factors is shown in Table 4.

Table 3. Initial eigenvalues and variances, January 1 – December 31, 2000

Component	Initial eigenvalues		
	total variance	relative variance (%)	cumulative variance (%)
1	2.823	14.858	14.858
2	2.272	11.958	26.816
3	1.965	10.343	37.159
4	1.847	9.722	46.881
5	1.613	8.489	55.370
6	1.537	8.089	63.460
7	1.399	7.361	70.820

Geographic interpretation of the factors. Henceforth, factor loadings belonging to the retained 7 factors were analysed, their relationship was studied and then these 7 factors received the so-called collective nouns on the relation of the individual factor loadings to the original variables. However, these collective nouns do not represent the character of the given factor in any case. The basic concern is that part of the original variables is of natural ones (e.g. degree days), while other part of them is of social ones (e.g. water use (per capita per year)). Due to this, causal relationship can generally not be detected between factor loadings of a given factor; hence, the character of the given factor can be interpreted with difficulty.

Factor 1 shows the strongest relationship with the following variables: drained-off waste water total (v_{10} = variable of serial No 10; see Table 4; Table 1), public sewerage system (v_8), water use (v_1), ratio of dwellings connected to public sewerage system (v_7), on the other hand, it indicates a rather strong negative relationship to the supply with passenger car (v_9). According to the above, this factor may be called as factor or component of 'water and sewerage public utilities supply'. Factor 2 shows the strongest relationship with the ratio of households connected to the gas conduit network (v_5); on the other hand, it indicates strong negative connection to the electric energy consumption (v_3) and the gas consumption (v_2).

Table 4. Factor loadings for the period January 1 – December 31, 2000 (only values higher than |0.60| are presented)

Serial No	Element	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
1	Water use	0.703						
2	Gas consumption		–0.787					
3	Electric energy consumption		–0.793					
4	Degree days					0.668		
5	Ratio of households connected to gas conduit network		0.733					
6	Ratio of dwellings connected to drinking water conduit network					–0.735		
7	Ratio of dwellings connected to public sewerage system	0.628						
8	Public sewerage system	0.735						
9	Supply with passenger car	–0.617						
10	Drained-off waste water total	0.789						
11	Total waste removed							
12	Ratio of dwellings connected to regular waste removal system			0.842				
13	Public green area							
14	Ratio of constructed inner roads				0.793			
15	Ratio of constructed public surfaces cleaned regularly							0.820
16	Housing			0.753				
17	Average concentration of particulates deposited				0.743			
18	Average concentration of sulphur dioxide						0.771	
19	Average concentration of nitrogen dioxide						0.748	

Values higher than |0.21| are statistically significant at the 95% level; however, Table 4 shows only those exceeding |0.60|; This means that at least 36% of the total variance of an element can be explained by a single Factor.

Accordingly, this *component* may receive the name *of* ‘energy’. Factor 3 shows a very strong relation with the ratio of dwellings connected to regular waste removal system (v_{12}) and with the housing (v_{16}). This component may receive the name of ‘waste management’. Factor 4 shows strong relationship with the ratio of constructed inner roads (v_{14}) and with the average concentration of deposited particulates (v_{17}). Therefore, this component may be called as component of ‘dust’. Factor 5 has a very strong positive relationship with the degree days (v_4) and, at the same time, a very strong negative relationship with the ratio of dwellings connected to drinking water conduit network (v_6). This component may receive the name of ‘climate’. Factor 6 has a very strong positive relationship with the average concentrations of both sulphur-dioxide (v_{18}) and nitrogen-dioxide (v_{19}). Therefore, this can be called as component of ‘air quality’ (though concentration of deposited particulates is an element of air quality, its role is so important that it forms a separate component). Factor 7 shows a very strong relationship with the ratio of constructed public surfaces cleaned regularly (v_{15}). Consequently, this is called as the component of ‘settlement amenities’ (Table 4, Table 1).

The value of the Spearman rank correlation coefficient between the sequence of the Green City Index belonging to the cities and the factor scores of the 1st eigenvector (comprising the highest ratio (14.86%) of the variance of the variables examined) is $r = 0.343$, which is significant at the 95% probability level.

In order to interpret the factor scores of the retained 7 eigenvalues, they were mapped (Figs 2*a*–*g*).

Component of ‘water and sewerage public utilities supply’. Settlements received factor scores between 3.443 (Budaörs) and –1.856 (Ózd). Higher values indicate better supply with water and sewerage public utilities. Distribution of factor scores is slightly distorted. It is striking that among those 10 cities having the most favourite position (having the highest factor scores); only 2 cities are found in the Hungarian Great Plain: Szolnok (9th) and Szeged (10th). On the other hand, among the 10 cities having the lowest factor scores (being in the most adverse position) 7 are found in the Great Plain, while the last 3 cities in the northern mountainous region. Factor scores map of this component separates two regions; namely, the northern part of Transdanubia with more favourable positive factor scores, while Eastern-Hungary and the northern mountainous region with negative factor scores reflecting their more adverse position (Fig. 2*a*).

Component of ‘energy’. Extension of the factor scores are between 2.470 (Dunaújváros) and –2.446 (Siklós). The highest factor scores indicate that the ratio of dwellings connected to the gas conduit network is very high and, at the same time, electric energy consumption and gas consumption are very low. Those 10 settlements having the most favourable position (with the highest factor scores) are found in the south-western part of Transdanubia (Nagykanizsa, Zalaegerszeg, Lenti) and in the northern mountainous region (Miskolc, Kazincbarcika, Tiszaújváros), together with further cities: Dunaújváros, Szolnok, Gyula and Békés. At the same time, those 10 cities being in the most adverse position (with the lowest factor scores) are all middle-sized or small settlements. Except for Záhony, they all are found in Transdanubia. On the factor scores map of the component, the mostly positive scores indicate the more favourable position of Eastern-Hungary, contrary to Transdanubia having dominantly negative scores (Fig. 2*b*).

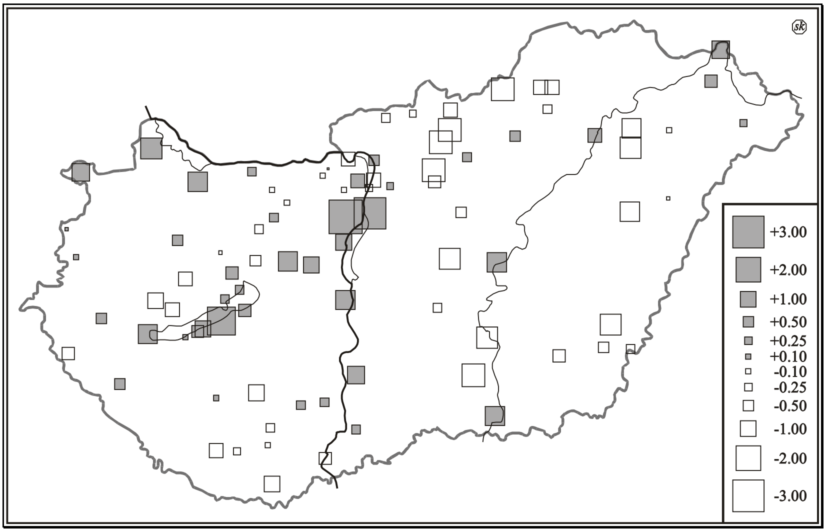

Fig. 2*a*. Factor scores map of the component of 'water and sewerage public utilities supply' (range of the factor scores: [–3; +3])

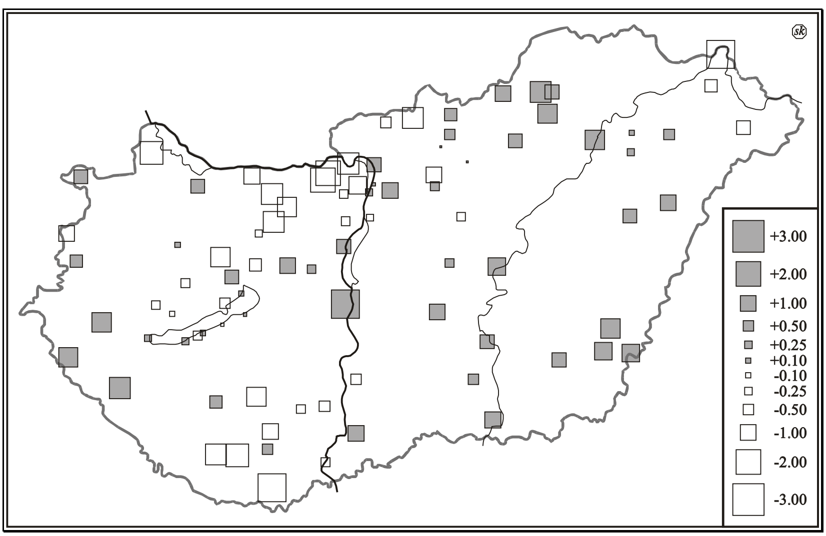

Fig. 2*b*. Factor scores map of the component of 'energy' (range of the factor scores: [–3; +3])

Component of 'waste management'. The highest factor score belongs to Veresegyház (1.726), while the lowest one to Balatonföldvár (–3.262). It is striking that cities with the most favourable position are partly around Budapest (Veresegyház, Pilisvörösvár, Göd, Százhalombatta), partly in Transdanubia except for the settlements around Lake Balaton and partly in North-eastern Hungary. Settlements being in the most adverse position (with the lowest factor scores) are Budapest, Nagymaros in the Danube bend, Gárdony at lake Velence and those around lake Balaton (Balatonfüred, Fonyód, Balatonlelle, Balatonalmádi, Balatonföldvár), furthermore Csongrád and Kistelek in the southern part of the Great Plain. The above results indicate that, even recently, waste management struggles with extraordinary deficiencies in the important recreational areas. According to the factor scores map of the component, further cities being in the most detrimental position, are found in Northern-Hungary and in the Great Plain (Fig. 2*c*).

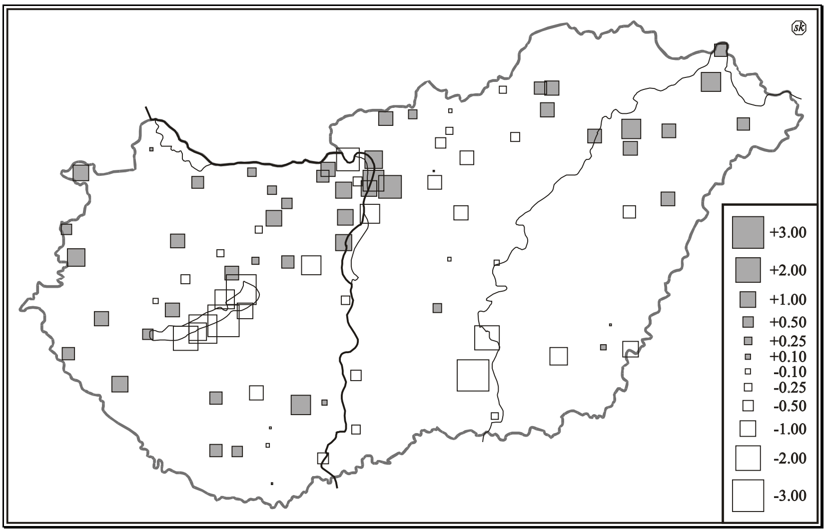

Fig. 2*c*. Factor scores map of the component of 'waste management' (range of the factor scores: [–3; +3])

Component of 'dust'. Factor sores are between 2.682 (Dunaújváros) and –3.345 (Göd). Higher factor scores indicate higher concentrations of particulates and vice versa. Namely, in this case settlements with positive factor scores are in adverse position, while those with negative scores have much less dust levels. In 6 of those 10 cities with the highest factor scores (Dunaújváros, Sajószentpéter, Komló, Oroszlány, Tatabánya, Kazincbarcika) heavy industry or power plants are operating. Cities with the most favourable position (with the lowest factor scores) are concentrated in the Budapest region. According to the factor scores map, further settlements with very low dust load are found in the lake Balaton region and in the cities of the Great Plain (Fig. 2*d*).

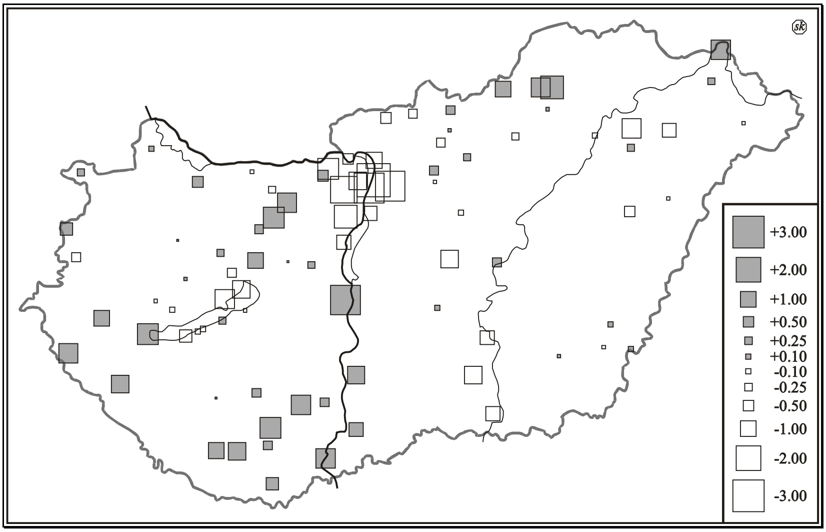

Fig. 2*d*. Factor scores map of the component of 'dust' (range of the factor scores: [–3; +3])

Component of 'climate'. Extension of the factor scores is between 3.411 (Záhony) and –2.118 (Balatonlelle). Higher scores indicate higher degree day values; namely, higher heating or cooling energy demand and vice versa. On the factor scores map, settlements with the lowest energy demand are more concentrated; they are almost exclusively found in Transdanubia. On the other hand, the northern mountainous region with mostly positive scores is in unfavourable position (Fig. 2*e*).

Component of 'air quality'. Factor scores interval is between 2.890 (Budapest) and –1.802 (Kalocsa). Higher factor scores indicate worse air quality, while cities with lower scores have cleaner air. Among the 10 cities with the highest scores (weakest air quality), Budapest is ranked the 1st. It is followed by further 3 cities with heavy industry (Sajószentpéter, Miskolc, Salgótarján), while the others are Esztergom, Szeged, Mór, Mosonmagyaróvár and Sopron. Those 10 cities with the lowest scores (with the best air quality) are, except for Jászberény and Kalocsa, all found in Transdanubia. On the factor scores map, three regions can loosely be separated with bad air quality (a wider region around Budapest, the northern mountainous region and the southern part of the Great Plain. On the other hand, the lake Balaton region and the southern part of Transdanubia are characterised by favourable air quality (negative scores (Fig. 2*f*).

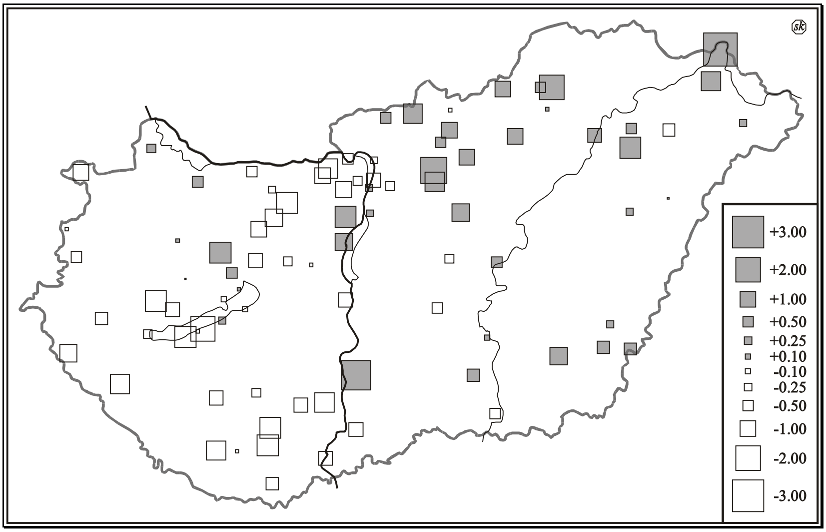

Fig. 2*e*. Factor scores map of the component of ‘climate’ (range of the factor scores: [–3; +3])

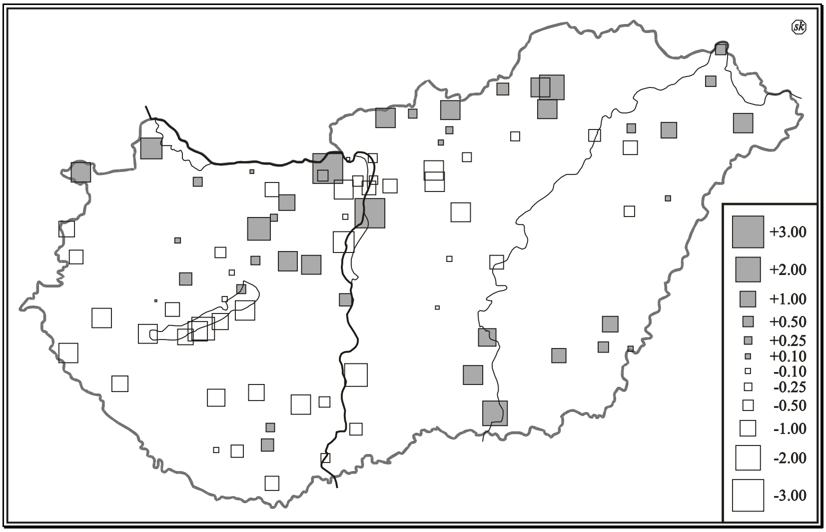

Fig. 2*f*. Factor scores map of the component of ‘air quality’ (range of the factor scores: [–3; +3])

Component of ‘settlement amenities’. Factor scores change between 2.388 (Tiszaújváros) and –2.130 (Pilisvörösvár). Higher factor scores indicate well organized and efficient maintenance of public premises (higher ratio of constructed public surfaces cleaned regularly), while lower scores denote to weak, deficiently operating minimal maintenance of public premises. Budapest is found among the 10 cities with the highest factor scores (with the best settlement amenities) but they are widely dispersed. Those 10 settlements with the lowest scores (with the weakest settlement amenities) are, except for Baja and Sajószentpéter, found all in Transdanubia. Among the cities with higher scores, there are many having power plant, mine and other facilities of heavy industry (Fig. 2*g*).

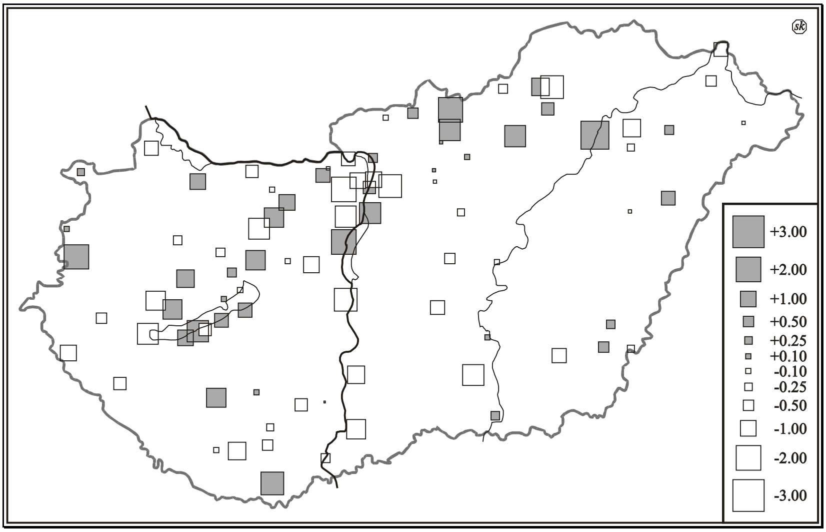

Fig. 2*g*. Factor scores map of the component of 'settlement amenities' (range of the factor scores: [–3; +3])

CLUSTER ANALYSIS

After performing factor analysis, cluster analysis is applied to the factor scores time series in order to objectively group cities according to their similar characteristics. In this paper, the agglomerative hierarchical technique is applied.

Geographic clustering of cities. The 88 cities were divided into 6 clusters (Fig. 3). Three clusters (clusters 2, 4 and 5) have few cities within them. Cluster 2 contains three settlements in Zala county (Nagykanizsa, Zalaegerszeg, Lenti), as well as Bonyhád, Keszthely and Dunaújváros. Four cities in Cluster 4 are located in the lake Balaton region (Balatonalmádi, Balatonlelle, Fonyód, Balatonföldvár), the remaining two, Csongrád and Kistelek, lie east. Cluster 5 cities group around Budapest (Göd, Veresegyház, Pilisvörösvár, Dunakeszi). Three clusters contain more than ten cities each; 14 in cluster 1, 30 in cluster 2 and 28 in cluster 6 (Fig. 3).

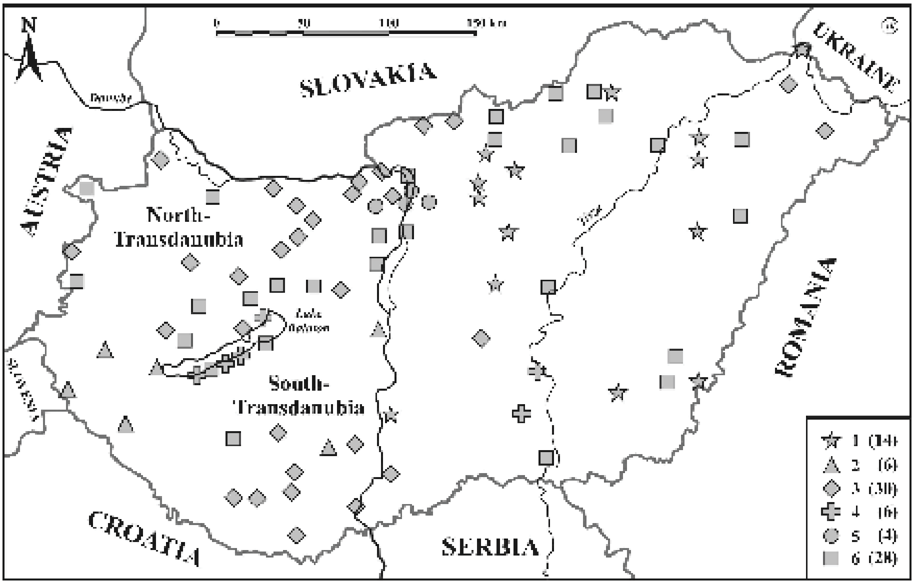

Fig. 3. Spatial distribution of cities, with symbols of their 6 clusters, using cluster analysis (right and down the sign, serial number of the cluster and the number of cities in the cluster (in parenthesis) are found)]

Ranking of the 6 clusters received was performed on the basis of the factor scores averages of the settlements found in the given cluster (Table 5). The lower the standard deviation of a factor scores average in a given cluster is, the more characteristic it is to the cluster. Considering this, in Table 5 those factor scores averages are indicated with bold, standard deviations of which in the given cluster are lower than 0.7.

On the factor score averages of the clusters received, cluster 1 (with 14 cities) is the first in the value of the so-called component of 'settlement amenities', namely, this group is the most efficient in settlement amenities factors (namely, maintenance of public premises is the most efficient in this group; furthermore, value of the component of 'energy' is the second highest (i.e., energy consumption per capita is very efficient (low)); value of the component of 'water and sewerage public utilities supply' is also the second highest (namely, public utilities supply is favourable and water consumption is low) (Table 5). At the same time, cluster 1 is before last ranked in the value of the component of 'climate' (i.e. heating and cooling energy demand is the second highest in this cluster); moreover, it is last in the value of component of 'air quality' (namely, air quality is the poorest in this cluster).

Table 5. Averages ($\overline{m}$) and standard deviations (σ) of the factor scores belonging to the 6 clusters received

Cluster	Number of the cities	Component of 'water and sewerage public utilities supply' (Factor scores of Factor 1)		Component of 'energy' (Factor scores of Factor 2)		Component of 'waste management' (Factor scores of Factor 3)		Component of 'dust' (Factor scores of Factor 4)		Component of 'climate' (Factor scores of Factor 5)		Component of 'air quality' (Factor scores of Factor 6)		Component of 'settlement amenities' (Factor scores of Factor 7)	
		$\overline{m}$	σ	$\overline{m}$	σ	$\overline{m}$	σ	$\overline{m}$	σ	$\overline{m}$	σ	$\overline{m}$	σ	$\overline{m}$	σ
1	14	0.27	1.24	**0.59**	**0.57**	**0.26**	**0.64**	**–0.10**	**0.61**	**0.14**	**0.65**	0.23	1.06	0.86	0.88
2	6	**–0.04**	**0.55**	–0.86	0.87	**0.07**	**0.67**	0.23	0.75	–0.42	0.83	0.22	0.87	–0.24	0.75
3	30	0.09	1.53	**0.25**	**0.27**	**–2.62**	**0.63**	**–0.59**	**0.53**	–0.46	1.11	–0.15	1.21	–0.07	0.92
4	6	**0.51**	**0.69**	1.13	0.99	**0.61**	**0.52**	**1.47**	**0.63**	**–0.79**	**0.32**	–0.91	0.77	**–0.99**	**0.56**
5	4	–0.67	0.96	0.02	0.87	–0.18	0.74	0.12	0.81	1.28	1.04	–0.25	0.97	**–0.46**	**0.58**
6	28	**–0.19**	**0.37**	**0.22**	**0.51**	**1.25**	**0.40**	**–2.79**	**0.42**	**–0.43**	**0.51**	**–0.81**	**0.43**	–1.02	1.20

Bold: standard deviation of the factor scores averages in the given cluster is lower than 0.7.

Cluster 2 consists of 6 cities. This group indicates the second highest dust load (component of 'dust'); furthermore, the least efficient energy use and the highest energy consumption per capita (the smallest value of the component of 'energy'). Cluster 3 is the largest with 30 cities. It shows the second lowest dust load (component of 'dust'); heating and cooling energy demand is the third highest (component of 'climate'); public utilities supply is the second most efficient (component of 'settlement amenities'); at the same time, this group comprises far the most deficiencies in waste management (component of 'waste management'). Cluster 4 consists of 6 cities. It shows the best supply in water and waste water public utilities (component of 'water and sewerage public utilities supply'); the far lowest energy consumption per capita (component of 'energy'); the lowest heating and cooling energy demand (component of 'climate'); the best air quality (component of 'air quality'), characterised by the lowest SO_2 and NO_2 levels; the second best on the field of waste management (component of 'waste management'); however, this group indicates the highest dust load (component of 'dust'); and the position of the settlement amenities is the second weakest (component of 'settlement amenities'). Cluster 5 comprises only 4 cities. It shows the weakest supply in water and waste water public utilities (component of 'water and sewerage public utilities supply'); the second weakest position in energy consumption per capita (component of 'energy') as well as in waste management (component of 'waste management'); on the other hand, the highest heating and cooling energy demand (component of 'climate'). Cluster 6 is defined by 28 cities. It has the best position in the field of waste management (component of 'waste management'); it indicates the lowest dust load (component of 'dust'); the second lowest SO_2 and NO_2 levels (component of 'air quality'); at the same time, it shows the weakest supply in water and waste water public utilities (component of 'water and sewerage public utilities supply'); and the lowest quality in settlement amenities factors (component of 'settlement amenities') (Table 5).

The 6 clusters of the cities, considered to be the most homogeneous ones according to the cluster analysis, do not form a comprehensive (contiguous) spatial system. All the 14 cities of cluster 1 are found either in eastern or northern Hungary, indicating considerable dispersion. Cluster 2 consists of 6 settlements: 4 are located in the southwestern part of Transdanubia, while the other two are far from them, in the Southern Great Plain. The 30 cities of cluster 3 also exhibit a considerable spatial dispersion. Here, two distinct sub-groups are found; one in the southern part of Transdanubia and the other in the northern part. Four cities in cluster 4 are found in South-west Transdanubia, while the other two are in the eastern part of Transdanubia. All the 4 cities of cluster 5 are found around Budapest. Though settlements belonging to cluster 6 (28 cities) show density junctions in the middle part of Transdanubia, south of Budapest and Northern Hungary; however, they are considerably dispersed (Fig. 3).

Average Green City Index of the 6 clusters was also calculated. According to this, cluster 2 showed the minimum index value (36.18) with the best environmental quality, then in increasing order (indicating ever weakening environmental quality) follow clusters 4 (39.86), 6 (40.87), 5 (45.22), 3 (47.36) and 1 (49.33). In this way, environmentally friendly and adverse cities form separate clusters. However, it should be noted that the clusters are not compact. Each of them involves cities far from the region, where they condense (Fig. 3).

CONCLUSIONS

The aim of the study was to rank and classify Hungarian cities according to their environmental quality.

The five most environmentally friendly cities are, in descending order, Nagykanizsa, Balatonföldvár, Balatonboglár, Balatonlelle and Szombathely. The bottom five are, starting with the most adverse, Mosonmagyaróvár, which is followed by Mór, Balassagyarmat, Sajószentpéter and Tiszavasvári. Cities situated in the western and southwestern part of Transdanubia have the best environmental quality. In the rest of the country, cities with either favourable or unfavourable positions are mixtured, forming no comprehensive regional patterns.

After performing factor analysis, the retained factors received the so-called collective nouns on the relationship of the individual factor loadings to the original variables. It was concluded that these collective nouns do not represent the character of the given factor in any case. Its reason is that part of the original variables is of natural ones, while other part of them is of social ones. Due to this, causal relationship can generally not be detected between factor loadings of a given factor; hence, the character of the given factor can be interpreted with difficulty.

According to the factor scores map of the retained factors, it can be established that the region around Budapest indicates favourable supply with water and sewerage public utilities, with waste management and with settlement amenities. Transdanubia shows favourable position in waste management, climate, air quality and settlement amenities. The Hungarian Great Plain indicates low energy consumption, friendly waste management and low dust levels. However, the northern mountainous region does not show favourable properties in any component. It should be noted that some cities with heavy industry perform well in some social variables, especially in category of 'Public utilities supply'. Its reason is that public utilities were build there during the so-called socialist political system, well before 1989, the political turn.

Concerning the lake Balaton region, the first recreational area of Hungary, it is favourable in all components analysed, except for waste management. This reflects the fact that waste management, even recently, struggles with deficiencies in important recreational areas.

Cluster analysis resulted in 6 most homogenous groups of cities, which did not form comprehensive spatial patterns. Cluster averages of the GCI values confirm that the environmentally highest ranked cities are found in the southwestern part of Transdanubia, while those with the most adverse environmental conditions are condensed in the northern mountainous region and in the eastern part of the Great Plain.

On the whole, the western part of the country (Transdanubia) enjoys favourable position in almost all of the components compared to the estern part (the Great Plain and the northern mountainous region). This can be traced back to historic reasons. Transdanubia, as the neighbour of Austrian provinces, through their mutual and diversified economic relationships has always higher developed economy than East-Hungary, which has greatly influenced the values of elements considered in the study.

The elements considered are a mixture of natural and social ones. Values of degree days are independent of humans. Extension of public green areas is free from financial background and depends only from local urban planning. Air quality elements depend on traffic and industry. Public utilities supply basically depends on the financial background available. Energy consumption partly depends on environmental consciousness. How to improve the position of cities with adverse environmental quality? Although values of several elements involved in the study are of financial source dependent; however, the first and most important is the environmental consciousness. The first is the human, the smallest element of the society. The steps taken on this level are added and will form then the decisions of the local bodies.

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REFERENCES

1. A. KERÉNYI: General Environmental Protection. Global Concerns, Possible Solutions. Mozaik Oktatási Stúdió, Szeged, 1995 (in Hungarian).
2. S. L. CUTTER: Green Cities. Ranking Major Cities by Environmental Quality Reveals Some Surprises. In: Environmental Almanac (Ed. A. Hammond). World Resources Institute, Houghton Mifflin Company, Boston, 1992, 169–186.
3. L. BENTON-SHORT, M. D. PRICE, S. FRIEDMAN: Globalization from Below: the Ranking of Global Immigrant Cities. Int J Urban Regional, **29** (4), 945 (2005).
4. R. GIFFINGER, G. HAINDLMAIER: Smart Cities Ranking: an Effective Instrument for the Positioning of the Cities? ACE: Architecture, City and Environment, **4** (12), 7 (2010).

5. K. A. GRANT, S. CHUANG: An Aggregating Approach to Ranking Cities for Knowledge-based Development. Int J Knowledge-Based Development, **3** (1), 17 (2012).
6. B. ULENGIN, F. ULENGIN, U. GUVENC: A Multidimensional Approach to Urban Quality of Life: the Case of Istanbul. Eur J Oper Res, **130** (2), 361 (2001).
7. S. A. HAM, S. LEVIN, A. I. ZLOT, R. R. ANDREWS, R. MILES: Ranking of Cities According to Public Health Criteria: Pitfalls and Opportunities. Am J Public Health, **94** (4), 546 (2004).
8. P. LERCHER: Which Health Outcomes Should Be Measured in Health Related Environmental Quality of Life Studies? Landscape Urban Plan, **65**, 63 (2003).
9. S. ALI, K. ROGER: Global Cities and the Spread of Infectious Disease: the Case of Severe Acute Respiratory Syndrome (SARS) in Toronto. Canada. Urban Stud, 9, 491 (2006).
10. E. MCCANN: ‘Best Places’: Interurban Competition, Quality of Life and Popular Media Discourse. Urban Stud, 41 (10), 1909 (2004).
11. N. ZACHARY: Culinary Deserts, Gastronomic Oases: a Classification of US Cities. Urban Stud, **43** (1), 1 (2006).
12. V. ROYUELA, J. SURIÑACH: Constituents of Quality of Life and Urban Size. Soc Indic Res, **74** (3), 549 (2005).
13. R. A. CUMMINS, R. ECKERSLEY, J. PALLANT, J. van VUGT, R. A. MISAJON: Developing a National Index of Subjective Wellbeing: the Australian Unity Wellbeing Index. Soc Indic Res, 64 (2), 159 (2003).
14. A. PETRUCCI, S. S. D’ANDREA: Quality of Life in Europe: Objective and Subjective Indicators. A Spatial Analysis Using Classification Techniques. Soc Indic Res, 60 (1–3), 55 (2002).
15. R. W. MARANS: Understanding Environmental Quality through Quality of Life Studies: the 2001 DAS and Its Use of Subjective and Objective Indicators. Landscape Urban Plan, **65**, 73 (2003).
16. K. WITTEN, D. EXETER, A. FIELD: The Quality of Urban Environments: Mapping Variation in Access to Community Resources. Urban Stud, **40** (1), 161 (2003).
17. M. PACIONE: Urban Environmental Quality and Human Wellbeing – a Social Geographical Perspective. Landscape Urban Plan, **65**, 19 (2003)
18. M. BONAIUTO, F. FORNARA, M. BONNES: Indexes of Perceived Residential Environment Quality and Neighbourhood Attachment in Urban Environments: a Confirmation Study on the City of Rome. Landscape Urban Plan, **65**, 41 (2003).
19. A. L. BROWN: Increasing the Utility of Urban Environmental Quality Information. Landscape Urban Plan, **65**, 85 (2003).
20. J. NICHOL, M. S. WONG: Modeling Urban Environmental Quality in a Tropical City. Landscape Urban Plan, **73**, 49 (2005).
21. I. van KAMP, K. LEIDELMEIJER, G. MARSMAN, A. de HOLLANDER: Urban Environmental Quality and Human Well-being. Towards a Conceptual Framework and Demarcation of Concepts; a Literature Study. Landscape Urban Plan, **65**, 5 (2003).
22. L. HEMPHILL, S. MCGREAL, J. BERRY: An Indicator-based Approach to Measuring Sustainable Urban Regeneration Performance: Part 2, Empirical Evaluation and Case-study Analysis. Urban Stud, **41** (4), 757 (2004).
23. Statistical Yearbook of Hungary Cities 2000: CD/MSTAT. Central Statistical Office, Budapest, 2001a (in Hungarian).
24. Statistical Yearbook of Hungary Census 2000: CD. ArtCensus, Budapest, 2001b (in Hungarian).
25. B. VASKÖVI: National Air Quality (Immission) Data: October 1999 – March 2000, Heating Half-year. Health and Science (Egészségtudomány), **44** (2), 184 (2000a) (in Hungarian).
26. B. VASKÖVI: National Air Quality (Immission) Data: April – September 2000, Non-Heating Half-year. Health and Science (Egészségtudomány), **44** (4), 366 (2000b) (in Hungarian).

27. B. VASKÖVI: National Air Quality (Immission) Data: October 2000 – March 2001, Heating Half-year. Health and Science (Egészségtudomány), **45** (4), 370 (2001) (in Hungarian).
28. I. T. JOLLIFFE: Principal Component Analysis: a Beginner's Guide – I. Introduction and Application. Weather, **45**, 375 (1990).
29. I. T. JOLLIFFE: Principal Component Analysis: a Beginner's Guide – II. Pitfalls, Myths and Extensions. Weather, **48**, 246 (1993).
30. M. R. ANDERBERG: Cluster Analysis for Applications. Academic Press, New York, 1973.
31. J. F. HAIR, R. E. ANDERSON, R. L. TATHAM, W. C. BLACK: Multivariate Data Analysis. Prentice Hall, New Jersey, 1998.
32. G. ARGYROUS: Statistics for Research: with a Guide to SPSS. SAGE, London, 2005.
33. SPSS 15.0 Command Syntax Reference SPSS Inc., Chicago, Illinois, 2006.

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