Journal of Civil Engineering and Management
ISSN 1392-3730 / eISSN 1822-3605
2018 Volume 24 Issue 1: 79–92
https://doi.org/10.3846/jcem.2018.303

CHOICE OF ABANDONED TERRITORIES CONVERSION SCENARIO ACCORDING TO MCDA METHODS

Vytautas BIELINSKAS[1], Marija BURINSKIENĖ[1*], Askoldas PODVIEZKO[2]

[1]Department of Roads, Faculty of Environment Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
[2]Department of Economics Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
Institute of Economics, Mykolas Romeris University, Ateities g. 20, LT-08303 Vilnius, Lithuania

Received 28 October 2017; accepted 10 January 2018

Abstract. Urban brownfields are found in all parts of the world. They suffer from a negative image and are generally being viewed as problem areas. However, urban brownfields also offer potentials for new uses and for the ecological regeneration of cities. Strategic decision-making has a long term impact on the quality of life, ecological balance and urban structure. Therefore, the paper is aimed at providing a methodology for selecting the optimal scenario for urban brownfields regarding criteria for urban development and focuses on three possible scenarios representing sustainable urban development in the city. The results of the research are provided as a priority list for each scenario in the context of every neighbourhood of Vilnius city. The obtained results show the scenario optimal for each neighbourhood having the highest priority to implementing solutions in real life. Economic, social, physical (urbanistic) and environmental criteria are considered. Geographic information system (GIS) tools are employed for collecting spatial information, obtaining the initial set of criteria and deriving statistical data. Different MCDA methods, including TOPSIS, EDAS, COPRAS and SAW are used in the research. The correlation between the values of the sets pairs of cumulative criteria for the applied MCDA methods appeared to be satisfactory for the conducted re-search. The developed framework will support the decision-making process in brownfield land redevelopment aiding sustainable urban planning.

Keywords: urban brownfields, urban planning, urban indicators, MCDA, EDAS, COPRAS, TOPSIS.

Introduction

Vilnius city, including its most attractive parts, may face a number of empty or poorly built spaces that need to be exploited. The potential for these spaces is enormous: the preparation of the city's general plan has counted approximately 500 ha of brownfields of neglected former factories, warehouse areas, etc. approximately 120 ha of which are in the central and adjoining part of the city. Such spatial urban trans-formations are typical of many metropolises in Central and Eastern Europe (Giddens 1991; Warf, Arias 2008).

Due to the unstable economic situation and the processes of the real estate market and environmental challenges, these urban area transformations have attracted serious political attention (Tölle 2009; Frantál *et al.* 2012). The problem of urban brownfields treated as an unexploited resource for urban development is raised by a large number of foreign scientists (Mathey *et al.* 2016; de Sousa, Tiesdell 2008; Bjelland 2002, etc.). In addressing the issue of brownfields, it is necessary to develop an effective strategy based on the assessment of stakeholders (politicians, society, experts in the field) and provide effective scenarios for using such areas for a long-term perspective (Alexandrescu *et al.* 2012, 2014; Schädler *et al.* 2011, 2013; Agostini *et al.* 2007; Rădulescu *et al.* 2016, etc.).

Considering the diverse definitions and perceptions regarding brownfields Alker *et al.* (2000) presented a set of factors that are relevant for achieving a universally accepted definition (Loures, Vaz 2016):

1. Brownfield land is land that has previously been developed.

*Corresponding author. E-mail: *marija.burinskiene@vgtu.lt*

2. All land which is not in current use, and which presents actual or suspected land contamination, is also brownfield land.
3. Land which is wholly currently developed and used is not brownfield, even if contaminated.
4. Brownfield land exists in rural and urban locations.
5. Brownfield land may exist within Green Belt.
6. Some brownfield sites, or parts of such sites, may also be (but are not necessarily) contaminated land.
7. Some brownfield land or parts of such sites are also classifiable as derelict land.
8. Some brownfield land or parts of such sites are also classifiable as vacant land.

In the run-up to brownfield dispersion analysis, the authors have found that their numbers are gradually decreasing as business discovered suitable areas. Different outgrown morally obsolete or simply unnecessary structures and buildings-ghosts erected in the attractive places in Vilnius start running out of stagnation. These processes include private capital the representatives of which require the provision of favourable economic, urban and social conditions for the development of real estate projects. Due to planning groundless monofunctional areas, the threat of the criminogenic environment is posed (Bielinskas *et al.* 2014) and threats as well as other urban irritants from industrial areas to the natural environment are constituted. Therefore, it is necessary to regulate brownfield conversion processes in accordance with the techniques and means established by scientific methods.

With reference to the research carried out in foreign countries, brownfields appear as an important factor determining the plans of investors for urban development. The main problem is lack of information on how brownfields should be considered. So far, no detailed brownfield geostatistical and qualitative research analysis the results of which should provide objective conclusions of how to integrate them into the urban framework thus controlling the socio-urban, cultural and economic environment of the city has been carried out in Lithuania.

Brownfields are a latent resource in sustainable land management. Brownfields are symptom of changing times. Brownfields are often not economically competitive for regeneration compared with greenfield sites without public intervention. In order to reshape city to compact structured model it is better to use brownfields located inside city instead of Greenfields which land is empty and has common edges with Green ring and with other naturally sensitive areas. The economic, environmental and social barriers present at the site frequently hinder returning brownfields to beneficial use (Thornton *et al.* 2007). The scale of the brownfield regeneration instruments shows, that especially the land use planning systems in central and southern European countries were influenced by the dominance of architectural dimension of spatial planning (urban-ism) putting a strong emphasis on the architectural flavour and concerned with urban design, townscape and building control, with the lack of economic approaches (Jamecny, Husar 2016). The authors of the previous studies developed an optimal system for criteria assessing brownfields (Burinskienė *et al.* 2015) and identified the most important standards of making decisions on the conversion of brownfields into the following defined scenarios:

1. T_1 – conversion to Green area.
2. T_2 – conversion to Commercial area.
3. T_3 – conversion to Recreational Activity area.
4. T_4 – conversion to Industrial area.
5. T_5 – conversion to Residential area.
6. T_6 – conversion to city's Land Reserve.

In the previous studies, the authors set the lines of criterion significance to identify the most important criteria that must be taken into account performing brownfield conversion employing the selected scenario T_1–T_6 (Bielinskas *et al.* 2014). The conducted research is focused on answering the question of what brownfield conversion scenarios must be implemented in different city neighbourhoods. This research is important in view of the annually changing social and economic environment, the recently created engineering infrastructure, varying resident habits and a dynamic urban environment. Regarding to benefits that most brownfields has in common as unused resources for city needs authors constructed a list representing potential overarching benefits of brownfields redevelopment (see Table 1).

The table above emphasizes the complexity of the problem. As benefits are grouped into different categories then by involving analysis of scientific literature specific criteria can be derived. In 2016–2017, the development of real estate in Vilnius changed the direction of investment from the peripheral to central urban areas with advanced engineering, which minimizes construction costs. In addition, these areas are becoming increasingly attractive to those urban residents and business entities the travel time factor from the object to the city centre for which is a priority to planning investments.

In the context of these changes, construction volumes have rapidly increased over the past years. This has led to the fact that urban brownfields have begun to be viewed not as urban wounds but as untapped opportunities for investments that create a common good for the population and business environment. The proportions of brownfields in the functional zones of Vilnius are presented in Figure 1.

Figure 1. The share of brownfields in the functional areas of Vilnius

When we are taking consideration about 'Greeneries for intensive use', we think open space for society like park, square, but 'Areas of gardening communities' we think about intensive land use for agriculture, it is soviet time heritage, small parcel of land for agriculture need.

Experts in the field agree that Vilnius will continue to grow rapidly. The only question is which direction – in width, height or density – will be preferred. In terms of demographic changes, Vilnius still remains the main attraction centre in Lithuania for jobs, high school density and dissemination.

The density of residential areas, particularly those located closer to the centre, further increases, as this is a viable solution: the current population density of the capi-

Table 1. Potential overarching benefits of brownfields redevelopment (developed by authors)

Economic	Urbanistic criteria
Site value; Neighbouring property values; Employment and investment benefits; Leverage of additional investment; Leverage of additional employment; Improvement in local property values; Improvement of local taxation revenues; Avoidance of Greenfield infrastructure requirements/ agglomeration benefits (e.g. greater urban density).	Creation of multifunctional urban structure; Minimization of anonymous spaces (reducing criminogenic environment); Creating comfortable areas for residents to migrate from and to work, home and neighbourhood centers; Compact city model. Lower distances and transport costs.
Social	**Environmental**
Reduced threat to public health; Reduced traffic (from reduced transportation needs to more distant Greenfield locations); Amenity benefits such as improved appearance; Health benefits.	Reduced use of Greenfield sites; Air quality improvements (from reduced transportation needs to more distant Greenfield locations); Reduced energy consumption and greenhouse gas production (from reduced transportation needs to more distant Greenfield locations); Water quality benefits.

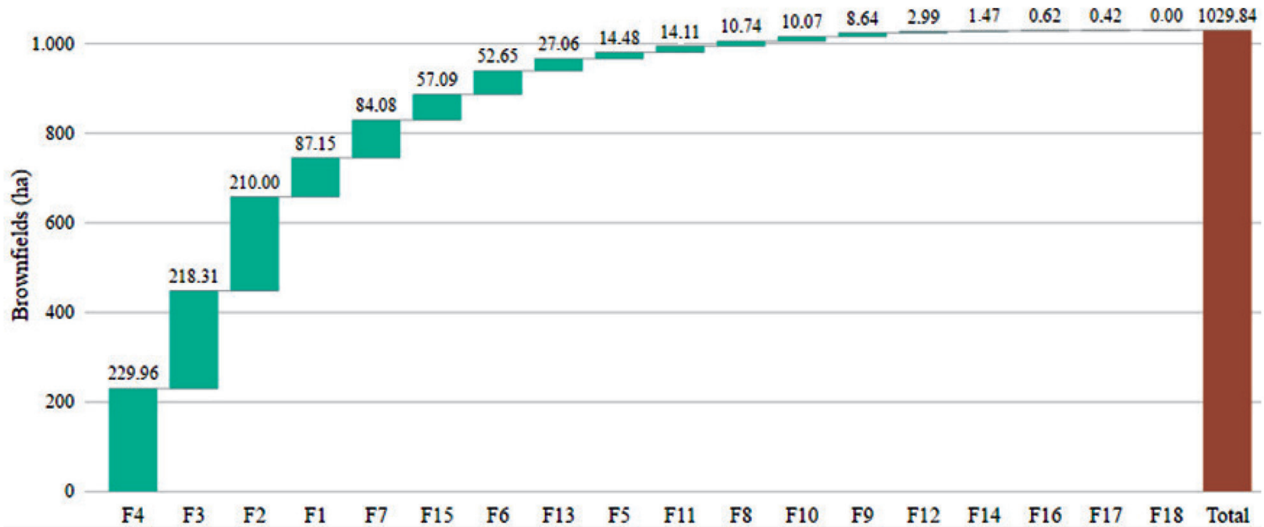

Figure 1. The share of brownfields in the functional areas of Vilnius

Notes: Functional zones: F_1 – Infrastructure areas; F_2 – Fixed-term agricultural and other undeveloped areas; F_3 – Business, manufacturing and industrial areas; F_4 – Residential areas of low-building intensity; F_5 – Areas for the needs of society, specific purposes and multi-use, F_6 – Neighbourhood centres and other mixed high-building intensity residential areas; F_7 – Greeneries for intensive use; F_8 – Areas for the needs of society, specific purposes and multi-use with a large amount of greeneries; F_9 – City centre and the most important local centres; F_{10} – Greeneries for extensive use, F_{11} – Residential areas of average-building intensity; F_{12} – Old town; F_{13} – Intense-building residential areas; F_{14} – Watering areas; F_{15} – Woods and wooded areas; F_{16} – Lakes, rivers and ponds; F_{17} – The conversion of gardening communities into the residential areas of low-building intensity; F_{18} – The areas of gardening communities. Authors' calculations.

tal of Lithuania is one of the smallest in comparison with other modern Western European and even Lithuanian cities: Vilnius has plenty of vacant non-urbanized areas (9.9 km^2) that can be used for projects on area regeneration and conversion considering precisely defined and important strategic planning criteria for city inhabitants and investors.

1. Descriptions of conversion scenarios and examined territorial units

The authors digitized spatial data on the General Plan of Vilnius City by 2015 (2007), which assisted in analysing the characteristic features of the considered conversion scenarios.

The collected data enabled us to conclude that even if the redevelopment of the different brownfield typologies

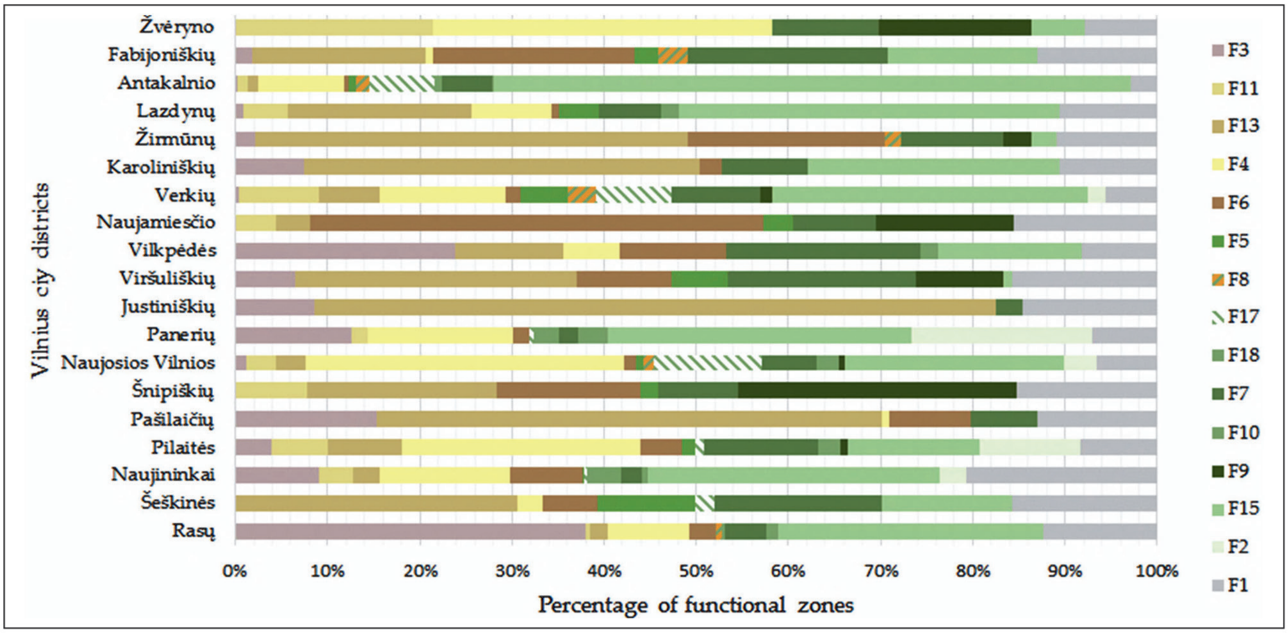

Figure 2. The structure of Vilnius city neighbourhoods according to functional areas and the number of brownfields

Notes: Functional zones: F_1 – Infrastructure areas; F_2 – Fixed-term agricultural and other undeveloped areas; F_3 – Business, manufacturing and industrial areas; F_4 – Residential areas of low-building intensity; F_5 – Areas for the needs of society, specific purposes and multi-use, F_6 – Neighbourhood centres and other mixed high-building intensity residential areas; F_7 – Greeneries for intensive use; F_8 – Areas for the needs of society, specific purposes and multi-use with a large amount of greeneries; F_9 – City centre and the most important local centres; F_{10} – Greeneries for extensive use, F_{11} – Residential areas of average-building intensity; F_{12} – Old town; F_{13} – Intense-building residential areas; F_{14} – Watering areas; F_{15} – Woods and wooded areas; F_{16} – Lakes, rivers and ponds; F_{17} – The conversion of gardening communities into the residential areas of low-building intensity; F_{18} – The areas of gardening communities. Authors' calculations.

have direct and indirect benefits at different dimensions, they are very diverse influencing society and citizens' life's quality on different ways. Due to this reason the conversion of brownfields in different Vilnius city neighbourhoods can be assessed differently depending on the social, economic, urban and natural environment. The authors address the following three territories conversion scenarios:

T_2 – conversion to Commercial area.

T_4 – conversion to Industrial area.

T_5 – conversion to Residential area.

Conversion scenarios have been analysed in 20 neighbourhoods covering the full area of Vilnius city (401 km^2). The structure of the neighbourhoods is presented in accordance with the functional zones prevailing therein (see Figure 2).

Figure 2 shows the neighbourhoods indexed with D where D_1 is the neighbourhood having the highest number of brownfields, and D_{19} is the neighbourhood with the least number of brownfields. Taking into account the potential features of conversion scenarios T_2, T_4 and T_5, a possible impact on the environment and population, the authors applied to the criteria by identifying the most suitable neighbourhoods for conversion:

business, manufacturing and industrial areas make more than 5% of the total area of the neighbourhood;

the residential areas of average-building intensity make more than 5% of the total area of the neighbourhood;

intense-building residential areas make more than 5% of the total area of the neighbourhood;

neighbourhood centres and other mixed high-building intensity residential areas make more than 5% of the total area of the neighbourhood;

city centre and the most important local centres make more than 10% of the total area of the neighbourhood;

infrastructure areas make more than 10% of the total area of the neighbourhood.

After calculating the priority of conversion processes according to the established criteria, the authors have created a priority list of the neighbourhoods taking into account the attractiveness of carrying out the conversion of brownfields (Table 2).

In many European countries densely urbanised areas might benefit from more open space. Open spaces in urban areas can provide multiple services (Chiesura 2004; Bolund, Hunhammar 1999), including human health benefits.

The redevelopment of a brownfield can provide a range of societal, environmental but also economic benefits for a number of entities (Glumac *et al.* 2015). In most cases, a brownfield redevelopment seeks a form of partnership.

Table 2. The priority sequence of brownfield conversion considering the neighbourhoods of Vilnius city

Level of priority	neighbourhood	Level of priority	neighbourhood	Level of priority	neighbourhood
I	Viršuliškių	III	Žvėryno	IV	Fabijoniškių
	Šnipiškių		Karoliniškių		Lazdynų
II	Žirmūnų		Naujamiesčio		Senamiesčio
	Verkių		Justiniškių		Panerių
	Vilkpėdės		Pilaitės		Naujosios Vilnios
	Pašilaičių		Šeškinės		Antakalnio
	Naujininkai		Rasų		

A public private partnership (PPP) is a concept frequently used in development practice (Koppenjan, Enserink 2009; Polyakova, Vasylyeva 2016) although a uniform definition is still lacking (Weihe 2005). Public procurement has changed remarkably in the last 30 years. Traditional public procurement that emphasizes transactional exchange and arm's length relationships between public and private organizations (Lian, Laing 2004) has confronted challenges of providing solutions for urban and economic development (Guzmán, Sierra 2012). A public–private partnership (PPP, 3P or P3) is a cooperative arrangement between two or more public and private sectors, typically of a long-term nature. Governments have used such a mix of public and private endeavours throughout history. However, the past few decades have seen a clear trend towards governments across the globe making greater use of various PPP arrangements.

PPPs are particularly useful when circumstances are not favourable for a piecemeal development via interventions by individual owners (Grimsey, Lewis 2002). In such cases a comprehensive integrated approach, with private owners/developers collaborating with the responsible public authorities, may be more efficient and profitable. Another important reason for the establishment of a PPP can be limitations to public funding available, making a public sector led redevelopment impossible. This has led local governments to invite the private sector into various long term arrangements for capital intensive real estate development projects.

Private investors must assess the risk of the project, its potential effectiveness and the feasibility of solutions. In order to purify these processes, it is necessary to prepare a methodology for selecting a functional brownfield scenario acceptable and understandable to all interested parties.

PPP projects are implemented in accordance with the following steps: a PPP contract is signed upon selecting a private PPP object or a private entity, and the initial investment, construction or maintenance works are started. Upon the completion of works within the time limit set, the private sector provides services or engages in commercial activities in accordance with the terms and conditions stipulated in the agreement thus ensuring that all assets are transferred to the public entity after the expiry of the PPP contract provided in the agreement (Kaklauskas *et al.* 2012).

2. Research methodology

2.1. System of criteria

Therefore, an initial set of 152 criteria was established as described in previous author's studies (Burinskienė *et al.* 2015, 2017). 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 (TIMBRE 2012). It would be difficult to handle such a large body of information; therefore, the authors confined this study to 48 of them (secondary indicators), and selected only those 15 strictly meeting the set aims. When the hierarchy of the indicators regarding economic, social, building and infrastructure, and natural groups of city setting were established, the authors selected the 18 most significant preventive indicators for brownfields (Figure 3).

The GIS technology was used to capture and digitize spatial data on brownfield land in 20 neighbourhood of Vilnius city, as well as to combine and link up various data, including economic, social, physical and environmental indicators as described previously (Burinskienė, Rudzkienė 2009), used for evaluation of each criterion from the final set of 18 criteria. As a result, the data set of 360 different multi-dimensional indicators was established. This data set was used for evaluation of criteria and establishing their relative weights. The digitalization has been implemented by Spatial join, Spatial Intersect methods (Figure 4) and Inverse Distance Weightening (IDW) Interpolation methods.

The GIS data collected in Lithuania showed that the capital city, Vilnius, contains a brownfield land area of 10.9 km^2, the major part of which (83%) is a vacant land. Twenty neighbourhood of Vilnius city, identified as important for redevelopment of brownfield land, were selected for case study. With the help of GIS technology, the data set of 360 different multidimensional indicators was created for 20 neighbourhood of the city providing data platform for the multiple criteria evaluation. All investigated indicators were attributed to a certain group of criteria C_j as in Figure 3. In the final set of criteria, each criteria group comprises of up to five criteria as follows: $\{E_1, ..., E_4\} \in C_1$; $\{U_1, ..., U_5\} \in C_2$; $\{S_1, ..., S_5\} \in C_3$; $\{N_1, ..., N_4\} \in C_4$.

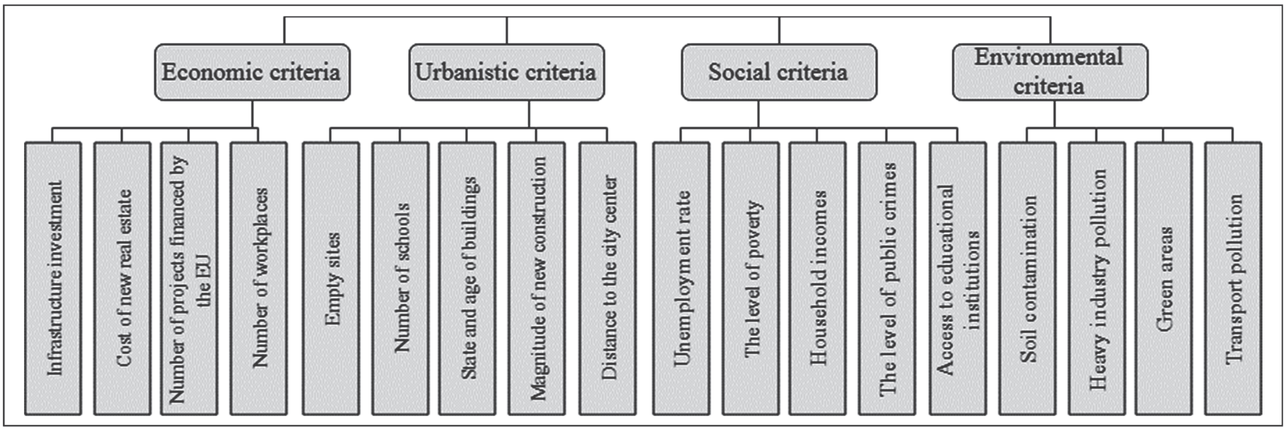

Figure 3. System of research criteria *C*

2.2. The initial stage of MCDA analysis

For the purpose of evaluating twenty neighbourhoods of the city of Vilnius in terms of the three scenarios as above, and making projects on development of the city in such areas multiple criteria methods were chosen for performing evaluation. Chosen in Section 2.1 criteria of evaluation cover a wide variety of dimensions as complexity of urban development has to comprise economic, natural, demographic, technical, environmental, or managerial aspects in order to make urban development sustainable. Such aspects have mutual influence, and overall influence on the perception of quality of life by citizens of a city. Complexity of effects of various criteria, and desire to have an effective tool of evaluation naturally led to the choice in favour of MCDA methods (Podviezko 2014, 2016; Jacyna-Golda *et al.* 2017). In addition, the choice in favour of the MCDA methods was technically determined because of the structure of data (Podviezko, A., Podviezko, V. 2015), and an effective possibility to comprise opinions of experts on how the city should develop in relation to corresponding ideas of the tasks.

The major idea of the MCDA method is to create a cumulative criterion for each alternative, reflecting the attractiveness of the alternative in quantitative terms, expressed in a single number related to each alternative (Brauers *et al.* 2012; Ginevicius *et al.* 2012; Jakimavicius *et al.* 2016; Palevicius *et al.* 2016). Such a cumulative criterion comprises both weights of importance of criteria chosen for evaluation and values criteria in a way that a more attractive alternative outranks a weaker alternative in case the cumulative criterion of this alternative appears to be larger. Values of criteria could be normalized in many different ways, according to the problem investigated (Podviezko 2015; Podviezko A., Podvezko V. 2015) or using transformation proprietary for the MCDA method used. In the paper we will use the simplest MCDA method SAW (Simple Additive Weighing), which is a core MCDA method as it encompasses and reflects in a clear way major ideas of MCDA methods; created in Lithuania popular method COPRAS (Complex Proportional Assessment); the TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) methods as a popular contemporary method, and the newly proposed EDAS (Evaluation Based on Distance from Average Solution) method. Several methods must be used as there is no single best MCDA method, which guarantees precision of evaluation. Each MCDA method can be discerned by its specific features and logic therefore discrepancies within the results can be reduced by simultaneous use of several MCDA methods.

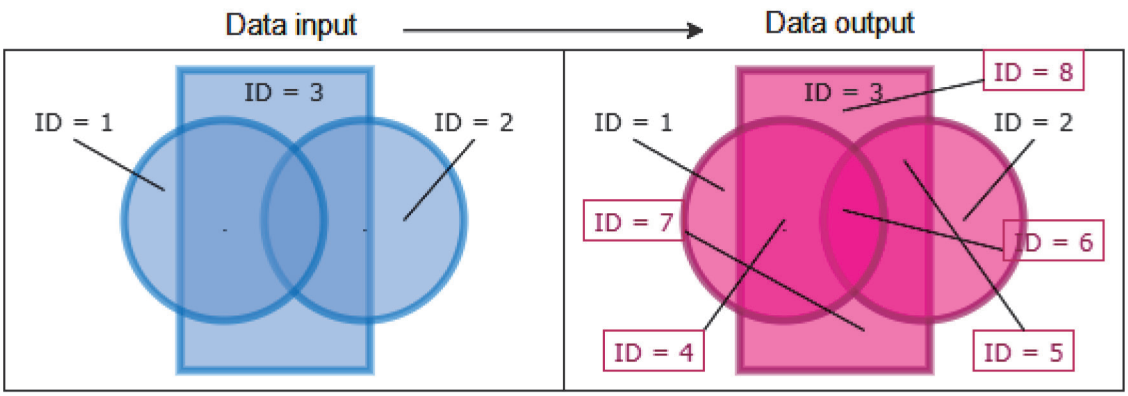

Figure 4. Principle scheme of Spatial Intersect method in GIS

In all MCDA methods the same decision matrix is used for each problem of the three. The matrices contain statistical data $R = \left\| r_{ij} \right\|$, which describe the objects being evaluated. Weights of criteria are denoted as $\omega_i \left(\sum_{i=1}^{n} \omega_i = 1 \right)$, $i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$, where n is the number of criteria, n is the number of the evaluated objects or alternatives. Weights are different for the three problems investigated, but as they will be solved separately, we will not use a separate index for each such a problem. Criteria must be a priori defined as maximising or minimising. The larger is the value of maximising criteria, the better it is in terms of attractiveness; the smaller is the value of a minimising criterion for an alternative, the more attractive it becomes.

Four MCDA methods were chosen in order to smoothen the effect of transformations of values of criteria. In the chosen MCDA methods types of transformation of data are based on different logic and ideas (Podviezko, A., Podvezko, V. 2015; Ginevicius *et al.* 2012).

2.3. The SAW method

The name of the method (Simple Additive Weighing) reflects its simplicity. Therefore we will provide only a succinct its description. Normalized values of criteria are multiplied by weights of significance of each criterion and are summed to the cumulative criterion of the method S_j:

$$S_j = \sum_{i=1}^{m} \omega_i \cdot \tilde{r}_{ij}. \qquad (1)$$

S_j is the cumulative criterion of the SAW method. The method deals only with maximising criteria, therefore all minimizing criteria should be transformed to maximizing ones by any chosen method, e.g. by taking their inverse values (Podviezko, A., Podvezko, V. 2014).

We used the following normalisation of values of criteria (Eqn (2)) as it appears to be suitable in such cases as ours, when some values of criteria are negative. Nevertheless, in case when values of criterion differ insignificantly among alternatives such a normalization will overemphasise influence of such a criterion. A test of differences of values of criteria was performed. Two cases of rather insignificant differences were revealed: values of criterion "Number of projects funded by the EU" varied 31% at most, while values of criterion "Household incomes" varied even less, no more than 24%. For such two criteria the classic normalization was used: values of criteria were divided by the sum of their values over all alternatives. Such normalized values will be also used in the COPRAS method. Normalisation (Eqn (2)) is also a convenient tool for the purpose of in-depth analysis of influence of each criterion on the major result of evaluation.

We pay attention that results of evaluation depend on direction of criteria, which can be different depending on the task. In Table 3 directions of criteria are provided.

Table 3. Direction of criteria depending on the task

Criterion \ Task	T_2	T_4	T_5
E_1 – Infrastructure investment	max	max	max
E_2 – Cost for new real estate	min	min	min
E_3 – Number of projects funded by EU	max	max	max
E_4 – Number of workspaces	max	max	min
S_1 – The level of unemployment	max	max	min
S_2 – The level of poverty	min	min	max
S_3 – Household incomes	max	max	min
S_4 – The level of public crimes	max	max	max
S_5 – Access to educational institutions	max	max	min
U_1 – Empty sites	max	max	min
U_2 – Number of schools	min	min	min
U_3 – State and average age of new constructions	max	min	max
U_4 – Magnitude of new constructions	min	min	min
U_5 – Distance to the city centre	max	max	min
N_1 – Soil contamination	min	min	max
N_2 – Heavy industry pollution	min	max	min
N_3 – Green areas	min	max	min
N_4 – Transport pollution	max	min	max

$$\tilde{r}_{ij} = \begin{cases} \dfrac{r_{ij} - \min_j \cdot r_{ij}}{\max_j \cdot r_{ij} - \min_j \cdot r_{ij}}, & \text{if } i \text{ is a maximising criterion} \\ \dfrac{\max_j \cdot r_{ij} - r_y}{\max_j \cdot r_{ij} - \min_j \cdot r_{ij}}, & \text{if } i \text{ is a minimising criterion.} \end{cases} \qquad (2)$$

2.4. The COPRAS method

The COPRAS method uses a similar idea as the SAW method for the maximising criteria (Podviezko 2011, 2012). Contrary, for the minimising criteria a proprietary transformation of the method is used. The cumulative criterion of the method is as follows:

$$Z_j = S_{+j} + \frac{\sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{1}{S_{-j}}}, \qquad (3)$$

where $S_{+j} = \sum_{i=1}^{m} \omega_{+i} \tilde{r}_{+ij}$ is the sum of normalised values of maximising criteria multiplied by weights (as is in the SAW method); $S_{-j} = \sum_{i=1}^{m} \omega_{-i} \tilde{r}_{-ij}$ is the sum of normalised values of minimising criteria multiplied by weights, $\tilde{r}_{+ij}$,

j = 1, 2, ..., n are normalised values of the maximising criteria; $\tilde{r}_{-ij}$, j = 1, 2, ..., n are normalised values of the minimising criteria.

2.5. The TOPSIS method

The TOPSIS method (Opricovic, Tzeng 2004) is one of the most popular and interesting contemporary MCDA methods among researchers (Parfenova *et al.* 2016; Palevicius *et al.* 2017; Jakimavicius *et al.* 2016). An alternative is considered to be better in the in case, if its Euclidean distance from the best hypothetical solution is smaller and the distance to the worst hypothetical solution is larger than of than its peer. The method requires a proprietary normalisation of values of criteria, in accordance with formula:

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sqrt{\sum_{j=1}^{n} r_{ij}^2}}. \quad (4)$$

The idea of the TOPSIS method is as follows. Denote the best benchmark solution as V^*. It is found in accordance with the following Eqn (5):

$$V^* = \left\{V_1^*, V_2^*, ..., V_m^*\right\} = \left\{\left(\max_j \omega_i \cdot \tilde{r}_{ij} / i \in I_1\right)\right\},$$
$$\left(\min_j \omega_i \mp \cdot \tilde{r}_{ij} / i \in I_2\right), \quad (5)$$

where I_1 is the set of indices of the maximizing criteria, I_2 is the set of indices of the minimizing criteria.

Similarly, the worst benchmark solution V^- is found in accordance with the Eqn (6):

$$V^- = \left\{V_1^-, V_2^-, ..., V_m^-\right\} = \left\{\left(\min_j \omega_i \cdot \tilde{r}_{ij} / i \in I_1\right)\right\},$$
$$\left(\max_j \omega_i \mp \cdot \tilde{r}_{ij} / i \in I_2\right). \quad (6)$$

At the next stage the Euclidean distance to the best and the worst benchmark solutions is calculated in accordance to the following formula:

$$D_j^* = \sqrt{\sum_{i=1}^{m} \left(\omega_i \cdot \tilde{r}_{ij} - V_i^*\right)^2}; \quad (7)$$

$$D_j^- = \sqrt{\sum_{i=1}^{m} \left(\omega_i \cdot \tilde{r}_{ij} - V_i^-\right)^2}. \quad (8)$$

And at the next stage the cumulative criterion of the method C_j^* for each alternative j is calculated:

$$C_j^* = \frac{D_1^-}{D_j^* + D_j^-}, \ (j = 1, 2, ..., n), \ (0 \le C_j^* \le 1) \quad (9)$$

Consequently, the smaller distance to the best benchmark solution, or the larger is the distance to the worst benchmark solution, the better is the alternative.

2.6. The EDAS method

The idea and prominence of the EDAS method are reflected in the name of the method. In contrast to the TOPSIS method, the EDAS method uses now the solution with average values of criteria as a bench-mark solution AV, found as follows (Keshavarz Ghorabaee *et al.* 2015):

$$AV_i = \frac{\sum_{j=1}^{m} r_{ij}}{m}. \quad (10)$$

At the next step positive and negative distances from AV are calculated for each alternative and each criterion as follows, separately for maximising:

$$PDA_{ij} = \frac{\max\left(0, \left(r_{ij} - AV_i\right)\right)}{AV_i}; \quad (11)$$

$$NDA_{ij} = \frac{\max\left(0, \left(AV_i - r_{ij}\right)\right)}{AV_i}; \quad (12)$$

$$PDA_{ij} = \frac{\max\left(0, \left(AV_i - r_{ij}\right)\right)}{AV_i}; \quad (13)$$

$$PDA_{ij} = \frac{\max\left(0, \left(AV_i - r_{ij}\right)\right)}{AV_i}; \quad (14)$$

At the next step weights are incorporated to find NSP_j and NSN_j:

$$NSP_j = \frac{\sum_{i=1}^{n} \omega_i \cdot PDA_{ij}}{\max_j \sum_{i=1}^{n} \omega_i \cdot PDA_{ij}}; \quad (15)$$

$$NSP_j = 1 - \frac{\sum_{i=1}^{n} \omega_i \cdot PDA_{ij}}{\max_j \sum_{i=1}^{n} \omega_i \cdot NDA_{ij}}. \quad (16)$$

Finally, the cumulative criterion of the method is found by the Eqn (17):

$$AS_j = \frac{1}{2} \cdot \left(NSP_j + NSN_j\right). \quad (17)$$

3. The results

The results obtained using mentioned MCDA methods are presented in Tables 4–9. As still there is no most prominent MCDA method available, and each method normally yield different results, in order to reduce chances for discrepancies the ultimate result was combined from the four employed methods by using the coefficient of variation of the results obtained by each method keeping in mind

Table 4. Results of MCDA evaluation for the task T_2

Alternatives:		1	2	3	4	5	6	7	8	9	10
SAW	S_j	0.426	0.349	0.337	0.343	0.334	0.381	0.424	0.342	0.505	0.373
	No.	5	13	17	15	19	11	7	16	1	12
TOPSIS	C_j^*	0.372	0.289	0.291	0.283	0.279	0.439	0.393	0.265	0.597	0.317
	No.	8	16	14	17	18	2	3	20	1	12
COPRAS	Z_j	0.058	0.044	0.043	0.044	0.047	0.053	0.044	0.042	0.070	0.049
	No.	2	14	18	16	12	6	17	20	1	11
EDAS	AS_j	0.914	0.604	0.564	0.608	0.660	0.858	1.043	0.653	1.137	0.787
	No.	6	18	20	17	15	9	3	16	1	12
Ultimate rank		**5**	**16**	**19**	**17**	**15**	**8**	**3**	**18**	**1**	**12**

Notes: Alternatives are neighbourhood of the city of Vilnius: 1 – Antakalnis, 2 – Fabijoniškės, 3 – Justiniškės, 4 – Karoliniškės, 5 – Lazdynai, 6 – Naujamiestis, 7 – Naujininkai, 8 – Naujoji Vilnia, 9 – Paneriai, 10 – Pašilaičiai. Authors' calculations.

Table 5. Results of MCDA evaluation for the task T_2

Alternatives:		11	12	13	14	15	16	17	18	19	20
SAW	S_j	0.425	0.472	0.403	0.336	0.429	0.446	0.389	0.317	0.346	0.405
	No.	6	2	9	18	4	3	10	20	14	8
TOPSIS	C_j^*	0.365	0.382	0.393	0.289	0.384	0.383	0.347	0.277	0.304	0.360
	No.	9	7	4	15	5	6	11	19	13	10
COPRAS	Z_j	0.047	0.052	0.055	0.044	0.058	0.050	0.043	0.050	0.050	0.055
	No.	13	7	5	15	3	9	19	10	8	4
EDAS	AS_j	0.986	1.060	0.849	0.696	0.886	1.001	0.898	0.599	0.773	0.849
	No.	5	2	11	14	8	4	7	19	13	10
Ultimate rank		**6**	**2**	**10**	**14**	**7**	**4**	**9**	**20**	**13**	**11**

Notes: Alternatives are neighbourhood of the city of Vilnius: 11 – Pilaitės, 12 – Rasų, 13 – Senamiesčio, 14 – Šeškinės, 15 – Šnipiškių, 16 – Verkių, 17 – Vilkpedės, 18 – Viršuliškių, 19 – Žirmūnų, 20 – Žveryno. Authors' calculations.

Table 6. Results of MCDA evaluation for the task T_4

Alternatives:		1	2	3	4	5	6	7	8	9	10
SAW	S_j	0.441	0.401	0.368	0.389	0.403	0.588	0.544	0.381	0.459	0.450
	No.	10	15	20	19	17	1	2	18	5	12
TOPSIS	C_j^*	0.402	0.402	0.395	0.395	0.399	0.577	0.499	0.388	0.510	0.441
	No.	15	16	18	19	17	1	3	20	2	12
COPRAS	Z_j	0.047	0.050	0.046	0.044	0.044	0.067	0.055	0.040	0.052	0.056
	No.	15	11	16	18	19	1	7	20	9	2
EDAS	AS_j	0.398	0.328	0.293	0.310	0.341	0.809	0.645	0.329	0.509	0.460
	No.	14	18	20	19	15	1	2	17	10	12
Ultimate rank		**14**	**17**	**20**	**19**	**16**	**1**	**2**	**18**	**6**	**12**

Notes: Alternatives are neighbourhood of the city of Vilnius: 1 – Antakalnis, 2 – Fabijoniškės, 3 – Justiniškės, 4 – Karoliniškės, 5 – Lazdynai, 6 – Naujamiestis, 7 – Naujininkai, 8 – Naujoji Vilnia, 9 – Paneriai, 10 – Pašilaičiai. Authors' calculations.

Table 7. Results of MCDA evaluation for the task T_4

Alternatives:		11	12	13	14	15	16	17	18	19	20
SAW	S_j	0.447	0.482	0.466	0.414	0.473	0.490	0.456	0.401	0.476	0.466
	No.	13	3	9	14	6	4	11	16	7	8
TOPSIS	C_j^*	0.474	0.460	0.482	0.420	0.460	0.481	0.476	0.403	0.455	0.469
	No.	7	10	4	13	9	5	6	14	11	8
COPRAS	Z_j	0.050	0.049	0.056	0.048	0.056	0.056	0.051	0.046	0.055	0.052
	No.	12	13	3	14	4	5	10	17	6	8
EDAS	AS_j	0.543	0.537	0.575	0.402	0.528	0.569	0.542	0.338	0.500	0.525
	No.	5	7	3	13	8	4	6	16	11	9
Ultimate rank		8	5	4	13	9	3	7	15	11	10

Notes: Alternatives are neighbourhood of the city of Vilnius: 11 – Pilaitės, 12 – Rasų, 13 – Senamiesčio, 14 – Šeškinės, 15 – Šnipiškių, 16 – Verkių, 17 – Vilkpedės, 18 – Viršuliškių, 19 – Žirmūnų, 20 – Žveryno. Authors' calculations.

Table 8. Results of MCDA evaluation for the task T_5

Alternatives:		1	2	3	4	5	6	7	8	9	10
SAW	S_j	0.447	0.556	0.617	0.596	0.549	0.465	0.410	0.476	0.314	0.547
	No.	17	7	1	2	8	16	18	15	20	9
TOPSIS	C_j^*	0.533	0.593	0.623	0.620	0.589	0.512	0.426	0.533	0.410	0.591
	No.	16	6	1	2	8	17	19	15	20	7
COPRAS	Z_j	0.046	0.056	0.065	0.058	0.050	0.044	0.037	0.040	0.052	0.054
	No.	13	5	1	2	11	17	20	18	9	8
EDAS	AS_j	0.539	0.746	0.847	0.779	0.654	0.421	0.202	0.513	0.417	0.657
	No.	12	4	1	2	8	17	20	13	18	7
Ultimate rank		**15**	**5**	**1**	**2**	**9**	**17**	**20**	**13**	**18**	**7**

Notes: Alternatives are neighbourhood of the city of Vilnius: 1 – Antakalnis, 2 – Fabijoniškės, 3 – Justiniškės, 4 – Karoliniškės, 5 – Lazdynai, 6 – Naujamiestis, 7 – Naujininkai, 8 – Naujoji Vilnia, 9 – Paneriai, 10 – Pašilaičiai. Authors' calculations.

Table 9. Results of MCDA evaluation for the task T_5

Alternatives:		11	12	13	14	15	16	17	18	19	20
SAW	S_j	0.504	0.403	0.575	0.564	0.573	0.492	0.506	0.587	0.518	0.539
	No.	13	19	4	6	5	14	12	3	11	10
TOPSIS	C_j^*	0.549	0.493	0.584	0.600	0.613	0.547	0.548	0.616	0.577	0.585
	No.	12	18	10	5	4	14	13	3	11	9
COPRAS	Z_j	0.046	0.039	0.054	0.055	0.057	0.046	0.045	0.056	0.049	0.051
	No.	14	19	7	6	3	15	16	4	12	10
EDAS	AS_j	0.481	0.348	0.650	0.680	0.709	0.505	0.457	0.772	0.583	0.616
	No.	15	19	9	6	5	14	16	3	11	10
Ultimate rank		**12**	**19**	**8**	**6**	**4**	**14**	**16**	**3**	**11**	**10**

Notes: Alternatives are neighbourhood of the city of Vilnius: 11 – Pilaitės, 12 – Rasų, 13 – Senamiesčio, 14 – Šeškinės, 15 – Šnipiškių, 16 – Verkių, 17 – Vilkpedės, 18 – Viršuliškių, 19 – Žirmūnų, 20 – Žveryno. Authors' calculations.

Table 10. Correlation between pairs of sets of values of cumulative criteria of MCDA methods

Methods Tasks	SAW/ TOPSIS	SAW/ COPRAS	TOPSIS/ COPRAS	SAW/ EDAS	COPRAS/ EDAS	TOPSIS/ EDAS
T_2	0.854	0.667	0.794	0.941	0.56	0.822
T_4	0.908	0.873	0.862	0.964	0.871	0.962
T_5	0.961	0.711	0.714	0.861	0.910	0.901

that it reflects the magnitude of variation of the result of evaluation. As a method with a higher coefficient of variation provides more reliable reflection of attractiveness of alternatives, corresponding coefficient of variation was used as a proportion of influence of the method on the ultimate rank. Ultimate results are provided in Tables 3–8 at the bottom row.

Correlation between pairs of sets of values of cumulative criteria of MCDA methods used appeared to be satisfactory with few slight exceptions for the COPRAS method (Table 10). Such discrepancies most probably are appearing because of different influence of minimising criteria on the result (Podvezko 2011). Nevertheless, the method was not eliminated because of its popularity.

Average values of correlation coefficient were ranked in the descending order and are presented in Figure 5. It can be observed that the best correlation relate to the pairs of results obtained by TOPSIS, EDAS, and SAW methods.

As still some variations in obtained rankings by different methods somewhat differ, classification of alternatives into 2 or groups by attractiveness (e.g. attractive, less attractive, non-attractive) could be suggested (Doumpos, Zopounidis 2002). Similarly, we will name five best territories to be converted under each scenario. Under scenario T_2 the most suitable territories to be converted to commercial use are: Panerių, Rasų, Naujininkų, Verkių, Antakalnis, and Pilaitės. Under scenario T_4 the most suitable territories to be converted to industrial activity use are: Naujamiestis, Naujininkai, Verkių, Senamiesčio, Rasų. Finally, under scenario T_5 the most suitable territories to be converted to residential use are: Justiniškės, Viršuliškių, Šnipiškių, and Fabijoniškių.

Causes of prominence for the scenario T_2 of distinguished after the evaluation three best alternatives may be revealed by analysing of suitability of values of separate criteria for conversion of the neighbourhoods to commercial area. Panerių neighbourhood gained prominence because of its best position in Vilnius in terms of the following criteria: E_2 – Cost for new real estate; U_1 – Empty sites; U_5 – Magnitude of new constructions; S_1 – The level of unemployment, N_3 – Green areas, and rather good position in terms of U_2 – Number of schools. Rasų neighbourhood did not attain the best positions in neither of criteria. Nevertheless, it has very good positions in terms of S_4 – The level of public crimes; S_5 – Access to educational institutions; U_2 – Number of schools; U_5 – Distance to the city centre; N_1 – Soil contamination; N_2 – Heavy industry pollution. Naujininkų neighbourhood has the maximal transport pollution, and has very good positions in terms of E_1 – Infrastructure investment; S_5 – Access to educational institutions; U_2 – Number of schools; N_1 – Soil contamination; N_2 – Heavy industry pollution.

Causes of prominence for the scenario T_4 of distinguished three best alternatives may be again revealed by analysing of suitability of values of separate criteria for conversion of the neighbourhoods to industrial area. Naujamiestis neighbourhood gained prominence because of its best position in Vilnius in terms of the following criteria: E_1 – Infrastructure investment; E_4 – Number of workspaces; N_1 – Soil contamination; N_2 – Heavy industry pollution; N_3 – Green areas; while it has rather good characteristics in terms of S_2 – The level of poverty, and S_4 – The level of public crimes. Naujininkai neighbourhood has the best value only in terms of criterion N_4 – Transport

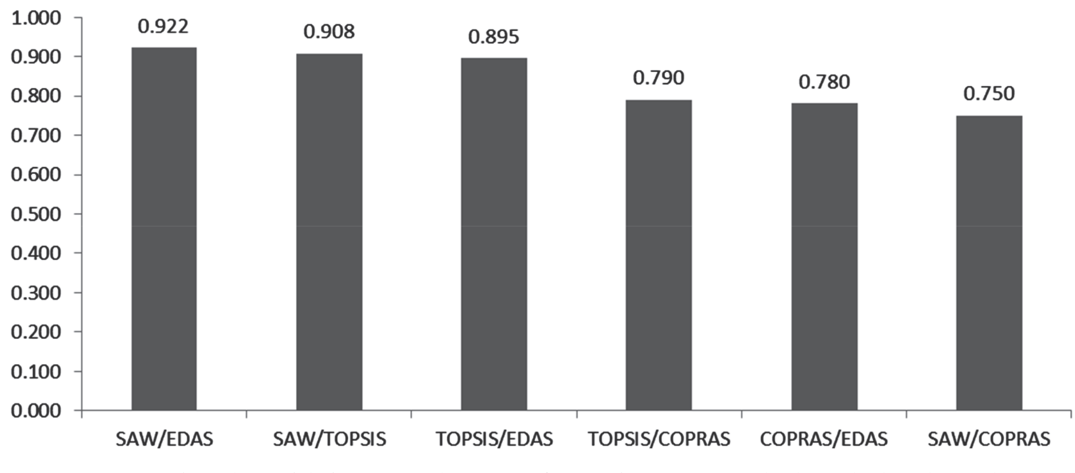

Figure 5. The values of different correlation coefficients for MCDA methods applied in the study

pollution criterion, and relatively good position in terms of ther following criteria: E_1 – Infrastructure investment; U_2 – Number of schools; S_5 – Access to educational institutions; and N_3 – Green areas. And Verkių neighbourhood has the best values of such criteria as U_2 – Number of schools; S_5 – Access to educational institutions; and N_3 – Green areas.

The three best alternatives for the scenario T_5 (conversion to Residential area) are distinguished by the following criteria. Justiniškės neighbourhood has the best values of such criteria as E_4 – Number of workspaces; U_3 – State and average age of new constructions; S_4 – The level of public crimes; N_3 – Green areas; N_4 – Transport pollution, S_1 – The level of unemployment; S_2 – The level of poverty; and N_1 – Soil contamination. Viršuliškių neighbourhood has the best values of such criteria as E_4 – Number of workspaces; U_1 – Empty sites; S_1 – The level of unemployment; S_4 – The level of public crimes; N_1 – Soil contamination; and N_4 – Transport pollution. Šnipiškių neighbourhood has the best values of such criteria as U_1 – Empty sites; U_4 – Magnitude of new constructions; U_5 – Distance to the city centre; S_4 – The level of public crimes; N_4 – Transport pollution.

Such an analysis of values of criteria would not produce a useful result without MCDM methods as prominence in terms of a few criteria does not guarantee that the alternative will be a good choice by a decision-maker. Ranking of alternatives based on the methodology suggests comprises values of all criteria, and accounts influence of criteria in terms of weights.

Conclusions

According to the methodology developed by the authors, and in order to determine Vilnius city neighbourhoods that require urban development using brownfields as an untapped urban resource, the authors have selected conversion scenarios T_2, T_4, T_5 most accurately representing urban development.

The authors made brownfield clusters in Vilnius city, which formed high (areas that belong to the neighbourhoods assigned to group 1), lower and the lowest (areas that belong to the neighbourhoods as-signed to group IV) level clusters. The following research results are classified according to these priority groups.

By calculating correlation coefficients for conversion scenarios selected employing different MCDA methods, the authors have determined that SAW, TOPSIS and EDAS are the most appropriate methods for scenarios T_2, T_4, T_5. Based on the obtained results, the authors argue that these methods can be successfully applied for calculating the values of brownfield scenarios in Vilnius city neighbourhoods, other cities or their territorial units.

The research revealed that under scenario T_2 the most suitable territories to be converted to commercial use are: Panerių, Rasų, Naujininkų, Verkių, Antakalnis, and Pilaitės. Under scenario T_4 the most suitable territories to be converted to industrial activity use are: Naujamiestis, Naujininkai, Verkių, Senamiesčio, Rasų. Finally, under scenario T_5 the most suitable territories to be converted to res-idential use are: Justiniškės, Viršuliškių, Šnipiškių, and Fabijoniškių.

Similar values of correlation coefficients indicate that, in this particular case, several conversion scenarios can be used in a single area, which allows planning mixed purpose areas instead of the existing brownfields: with reference to the obtained results, it is expedient to plan them in the neighbourhoods of Naujininkai, Rasos and Senamiestis. Sustainable urban development in these places of Vilnius city must be based on brownfield conversion into the creation of multifunctional areas.

Unlike other conversion scenarios analyzed in the paper, mixed-use development in brownfields reduces their anonymity and plays a role of criminogenic prevention. Such a trend of development is particularly relevant for the urban areas where a high level of crime, the concentration of marginal communities, low economic level and the aesthetic image of the environment do not meet identity criteria.

Taking into account priority groups prepared by the authors and assigned to the neighbourhoods, conversion scenarios must be primarily implemented in Šnipiškės (conversion scenario T_2, conversion into the commercial area) and Naujininkai (conversion scenarios $T_{4,5}$, creation of multifunctional areas, conversion into residential and non-industrial areas) neighbourhood.

The author's methodology and research results organized by the author can be applied for implementing the strategic planning of Vilnius and other metropolises in Central Europe considering the problems of brownfields and assessing them as an untapped resource for urban development.

Disclosure statement

Authors do not have any competing financial, professional, or personal interests from other parties.

References

Agostini, P.; Carlon, C.; Critto, A.; Marcomini, A. 2007. A step toward contaminated megasites management: six European experiences at comparison, in A. A. Velinni (Ed.). *Landfill research trends*. New York: Nova Science Publishers Inc., 47–75.

Alexandrescu, F.; Bleicher, A.; Werner, F.; Martinát, S.; Frantál, B.; Krupanek, J.; Michaliszyn, B.; Bica, I.; Iancu, I. 2012. *Report on regional decision structures and key actors*. Deliverable D2.1 Version 3 of EC Funded TIMBRE project (FP7-ENV-2010.3.1.5-2-265364) [online], [cited 21 December 2017]. Available from Internet: http://timbre-project.eu/tl_files/timbre/Intern/4%20Work%20Packages/WP8/Deliverables/timbre_265364_D2.1_V3.pdf

Alexandrescu, F.; Martinát, S.; Klusáček, P.; Bartke, S. 2014. The path from passivity toward entrepreneurship: Public sector actors In brownfield regeneration processes in Central and Eastern Europe, *Organization & Environment* 27(2): 181–201. https://doi.org/10.1177/1086026614529436

Alker, S.; Joy, V.; Roberts, P.; Smith, N. 2000. The definition of brownfield, *Journal of Environmental Planning and Management* 43(1): 49–69. https://doi.org/10.1080/09640560010766

Bielinskas, V.; Staniūnas, E.; Beconytė, G.; Balčiūnas, A.; Vasiliauskas, D. 2014. Public safety in monofunctional zones of Vilnius city, in *The 9th International Conference "Environmental Engineering"*, 22–23 May 2014, Vilnius, Lithuania.

Bjelland, M. 2002. Until justice and stewardship embrace: or, how a geographer thinks about brownfield sites, *Christian Scholar's Review* 31(4): 393–412.

Bolund, P.; Hunhammar, S. 1999. Ecosystem services in urban areas, *Ecological Economics* 29(2): 293–301. https://doi.org/10.1016/S0921-8009(99)00013-0

Brauers, W. K.; Ginevicius, R.; Podviezko, A. 2012. Evaluation of performance of Lithuanian commercial banks by multi-objective optimization, in *The 7th International Scientific Conference "Business and Management'2012"*, 2012. Selected papers.

Burinskiene, M.; Bielinskas, V.; Podviezko, A.; Gurskiene, V.; Maliene, V. 2017. Evaluating the significance of criteria contributing to decision-making on brownfield land redevelopment strategies in urban areas, *Sustainability* 9(5): 759. http://doi:10.3390/su9050759.

Burinskiene, M.; Lazauskaitė, D.; Bielinskas, V. 2015. Preventive indicators for creating brownfields, *Sustainability* 7: 6706–6720. https://doi.org/10.3390/su7066706.

Burinskienė, M.; Rudzkienė, V. 2009. Future insights, scenarios and expert method application in sustainable territorial planning, *Technological and Economic Development of Economy* 15(1): 10–25. https://doi.org/10.3846/1392-8619.2009.15.10-25

Chiesura, A. 2004. The role of urban parks for the sustainable city, *Landscape and Urban Planning* 68(1): 129–138. https://doi.org/10.1016/j.landurbplan.2003.08.003

de Sousa, C.; Tiesdell, S. 2008. *Brownfields redevelopment and the quest for sustainability*. Emerald Group Publishing Limited.

Doumpos, M.; Zopounidis, C. 2002. *Multicriteria decision aid classification methods*. Dordrecht; Boston: Kluwer Academic Publishers.

Frantál, B.; Klusáček, P.; Kunc, J.; Martinát, S. 2012. *Report on results of survey on brownfield regeneration and statistical analysis*. Deliverable D3.1 of the TIMBRE project [online], [cited 14 December 2017]. Available from Internet: http://www.andrea-kubitz.de/timbre/tl_files/timbre/Intern/4%20Work%20Packages/WP8/Deliverables/timbre_265364_D3.1_V3.pdf

Giddens, A. 1991. *The consequences of modernity*. Stanford: Stanford University Press.

Ginevicius, R.; Podvezko, V.; Podviezko, A. 2012. Evaluation of isolated socio-economical processes by a multi-criteria decision aid method ESP, in *The 7th International Scientific Conference "Business and Management'2012"*, 2012. Selected papers.

Glumac, B.; Han, Q.; Schaefer, W.; van der Krabben, E. 2015. Negotiation issues in forming public–private partnerships for brownfield redevelopment: Applying a game theoretical experiment, *Land Use Policy* 47: 66–77. https://doi.org/10.1016/j.landusepol.2015.03.018

Grimsey, D.; Lewis, M. K. 2002. Evaluating the risks of public private partnerships for infrastructure projects, *International Journal of Project Management* 20: 107–118. https://doi.org/10.1016/S0263-7863(00)00040-5

Guzmán, F.; Sierra, V. 2012. Public–private collaborations: Branded public services? *European Journal of Marketing* 46(7/8): 994–1012. https://doi.org/10.1108/03090561211230160

Jacyna-Golda, I.; Izdebski, M.; Podviezko, A. 2017. Assessment of efficiency of assignment of vehicles to tasks in supply chains: a case study of a municipal company, *Transport* 32(3): 243–251. http://doi.org/10.3846/16484142.2016.1275040

Jakimavicius, M.; Burinskiene, M.; Gusaroviene, M.; Podviezko, A. 2016. Assessing multiple criteria for rapid bus routes in the public transport system in Vilnius, *Public Transport* 8(3): 365–385. http://doi.org/10.1007/s12469-016-0146-7

Jamecny, L.; Husar, M. 2016. From planning to smart management of historic industrial brownfield regeneration, *Procedia Engineering* 161: 2282–2289. https://doi.org/10.1016/j.proeng.2016.08.829

Kaklauskas, A.; Zavadskas, E. K.; Bardauskienė, D.; Dargis, R. (Eds). 2012. *Darnus nekilnojamojo turto vystymas* [Sustainable real estate development]. Vilnius: Technika, 16–20. http://dx.doi.org/10.3846/1320-S

Keshavarz Ghorabaee, M.; Zavadskas, E. K.; Olfat, L.; Turskis, Z. 2015. Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS), *Informatica* 26(3): 435–451. https://doi.org/10.15388/Informatica.2015.57

Koppenjan, J. F. M.; Enserink, B. 2009. Public–private partnerships in urban infrastructures: reconciling private sector participation and sustainability, *Public Administration Review* 69: 284–296. https://doi.org/10.1111/j.1540-6210.2008.01974.x

Lian, P. C. S.; Laing, A. W. 2004. Public sector purchasing of health services: A comparison with private sector purchasing, *Journal of Purchasing and Supply Management* 10(6): 247–256. https://doi.org/10.1016/j.pursup.2004.11.005

Loures, L.; Vaz, E. 2016. Exploring expert perception towards brownfield redevelopment benefits according to their typology, *Habitat International*. In Press, Corrected Proof. https://doi.org/10.1016/j.habitatint.2016.11.003

Mathey, J.; Arndt, T.; Banse, J.; Rink, D. 2016. Public perception of spontaneous vegetation on brownfields in urban areas – Results from surveys in Dresden and Leipzig (Germany), *Urban Forestry & Urban Greening*. In Press, Corrected Proof. https://doi.org/10.1016/j.ufug.2016.10.007

Opricovic, S.; Tzeng, G.-H. 2004. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS, *European Journal of Operational Research* 156(2): 445–455. http://doi:10.1016/S0377-2217(03)00020-1

Palevicius, V.; Grigonis, V.; Podviezko, A.; Barauskaite, G. 2016. Developmental analysis of park-and-ride facilities in Vilnius, *PROMET – Traffic & Transportation* 28(2): 165–178. https://doi.org/10.7307/ptt.v28i2.1767

Palevicius, V.; Sivilevicius, H.; Podviezko, A.; Griskeviciute-Geciene, A.; Karpavicius, T. 2017. Evaluation of park and ride facilities at communication corridors in a middle-sized city, *Economic Computation & Economic Cybernetics Studies & Research* 51(2): 231–248.

Parfenova, L.; Pugachev, A.; Podviezko, A. 2016. Comparative analysis of tax capacity in regions of Russia, *Technological and Economic Development of Economy* 22(6): 905–925. https://doi.org/10.3846/20294913.2016.1216019

Podvezko, V. 2011. The comparative analysis of MCDA methods SAW and COPRAS, *Inzinerine Ekonomika - Engineering Economics* 22(2): 134–146. http://doi:10.5755/j01.ee.22.2.310

Podviezko, A. 2012. Augmenting multicriteria decision aid methods by graphical and analytical reporting tools, in L. Niedrite; R. Strazdina; B. Wangler (Eds). *Lecture notes in business information processing*. Berlin, Heidelberg: Springer, 236–251. https://doi.org/10.1007/978-3-642-29231-6_19

Podviezko, A. 2014. Influence of processes of transformation of economy on financial stability, in *The 8th International Scien-*

tific Conference "Business and Management 2014", 2014, Vilnius, Lithuania, 563–570. http://doi.org/10.3846/bm.2014.068

Podviezko, A. 2015. Use of multiple criteria decision aid methods in case of large amounts of data, *International Journal of Business and Emerging Markets* 7(2): 155–169. http://doi.org/10.1504/IJBEM.2015.068351

Podviezko, A. 2016. On multiple dimensions of criteria representing financial globalisation, in *The 9th International Scientific Conference "Business and Management 2016"*, 2016, Vilnius, Lithuania, 1–8. http://doi.org/10.3846/bm.2016.31

Podviezko, A.; Podvezko, V. 2015. Influence of data transformation on multicriteria evaluation result, *Procedia Engineering* 122: 151–157. http://doi.org/10.1016/j.proeng.2015.10.019

Podviezko, A; Podvezko, V. 2014. Absolute and relative evaluation of socio-economic objects based on multiple criteria decision making methods, *Engineering Economics - Inzinerine Ekonomika* 25(5): 512-529. https://doi.org/10.5755/j01.ee.25.5.6624

Polyakova, I.; Vasylyeva, E. 2016. Benefits of public-and-private partnership for the creation of the infrastructure of the urbanized territories in Russia, *Procedia Engineering* 165: 1380–1387. https://doi.org/10.1016/j.proeng.2016.11.868

Rădulescu, C. M.; Ştefan, O.; Rădulescu, G.; Rădulescu, A.; Rădulescu, M. 2016. Management of stakeholders in urban regeneration projects. Case study: Baia-Mare, Transylvania, *Sustainability* 8(3): 238. http://doi:10.3390/su8030238

Schädler, S.; Finkel, M.; Bleicher, A.; Morio, M.; Gross, M. 2013. Spatially explicit computation of sustainability indicator values for the automated assessment of land-use options, *Landscape and Urban Planning* 111: 34–45. https://doi.org/10.1016/j.landurbplan.2012.12.002

Schädler, S.; Morio, M.; Bartke, S.; Rohr-Zänker, R.; Finkel, M. 2011. Designing sustainable and economically attractive brownfield revitalization options using an integrated assessment model, *Journal Environmental Management* 92(3): 827–837. https://doi.org/10.1016/j.jenvman.2010.10.026

Tailored Improvement of Brownfield Regeneration in Europe (TIMBRE). 2012 [online], [cited 4 October 2017]. Available from Internet: http://www.timbre-project.eu/

Thornton, G.; Franz, M.; Edwards, D.; Pahlen, G.; Nathanail, P. 2007. The challenge of sustainability: incentives for brownfield regeneration in Europe, *Environmental Science & Policy* 10(2): 116–134. https://doi.org/10.1016/j.envsci.2006.08.008

Tölle, A. 2009. *Report about concepts and tools for brownfield redevelopment activities*. Output No. 3.1.1 of the COBRAMAN project). Bydgoszcz, Poland [online], [cited 24 October 2017]. Available from Internet: http://www.central2013eu/fileadmin/user_upload/Downloads/outputlib/cobraman_tools_brownfield_regeneration.pdf

Warf, B.; Arias, S. 2008. *The spatial turn: Interdisciplinary perspectives*. Routledge.

Weihe, G. 2005. Public–private partnerships: addressing a nebulous concept, in *The 10th International Research Symposium on Public Management (IRSPM X)*, 2005, International Center for Business and Politics Copenhagen Business School, Copenhagen.