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# CONCEPT OF THE MULTICRITERIA MODEL OF SPATIAL ANALYSES AS SUPPORT OF SPACE DEVELOPMENT IN RURAL AREAS

***Katarzyna Sobolewska-Mikulska, Wioleta Krupowicz***
*Warsaw University of Technology*

***Abstract***

The land consolidation process is a measure transforming the spatial structure of rural areas in the countries of the European Union and Poland. It is a complex, extremely labour-consuming investment process preceded by a detailed inventory of the existing state, and analysis of objectives and tools as well as effects expected after its completion. It should constitute a component of sustainable and multifunctional development of rural areas, stimulating the development of functions fulfilled by such areas in the economic, social, and environmental aspect. Through changes in the ownership structure and land use, it permits designation of functional-spatial areas, therefore reducing potential spatial conflicts. It has a positive effect on the development of agriculture, and particularly ecological production, and other non-agricultural functions.

The article presents a concept of the multicriteria model of spatial analyses aimed at supporting sustainable and multifunctional development of rural areas, with particular consideration of the land consolidation process. The concept of the model was prepared in accordance with the assumptions of the AHP (Analytic Hierarchy Process) method. This permitted ordering the rich resource of diverse input data in a logical structure for the purpose of development of multi-variant solutions to a given decision problem , and selection of the exclusive, most appropriate proposal. The model is a tool in the GIS (Geographic Information System) environment. Due to this, information obtained as a result of analyses can be presented in the form of legible thematic maps. This will undoubtedly support the process of space development in rural areas. It is an important, efficient opinion-making tool allowing for a broader insight exceeding individual interests.

**Key words:** rural development, land consolidation process, GIS, multiple-criteria spatial analyses

## INTRODUCTION

The policy of the European Union towards rural areas is oriented at the implementation of the idea of multifunctional and sustainable development. The application of both of the ideas leads to simultaneous complex social-economic development, next to the agricultural and forest issues also considering recreational issues and all possible and socially justified ways of land use, together with cultural heritage, environmental protection, and landscape development. Of course, food production remains the basic function.

In Poland in the perspective by 2020, rural development is currently stimulated by the Rural Development Programme (RDP) 2014-2020. In the scope of the programme-financial perspective, it is planned to among others increase the profitability of farms and competitiveness of all kinds of agricultural economy in all regions, promote innovative technologies in farms, and an increase in sustainable management of forests. These are very diverse activities supporting structural transformations of Polish rural areas, aimed at non-agricultural economic activation, and improvement of the quality of life of the local community, the implementation of which is possible among others through the performance of geodesic works in a broad scope, i.e. land consolidation.

Land consolidations constitute a component of the broadly defined process of rural development, stimulating the development of functions fulfilled by such areas in the economic, social, and environmental aspect. A land consolidation project covers all issues concerning (Bielska et al. 2015):

1. soil-agricultural conditions (including soil classes and agricultural usefulness complexes);
2. land use structures (prevailing types of land use and contribution of grasslands, mosaic character of land, forest cover);
3. natural physiographic conditions (land relief, slopes, threat of water and wind erosion);
4. land governance structure (number and size of registered plots, occurrence of mosaic of agricultural farms, contribution of the private sector);
5. infrastructural factors (water meliorations, linear infrastructure, including the agricultural roads system, building development).

The solutions of a consolidation project also enable land development in a direction favouring the creation of alternative sources of income for agricultural families through the designation of land with the following purpose (Bielska et al. 2015, Sobolewska-Mikulska and Pułecka 2007):

- residential development, including holiday and recreational development,
- agricultural processing plants and crop collection centres,
- public utility and didactic facilities, sports objects, playgrounds, mechanical workshops, service and sales points, etc.,
- waste and plant protection products disposal centres, agricultural machinery washes, and sewage treatment plants,
- parking lots,
- cycling, walking, and equestrian paths (particularly in areas attractive due to their landscape values),
- marinas, beaches, camp sites, etc.,
- fish ponds for the development of angling.

Due to the complexity of the land consolidation process, it is required to consider a rich resource of data on the transformed land and preferences of consolidation participants concerning the distribution of the newly designed parcels, as well as to perform many spatial analyses, and make decisions concerning selection of optimum project solutions among many scenarios. The primary challenge for the surveyor-designer is to consider the social conditions directly concerning the interested residents. Consolidation participants can vary in terms of preferences. Reaching an agreement is often very difficult. A syndrome commonly occurring in the process of land consolidation, expressing social opposition towards changes in the manner of development and use of local space is called NIMBY. Its name comes from the English phrase "Not In My Back Yard" (Matczak 1996). The entire process of spatial planning in rural areas, and particularly land consolidation, requires the application of a research-information instrument for searching optimum solutions acceptable for all interested persons. The multicriteria model of spatial analyses is such a solution.

The article presents a concept of the multicriteria model of spatial analyses aimed at supporting sustainable and multifunctional rural development, with particular consideration of the land consolidation process. The concept of the model was developed in the GIS (Geographic Information System) environment in accordance with the assumptions of the AHP (Analytic Hierarchy Process) method. This permitted ordering in a logical structure as well as verification and updating of source reference data and thematic data necessary for a complex diagnosis of the existing state, and assessment of the potential of the natural environment, and then their comprehensive analysis and visualisation of results in the form of legible thematic maps.

## MULTICRITERIA ANALYSES IN RESEARCH ON PHENOMENA IN THE SPATIAL ASPECT

The multicriteria character of the analyses is a necessity in the case of space development in rural areas, where numerous correlations and impacts of social, economic, and environmental factors occur. The method supporting analyses and solving complex (multicriteria) decision problems is known in the literature as the Multiple-Criteria Decision Analysis or Multiple-Criteria Comparative Analysis (MCDA), and/or Multiple-Criteria Decision Making (MCDM). A commonly used tool of MCDA in solving decision problems is the method of Analytic Hierarchy Process – AHP (Malczewski and Rinner 2015).

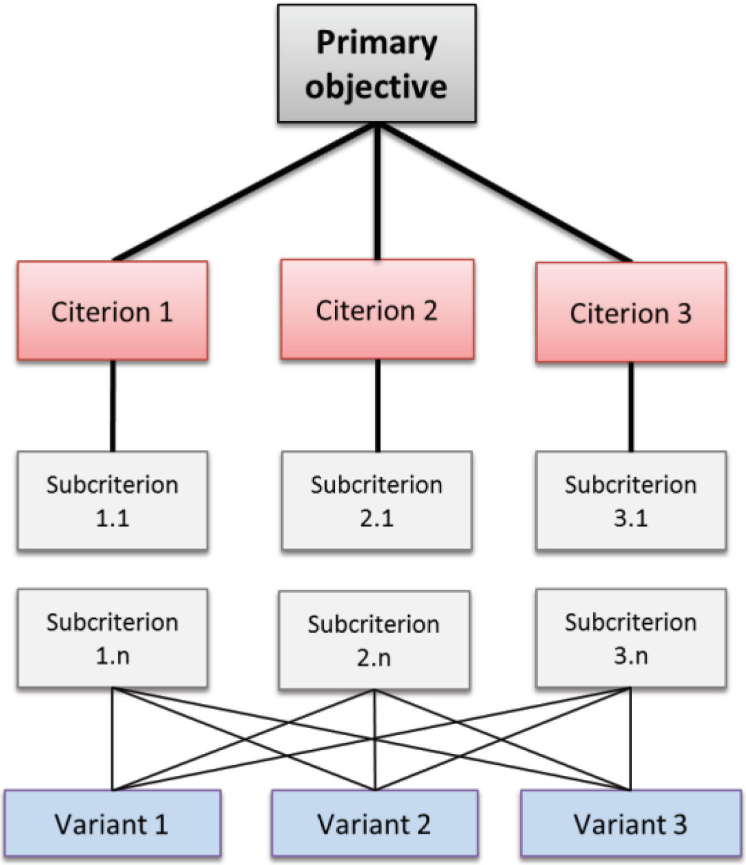


**Figure 1.** Example hierarchical structure in the AHP model (own elaboration based on: Prusak and Stefanów 2014)

Stages of the AHP analysis and their mathematical basics were presented in numerous publications by Thomas L. Saaty (among others Saaty 1994, 2000, 2008). The AHP method is based on the assumption that the majority of complex decision problems can be broken down to basic components, and presented in the form of a hierarchical tree (hierarchical structure). This permits avoiding difficulties described by Benjamin Franklin in his famous letter directed in 1772 to the well-known chemist and philosopher Joseph Priestley: *"when these difficult cases occur, they are difficult chiefly because while we have them under consideration all the reasons pro and con are not present to the mind at the same time"* (ProCon.org). An example of the simplest structure is presented in Fig. 1.

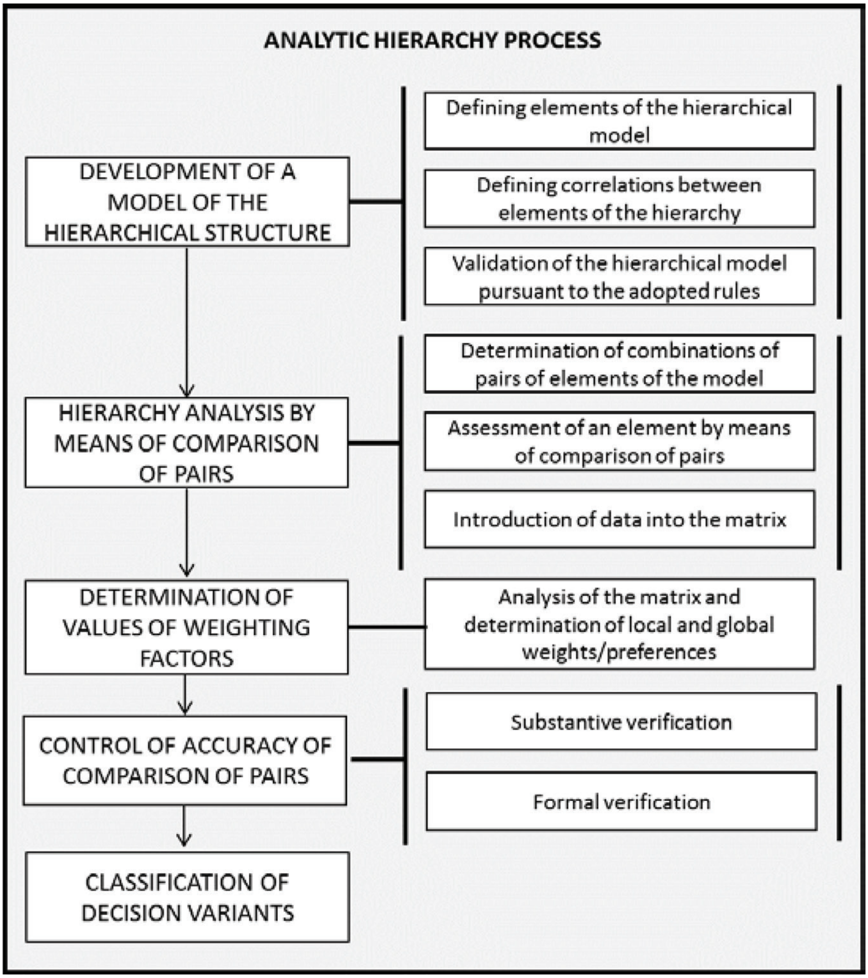


**Figure 2.** Procedure of solving a decision problem by means of the AHP method (own elaboration based on: Prusak and Stefanów 2014)

It is composed of several levels. The highest level is the primary objective of the decision problem. The implementation of the objective is influenced by criteria located one level below, and these in turn depend on the corresponding sub-criteria (factors). Decision variants are located at the bottom. This relatively simple hierarchy can be expanded. Intermediate stages can be introduced, such as auxiliary (subordinate) objectives or groups of stakeholders (decision-makers) with differing preferences – this way, the obtained result will also depend on the value of assessments included in the decision making process.

The hierarchical structure is then subject to analysis by comparison of pairs of its individual elements, and calculation of relevant weighting factors. This way, the AHP method orders decision variants from optimal to the least desired, therefore facilitating making the decision in terms of selection of one of them. The course of the decision making procedure based on the AHP method is presented in Fig. 2.

The method, performed in the GIS environment, has an evident spatial context visible both in the defined objective (related to spatial planning) and in the set of criteria (referring to various aspects of space), and spatial data for the implementation of the criteria. In this form, it can be included in procedures of spatial analyses constituting a GIS functionality (Malczewski 1999, Chmiel 2013). It then covers tasks in the scope of usefulness of land for a specified purpose, including the determination of optimum location (Carr and Zwick 2007, Hejmanowska and Hnat 2009, Jaroszewicz and Degórska 2009, Oh and Jeong 2007), and general tasks involving comparison of specified variants of solutions for the purpose of selection of the best one, e.g. concerning the course of a road (Geneletti 2005).

A great advantage of GIS technology involves its analytical possibilities which can be formalised in the form of developed models of spatial analyses – creating sets of new, ready to use tools supporting the decision making process in the scope of functional division of space. For this purpose, it is necessary to provide the system with valid high quality data. It is important for the data to be ordered in a logical structure, and subject to relevant verification and validation permitting their integration, followed by their comprehensive analysis and presentation of results. Presentation is defined here as a system of maps – from analytical maps imaging particular criteria to synthetic maps showing analysis results, permitting accurate reception and understanding of the proposed solutions. The fact is of high importance at the stage of social communication in the scope of arrangements for the assumptions of a land consolidation project.

## SCOPE OF DEVELOPMENT OF A DECISION MODEL SUPPORTING SPACE DEVELOPMENT IN RURAL AREAS

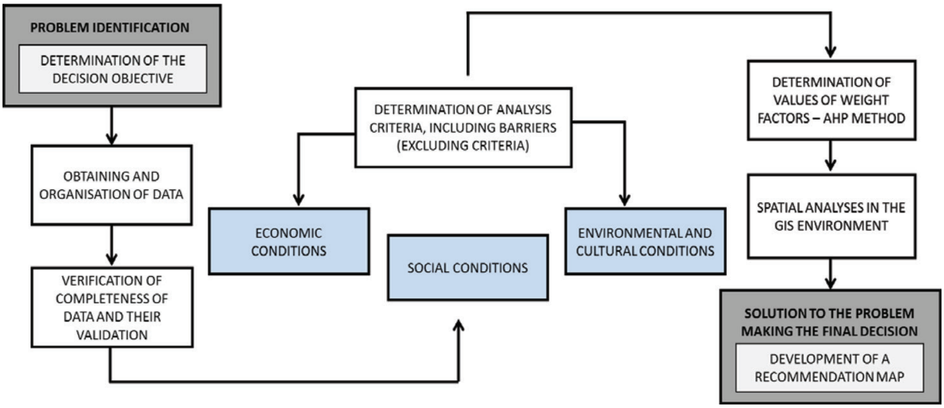


**Figure 3.** Organisational chart of a model supporting decision making concerning space development in rural areas in the process of land consolidation (own elaboration)

Pursuant to Fig. 3, the development of the multicriteria model of spatial analyses covers the following stages:

### 1. Problem identification

The decision making process starts with the identification and defining of the decision problem, and its presentation in the form of a hierarchical structure in accordance with the assumptions of the AHP method (Fig. 1). In the scope of space development in rural areas, the considered decision problems concern in particular:

- location of objects – determination of the optimum location of a point, linear, or areal object, related to e.g. improvement of spatial organisation of farms, arrangement of agricultural transport roads, or anti-erosion activities,
- allocation of land – allocation of land to particular purposes, e.g. for forestation, melioration, or reclamation (ploughing, shrub removal, flatwork, liquidation of depressions, etc.),
- determination of rules of management and building development of land in accordance with the requirements of protection of cultural heritage.

## 2.Obtaining and organisation of data

The broad thematic scope of consolidation works makes it necessary to use a rich set of various input data on the terrain and objects constituting rural space. An important problem is currently ensuring full integration of data, i.e. their unification in terms of degree of detail, reference system, validity, and manner of disclosure. The structure and organisation of data must be coherent, and cover all aspects related to the description of the area and analyses of the natural environment, but it should enable adding new elements at any moment. Part of disclosed data is organised in the form of spatial data bases. Others are composed of a description and graphic attachments. Obtaining such data for the geographic information system requires additional work (e.g. providing georeference of raster images or vectorisation). The set of input data necessary for the assessment of the existing state and potential of the natural environment in the aspect of sustainable and multifunctional rural development is presented in Table 1. It is an open set which can be expanded by descriptive data, or documents prepared by expert institutions concerning among others environmental-landscape issues, directly related to the study area.

## 3. Verification of the completeness of data and their validation

Before commencing work on the analytical part of the model, the obtained data should be validated based on an inventory of the existing state of the natural environment, technical infrastructure, and characteristic of agricultural production space.

## 4. Determination of the analysis criteria

Due to the adopted primary objective of the problem, relevant criteria of its assessment should be selected. Criteria for the implementation of sustainable and multifunctional development of rural areas concern: A. environmental and cultural conditions (Table 2); B. economic conditions (Table 3); C. social conditions (Table 4).

A special group was distinguished in the set of criteria, namely barriers, identifying areas excluded from the analysis. They result from legal conditions. They constitute an obligatory requirement of common law, or constitute a requirement of other legal acts, and particularly local law (e.g. local spatial development plan).

## 5. Determination of values of weight factors

Another step is the determination of weights of the discussed criteria in accordance with the AHP procedure. In a simple approach, weights can also be determined based on the knowledge and experience of the person conducting the analysis – surveyor-designer. Preferences of decision makers, i.e. consolidation participants, landscape architects, experts in the scope of environmental protection and transport engineering, should be expressed in the form of weights ascribed to the discussed criteria.

**Table 1.** Source reference data from national resources and thematic data supplied to the model – examples (own elaboration)

| No. | DATA SOURCES | FORM | CONTENT |
|---|---|---|---|
| REFERENCE SOURCE DATA | | | |
| 1. | Cadastral data base | Vector, SHP | • boundaries and designations of cadastral areas, registered plots and classification contours<br>• delineations and designations of buildings |
| 2. | Base map | Raster/ Vector, SHP | • spatial distribution of general geographic objects<br>• elements of the land and mortgage register<br>• infrastructural network |
| 3. | Topographic Object Data Base (BDOT) | Vector, SHP | • sewage networks<br>• road and railway networks<br>• infrastructural networks<br>• land cover<br>• buildings and facilities<br>• land use<br>• other objects |
| 4. | Digital Elevation Model | TIN | • elevation data |
| 5. | Ortophotomap | Raster | • land cover |
| 6. | Soil-agricultural map | Raster/ Vector, SHP | • boundaries and designations of soil-agricultural contours (number of agricultural usefulness complex, types of soil, grain structure) |
| THEMATIC DATA | | | |
| 7. | Spatial development documents | Raster/ WMS service | • predestination of land (or directions of spatial management of land) |

| | | | |
|---|---|---|---|
| 8. | Arrangement-agricultural plan for rural areas | Raster | • design of the planned agricultural transport road network<br>• design of works regarding development of environmental and cultural landscape<br>• design of improvement of the melioration network<br>• directions of land management<br>• village renewal plan |
| 9. | Inventory | Raster-photographs | • current land management |
| 10. | Social consultations | Audio | • identification of needs of the local community |
| 11. | Environmental map of Poland | Raster/ Vector, SHP | • fossil deposits<br>• surface and groundwaters<br>• ground conditions<br>• environmental protection<br>• threats to the ground surface |
| 12. | Detailed geological map of Poland | Raster | • geological structure<br>• land relief<br>• infrastructure<br>• ground properties<br>• hydrography<br>• environmental protection<br>• economics and management |
| 13. | Hydrogeological map of Poland | Raster/ Vector, SHP | • quality and degree of threat to groundwaters<br>• aquifers in the area<br>• quality of surface waters<br>• water intakes |
| 14. | Flood risk map | WMS service | • areas under particular flood threat<br>• river network<br>• surface waters<br>• water depth<br>• water flow velocity<br>• flood embankments |
| 15. | Geoservice GDOŚ | WMS service | • protected areas and ecological corridors |

**Table 2.** Criteria of assessment of the decision problem concerning environmental and cultural conditions of space development in rural areas in the process of land consolidation (own elaboration)

| **A. ENVIRONMENTAL AND CULTURAL CONDITIONS** | | |
|---|---|---|
| **No.** | **CRITERIA** | **SUBCRITERIA** |
| 1. | Soil bonitation | • arable land: I, II, IIIa, IIIb, IVa, IVb, V, VI (VIz)<br>• grasslands: I, II, III, IV, V, VI<br>• soils under forests: I, II, III, IV, V, VI |

| | | |
|---|---|---|
| 2. | Agricultural usefulness complexes | • very good and good soils (1, 2, 3, 4, 8)<br>• weak soils (5, 6, 9)<br>• very weak soils (7) |
| 3. | Hydrological conditions of the ground | • optimal<br>• periodically too dry or periodically too wet<br>• permanently too dry or permanently too wet |
| 4. | Erosion threat/susceptibility to erosion | • strong<br>• medium<br>• weak<br>• not occurring |
| 5. | Land relief | • plains<br>• hilly areas<br>• high elevation differences |
| 6. | Bedrock | • soils developed from clays, dusts, silts, and loesses<br>• soils developed from gravels and sands |
| 7. | Type of building development | • homestead development<br>• single-family residential development<br>• service and commercial development<br>• holiday and recreational development |
| 8. | Settlement unit | • compact<br>• loose<br>• scarce<br>• none |
| **DESIGN BARRIERS – EXCLUDING CRITERIA** | | |
| 9. | Legal forms of protection of nature and landscape | • national parks<br>• nature reserves<br>• landscape perks<br>• areas of protected landscape<br>• Natura 2000 areas<br>• nature monuments<br>• documentation sites<br>• ecological grounds<br>• environmental-landscape complexes |
| 10. | Protection of soils of arable land | • arable land developed from soils of mineral and organic origin, included in classes I, II, III, IIIa, IIIb<br>• arable land developed from soils of organic origin, included in classes IV, IVa, IVb, V, VI |
| 11. | Forests | |
| 12. | Areas of direct protection of surface and groundwater intakes | |
| 13. | Areas of surface inland waters | |
| 14. | Areas of direct flood threat | |
| 15. | Landslides and areas under threat of mass wasting | |
| 16. | Protection of cultural heritage and historical sites | |

**Table 3.** Criteria of assessment of the decision problem concerning economic conditions of space development in rural areas in the process of land consolidation (own elaboration)

| B. ECONOMIC CONDITIONS | | |
|---|---|---|
| **No.** | **CRITERIA** | **SUBCRITERIA** |
| 1. | Technical infrastructure | • water supply network<br>• sewage network<br>• gas network |
| 2. | Type of surface of agricultural roads | • hardened tempered<br>• hardened not tempered<br>• dirt road |
| 3. | Number of parcels in a farm | • more than 8<br>• 8-6<br>• less than 6 |
| 4. | Mean parcel area | • up to 0.3000 ha<br>• 0.3000-0.6000 ha<br>• more than 0.6000 ha |
| 5. | Distance of agricultural land from settlements | • more than 3 km<br>• 3-1 km<br>• up to 1 km |
| 6. | Current land use | • arable land and orchards<br>• grasslands<br>• forest areas<br>• fallow land |
| 7. | The legal situation | • legal person<br>• corporate person<br>• State Treasury<br>• territorial self-government unit<br>• undefined owner |
| **DESIGN BARRIERS – EXCLUDING CRITERIA** | | |
| 8. | Provisions of the local spatial development plan | |
| 9. | Developed agricultural land, developed and urbanised land | |

**Table 4.** Criteria of assessment of the decision problem concerning social conditions of space development in rural areas in the process of land consolidation (own elaboration)

| C. SOCIAL CONDITIONS | | |
|---|---|---|
| **No.** | **CRITERIA** | **SUBCRITERIA** |
| 1. | Age | • pre-working<br>• working<br>• post-working |

| | | |
|---|---|---|
| 2. | Natural increase | • positive<br>• negative |
| 3. | Business entity by type of activity | • agriculture, hunting, forestry, fishing<br>• industry and construction<br>• trade<br>• others |
| 4. | Population density index | |

## 6. Spatial analyses in the GIS environment

The last stage of the process is conducted in the GIS environment:

- development of maps of criteria (raster maps of single layers of values of criteria),
- standardisation (normalisation) of values of criteria,
- development of maps of normalised values of criteria,
- development of maps of land usefulness for particular groups of criteria (combined criteria in mixed approach – method of weighted linear combination),
- development of a map of usefulness of land for the primary purpose,
- development of a map presenting recommendations for making decisions regarding the allocation of land for a specified primary purpose,
- sensitivity analysis (determination of reliability, certainty of the model).

## 7. Solving the problem, making the final decision

The solution of the decision problem should be based on the specified ranking of decision variants and sensitivity analysis. At this stage, visualisation techniques are of high importance. The recommendations must be presented in a legible and clear way to consolidation participants.

## SUMMARY AND CONCLUSIONS

Advantages of the application of the multicriteria model of spatial analyses in the process of space development in rural areas in the scope of land consolidation include:

- consideration of a number of criteria in the decision making process, and assessment of the importance of each criterion in comparison to other criteria;
- consideration of the preferences of the surveyor-designer and consolidation participants concerning particular groups of criteria – the ob-

tained result depends not only on the spatial distribution of values of particular criteria, but also on the values of judgements included in the decision making process;

- ordering in a logical structure as well as verification and updating of source reference data and thematic data necessary for the assessment of the existing state and potential of the natural environment, followed by their comprehensive analysis;
- presentation to the stakeholders (e.g. residents, farmers, local authorities, entrepreneurs, and investors) of the obtained solutions in the form of maps, almost in real time, and possibilities of making optimum decisions with their active participation;
- consideration of the requirements of sustainable and multifunctional development of rural areas, and possibility of their implementation in the scope of surveying works – land consolidations.

## REFERENCES

Bielska A., Leń P. (ed.), Balawejder M., Gniadek J., Król Ż., Kupidura A., Oleniacz G., Sobolewska-Mikulska K., Turek A. (2015). *Scalenia gruntów determinantem wielofunkcyjnego rozwoju obszarów wiejskich [Land consolidations as a determinant of multifunctional development of rural areas]*, Wyższa Szkoła Inżynieryjno-Ekonomiczna, Rzeszów, 8-20. (in Polish)

Carr M.H., Zwick P.D. (2007). *Smart Land-Use Analysis: The LUCIS Model Land Use Identification Strategy*, ESRI Press, California.

Chmiel J. (2013). *Analizy przestrzenne i modelowanie [Spatial analyses and modelling]* [In:] Białousz S. (ed.), *Informacja przestrzenna dla samorządów terytorialnych [Spatial information for territorial self-governments]*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 217-266. (in Polish)

Geneletti D. (2005). *Multicriteria analysis to compare the impact of alternative road corridors: a case study in northern Italy*, Impact Assessment and Project Appraisal, vol. 23, no. 2, 135-146.

Hejmanowska B., Hnat E. (2009). *Wielokryterialna analiza lokalizacji zabudowy na przykładzie gminy Podegrodzie [Multicriteria analysis of location of building development based on the example of the Podegrodzie commune]*, Archiwum Fotogrametrii, Kartografii i Teledetekcji, vol. 20, 109-121. (in Polish)

Jaroszewicz J., Degórska B. (2009). *Koncepcja modelu analiz przestrzennych do identyfikacji terenów wyłączonych z zabudowy, na potrzeby studiów uwarunkowań i kierunków zagospodarowania przestrzennego gmin miejskich [Concept of a model of spatial analyses for the identification of land excluded from building development, for the purposes of studies of the conditions and directions of spatial management of urban communes]*, Archiwum Fotogrametrii, Kartografii i Teledetekcji, vol. 20, 147-160. (in Polish)

Malczewski J. (1999). *GIS and multicriteria decision analysis*, John Wiley & Sons, Inc., Canada.

Malczewski J., Rinner C. (2015). *Multicriteria Decision Analysis in Geographic Information Science*, Springer, New York.

Matczak P. (1996). *Społeczne uwarunkowania eliminacji syndromu NIMBY [Social conditions of elimination of the NIMBY syndrome]* [In:] Cichocki R. (ed.), *Podmiotowość społeczności lokalnych [Subjectivity of local communities]*, Media-G.T., Poznań. (in Polish)

Oh K., Jeong S. (2007). *Assessing the spatial distribution of urban parks using GIS*, Landscape and Urban Planning, vol. 82, 25-32.

ProCon.org. *Benjamin Franklin's 1772 letter to Joseph Priestley*. Available from Internet: http://www.procon.org/view.background-resource.php?resourceID=1474

*Program Rozwoju Obszarów Wiejskich 2014-2020 [Rural Development Programme 2014-2020]*, http://www.minrol.gov.pl/Wsparcie-rolnictwa/PROW-2014-2020 (access: 08.05.2016). (in Polish)

Prusak A., Stefanów P. (2014). *AHP – analityczny proces hierarchiczny. Budowa i analiza modeli decyzyjnych krok po kroku [AHP – analytic hierarchy process. Development and analysis of decision models step by step]*, Wydawnictwo C.H. Beck, Warszawa. (in Polish)

Saaty T.L. (1994). *How to make a decision: The Analytic Hierarchy Process*, European Journal of Operational Research, no. 48, 9-26.

Saaty T.L. (2000). *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*, vol. 6 of the AHP Series, RWS Publications, Pittsburgh.

Saaty T.L. (2008). *Decision Making with the Analytic Hierarchy Process*, International Journal of Services Sciences, no. 1(1), 83-98.

Sobolewska-Mikulska K., Pułecka A. (2007). *Scalenia i wymiany gruntów w rozwoju obszarów wiejskich [Consolidations and exchange of land in the development of rural areas]*, Oficyna Wydawnicza Politechnika Warszawskiej, Warszawa. (in Polish)

Prof. Katarzyna Sobolewska-Mikulska, Ph. D., Eng.
Department of Cadastre and Land Management
Warsaw University of Technology
Politechniki 1 Sq., 00-661 Warsaw, Poland
phone (+48) 22 234 7589, e-mail: k.sobolewska@gik.pw.edu.pl

Wioleta Krupowicz, Ph. D., Eng.
Department of Spatial Planning and Environmental Sciences
Warsaw University of Technology
Politechniki 1 Sq., 00-661 Warsaw, Poland
phone (+48) 22 234 1569, e-mail: w.krupowicz@gik.pw.edu.pl

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