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**THE APPLICATION OF THE AHP-LP METHOD TO ASSESS
THE SIGNIFICANCE OF STRATEGIC OBJECTIVES AND TASKS
INFLUENCING THE SOCIOECONOMIC DEVELOPMENT OF THE
COMMUNE**

*ZASTOSOWANIE METODY AHP-LP DO OCENY WAŻNOŚCI CELÓW
I ZADAŃ STRATEGICZNYCH WPLYWAJĄCYCH NA ROZWÓJ
SPOŁECZNO-GOSPODARCZY GMINY*

Key words: AHP-LP, socioeconomic development, commune

Słowa kluczowe: AHP-LP, rozwój społeczno-gospodarczy, gmina

Abstract. The aim of the study was to present the possibility of applying the AHP-LP method to assess the significance of strategic factors (strategic goals and tasks) influencing the socioeconomic development of the commune. The Commune of Chrzypsko Wielkie in the Wielkopolskie Voivodeship was used to illustrate the suggested approach. The study was based on the data from questionnaire surveys conducted among the councillors of the Commune of Chrzypsko Wielkie in 2012. The empirical studies proved the usefulness of the AHP-LP for assessment of the significance of strategic factors. The method enabled quantification of the significance of individual strategic factors. The most important aims in the Commune of Chrzypsko Wielkie include improvement of technical infrastructure, followed by development of the economy. The reduction of unemployment and modernisation of agriculture were the most important tasks. The suggested approach may be used in the process of making development strategies of administrative units.

Introduction

Socioeconomic development is a complex phenomenon, which is influenced by social, economic, infrastructural, political and cultural processes. In spite of the complexity of this phenomenon and numerous problems which appear in its assessment, it is necessary to take developmental action. Long-term planning of such actions is the basis for creating a desirable strategy for future development of the commune. Hence, it is necessary to set strategic goals¹, which should concentrate on significant general problems and delineate the trends of development of the commune for the nearest several years. It is necessary to implement specific tasks in order to achieve the goals. Besides, in order to achieve the goals and implement the tasks they need to be hierarchically arranged and their significance needs to be assessed. In this study the AHP-LP method has been suggested to assess the significance of strategic goals and tasks. It integrates the method of analytic hierarchy process and linear programming [see Gao, Zhang, Cao 2009]. The author, also with co-authors in previous studies applied the method of AHP to development planning in the evaluation of goals and tasks [Łuczak, Wysocki 2005, Łuczak, Korsak 2010]. However, the method AHP-LP has not yet been used for this purpose. The method consists in paired comparison of the significance of strategic development factors made by experts. The qualitative description of advantage of the significance of one factor over another is converted into real numbers according to the Saaty scale [1980, 2004]. The numbers constitute the basis for designation of the weights of significance of strategic factors, i.e. global priorities. They are calculated by means of linear programming. The aim of the study was to present the possibility of

¹ The strategic goal is the future state of the commune, which is to be achieved and which results from its needs.

applying the AHP-LP method to assess the significance of strategic factors (strategic objectives and tasks) influencing the socioeconomic development of the commune. The suggested approach was used to assess the significance of strategic goals and tasks in the Commune of Chrzypsko Wielkie, Międzyzchód County, Wielkopolska Voivodeship, Poland.

Research methodology

The significance of strategic goals and tasks can be assessed by means of the analytic hierarchy process² based on linear programming (AHP-LP) [Gao et al. 2009]. According to the authors' method – Gao, Zhang, Cao – the new method has fast convergence and smaller computational complexity. The method is a nonlinear programming, but it is translated into linear programming. The suggested approach involves the following stages:

1. Construction of a hierarchical decision-making scheme,
2. Pairwise comparisons of the significance of decision-making elements,
3. Checking the consistency of pairwise comparisons,
4. Construction of an optimisation model and calculating the priorities.

Stage 1. Construction of a hierarchical scheme. The scheme is constructed by decomposition of the problem into its components: the main goal, subordinate goals and tasks [Saaty 1980, 1990, 2004, Łuczak, Wysocki 2005]. The main goal is placed at the top of the hierarchy (Level I). The subordinate goals provide details of the main goal and they constitute the second level. The third level consists of the tasks which are necessary to achieve the subordinate goals.

Stage 2. Pairwise comparisons of the significance of decision-making elements. The comparison is made by experts at each hierarchy level by means of the Saaty nine-grade scale [1980]. The results of comparison are summed into a pairwise comparison matrix:

$$A_k = \begin{bmatrix} 1 & a_{12} & \dots & a_{1(\bullet)} \\ 1/a_{12} & 1 & \dots & a_{2(\bullet)} \\ \vdots & \vdots & \dots & \vdots \\ 1/a_{1(\bullet)} & 1/a_{2(\bullet)} & \dots & 1 \end{bmatrix}, k=1, \dots, n+1.$$

where: $a_{ij} = \left(\sqrt[Q]{\prod_{c=1}^Q a_{ij}^{(c)}} \right)$, where $a_{ij}^{(c)}$ – the strength of advantage of the significance of the i -th

decision-making element over the j -th element gained in the expert comparison c ($c = 1, \dots, Q$, Q – the number of experts), $i, j = 1, \dots, (\bullet)$, (\bullet) – is n – the number of subordinate goals or p_l ($l = 1, \dots, n$) – the number of tasks in the subordinate goal l .

If the advantage of the significance of the i -th factor over the j -th factor equals a_{ij} in matrix A_k , then $a_{ij}^{-1} = a_{ji}$ (transitivity of assessments) and if the i -th factor is relatively equally significant to the j -th factor, then $a_{ij}^{-1} = a_{ji} = 1$ (equivalence of assessments).

Stage 3. Checking the consistency of pairwise comparisons of decision-making elements. The comparisons are checked for their correctness. In order to do so the inconsistency ratio CR is calculated. It measures the consistency of pairwise comparisons, i.e. it determines to what extent the mutual comparisons of the significance of characteristics are inconsistent: $CR = CI/RI \cdot 100\%$, where $CI = (\lambda_{max} - (\bullet))/((\bullet) - 1)$ is the inconsistency index, λ_{max} is the maximum or main eigenvalue in the pairwise comparison matrix A_k , whereas RI is the mean random inconsistency index calculated from a randomly generated matrix. The index is expected to assume the lowest possible values. This study assumed that the index should not be greater than 10% [Saaty, Vargas 1991].

² The analytic hierarchy process is one of the methods used to solve decision-making problems, i.e. ranking, the choice of one from several alternatives, determining the significance of decision-making elements, resource allocation, benchmarking, conflict resolution and quality management [Saaty 1980]. AHP has been used in almost all the applications related with decision-making [Wasil, Golden 2003, Vaidya, Kumar 2006, Ho 2008, Ishizaka, Labib 2011, Subramanian, Ramanathan 2012].

Stage 4. Construction of an optimisation model and calculating the priorities. Saaty [1980] suggested the eigenvector method to estimate the priority vector. There were alternative methods to this approach, i.e. the least-squares method, the least distance method, the goal programming method, the fuzzy programming method [Lin et. al 2013]. This study proposed the AHP-LP to estimate the priority vector. It is also known as the minimax method, based on nonlinear programming [Gao et. al 2009, Jablonský 2014]:

$$\min \max_{1 \leq i, j \leq (\bullet)} |a_{ij} w_j - w_i|$$

with the following limiting conditions: $\sum_{i=1}^{(\bullet)} w_i = 1, w_i \geq 0, i = 1, 2, \dots, (\bullet)$,

where w_i, w_j are the weights of the i -th and j -th elements, respectively, $i, j = 1, 2, \dots, n$; $a_{ij} w_j - w_i = \varepsilon_{ij}$ is the error made in the assessment of the advantage of the significance of the i -th element over the j -th element [Saaty 1980, 1990].

The abovementioned model can be converted into linear model as follows:

$$\min v$$

with the following limiting conditions:

$$a_{ij} w_j - w_i \leq v, a_{ij} w_j - w_i \geq -v (i, j = 1, 2, \dots, (\bullet)); i \neq j, \sum_{i=1}^{(\bullet)} w_i = 1, w_i \geq 0, i = 1, 2, \dots, (\bullet),$$

The model with the decision-making variables $v, w_i, w_j (i, j = 1, 2, \dots, (\bullet))$ can be solved with the simplex method.

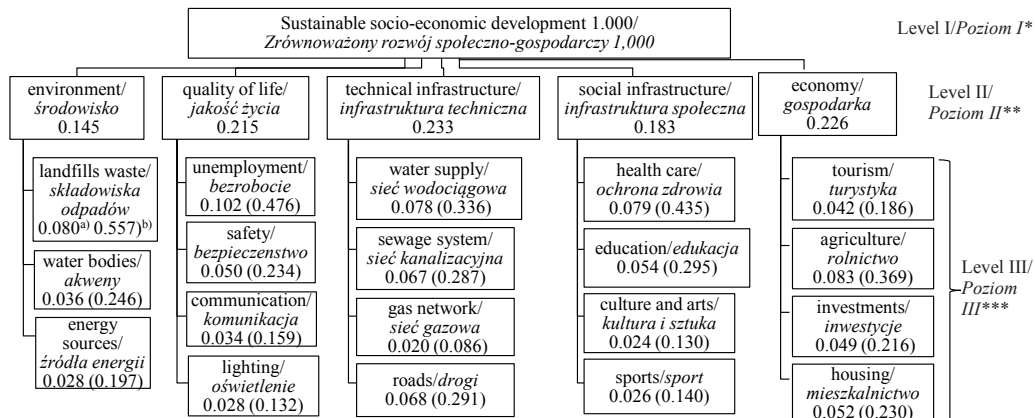
Local priorities specify the relative significance of decision-making elements (goals and tasks) at each hierarchy level. On the other hand, the global priorities of a particular level represent the share of the decision-making element in the implementation of the main criterion. At Level II the local and global priorities are the same for the subordinate criteria. Global priorities for the tasks are calculated by multiplying the values of local priorities for tasks by the value of the global priority for the appropriate subordinate criterion. The study was based on the data from questionnaire surveys conducted among the councillors of the Commune of Chrzypsko Wielkie in 2012.

Research findings

The main goal, subordinate goals and tasks were determined on the basis of civilisation trends, which point to the equilibrium in the society-economy-environment macrosystem, and on the basis of the premises from the *Sustainable Development Strategy [Strategia zrównoważonego rozwoju... 2000]* and *Local Development Plan [Plan rozwoju... 2005]*. Sustainable development of the commune was assumed as the main strategic goal, whereas the subordinate goals concerned the natural environment, people's living standard, technological infrastructure, social infrastructure and economy (fig. 1). The subordinate objectives are complex and too general, and therefore to achieve them, packages of strategic tasks were made:

- subordinate objective 1: improving the environment (environment)³: organizing of the system of waste segregation and utilisation (landfills waste), use of water bodies (water bodies), use of alternative energy sources (energy sources),
- subordinate objective 2: increasing the quality of life (quality of life): reducing unemployment (unemployment), increased sense of safety (safety), expansion and modernization of communication (communication), improvement of street lighting (lighting),
- subordinate objective 3: improving the technical infrastructure (technical infrastructure): expansion and modernisation of the water supply (water supply), construction of sewage system (sewage system), development of the gas network (gas network), modernisation of roads (roads),
- subordinate objective 4: improving social infrastructure (social infrastructure): improvement of health care (health care), improvement of the level of education (education), development of culture and the arts (culture and arts), construction of sports facilities (sports),

³ Key words that will be used in the further part of the paper.



* main objective/cel główny; ** subordinate objectives/cele podrzędne, *** tasks (activities)/zadania (działania)

Figure 1. Hierarchical structure and value of importance of the factors influencing the sustainable socio-economic development the Commune of Chrzypsko Wielkie
Rysunek 1. Hierarchiczna struktura i ocena ważności czynników wpływających na zrównoważony rozwój społeczno-gospodarczy gminy Chrzypsko Wielkie

^{a)} Global priority/Priorytet globalny ^{b)} Local priority/Priorytet lokalny

Source: own study based on the results of the questionnaire study among councillors in the Commune Chrzypsko Wielkie commune [Śmigielka 2013]

Źródło: opracowanie własne na podstawie wyników badania ankietowego przeprowadzonego wśród radnych w gminie Chrzypsko Wielkie [Śmigielka 2013]

- subordinate objective 5: improvement of the state of the economy (economy): development of tourism (tourism), modernization of agriculture (agriculture), use of land for investment (investments), housing development (housing).

In order to estimate the significance of subordinate goals and strategic tasks 15 councillors of the Commune of Chrzypsko Wielkie, Międzychód County, Wielkopolska Voivodeship, Poland were given a questionnaire survey in 2013. First the councillors made a pairwise assessment of the significance of subordinate goals in reference to the main goal and then they assessed the significance of strategic tasks within each subordinate goal. The Saaty nine-grade scale was used for the comparisons. The results of the comparisons were averaged by means of the geometric mean and they were checked by means of the inconsistency ratio CR. In each case the value of the ratio was under 10%, which means that the comparisons were consistent. The priorities of local and global were calculated using the add-in Solver in Excel.

The goal related to the technical infrastructure achieved the highest global priority value (0.233) in the results of the questionnaire survey. This means that the influence of the technical infrastructure on the development of the Commune of Chrzypsko Wielkie was evaluated as greater than 23%. This goal was indicated as the most important due to the fact that the technical infrastructure is poorly developed in the commune and it is one of the problems of priority there. Apart from that, it is a fundamental condition to increase the economic attractiveness of the commune [Strategia zrównoważonego... 2000, Plan odnowy... 2011]. Economic development was the next important goal, as its global priority value amounted to 0.226. The weak points of the commune were: the absence of the agri-food industry, low number of business entities (60 entities per 1000 inhabitants) and poorly developed agritourism. Simultaneously, the weak points included the lack of own finances for the development of the entities operating in the commune and external investors' lack of interest in building enterprises in the commune. For these reasons the goal concerning the economic improvement was assessed to be significant. The goal related to the living standard was found to be

of similar importance (0.215). The goals related to the social infrastructure and natural environment were found to be the least significant (0.183 and 0.145, respectively).

The reduction of unemployment is one of the most significant strategic tasks (0.102). It is caused by the problem of increasing unemployment and the absence of job market, whereas simultaneously, hidden unemployment can be observed in many farms. The modernisation of agriculture was the second important task (0.083). Agriculture is the main area of business activity in the commune. In 2010 there was about 1.5 ha of farmland per head in the commune, whereas in the Wielkopolska Voivodeship this index was three times lower and amounted to about 0.5 ha. Therefore, improvement of the agricultural service in the commune by counselling and trainings for farmers, improvement of the sales of crops as well as the development of organic farming and special sectors of agricultural production would be important elements in the modernisation of agriculture. Moreover, creation of agro-tourism farms is very important [*Strategia zrównoważonego... 2000, Plan odnowy... 2011*]. Resolving the problem of waste (0.080), improvement of the state of the health service (0.079) as well as modernisation of the water supply network (0.078) were found to be of lesser importance. The commune does not have a solid waste landfill and its construction is not planned, because the entire area of the commune is situated in a protected landscape zone. Also, the commune has not organised the system of waste segregation and utilisation [*Plan rozwoju... 2005*]. For these reasons this task was also indicated as a priority. On the other hand, insufficient security related with healthcare caused the councillors to indicate improvement of health service as an important task. Apart from that, the extension and modernisation of the water supply system was also indicated as a priority due to the emergence of problems related with the quality of drinking water, the unreliability of the transmission network and the maintenance costs. Additionally, part of the water supply system was made from asbestos pipes, which caused a serious life hazard to the users [*Strategia zrównoważonego... 2000*].

The tasks related to the extension of the gas network and development of culture and art had the smallest influence on the achievement of the main goal (0.020 and 0.024, respectively). The commune does not have a gas network and there are no plans to construct one because of economic reasons. The commune uses alternative sources of energy for heating. The development of culture and art was the second lowest-rated task. The Commune Public Library is the main cultural institution in the Commune of Chrzypsko Wielkie. Its activity is extended by the functions which are typical of community centres. Apart from that, there are sport facilities or playgrounds almost in every village and there are a few sport organisations which operate successfully in the commune [*Plan rozwoju... 2005*]. The councillors were of the opinion that the influence of those tasks on the achievement of the main goal was not greater than 2.5%. For these reasons the tasks were not considered to be priorities.

Conclusions

The empirical research confirmed the usefulness of the AHP-LP method for the assessment of the significance of strategic factors – strategic goals and tasks. The method is a nonlinear programming, but it is translated into linear programming and has smaller computational complexity. The method enabled quantification of the significance of individual factors.

The priority goals in the Commune of Chrzypsko Wielkie include improvement of technical infrastructure, followed by economic development. The third most important goal was to improve the living standard. The councillors expressed the opinion that the goals related to the improvement of social infrastructure and natural environment were the least important. The councillors thought that the reduction of unemployment and modernisation of agriculture were the tasks which had the greatest impact on achievement of the main goal. The councillors regarded extension of the gas network and development of culture and art to be the least significant tasks to the development of the commune.

The study suggested a practical approach, which can be used by administrative units to make development strategies.

Bibliography

- Gao S., Zhang Z., Cao C. 2009: *New methods of estimating weights in AHP*, Proceedings of the 2009 International Symposium on Information Processing (ISIP'09), Huangshan, P.R. China, August 21-23, 201-204.
- Jablonský J. 2014: *Analysis of methods for deriving priorities in pairwise comparisons*, [in:] *Hradec Economic Days 2014*, Hradec Králové, Gaudeamus, 234-240.
- Lin C., Kou G., Ergu D. 2013: *A heuristic approach for deriving the priority vector in AHP*, *Appl. Mathem. Model.*, vol. 37, Issue 8, April 15, 5828-5836.
- Łuczak A., Korsak S. 2010: *Programowanie rozwoju gminy z wykorzystaniem analitycznego procesu hierarchicznego*, *J. Agribus. Rural Develop.*, vol. 3(17), 75-88.
- Łuczak A., Wysocki F. 2005: *Wykorzystanie metod taksonometrycznych i analitycznego procesu hierarchicznego do programowania rozwoju obszarów wiejskich*, Wyd. AR im. Augusta Cieszkowskiego w Poznaniu, Poznań.
- Plan rozwoju lokalnego gminy Chrzypsko Wielkie*. 2005: <http://bip.chrzypsko.pl>, accessed February 17, 2014.
- Plan odnowy miejscowości Chrzypsko Wielkie na lata 2008-2018*. 2011: Aktualizacja kwiecień 2011, <http://bip.old.chrzypsko.msriver.pl/zalaczniki/ChrzypskoWlk.pdf>, accessed June 2, 2014.
- Saaty T.L. 1980: *The Analytic Hierarchy Process Planning. Priority Setting, Resource Allocation*, MacGraw-Hill, New York International Book Company.
- Saaty T.L. 1990: *How to make a decision: The analytic hierarchy process*, *Europ. J. Oper. Res.*, vol. 48(1), 9-26.
- Saaty T.L. 2004: *Decision making – The analytic hierarchy and network processes (AHP/ANP)*, *J. Syst. Sci. Syst. Eng.*, vol. 13, no. 1, 1-34.
- Saaty T.L., Vargas L.G. 1991: *Prediction, projection and forecasting: applications of the analytic hierarchy process in economics, finance, politics, games and sports*, Pittsburgh, Pennsylvania, RWS Publications.
- Strategia zrównoważonego rozwoju gminy Chrzypsko Wielkie 2000*, Chrzypsko Wielkie. <http://bip.chrzypsko.pl>, accessed February 17, 2014.
- Subramanian N., Ramanathan R. 2012: *A review of applications of Analytic Hierarchy Process in operations management*, *Inter. J. Prod. Econ.*, vol. 138, 215-241.
- Śmigielska K. 2013: *Zastosowanie metody analitycznego procesu hierarchicznego do wyboru scenariuszy rozwoju gmin powiatu międzychodzkiego*, Materiał źródłowy, Uniwersytet Przyrodniczy w Poznaniu, Poznań.
- Vaidya O.S., Kumar S. 2006: *Analytic hierarchy process: An overview of applications*, *Eur. J. Operat. Res.*, vol. 169, 1-29.
- Wasil E., Golden B. 2003: *Celebrating 25 years of AHP-based decision making*, *Computers & Operations Research*, vol. 30, Issue 10, 1419-1420.

Streszczenie

Celem badań było przedstawienie możliwości zastosowania AHP-LP do oceny ważności czynników strategicznych (celów strategicznych i zadań) w gminie, na przykładzie gminy Chrzypsko Wielkie w województwie wielkopolskim. W badaniach wykorzystano dane z badań ankietowych przeprowadzonych wśród radnych tej gminy w 2013 roku. Przeprowadzone badania empiryczne potwierdziły przydatność AHP-LP do oceny ważności czynników strategicznych. Metoda ta pozwoliła na skwantyfikowanie ważności poszczególnych czynników strategicznych. Do najważniejszych celów w gminie Chrzypsko Wielkie zaliczyć należy poprawę infrastruktury technicznej i gospodarkę. Wśród zadań najważniejsze były: zmniejszenie bezrobocia i modernizacja rolnictwa. Metoda ta jest użyteczna w planowaniu rozwoju.

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