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Article

Preventive Indicators for Creating Brownfields

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Abstract: Although the problem of brownfields in urban territories is successfully limited, it is a negative phenomenon of a sustainable city. Moreover, the number of recently created brownfield territories has become higher than that of the regenerated ones. Such territories reduce the quality of the social and economic setting of a city as well as visually and physically affect the life quality of city residents. Unfortunately, methods for the revitalization of brownfield land have been applied to deal with the consequences of the problem rather than to limit the problem itself. The authors of the article have investigated the aspects to be avoided to not create brownfields. The indicators that enable predicting the probability of a territory becoming a brownfield have been analyzed in this paper. Countries develop and exist under different social and economic conditions. Therefore, there is no uniform and universally accepted system of indicators for brownfield prevention that can be applied in any country or city. The authors have attempted to implement a recently developed idea of *indicators for prevention* under Lithuanian conditions and have selected those facilitating the identification of brownfields with an aim of identifying the most significant ones warning about the potential harm from the creation of brownfields in Lithuania. The selected indicators have been grouped, taking into account social, economic, natural, building and infrastructure settings of the city and ranked by a group of experts in urban planning. The established hierarchy of indicators in the groups of urban setting has allowed the authors to select the most significant *preventive indicators* for brownfields. The created system of indicators could be applied in practice as a basis for monitoring pertinent data and tracking their change.

Keywords: brownfield; preventive indicator; experts' ranking; multiple-criteria evaluation

1. Introduction

The changing needs of population impact on economic and other activities have been taking place in cities. Transition from one kind of activity to another has an unambiguous negative impact on the setting of a city [1]. The developmental cycle of a city faces numerous changes in activity, whereas gaps in legislation that do not define the obligation of owners to take care of their land when terminating activity, tendentiously increase the number of brownfields [2]. Existing buildings in Lithuania are abandoned, and new ones are built, thus leaving uncontrolled objects as well as the surrounding land untended. The wish and potential for starting development of new activity in the abandoned objects is sufficient; however, frequently, these are activities that do not require huge investments in managing existing buildings or adapting the setting and features of the territory [3]. Such *second-hand* use, or the re-use of the land, is only a short-term and impoverished objective. In the long run, there is no interest in using a completely impoverished property and its buildings, as it turns out to be much more convenient and cheaper to start new activity in a new place.

Brownfields reduce the quality of an urban setting; both visually and physically impacting the wellbeing of city dwellers living in the neighborhood as well as potential investors and business people. In the long run, the locus of the brownfield has become non-competitive, unattractive, and the quality of its social and economic setting has decreased. Therefore, brownfields impact on activities and sociality in the neighborhood, and also a decline in population can be observed [4,5]. With a reduction in the population, demand as well as business interest decrease. A city that faces the problem of brownfields does not meet the principles of sustainable development or criteria for the quality of life; moreover, a continuous development of territories is hardly conceivable in such a place [6].

All responsibility to limit the problem of brownfields falls on a city's administration, which has failed to find ways to oblige owners of separate land areas to take care of their property or to encourage new entrepreneurs to invest in them. Instead, permits to start new activity in other area of the city are issued [7]. Meanwhile, as city planners are obliged to solve the problem of brownfields, they employ methods for the redevelopment of brownfields, such as conversion and revitalization plans [8].

The logic of solving the task is correct: the problem has been recognized, its scope has been identified and the method for finding a solution has been presented. However, could it be stated that the selected solution to the problem precludes the occurrence of the issue? Can redevelopment plans for brownfields be considered as the prevention of brownfield creation?

Although brownfields have been successfully regenerated on the basis of the current rate, it could be stated that more territories have become brownfields than they have been regenerated [9–11]. Moreover, regenerated territories, like other operating areas, could always become brownfields [12]. Therefore, in this case, a more important issue of what should be avoided so that the currently built-up or regenerated territories do not to become brownfields arises [13].

Scientific literature contains a large body of information on the revitalization of brownfields, the potential for reusing them as well as offers methods for managing them [14–16]. Such progressed countries as US, UK, Netherlands, French, Germany, *etc.*, to admit and limit the problem of the brownfield, share experience and advice on how to identify them, describe the best practices on project implementation as well as present a number of recommendations on who should initiate solutions and manage the revitalization process.

Political changes at the end of the 1980s and in the 1990s in the former socialist countries represent a special case, because the factors that shaped cities in the previous period were very different from those faced by the rest of Europe. South and East European cities are more challenged by the issues of sustainability (strong suburbanization trends, less public resources for improving the environment, *etc.*) [17]. When industrial society emerged and negative consequences were foreseen, a general attitude was that negative impacts could be excused by referring to the benefits of human development. The main difference, probably, was that the system in East Europe had been less efficient, both in creating industrial growth and improving remedies for emerging brownfields [18]. Therefore, Eastern European countries, with regard to solutions to brownfields, need sufficient local know-how, which can supply missing local knowledge and help with forming suitable national and local policies and program priorities.

Countries that are less-experienced in brownfield limitation (for instance, those that faced economic breakthroughs at a later stage and suffered under the Soviet regime as Lithuania, Czech Republic, Serbia, *etc*.) can describe the current situation more effectively, identify brownfields and propose the concepts of their redevelopment by implementing tested solutions to various urban, social, economic and natural conditions [19]. However, a huge bulk of information frequently aggravates the selection of the most effective methods used for limiting brownfields. When implementing the best practices of foreign countries and redeveloping brownfields in a city, we never think of the future when they might become unusable and do not look for the ways to avoid that.

Meanwhile, the latest research presents more and more new ideas of how to more effectively solve the problems of brownfields, for example, learning from practice, evaluating changes in demographic, economic and social indicators, collaborating with foreign partners, *etc.* [20]. The authors consider that one of these is extremely valuable and could be a good preventive means for limiting the problem of brownfields.

The Holistic Management of Brownfield Regeneration (HOMBRE) project (2013) has proposed to analyze the problem of brownfields through their life-cycle. The managed land can be considered as the one at a certain stage within a cycle: the allocation of building land, development, use, abandonment and re-use. HOMBRE has introduced the idea of *preventive (“early”) indicators*. The goal of the “early indicator” within this framework is to have a signaling function towards persons or organizations responsible for such land management at the early stages of the process of brownfield formation. The “early indicators” for HOMBRE can aid in anticipating brownfield formation and related problems at an early stage.

Limiting the problem of brownfields in Lithuania is based on *preventive indicators* that would warn interested people or territorial planners about dangers that a territory will become a brownfield. This research is aimed at developing preventive indicators for Lithuania with the possibility of applying them to other Eastern European countries. With the help of management intervention, it could be solved and the negative outcomes of brownfields concerning sustainable territorial development would be avoided in advance. Therefore, access to data and monitoring information are the issues of utmost importance when implementing the idea of using early indicators in land management. Such prevention would be extremely important, as it could decrease contamination, improve the well-being of city dwellers and increase the sustainability of territorial development in Lithuania and other similar Eastern European countries [21].

Many overseas studies demonstrate that the issues of brownfield territories are an important factor in determining investment plans for urban development. The main axis of brownfield issues is an uncertainly of the system for indicators, the purpose of which is evaluating these territories. The carried out assessment has revealed the most objective indicators for defining the issues of brownfield territories. The authors have prepared a theoretical model of the most important indicators, broadly consistent with Lithuania, as well as with many other countries that were occupied by the Soviet Union. For this reason, this theoretical model of brownfield indicators can be used as a lever system that allows evaluating an investment project on a brownfield site in the context of the economic, social, urban and ecological environment.

2. Experimental Model

A survey of pertinent scientific literature has shown that the numerous indicators defining brownfields may vary. A set of 152 indicators suitable for such prediction has been found [5,22–27]. It would be difficult to handle such a large body of information; therefore, the authors confined this study to 48 (12 indicators for each group, see Table 1) of them (secondary indicators), and selected only those 15 strictly meeting the set aims (see *System for selecting indicators in* Figure 1).

Table 1. The arrangement of indicators in social, economic, natural and urban environments used for studying a certain setting of the brownfield.

Economic	Social
1. Percentage of GDP in industry and service provision areas 2. Rental rates 3. Ratio of the property price in a municipality to neighboring municipalities 4. National GDP 5. Industrial production 6. Wholesale and retail trade 7. Real estate value 8. Investments (private and public sectors) 9. Movement of enterprises (migration to/from) 10. Spatial incompliance between the number of employees and job vacancies 11. Reduction in administrative institutions on the territory 12. Land price	1. Work level 2. Long-term unemployment rate 3. Percentage of job vacancies in industry and service provision areas 4. Average actual income 5. Percentage of people living below the poverty line 6. Percentage of permanent houses/dwellings compared with houses for sale 7. Change in the percentage of social groups during a certain period 8. Percentage of residents with a university/higher education degree within a certain period 9. Criminal rate 10. Minor offences registered during a certain period compared with the statistics of the region 11. Average life expectancy 12. Percentage of renting social dwelling

Table 1. *Cont.*

Urban	Natural
1. Change in the percentage of territories used for industry	1. Level of soil contamination
2. Area of location for industry, retail trading and enterprises	2. Level of water pollution
3. Area of vacant land plots	3. Distance to surface water and the area of the safety zone
4. A number of new permits for construction	4. Materials emitted from local industrial companies/residential areas/dwellings
5. Residential objects	5. Decrease in biological variety
6. Commercial property	6. Noise level
7. Percentage of road/bridge systems below the standard level	7. Hazardous waste/other contamination sources
8. Age of installing infrastructural elements	8. Percentage of green areas in the territory/land plot and their quality
9. Average time from the service provision point to the main motorway	9. Green area per inhabitant
10. Time spent in traffic jams	10. Area of parks
11. Accident rate	11. Accessibility of the green area to society
12. Average distance from school/shopping center/entertainment place (*etc.*) to the place of residence	12. Level of pollutants emitted from vehicles

According to the review of scientific literature, and the results of expert ranking, the authors prepared a hierarchical system for the indicators that fell into three classes:

- Primary indicators were identified by reveiwing scientific literature (152 indicators in the yellow area of Figure 1).
- Secondary indicators act as the subset of primary indicators that eliminates duplicate indicators, according to their impact, meaning and sources (48 indicators in the red area of Figure 1).
- Final indicators were selected by expert ranking and applying the Multiple criteria decision making (MCDM) method (15 indicators in the green area of Figure 1).

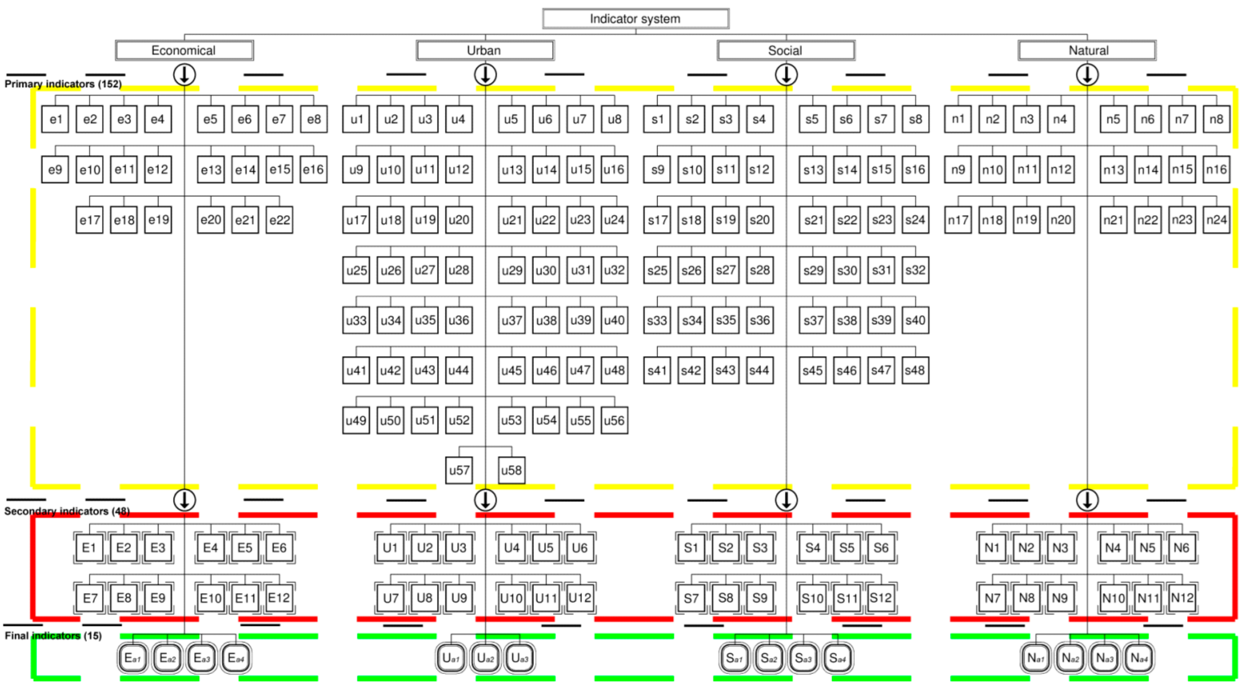

Figure 1. System for selecting indicators primary indicators; secondary indicators; and final indicators.

As for the scientific literature, the selected indicators are used for studying a certain setting of brownfield, *i.e.*, social, economic, natural, building or infrastructure. When selecting the indicators, 22 economic [$e_1 \ldots e_{22}$], 48 social [$u_1 \ldots u_{58}$], 58 building and infrastructure [$s_1 \ldots s_{48}$] and 24 natural [$n_1 \ldots n_{24}$] indicators were picked out (*primary indicators*). The majority of the indicators were mentioned more than once in the scientific literature, which confirms their significance. The recurrent indicators were eliminated by leaving one in each group. Following the first stage of selecting indicators, 48 of those (12 in each group of indicators: [$E_1 \ldots E_{12}$]; [$U_1 \ldots U_{12}$]; [$S_1 \ldots S_{12}$] and [$N_1 \ldots N_{12}$]) remained (*secondary indicators*).

When analyzing brownfields in Lithuanian cities, only the most important *preventive indicators* for brownfields should be selected (*final preventive indicators*). The final indicators are represented in the green bordered section in Figure 1 as the following subsets: [$E_{a1} \ldots E_{a4}$]; [$U_{a1} \ldots U_{a3}$]; [$S_{a1} \ldots S_{a4}$]; [$N_{a1} \ldots N_{a4}$]. From a practical point of view, the number of selected indicators will not exceed 15 [26]. For the experimental model, the authors attempted to select 20 indicators (five indices for each group of the urban setting). It is often difficult to collect enough data in practice; therefore, indices with a lack of values can be changed with other indices, and the number of indicators was reduced to 15.

A smaller number of indicators reduces accuracy and informativeness; in order to avoid this, a method for selecting indicators and groupings based on expert rankings and analysis of scientific literature was applied.

3. Results and Discussion

For solving economic, social and technical problems, or predicting the development of a certain process, the method of expert ranking is frequently employed in scientific research. Researchers emphasize that expert ranking and attitude to the problem under investigation frequently differ, and can even be contradictory [28]. However, the latter method enables accepting the summarized ranking of an expert group as a possible solution to the encountered problem. To base the solution to the problem on expert ranking, an agreement among expert opinions must be taken into consideration. The agreement among expert ranking may be verified by employing multiple-criteria evaluation methods [29].

3.1. Application of the Method for Expert Ranking

The essence of expert ranking in this study lies in the 20 most significant *preventive indicators* for brownfields selected based on expert questionnaires and 48 general indicators falling into four groups (12 in each) (j = 1,2,…,m, where m = 12).

Expert ranking provisions are described below and have been set to address a questionnaire to a particular expert ($E_1, E_2, \ldots, E_n$): the expert should hold a university/higher education degree, be employed and have at least 5 years experience working in the fields of territorial planning as well as social, economic, environmental protection and design. Questionnaires were presented to municipal territory planners (as recommended in HOMBRE (2013) project), experts in municipality investments and social care, practitioners who prepared documents on territorial planning (architectural, social, economic, natural, engineering and communication infrastructure projects), representatives of non-profit organizations solving the general problems of municipality, designers-engineers as well as experienced specialists holding certificates in environmental protection and able to work out documents necessary for planned economic activity. Ten experts completed questionnaires to rank *preventive indicators* falling into each group (i = 1,2,...,n, where n = 10) according to their field of activity.

To follow the procedure for expert ranking based on their work experience, the experts were asked to rank the grouped indicators ($X_1, X_2, ..., X_m$) presented in the questionnaire prepared by the researchers. They were requested to point out the most significant indicators from the point of view of monitoring and change in time in order to warn about a high probability of this territory becoming a brownfield or abandoned territorial unit. The indicators of each group (economic, social, building and infrastructure, natural) were ranked by quantitative significance values, *i.e.*, points ($B_1, B_2, ..., B_m$) on a 10-point scale. The highest number of points (10) was given to the most significant indicator from the point of view of an expert (in terms of prediction) warning that a territory could become a brownfield in the future. The lowest number of points (0) was attributed to the least significant indicator of the group. Such expert ranking shows the priority given by the experts to the indicators of separate groups, and the significance weight of the indicators will be determined based on the obtained ranking. Then, the 20 most significant *preventive indicators* for brownfields will be distinguished.

The weights of significance given to the indicators of each expert group, based on the completed questionnaires and returned by the experts are shown in Table 2. For futher calculations total numbers of points were used.

Table 2. The values (points) of significance given by the experts to the *preventive indicators* in the economic group of brownfields.

Expert Code, i = 1,2,...,n	**Indicator and the Values of Its Significance j = 1,2, ,m**											
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
E_1	3	9	2	1	4	5	9	10	7	5	6	8
E_2	3	4	5	3	4	5	5	4	4	6	5	7
E_3	8	5	2	1	4	3	4	10	9	6	5	8
E_4	3	5	3	1	1	2	4	8	10	8	5	2
E_5	5	5	7	1	1	1	3	8	1	8	3	6
E_6	2	9	5	3	1	4	6	8	0	3	0	10
E_7	8	7	8	7	7	8	8	9	8	8	6	7
E_8	5	8	4	5	7	6	10	10	0	5	5	9
E_9	9	8	5	7	10	7	10	9	6	6	4	8
E_{10}	7	9	9	7	8	8	9	9	8	7	6	9
Total number of points $\sum_{i=1}^{n} B_{ij} = B_j$	53	69	50	36	47	49	68	85	53	62	45	74

When the data obtained from the expert survey are input, calculations are made to substantiate the agreement among evaluators' opinion.

3.2. Calculations Substantiating the Agreement Considering Evaluators' Opinion

If the number of evaluators is higher than two, the level of the agreement between the experts of the group is expressed by the coefficient of concordance [30,31]. The calculated sum of all values of ranks' standard deviation shows if an expert's ranking significantly differs from the total average ranking. Therefore, the dependence of ranking may be expressed by the expert-ranking coefficient of concordance showing the degree of the similarity of individual ranking. The values of the coefficient of concordance, W, vary within the range from 0 to 1 (in case of the agreement of all ranks, the coefficient of concordance is equal to 1). The higher is the coefficient of concordance, the stronger is the correlation of variables.

To calculate the coefficient of concordance, the expert ranking of the indicators has been applied [28]. The indicators are ranked as follows: the most significant indicator is given the rank of 1, the second most significant indicator is given a rank higher than 1, *etc.* until the last significant indicator is given number m, *i.e.*, the number equal to the number of the indicators in the group. If the significance of several indicators, according to the expert opinion, is the same, then, both indicators are given the same rank. The values of significance (in points, *i.e.*, B_{ij}) presented in Table 2 and provided by the experts are converted to ranks (R_{ij}). Ranking shows a hierarchy, and each rank indicates the level of significance in the hierarchy system. Equation (1) is employed for converting points to ranks:

$$R_{ij} = (m + 1 - B_{ij}) \tag{1}$$

where B_{ij} is the value of significance (point) given by expert i (i = 1,2,…,n) to indicator j (j = 1,2,…,m); n is the number of experts; and m is the number of indicators. The values of significance given by each expert to the indicator of the economic group are converted into ranks and presented in Table 3.

Table 3. Expert ranks in the group of economic indicators and their use for calculation purposes.

Expert code,	Indicator and the rank of its significance, j = 1,2, ,m											
i = 1,2,...,n	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
E_1	10	4	11	12	9	8	4	3	6	8	7	5
E_2	10	9	8	10	9	8	8	9	9	7	8	6
E_3	5	8	11	12	9	10	9	3	4	7	8	5
E_4	10	8	10	12	12	11	9	5	3	5	8	11
E_5	8	8	6	12	12	12	10	5	12	5	10	7
E_6	11	4	8	10	12	9	7	4	13	10	13	3
E_7	5	6	5	6	6	5	5	4	5	5	7	6
E_8	8	5	9	8	6	7	3	3	13	8	8	4
E_9	4	5	8	6	3	6	3	4	7	7	9	5
E_{10}	6	4	4	6	5	5	4	4	5	6	7	4
Sum of ranks $\sum_{i-1}^{n} R_{ij}$	77	61	80	94	83	81	62	44	77	68	85	56
Average rank $\bar{R}_j$	7.7	6.1	8.0	9.4	8.3	8.1	6.2	4.4	7.7	6.8	8.5	5.6
$\sum_{i=1}^{n} R_{ij} - \bar{R}$	12	−4	15	29	18	16	−3	−21	12	3	20	−9
$\left[\sum_{i=1}^{n} R_{ij} - \bar{R}\right]^2$	144	16	225	841	324	256	9	441	144	9	400	81

The agreement among expert ranking is determined by calculating Kendall's coefficient of concordance *W*.

Kendall's coefficient of concordance is related to the sum of the ranks of each indicator from the point of view of all experts [31]. The average rank of each indicator is calculated according to Equation (2):

$$\bar{R}_j = \frac{\sum_{j=1}^{n} R_{ij}}{n} \tag{2}$$

where $\bar{R}_j$ is a rank given by expert *i* to indicator *j*, and *n* is the number of experts.

The sum of the ranks of each indicator, from the point of view of all experts, is calculated according to Equation (3):

$$\bar{R}_j = \sum_{j=1}^{n} R_{ij} \, (j = 1, 2, \ldots, m) \tag{3}$$

A standard deviation from R_j values more accurately defines and shows correlation with Kendall's coefficient of concordance. The latter deviation is calculated according to Equation (4):

$$S = \sum_{j=1}^{m} (R_j - \bar{R})^2 \tag{4}$$

The total mean is calculated according to Equation (5):

$$\bar{R} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} R_{ij}}{m} \tag{5}$$

The coefficient of concordance is calculated by Equation (6) [29,32,33]:

$$W = \frac{12S}{n^2 (m^3 - m)} \tag{6}$$

Suppose that the number of indicators is *m* > 7 (in our case 12 > 7); then, the significance of the coefficient of concordance may be calculated by Pearson criterion χ^2 [31]:

$$\chi^2 = n(m-1)W = \frac{12S}{nm(m+1)} \tag{7}$$

A random value is distributed according to χ^2 distribution when the degree of freedom is $\upsilon = m - 1$. The accepted significance level α is 0.05 (in practice, value α is frequently used), and critical value $\chi^2_{kr} = \chi^2_{\upsilon;\alpha}$ is calculated according to χ^2 distribution table. The estimated $\chi^2 > \chi^2_{kr}$ shows that all evaluators are in complete agreement (see Table 4).

Table 4. Calculation results of the expert ranking agreement in the groups of economic, social, building and infrastructure, and natural settings.

	Economic Indicators	Social Indicators	Building and Infrastructure Indicators	Natural Indicators
S	2890	2851	3808	2558
W	0.202098	0.199371	0.266294	0.178881
χ^2	22.23077	21.93077	29.29231	19.67692
χ^2_{kr}	19.6751			
	Evaluation of the compliance of the expert ranking agreement to condition $\chi^2 > \chi^2_{kr}$			
	Yes	Yes	Yes	Yes

The calculation results enable stating that the expert ranking of all indicators in economic, social, building and infrastructure as well as natural settings is in complete agreement.

In practice, for making certain calculations, it is more convenient to apply to the indicators of similar significance the best value, of which is the highest value [29]. Significance indicators are estimated calculating $\overline{q}_j$ value according to Equation (8):

$$\overline{q}_j = \frac{\overline{R}_j}{\sum_{j=1}^{m} R_j} \tag{8}$$

When ranks have been normalized, the most significant indicator is the one that has the least estimated value. The final values are determined considering each indicator by calculating the reciprocal, $\overline{q}_j$, and then by estimating the value of significance taking into account each indicator. The sum of the calculated significance of indicators is equal to 1.

Reciprocal, d_j, is calculated according to Equation (9), and significance indicator, Q_j, of each indicator is calculated according to Equation (10) [34]. Significance indicator, Q_j, will enable researchers to prove the significance of the indicators by comparing them as well as to identify how many times one indicator is more significant than the other, which allows selecting the most significant indicators from a group of indicators and making a list of the 20 most significant indicators.

$$d_j = 1 - \overline{q}_j \tag{9}$$

$$Q_j = \frac{(m + 1 - \overline{R}_j)}{\sum_{j=1}^{m} \overline{R}_j} \tag{10}$$

where m is the number of the indicators showing the characteristics of brownfield creation; $\overline{R}_j$ is the average rank of indicator *j*, calculated according to Equation (2). The values of indicators for determining the hierarchy in each settings are represented in Table 5.

Table 5. The values of the indicators for determining the hierarchy in economic, social, urban and natural settings.

	Indicator, j = 1,2, ,m												
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	**Sum**
						Economic indicators							
$\overline{q}_j$	0.089	0.070	0.092	0.108	0.096	0.093	0.071	0.051	0.089	0.078	0.098	0.065	=1
d_j	0.911	0.930	0.908	0.892	0.904	0.907	0.929	0.949	0.911	0.922	0.902	0.935	
Q_j	0.061	0.079	0.058	0.041	0.054	0.056	0.078	0.099	0.061	0.071	0.052	0.085	=1
Hierarchy	7	3	8	12	10	9	4	1	6	5	11	2	
						Social indicators							
$\overline{q}_j$	0.081	0.063	0.104	0.069	0.062	0.068	0.095	0.103	0.071	0.068	0.123	0.093	=1
d_j	0.919	0.937	0.896	0.931	0.938	0.932	0.905	0.897	0.929	0.932	0.877	0.907	
Q_j	0.081	0.098	0.057	0.092	0.099	0.093	0.066	0.058	0.090	0.093	0.038	0.068	=1
Hierarchy	6_7	2	11	5	1	3_4	9	10	6_7	3_4	12	8	
						Urban indicators							
$\overline{q}_j$	0.100	0.078	0.062	0.062	0.072	0.091	0.077	0.070	0.081	0.103	0.114	0.092	=1
d_j	0.900	0.922	0.938	0.938	0.928	0.909	0.923	0.930	0.919	0.897	0.886	0.908	
Q_j	0.043	0.065	0.082	0.082	0.072	0.053	0.066	0.074	0.063	0.041	0.030	0.052	=1
Hierarchy	10	6	1_2	1_2	4	8	5	3	7	11	12	9	
						Natural indicators							
$\overline{q}_j$	0.075	0.068	0.116	0.065	0.119	0.091	0.054	0.075	0.081	0.101	0.081	0.075	=1
d_j	0.925	0.932	0.884	0.935	0.881	0.909	0.946	0.925	0.919	0.899	0.919	0.925	
Q_j	0.105	0.112	0.064	0.115	0.061	0.088	0.126	0.105	0.098	0.079	0.098	0.105	=1
Hierarchy	6	3	11	2	12	9	1	4_5	7_8	10	7_8	4_5	

The graphical view of the evaluated indicators using the MCDM method is represented in Figure 2.

The results of the calculations allow identifying the most significant indicator for the issues of brownfield territories featured by the common properties of economy, ecology and social and urban environment in the context of Vilnius City as well as with regard to other countries formerly occupied by the Soviet Union.

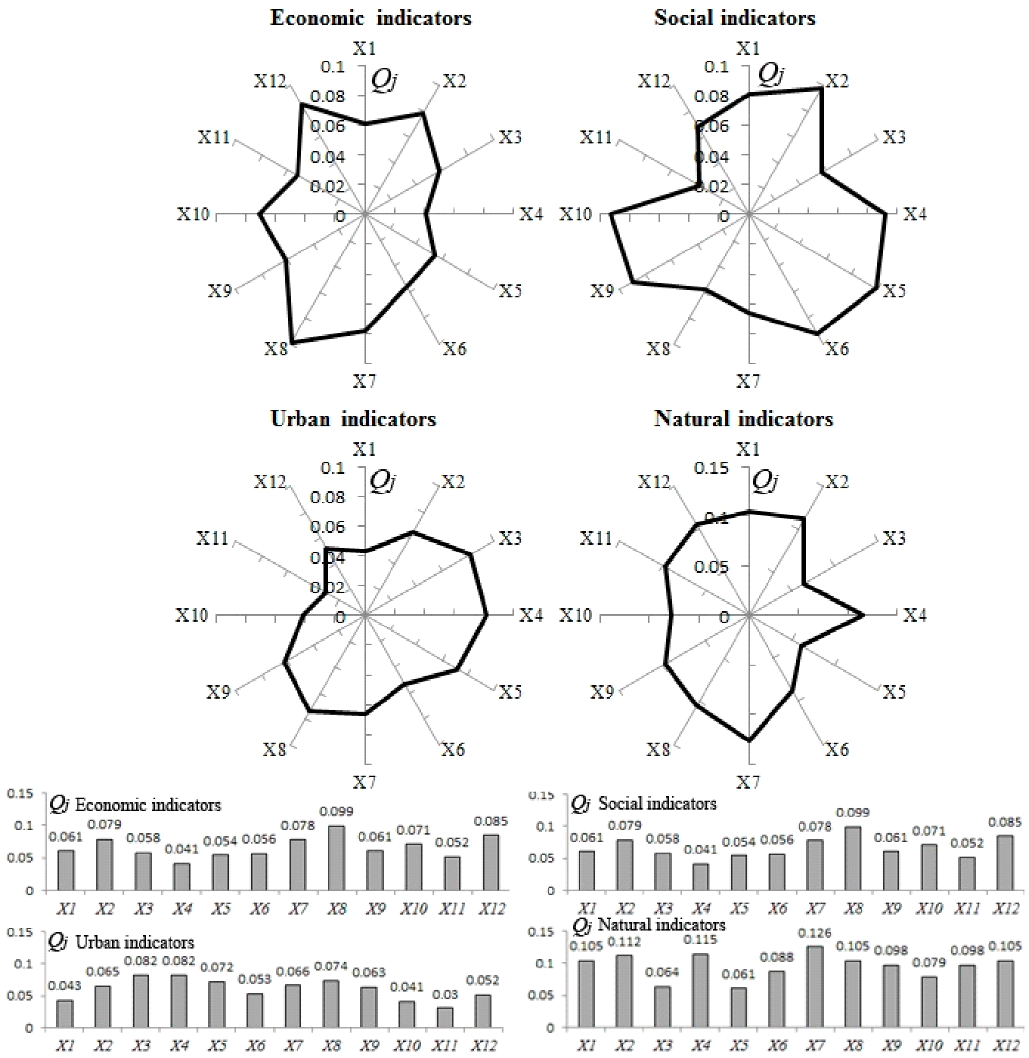

Figure 2. The calculated values of significance, considering each indicator in the secondary group of indicators. Schematic (at the top) and comparative (at the bottom) representation.

4. Conclusions

- The significance of the 48 *indicators* for brownfields selected, based on the analysis of the scientific literature, has been ranked by 10 competent experts in the economic, social, building and infrastructure, and natural groups of a city setting. Ranking has been made with reference to a 10-point-system.
- Calculations have been conducted to verify the agreement among expert (evaluator) rankings, which enabled the authors to state that all expert ranks are in complete agreement. Further calculations have allowed estimating the value of significance, considering each indicator from a separate setting of the city. On these grounds, the authors have established the hierarchy of the indicators in each group.
- When the hierarchy of the indicators regarding economic, social, building and infrastructure, and natural groups of city setting were established, the authors selected the 20 most significant *preventive indicators* for brownfields.

- The following most significant indicators in each group have been identified. The lists of the indicators specified for each group are represented in Table 6.
- The established system for the indicators may be applied in practice as a basis for monitoring data on the indicators and surveillance of their change in the avoidance of the newly built-up or regenerated territories to not become brownfield land. With management intervention, the problem of brownfields could be limited by identifying and predicting the potential of a territory becoming a brownfield.

Table 6. The most significant indicators for each group.

Economic Indicators	Social Indicators
•Investments •Land prices •Ratio of the property price in the territorial administrative unit to adjacent administrative territorial units •Real estate value •Spatial incompliance between employees and job vacancies	•Percentage of people living below the poverty line •Long-term unemployment rate •Percentage ratio of permanent dwelling and houses for sale •Minor offences registered during a certain period, compared with regional statistics •Average actual income of the population
Urban indicators	**Natural indicators**
•Area of vacant land •Number of new construction permits •Age of building construction •Residential objects •Percentage of road/bridge systems below standard condition.	•Hazardous waste material/other contamination sources •Pollutants emitted from local industrial enterprises/residential areas •Level of water pollution •Percentage and quality of green areas •Level of pollutants emitted from vehicles

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Author Contributions

The conducted research was designed by Marija Burinskienė. The research was performed, the obtained data was analyzed and the paper was written by Dovilė Lazauskaitė and Vytautas Bielinskas. All authors have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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