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Applicability of the Multiple-Criteria Decision-Making Method to Assess Potential for Watercourse Revitalisation in Urbanised Areas Based on the Wierzbak Watercourse

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1. Review of literature

It is increasingly accepted that revitalisation of rivers, including also headwaters and small watercourses flowing through urbanised areas, not only consists in the protection and generation of natural resources and quality space, but it is also a response to climate change (SMURF 2003, Janauer 2005, Boitsidis & Gurnell 2006, Kasperek et al. 2013, Mazur et al. 2015, Walczak et al. 2018). Revitalisation in the literal sense refers to "revival, restoration to life". This term is most frequently used in relation to objects or areas, which in view of various transformations (e.g. economic) have lost their original functions (Kaluza et al. 2014, Brandyk & Majewski 2013). In contrast to renaturisation, revitalisation covers a narrower scope of actions (Gurnell 2007, Schueler et al. 2005). In relation to rivers its role is to resolve the crisis and restore ecological functions of the river. Measures promoting revitalisation of small urban watercourses facilitate an improvement in the ecological status or potential of waters as stipulated in the Water Framework Directive (Directive 2000/60/EC). All enterprises aiming at watercourse revitalisation contribute to an improved ecological potential of waters and quality of urbanised areas (Janauer 2005, Houriet 2006, Laks et al. 2013, Kaluza et al 2015, Tomczyk et al. 2019). Unfortunately, very few revitalisation projects have been successfully implemented in urbanised areas. This results e.g. from many strong revitalisation barriers (Zalewski & Wagner-Lotkowska 2004, Trząski & Mana 2007). Among them social as well as scientific and information barriers are of greatest importance (Schueler 2004, Trząski et al. 2006, Trząski et al. 2010). Scientific and information barriers stem from the fact that scientific knowledge is not adequately used and adapted to the specific character of a given investment project. The number of advisory institutions and the amount of information available as guidelines for managing organs are insufficient. In turn, social barriers result mainly from the fact that the general public is not aware of the importance and need for revitalisation. People frequently underestimate the role of urban watercourses and neglect the problem of water deficits in the urban space, periodical flooding or improvement of environmental quality (Januchta-Szostak 2009, Tymiński & Kałuza 2012, Trząski et al. 2010).

When selecting the optimal solution we need to refer to multiple-criteria methods, which in turn may be divided in terms of the solution applied to the analysed problem. The first group comprises deterministic methods, in which decision variants are assessed based on criteria, the second group consists of stochastic methods, in which every decision variant is investigated in terms of individual criteria as a random variable, while the third group is composed of fuzzy logic methods, in which each solution is described by ordered fuzzy numbers (Trzaskalik 2014). The second significant criterion is connected with the time when factors are specified for multiple-criteria assessment. In the first group of factors the assessment criteria are defined only after the analysis has been completed. In the other group of methods factors are identified at the very beginning of the assessment process. The data envelopment analysis (DEA) belongs to the former group, while the latter group of factors includes the ELECTRE and SMART methods (Stypka & Flaga-Maryańczyk 2016). The AHP and REMBRANDT methods are most popular and used within a very wide range of applications in such areas as management, sociology, transport and logistics (Downarowicz et al. 2000) as well as environmental engineering (Stoltmann 2015, Kubicz et al. 2015, Stypka & Flaga-Maryańczyk 2016, Hämmerling 2019).

Search for the best solution to a given problem is a complicated task. Frequently problem solving decisions are expressed using one criterion, which does not present all parameters affecting a given problem. In such a case we deal with a single-criterion analysis, in which each variant is assessed in relation to one selected criterion, e.g. costs, operation parameters, etc. Such single criteria are not reliable. For this reason decisions should be made based on multiple criteria. Among other things, this requires comprehensive evaluation of solution variants, taking into consideration many characteristics (Adamus & Łasak 2010). This is provided by multiple-criteria methods, which facilitate thorough analyses of a given problem (Schueler & Brown 2004).

Taking into account the number of barriers and the need to search for an optimal solution, this paper analyses the application of the multiple-criteria decision-making method based on the analytic hierarchy process (AHP) for the revitalisation potential of watercourses in urbanised areas. The analyses were conducted on the Wierzbak watercourse flowing in the northern part of the city of Poznań, which segment as a storm sewer flows through the grounds of the Poznan University of Life Sciences and further (still as a storm sewer) discharges into the

Bogdanka River (a left-bank tributary of the Warta). Based on collected information and data the most advantageous solution for potential revitalisation of the Wierzbak watercourse was selected.

2. Description of object of study

The Wierzbak watercourse is the left-bank and the largest tributary to the Bogdanka River, to which it is discharged at Nad Wierzbakiem street downstream of the Stawy Sołackie ponds. Its total length is 7.85 km, of which 7.07 km lie within the administrative limits of Poznań (Biprowodmel 1998). As a result of progressing urbanisation within the Wierzbak watercourse catchment more than 1/2 of the Wierzbak length has been channeled and flows in a storm sewer under streets and housing districts. The total area of the watercourse catchment is 14.72 km^2 and it is an element of the Bogdanka catchment, which covers the north-western part of Poznań (i.e. the Podolany, Winiary, Sołacz, Piątkowo and Suchy Las districts). The Wierzbak originates from the headwater near Góra Moraska and next the channeled watercourse flows through housing districts. It reappears on the ground surface in the area of a water reservoir at Omańkowska street. In the vicinity of the Druskienicka and Strzeszyńska intersection another retention reservoir was built on the watercourse. Further the Wierzbak flows south through housing and industrial areas. Near Rabczańska street it flows under the Poznań-Piła rail tracks. In the southern part of the Literackie housing district two connected retention reservoirs with the total area of approx. 5110 m^2 were constructed on the Wierzbak. In its further course the Wierzbak flows through allotment gardens located between Lutycka and Dojazd streets. Towards the end of its course as a storm sewer it flows through two housing districts of Poznań, i.e. Sołacz and Winiary. Under Nad Wierzbakiem street it discharges into the Bogdanka (Hydroprojekt 1998). The course of the Wierzbak is presented in Fig. 1. A broken blue line denotes these segments of the watercourse, in which it flows in a storm sewer.

The Wierzbak collects precipitation waters from numerous areas, e.g. the Piątkow or Podolany districts. These waters are mostly polluted and need to be treated. Some of them are pre-treated in retention reservoirs built in the watercourse. Based on a study by the Institute of Meteorology and Water Management (1996), characteristic flows in the Wierzbak watercourse were estimated at the section of Szczawnicka street (for catchment area of 9.55 km^2). The figures are presented in Table 1. Design and control flows are given in Table 2. The design flow is the flow with the probability of occurrence p = 10%, while the control flow has p = 5%.

Fig. 1. The course of the Wierzbak in the city of Poznań

Table 1. Characteristic flows of the Wierzbak River at the cross-section of Szczawnicka Street

P.o.	Type of flow	Discharge [m^3/s]		
		Year	Summer	Winter
1	SNQ	0.007	0.005	0.011
2	SSQ	0.024	0.015	0.034
3	SWQ	0.420	0.160	0.390

Table 2. Design and control flows for different cross-sections of the Wierzbak River (IMiGW 1996)

No.	Cross-section location [km]	Catchment [km^2]	Discharge	
			$Q_{10\%}$ [m^3/s]	$Q_{5\%}$ [m^3/s]
1.	7+000	3.95	0.738	0.943
2.	4+560	5.86	0.961	1.228
3.	4+200	7.03	1.085	1.368
4.	3+240	9.55	1.330	1.700

In the northern part of the city the areas with high intensity housing and industrial development predominate, which has an effect on the quality of waters in the Wierzbak. The river also collects most precipitation waters in that area. Analyses of various flow variants in the Wierzbak river bed (Biprowodmel 1998) facilitates an assessment of flood risk. They showed that the watercourse in the area from Straży Ludowej street km 7+000 to the nearby water reservoir and in the stretch from Druskienicka street km 4+200 to Szczawnicka street km 3+240 may cause overflows and inundation of adjacent areas (which was recently the case in 2009, 2010 and 2017 due to further sealing of this part of the Wierzbak catchment). Thanks to restoration of the watercourse bed and the operation of the water reservoirs the mean maximum flow SWQ could be relatively safely discharged. However, discharge of the design flow $Q_{10\%}$, increased by design rainfall is connected with the risk of water overflow and inundation of adjacent areas.

In view of the fact that in many segments the watercourse flows through housing development areas and private plots currently the watercourse bed may not be expanded. Thus the present condition of the watercourse bed might be improved by such measures as e.g. reduction of direct inflow of precipitation waters to the watercourse and to its two tributaries, or greater utilisation of existing water reservoirs and their retention potential, as well as revitalisation of channeled segments and construction of new water reservoirs. There are segments in the Wierzbak catchment (between Dojazd and Urbanowska streets), where the channeled watercourse flows through green areas and garage facilities located in artificial depressions, found to have considerable potential related to revitalisation of this watercourse. This potential is indicated by the existing land development around the previously constructed water reservoirs on the Wierzbak (Fig. 2).

Fig. 2. View of the water reservoir on the Wierzbak near Strzeszyńska and Druskiennicka streets

3. Methodology

Considering the number of barriers and the need to search for the optimal solution to potential revitalisation of the Wierzbak watercourse, this paper analyses the applicability of the multiple-criteria decision-making method using AHP. Such methods are particularly suitable when solving such problems, in which selection criteria include both qualitative and quantitative factors. The method created by Saaty (Saaty 1994, Saaty 1996) has been further developed by many researchers (Sun et al. 2019, Wang et al. 2009), facilitating solution of deterministic, stochastic and fuzzy problems.

In view of the fact that comparisons of individual factors and solutions may be biased, literature sources present parameters, which verify cohesion of comparisons. One of the most important values determined in AHP and a measure of cohesion of comparisons reflecting proportionality of preferences is provided by the eigenvalue of a matrix (Stoltmann 2015). The maximum eigenvalue of matrix λ_{max} is calculated from the formula:

$$\lambda_{\max} = \frac{1}{n}\sum_{=1}^{n}\lambda_i \qquad (1)$$

where:
n – matrix size,
λ_i – eigenvalue of matrix for i-th row.

Due to partial bias in the case of these assessments, the Indeterminant Rate *IR* was calculated.

$$IR = \frac{CI}{RI} \tag{2}$$

where:
IR – Indeterminant Rate,
CI – consequence index,
RI – value of random index.

The value of the random index *RI* depends on the size of the comparison matrix. Validity assessment is considered convergent if the calculated *IR* value does not exceed 0.2 (Tułecki & Król 2007). The consequence index *CI* is determined following the formula:

$$CI = \frac{(\lambda_{śr} - n)}{(n-1)} \tag{3}$$

where:
n – matrix size,
$\lambda_{śr}$ – mean eigenvalue of matrix.

Analysis applying the AHP approach consisted in the decomposition of the problem, i.e. preparation of a hierarchical tree, which describes the aim, general factors, with increasingly more specific factors presented on the successive levels. The number of hierarchical tree levels in the AHP method may be unlimited, but solutions will always be found at the last level. Figure 3 presents a hierarchical tree for the selection of the most advantageous solution to the reconstruction of the Wierzbak watercourse. For the purpose of a detailed analysis of the problem several different barriers were considered, e.g. ecological, planning, social, economic and technological.

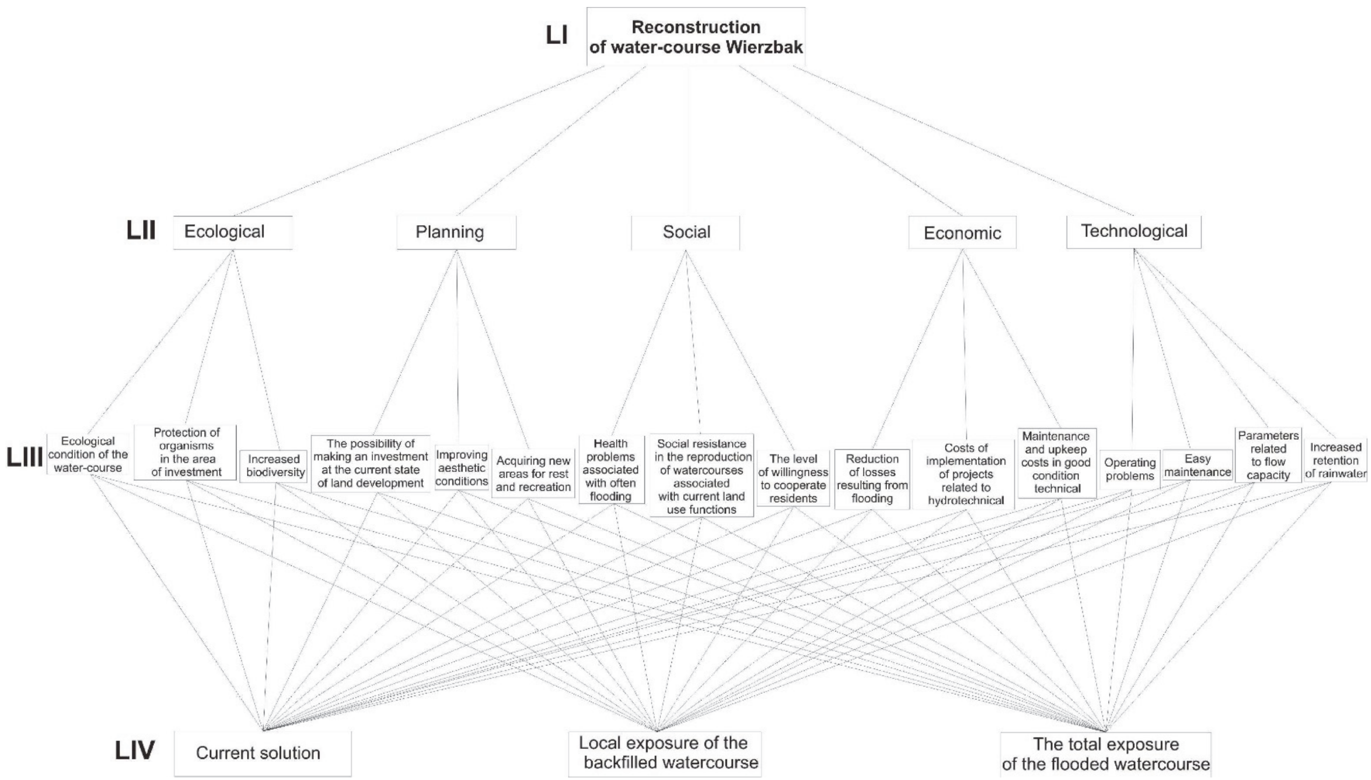

Fig. 3. Structure showing a hierarchical tree using the AHP method

In the next step the factors were compared pair-wise at levels LII and LIII creating matrices, which were next solved obtaining local and global vectors. Next a matrix was constructed for individual solutions from level LIV, which was analysed 16 times in terms of each factor from level LIII. Pair-wise comparisons in all the matrices were performed using a 9-point scale according to Saaty (Saaty 1994).

Since values in the Saaty scale ascribed to individual factors at level LII are highly subjective, several variants of their attribution were analysed. In variant A equal priorities were assumed for all factors at level LII, in variant B a very strong advantage was observed for ecological factors, in variant C a very strong advantage was found for planning factors, in variant D a very strong advantage was recorded for social factors, in variant E a very strong advantage was reported for economic factors, while in variant F a very strong advantage was presented for technological factors. Next the obtained global solution vectors were compared and those, which according to most variants were most advantageous, were selected.

4. Results

First analyses concerned the results obtained based on the assumptions of variant A, which assumed equal priorities of all factors at level LII. Figure 4 presents results of solutions for 5 matrices for factors from level LIII (local vector) and considering the priorities from level LII (global vector).

Analyses of local vectors from level LIII indicate that for each main factor from level LII we may find one specifying factor, which gained significant advantage over the others. For ecological factors it was an increase in biodiversity (0.68), for planning factors it was the possibility to execute the investment at the current land use (0.68), for social factors it was health problems resulting from continuous inundations (0.67), for economic factors it was the reduction of losses resulting from flooding (0.64), while for technological factors it was increased retention of precipitation waters (0.51). Figure 5 presents values of the hierarchical tree solution for variant A, in which all the factors at level LII were equivalent.

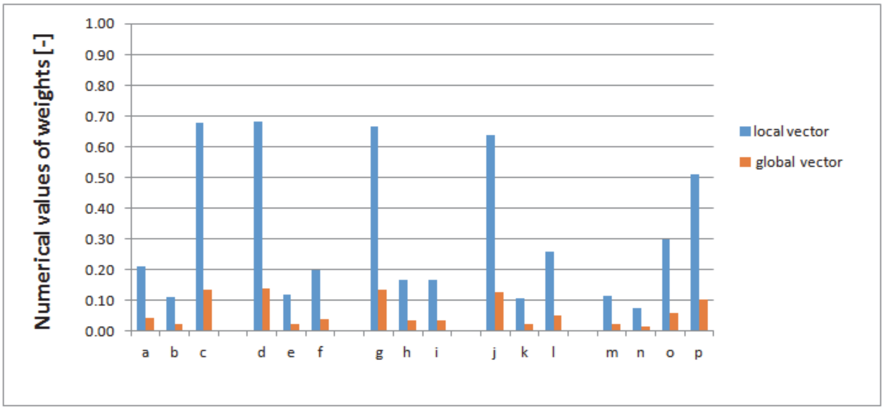

Fig. 4. Values of matrix solutions for level LIII hierarchical tree in variant A, including the division into local and global vectors; a – Ecological condition of the watercourse, b – Protection of organisms in the area of investment, c – Increased biodiversity, d – Potential for investment at the current state of land development, e – Improving aesthetic value, f – Acquiring new leisure and recreation areas, g – Health problems associated with frequent flooding, h – Social opposition to restoration of watercourses associated with current land use functions, i – Residents' willingness to cooperate, j – Reduction of losses resulting from flooding, k – Costs of implementation of hydrotechnical structure projects, l – Maintenance and upkeep costs, m – Operating problems, n – Easy maintenance, o – Parameters related to flow capacity, p – Increased rainwater retention

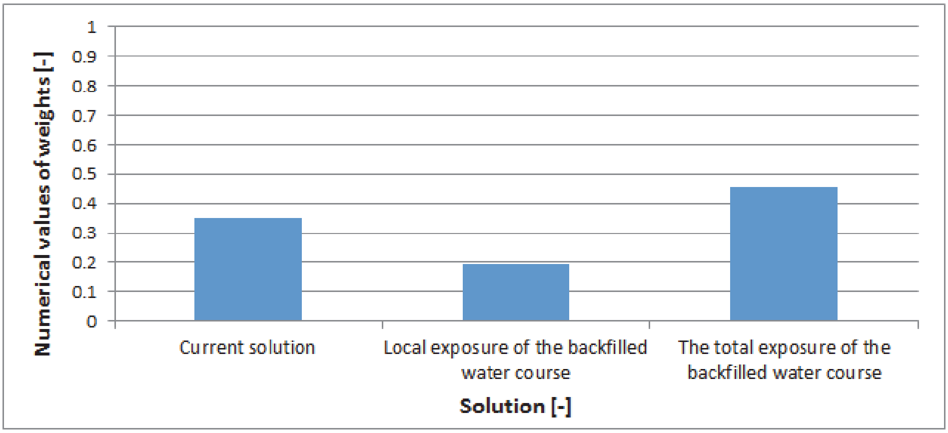

Fig. 5. Results of the analyzed problem solution for variant A

According to variant A the most advantageous solution was provided by complete exposure of the backfilled watercourse (0.46), while the least advantageous local exposure of the backfilled watercourse (0.18). The hierarchical tree was analysed in terms of individual variants (A – F), which results are presented in Table 3. Using such an approach a solution was searched for, which was most frequently the most advantageous solution.

Table 3. Results of level LIV matrix solutions for different variants (global vectors)

Variant	Priorities of selection at level LII of the hierarchical tree	Current solution	Local exposure of backfilled watercourse	Complete exposure of flood watercourse
		–	–	–
A	Equal priorities of all factors	0.35	0.19	0.46
B	Ecological	0.21	0.21	0.58
C	Planning	0.46	0.20	0.34
D	Social	0.33	0.25	0.43
E	Economic	0.56	0.14	0.30
F	Technological	0.20	0.17	0.63

Analysis of results showed that for the 4 variants (A, B, D, F) complete exposure of the watercourse was the most advantageous solution. The value greater than 0.5 for the complete exposure of the watercourse was obtained for variants B and F.

The current solution received a value greater than 0.5 for variant E including economic factors. In turn, the solution with local exposure of the backfilled watercourse did not receive any values of the solution greater than 0.5. Based on the multiple-criteria analysis it may be concluded that the most advantageous solution is to reconstruct the watercourse consisting in its complete exposure.

5. Discussion

The analysed revitalisation barriers may be divided according to (Trząski & Mana 2007) into six categories. These were economic, social, information, political, legislative and organisational barriers. Sources of decisive barriers are found in the social and scientific and information spheres. The most important aspect is connected with a lack of practical application of scientific information in the social sphere, determining prospects for revitalisation of rivers. Both the scientific and information sphere, as well as legislative and legal, economic and organisational spheres are sources of barriers directly affecting the practice. At the same time, a lack of good practical experience – resulting also from the existing barriers – contribute to the reinforcement of the barriers already in existence (Tymiński et al. 2017).

The division of barriers presented in this study in relation to the proposal by Trząski and Mana (2007) more effectively reflects the specific nature of problems connected with the revitalisation of rivers in urbanised areas is also more comprehensible for the general public. This paper also shows the justification for the application of the AHP method to solve decision-making problems of such complexity and connected with watercourse revitalisation. To date the AHP method has been used within a very wide range of problems such as management, sociology, transport and logistics (Downarowicz 2000) as well as environmental engineering. Górski et al. (2015) presented e.g. applicability of the AHP method when designing microtunnel chambers. The AHP approach was also applied by Chmist and Hämmerling (2016), who stated that the best method of lake reclamation is connected with inactivation of phosphorus. In a study Kubicz et al. (2015) verified the most advantageous solution with barrage damming using the AHP method. This approach is becoming increasingly popular as a useful tool in the process of making difficult environmental decisions.

Obtained results indicate that for most variants the most advantageous solution would be to completely expose the analysed watercourse. Such a solution indicates both the adoption of equivalent priorities for all factors at level II (variant A – 0.46), as well as adoption at level II for the absolute advantage for ecological factors (variant B – 0.58), social factors (variant D – 0.43) and technological factors (variant F – 0.63). For the other variants, in which advantage was observed for planning and economic factors, the most advantageous solution was to leave the analysed watercourse with no changes introduced.

Literature sources may provide many examples for the analyses concerning methods eliminating revitalisation barriers (e.g. Schueler 2004, Trząski et al. 2006, Trząski et al. 2010, Tymiński & Kałuża 2013). Nevertheless, the authors would like to stress that currently the basic direction of activity is to develop and implement local projects. For example, in several towns of the Czech Republic some local projects have been implemented (Trząski & Mana 2007). It may be concluded on this basis that despite all indicated obstacles it is feasible also in Poland. Execution and adequate promotion of one or several local projects may lead to weakening of the scientific and information barriers. A logical consequence of such a change may be related with an increased interest of the local communities and local decision-makers in revitalisation of urban rivers, particularly if the general public becomes aware of the relationship between improved quality of rivers and improved quality of urban space and comfort of life. Additionally, this would also result in a reduced risk of flooding and increased local retention of precipitation waters. This in turn may lead to weakening of social barriers. When selecting an optimal solution we may refer to tools of the multiple-criteria analysis, including the AHP approach.

6. Concluding remarks

The decision making process, in which many parameters and variables need to be considered, is complicated. This study showed justification for the application of the decision-making method using the AHP approach, which has not been used previously to identify the best watercourse reconstruction method. Application of such a method made it possible to take into consideration factors related with economics, ecology, technology, planning as well as social factors. In this study analyses were conducted on the effect of changes in the significance of individual factors at level LII on the obtained results (variants A-F). Thus the analysis of results obtained for most of the investigated variants (A, B, D, F) indicated the complete exposure of the watercourse as the most advantageous solution. It shows that despite differences in values obtained for global vectors at level LIV, a key role for the solution of the studied problem was played by specific factors, which were described at level LIII of the hierarchical tree.

The proposal presented in this study for analyses related with the potential revitalisation of the Wierzbak river valley in Poznań is a response to considerable interest in such solutions observed in Poland in recent years. The set of principles and criteria included ecological, planning, social, economic and technological aspects, since all of them need to be considered when making local revitalisation initiatives. The scope of analyses should comprise possibly the largest number of elements reflecting the target status of the watercourse and its valley. The proposed method to evaluate revitalisation with the properly selected assessment criteria seems to be feasible in the case of other valleys of small urban rivers also in other regions of Poland and Central Europe.

References

Adamus, W., & Łasak, P. (2010). Zastosowanie metody AHP do wyboru umiejscowienia nadzoru nad rynkiem finansowym. *Bank i kredyt*, *41*(4), 73-100.

Biprowodmel (1998). Studium programowo – przestrzenne Biura Projektów Wodnych Melioracji i Inżynierii Środowiska "BIPROWODMEL" Sp. z o.o. pt. "Biologiczna odnowa wód rzeki Bogdanki - Zadanie nr 6 Wierzbak" wyk. w 1998 r.

Boitsidis, A., & Gurnell, A. (2006). Environmental Sustainability Indicators For Urban River Management (http://www.smurf-project.info).

Brandyk, A., & Majewski G. (2013). Modeling of Hydrological Conditions for the Restoration of Przemkowsko-Przecławskie Wetlands. *Rocznik Ochrona Środowiska. 15,* 371-391.

Chmist, J., & Hämmerling, M. (2016). Wybór najskuteczniejszej metody rekultywacji zbiorników wodnych z wykorzystaniem metody AHP. *Acta Scientiarum Polonorum. Formatio Circumiectus*, *15*(2).

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities L 327/1, 22.12.2000.

Downarowicz, O., Krause, J., Sikorski, M., & Stachowski, W. (2000). Zastosowanie metody AHP do oceny i sterowania poziomem bezpieczeństwa złożonego obiektu technicznego. *Wybrane metody ergonomii i nauki o eksploatacji. Gdańsk, Wydaw. Politechniki Gdańskiej*, 7-42.

Górski, K., Ignatowicz, L. R., & Bykowski, J. (2015). Zastosowanie metody AHP do projektowania komór mikrotunelowych. Przegląd Naukowy. *Inżynieria i Kształtowanie Środowiska, 24*(4(70)).

Gurnell, A. (2007). Urban River Survey Manual 2007. Centre for Environmental Assessment, Management & Policy. http://www.kcl.ac.uk/ceamp.

Hämmerling, M. (2019). Selection of the optimal type of fish pass using the Rembrandt method. *Acta Sci. Pol. Formatio Circumiectus*, *18*(1), 51-61.

Houriet, J.P. (2006). *Der Gewässerschutz ist eine Daueraufgabe*. Wege des Wassers. Umwelt No 4.

Hydroprojekt (1998). *Koncepcja programowa kanalizacji deszczowej Kolektora Wierzbak w Poznaniu.* BSiPBW, HYDROPROJEKT Poznań.

IMGW (1996). Charakterystyka cieków m. Poznania – Przepływy Maksymalne.

Janauer, G.A. (2005). *Aquatic Habitats in Vienna*. Integrating Ecology and Urban Water Management. UNESCO-Workshop, Lodz.

Januchta-Szostak, A. (2009). *Study existing best practice in the Northern Poland*. Ekspertyza w ramach projektu REURIS na zlecenie Urzędu Miasta w Bydgoszczy (materiał niepublikowany).

Kaluza, T., Szoszkiewicz, K., Radecki-Pawlik, A., Walczak, N., Plesinski, K. (2015). *Impact of River Restoration on Hydromorphological Processes: the Flinta River as a Case Study*. In: GeoPlanet. Earth and Planetary Sciences, XXXIV. Springer.

Kaluza, T., Pietruczuk, K., Szoszkiewicz, K. & Tyminski, T. (2014). Assessment and Classification of the Ecological Status of Rivers in Poland According to the Requirements of the Water Framework Directive. *Wasserwirtschaft, 104(12),* 24-29.

Kasperek, R., Mokwa, M. & Wiatkowski, M. (2013). Modelling of pollution transport with sediment on the example of the Widawa river. *Archives of Environmental Protection, 39*(2), 29-43.

Kubicz, J., Hämmerling, M., & Walczak, N. (2015). The Use of AHP Method for the Determination of the Most Environmentally Beneficial Variants of Barrages. *Journal of Ecological Engineering, 16*(4), 36-43.

Laks, I. Kałuża, T., Sojka, M. & Wróżyński, R. (2013). Problems with Modelling Water Distribution in Open Channels with Hydraulic Engineering Structures. *Rocz. Ochrona Środ., 15*(1), 245-257.

Mazur, R., Kałuża, T., Chmist, J., Walczak, N., Laks, I., & Strzeliński, P. (2015). Influence of deposition of fine plant debris in river floodplain shrubs on flood flow conditionse – The Warta River case study. *Phys. Chem. Earth, 94*, 106-113.

Saaty, T. (1994). *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*, Pitssburgh, PA: RWS Publications.

Saaty, T.L. (1996). Decision Making for Leaders: The Analytical Hierarchy Process for Decisions in a Complex World. *The Analytical Hierarchy Process Series, 2*, 71-74.

Schueler, T. (2004). *An Integrated Framework to Restore Small Urban Watersheds*. CWP Urban Subwatershed Restoration Manual Series. No 1. Version 1.0. March 2004.

Schueler, T. & Brown, K. (2004). *Urban Stream Repair Practices*. Urban Subwatershed Restoration Manual No 4, CWP-USEPA.

Schueler, T. & Kitchell A. (2005). Methods to Develop Restoration Plans for Small Urban Watersheds. *Urban Subwatershed Restoration Manual. 2*. CWP-USEPA.

SMURF, (2003). SMURF Project Methodology and Techniques. Produced by Environment Agency King's College London, University of Birmingham and HR Wallingford Ltd, in association with Wallingford Software Ltd. July 2003 (http://www.smurf-project.info/ methodologyreport.pdf).

Stoltmann, A. (2015). *Zastosowanie metody ahp do porównania kryteriów wyboru lokalizacji budowy farmy wiatrowej*. Zeszyty Naukowe Wydziału Elektrotechniki i Automatyki Politechniki Gdańskiej, 42, 187-190.

Stypka, T. & Flaga-Maryańczyk, A. (2016). Możliwości stosowania zmodyfikowanej metody AHP w problemach inżynierii środowiska. *Ekonomia i Środowisko, 2*, 37-53.

Sun, B., Tang, J., Yu, D., Song, Z. & Wang, P. (2019). Ecosystem health assessment: A PSR analysis combining AHP and FCE methods for Jiaozhou Bay, China1. *Ocean & Coastal Management, 168*, 41-50.

Tomczyk, P., Wiatkowski, M. & Gruss, Ł. (2019). Application of Macrophytes to the Assessment and Classification of Ecological Status above and below the Barrage with Hydroelectric Buildings. *Water 11*(5), 1028.

Trzaskalik, T. (2014). *Wielokryterialne wspomaganie decyzji. Przegląd metod i zastosowań*. Zeszyty Naukowe. Organizacja i Zarządzanie/Politechnika Śląska.

Trząski, L., Korczak, K., Bondaruk, J. & Łabaj, P. (2006). Użytkowe funkcje zasobów wodnych oraz uszczelnienie zlewni – kryteria nowego podejścia do gospodarowania ciekami miejskimi. Prace Naukowe GIG. *Górnictwo i Środowisko, 1*, 63-72.

Trząski, L. & Mana V. (2007). Bariery rewitalizacji niewielkich cieków wodnych na terenach zurbanizowanych regionu górnośląsko-ostrawskiego. *Research Reports Mining and Environment Quarterly, 4*.

Trząski, T., Polaczek A., Kopernik M., Łabaj P. & Szendera W. (2010). Rewitalizacja miejskich przestrzeni nadrzecznych w Polsce – ocena planowania i wdrożeń w południowej części kraju. Prace Naukowe GIG. *Górnictwo i Środowisko, 1*, 59-71.

Trząski, L., Szendera, W. & Mana, V., (2010). Propozycja ogólnych zasad rewitalizacji doliny potoku miejskiego i kryteriów wyboru inwestycji pilotowej na przykładzie projektu REURIS w Katowicach. *Research Reports Mining and Environment Quarterly, 4.*

Tułecki, A. & Król, S. (2007). Modele decyzyjne z wykorzystaniem metody Analytic Hierarchy Process (AHP) w obszarze transportu. *Probl. Eksploatacji, 2*, 171-179.
Tymiński, T. & Kałuża, T. (2012). Investigation of Mechanical Properties and Flow Resistance of Flexible Riverbank Vegetation. *Polish Journal of Environmental Studies, 21*(1), 201-207.
Tymiński, T., Mumot, J., Karpowicz, D. & XiaJianxin (2017). Sedimentation of river load in a step-pool rock ramp fishway with biotechnical embedded elements. Meteorology. *Hydrology and Water Management – Research and Operational Applications, 5*(2), 35-42.
Tymiński T. & Kałuża, T. (2013). Effect of vegetation on flow conditions in the "nature-like" fishways. *Rocznik Ochrona Środowiska, 15*, 348-436.
Walczak, N., Walczak, Z., Kałuża, T., Hämmerling, M.& Stachowski, P. (2018). The Impact of Shrubby Floodplain Vegetation Growth on the Discharge Capacity of River Valleys. *Water, 10*, 556.
Wang, J. J., Jing, Y. Y., Zhang, C. F., & Zhao, J. H. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. *Renewable and sustainable energy reviews, 13*(9), 2263-2278.
Zalewski, M. & Wagner-Lotkowska, I. (eds) (2004). *Integrated Watershed Management – Ecohydrology and Phytotechnology-Manual*. UNESCO IHP, UNEP IETC.

Abstract

Revitalisation of even small watercourses in urbanised areas improves water retention conditions, while at the same time reducing the risk of flooding. It also contributes to improved condition or ecological potential of waters. Measures implemented to revitalise small urban watercourses are hindered by many obstacles. When selecting an optimal solution we need to refer to multiple-criteria methods. Considering the number of barriers and the need to search for the optimal solution this paper analyses the applicability of multiple-criteria decision-making method involving analytic hierarchy process (AHP) to assess potential for revitalisation of watercourses in urbanised areas. The investigations were conducted on the Wierzbak watercourse flowing in the northern part of the city of Poznań, which has been channeled in over 60% of its course and is discharged into the Bogdanka River (a left-bank tributary of the Warta) in an ouflow sewer. In order to analyse the problem in detail various barriers were investigated, e.g. ecological, planning, social, economic and engineering. The analyses were conducted for 6 variants. Based on the collected information and data the AHP method was applied to select the most advantageous solution to potential revitalisation of the watercourse. Analysis of the results showed that for 4 out of the 6 tested variants complete exposure of the watercourse would be the most advantageous option. In turn, ecological and social barriers were deemed to be the most important. The study confirmed applicability of the AHP method to solve such complicated decision-making problems.

Keywords:
watercourse revitalisation, the multiple-criteria decision-making method

Wykorzystanie metody wielokryterialnego wspomagania decyzji do oceny możliwości rewitalizacji cieków na terenach zurbanizowanych na przykładzie cieku Wierzbak

Streszczenie

Rewitalizacja nawet niewielkich cieków na terenach zurbanizowanych poprawia warunki retencjonowania wody, wpływa także na zmniejszanie ryzyka powodzi. Przyczynia się również do poprawy stanu lub potencjału ekologicznego wód. Działania na rzecz rewitalizacji małych miejskich cieków napotykają na wiele barier. W wyborze optymalnego rozwiązania należy odwołać się do metod wielokryterialnych. Uwzględniając ilość barier i konieczność szukania rozwiązania optymalnego, w pracy przedstawiono analizę wykorzystania metody wielokryterialnego wspomagania decyzji AHP do oceny możliwości rewitalizacji cieków na terenach zurbanizowanych. Jako przykład wskazano ciek Wierzbak płynący w północnej części Poznania, który w ponad 60% został skanalizowany i w postaci kolektora uchodzi do rzeki Bogdanki (lewobrzeżnego dopływu Warty). W celu szczegółowego przeanalizowania problemu uwzględniono szereg różnych barier takich jak: ekologiczne, planistyczne, społeczne, ekonomiczne, technologiczne. Badania przeprowadzono dla 6 wariantów. Na podstawie zebranych informacji i danych wykorzystując metodę AHP został wykonany wybór najbardziej korzystnego rozwiązania potencjalnej rewitalizacji cieku. Analiza wyników wykazała, że dla 4 z 6 badanych wariantów całkowite odsłonięcie cieku było rozwiązaniem najbardziej korzystnym. Za najważniejsze uznano bariery ekologiczne i społeczne. Wykazano celowość wykorzystania metody AHP do rozwiązywania tego rodzaju skomplikowanych problemów decyzyjnych.

Słowa kluczowe:
rewitalizacja cieków, metody wielokryterialnego wspomagania decyzji