APPLICATION OF TAXONOMETRIC AND DECISION-MAKING METHODS TO DRAFTING SCENARIOS OF RURAL AREA DEVELOPMENT*

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1. Introduction

The study presents the application of taxonometric methods and the analytical hierarchy process to writing scenarios[1] of rural area development[2] on the example of the Wielkopolska region. The scenarios were written on the basis of the typological clustering of *powiats* (secondary local authority units) in the Wielkopolskie Voivodship (province) according to the functional differentiation of rural areas. The clustering was done using fuzzy cluster taxonometric methods. Results of the typological clustering formed the premise for drafting rural area development scenarios according to the spatial layout of functional structure types.

The relevant literature presents many methods for building scenarios of entity development using statistical and heuristic methods. In this study we propose applying one of the more interesting methods developed from the idea of the analytic hierarchy process (AHP) presented by Saaty (Saaty and Bennett 1977, Saaty 1980, *Socio-Economic* 1986, Harker and Vargas 1990, Saaty and Vargas 1991, *Proceedings* 1991, 1994, 1996, 1999, Adamus and Szara 2000, Adamus 2002, Wysocki, Luczak 2002). Saaty's method, which combines certain mathematical and psychological concepts, is used to solve multi-criteria decision-making processes in which the hierarchical decision-making diagram is built by dividing the problem under consideration into the following decision-making criteria: the main goal, objectives, tasks and alternatives of the decision – i.e. scenarios[3]. The main goal is at the top of the hierarchy, while decision alternatives form its lowest level.

To use Saaty's method, it was necessary to make assumptions on the hierarchy of elements influencing rural area development. Taking into account the expert opinions presented in *Strategia* (2000), it was assumed that the main strategic goal is to ensure the best, multi-functional development of rural areas,

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[1] One of the methods of forecasting the future is scenario-writing (Kahn, Wiener 1967). This method consists in describing events and showing their logical and consistent results in order to decide how a given object should develop. Using this method, we obtain a set of possible future scenarios but no assessment of their importance.

[2] Rural areas are those sub-regions (*powiats* – secondary local authority units) which have a decidedly rural character (rural population of more than 50%) or a dominance of rural characteristics (with the share of rural population between 15% and 50%) (cf. *Strategia rozwoju* 2000). These criteria are fulfilled by all *powiats* of the voivodship (province) excluding cities with *powiat* rights.

[3] The main goal is a general intention which should be achieved in the future. The objective forms a more detailed part of the main goal. The task is an activity aimed at achieving a specific objective. The scenario is a system of events (objectives and tasks) combined into a logical and chronological sequence.

while objectives should be as follows: an improvement of the rural quality of life, an economic development of rural areas, the modernisation of rural infrastructure and, finally, an adjustment of the potential, structure and organisation of rural areas to facing the challenges of the 21st century. Within each objective a set of tasks (actions) was defined. The above assumptions were used to select the best rural area development scenario for each identified sub-region.

2. Methods

The procedure starts with adopting a set of features characterising the functional differentiation structure of rural areas in the *powiats* of the Wielkopolskie Voivodship (stage I).

The next calculation step is to transform output data by standardising features. This is the starting point for clustering *powiats* according to the functional structure of rural areas (stage IIa, step 1). In this study, a fuzzy clustering of *powiats* was done using the Dunn-Bezdek algorithm (cf. e.g. Milligan, Cooper 1985, Pal and Bezdek 1995, Wysocki 1996) to determine to what extent each *powiat* belongs to each cluster distinguished.

One of the hardest decisions in clustering is to choose the number of clusters (stage IIa, step 2). In this study, three methods of determining the most appropriate number of fuzzy clusters were used. Thy were based on analysing the values of the following clustering quality indices:

- *Xie-Beni* (Xie and Beni 1991, Pal and Bezdek 1995, 1997, Wysocki, Luczak 2001, a, b);
- *Kosko* (Kosko 1992, Fan, Xie and Pei 1999, Wysocki, Luczak 2001, a, b);
- *F&H*, where the F index is comparable to statistics F, and H is the entropy of clustering (Bezdek 1981, Vriend, van Gaans, Middelburg and de Nijs, 1998, Burrough, van Gaans and MacMillan, 2000, Wysocki, Luczak 2001, a, b).

The next stage of the procedure is the typological clustering of powiats, which consists in identifying and spatially delimiting functional structure types of rural areas. Identification is done using a set of primary, characteristic features, which are distinguished in every cluster by analysing the value of the test of mean differences in the population and in fuzzy clusters (Wysocki 1996). The unit typology developed forms the basis for generalising the pattern of types, if possible into continuous territorial entities called sub-regions (stage IIb).

The results of typological classification of *powiats* form the primary assumption for developing rural area development scenarios for the identified sub-regions (stage III). Scenarios are selected using the analytic hierarchy process (AHP) (Saaty and Benett 1977, Saaty 1980, *Socio-Economic* 1986, Harker and Vargas 1990, Saaty and Vargas 1991, *Proceedings* 1991, 1994, 1996, 1999, Adamus and Szara 2000, Adamus 2002, Wysocki, Luczak 2002). AHP is a method used to solve multi-criteria decision-making problems. The hierarchical decision-making diagram is built by dividing the decision-making problem under consideration into decision criteria: the main goal, objectives, tasks and the alternative decisions or scenarios (Figure 1).

The main goal is at the top of the hierarchy and consists of several objectives which make it more detailed. The next level of the decision-making diagram is made up of tasks which must be implemented to achieve the objectives. The tasks can also be divided into subordinate tasks. So the decision-making diagram contains several levels, whereas the number of levels depends on the level of generalisation to be maintained in the analysis. The last or lowest level consists of the possible alternative decisions – scenarios. The main goal, objectives and tasks should be inter-connected (stage III, step 1). At every hierarchy level, decision criteria are compared in pairs using, for example, the nine-point Saaty's scale[4] (stage III, step 2). What is compared is the importance of objectives in relation to the main goal, of tasks in relation to each objective and of scenarios in relation to each sub-objective.

If criteria importances have been compared correctly, then the calculated normalised eigenvectors of the comparison matrix **A** determine the relative importance of decision-making criteria (objectives, tasks and alternatives) at every hierarchy level, i.e. their local priorities. Local priorities of levels II-III indicate the contribution of a given decision-making criterion to achieving the criterion at the next higher level (stage III, step 4). Global priorities of a given level represent the contribution of every decision-making criterion (from particular levels) to the achievement of the main goal. The global priority is calculated in the way of multiplying the value of the local priority of this decision-making level by the value of the global priority of the next higher level (Harker and Vargas 1990).

For the last decision-making level, i.e. scenarios (alternatives), the procedure is similar to the one above and follows the steps below:

[4] Saaty (1980) proposed 27 different types of scales to be used in AHP.

1) Scenarios are compared in relation to particular tasks. As a result, the contributions of particular scenarios to the implementation of a given task (local priorities) are obtained.
2) These local priorities are multiplied by their respective global priorities of tasks. These values, called the component global priorities, indicate the contribution of a given scenario to the achievement of the main goal through implementing the task analysed.
3) The sum of component global priorities of a given scenario is its global priority.

The best scenario is the one with the highest global priority (stage III, step 5).

3. Results

In the first stage, 13 features representing different functions of rural areas in the *powiats*[5] of the Wielkopolskie Voivodship[6] were selected (stage I):

- commercial production of individual farms per 1 ha of arable land in PLN'000;
- industrial production sold per 1 industrial worker in PLN'000;
- total investment per 1 resident in PLN'000;
- employment in agriculture, hunting, forestry and fishing/fisheries to total employment (%)[7];
- employment in industry and construction to total employment (%);
- employment in market services to total employment (%);
- employment in non-market services to total employment (%);
- ratio of arable land to total area (%);
- ratio of forests to total area (afforestation ratio) (%);
- tourism and leisure development (number of beds per 1 km^2);
- number of companies per 100 people of productive age;
- balance of migration per 1000 population;
- population per 1 km^2.

The values of all K=13 features analysed for N=31 *powiats* of the Wielkopolskie Voivodship were arranged in a (31x13) matrix of data of the analysed structure. This formed the basis for the typology of *powiats* according to the functional differentiation of rural areas. Feature values were standardised. The Dunn-Bezdek algorithm was used to generate fuzzy clustering sequences for the number of clusters 2-10 (stage IIa, step 1).

Table 1. Values of *powiat* clustering quality indexes depending on the number of clusters

Index	Number of clusters								
	2	3	4	5	**6**	7	8	9	10
Xie-Beni	0.75	0.69	0.57	0.47	**0.36**	0.58	0.94	0.75	0.88
Kosko	0.26	0.19	0.17	0.20	**0.12**	0.18	0.24	0.18	0.17
F_s	0.73	0.77	0.81	0.82	**0.87**	0.86	0.84	0.86	0.85
H_s	0.58	0.42	0.32	0.26	**0.19**	0.21	0.22	0.19	0.19

Source: Own calculations

The divisions made were assessed using the following indices: *Xie-Beni*, *Kosko* and *F&H* (stage IIa, step 2). Xie-Beni and Kosko indices reached the global minimum for 6 clusters. The F_s index has a global maximum for 6 clusters, and the H_s index – a global minimum for the same number of clusters. The analysis of changes in index values shows that it is best to divide the *powiat* population of the Wielkopolskie Voivodship into 6 clusters (Table 1).

[5] Excluding cities with *powiat* rights, i.e. Kalisz, Konin, Leszno and Poznan.
[6] The input data for this research consisted of statistics presented in the following publications: *Rocznik Statystyczny Województw* (2000) (Voivodship Statistical Yearbook), *Wazniejsze dane o powiatach i gminach województwa wielkopolskiego 2000* (2000) (Principal data on *powiats* and *gminas* of the Wielkopolska Voivodship), *Powszechny Spis Rolny 1996* (1997) (1996 Farm Census), *Powiaty w Polsce* (1999) (Powiats in Poland).
[7] Excluding companies with less than 9 employees, including farming workers at individual farms.

Figure 1. Functional differentiation of rural areas in the Wielkopolskie Voivodship

Source: Own study.

This *powiat* clustering was the starting point for identifying rural area types. The main features for particular classes were established on the basis of values of the test of mean differences in the population and in clusters (stage IIb). By applying the taxonomic procedure used and the rural area typology adopted by OECD[8], six types were defined. Their spatial delimitation is shown in Figure 3. It appears that rural area types are relatively continuously distributed in the Wielkopolskie Voivodship, which makes it

[8] According to the OECD typology (*Agricultural Adjustment and Diversification: Implications for the Rural Economy, EOCD*, Paris 1996, Heller 2000) and the *Europa 2000 Plus* report of 1994 (*Rural Developments* 1997), rural areas are divided into three types: economically integrated areas developing in economic and demographic terms, usually located around urban centres; intermediate rural areas dominated by farming, showing poor economic development, with a clear demographic stagnation; and peripheral rural areas with sparse and dispersed population, whose economy is usually regressive.

possible to distinguish six sub-regions for which these types are characteristic (Figure 2).

For each identified sub-region, an attempt was made to draft scenarios of long-term rural area development using the Analytic Hierarchy Process – AHP (stage III). The first AHP step was to construct a hierarchy of criteria affecting rural area development. The main goal, objectives and tasks were adopted from *Strategia rozwoju rolnictwa i obszarów wiejskich w Wielkopolsce* (2000) (Figure 3). Seven possible alternatives, i.e. different development scenarios, were drafted for rural areas of the Wielkopolskie Voivodship (stage III, step 1).

The procedure of selecting the best scenario for rural area development using the AHP method is presented using the example of sub-region I. The essence of the process is to calculate priorities (local and global) for particular decision-making criteria (objectives, tasks and scenarios). This is done by a sequence of pairwise comparisons of decision-making criterion importance (at every hierarchy level), using Saaty's nine-point relative importance scale, and assigning weights on the basis of expert opinions presented in *Strategia* (2000) (stage III, step 2).

At level II, objectives were compared in relation to the main goal (Table 4). Priorities assessed by pairwise comparisons show that infrastructure modernisation and extension is the most important for sub-region I (priority: 0,395) and the next in importance is achieving the highest possible economic development in rural areas. The two remaining objectives were less important. Results of objective comparison in relation to the main goal for sub-region I are as follows:

$G(O_1, O_2, O_3, O_4)=0,186* O_1+0,314*O_2+0,395*O_3+0,105*O_4$

where: O_1 – quality of life, O_2 – economy, O_3 – infrastructure, O_4 – adjustment

Then, at level III, tasks were compared in relation to objectives, and at level IV alternatives were compared in pairs in relation to particular tasks. Comparison results were combined in comparison matrixes and their validity was checked using the inconsistency ratio (CR) (stage III, step 3). In every case the ratio was below 10%, which means that the comparisons obtained were consistent.

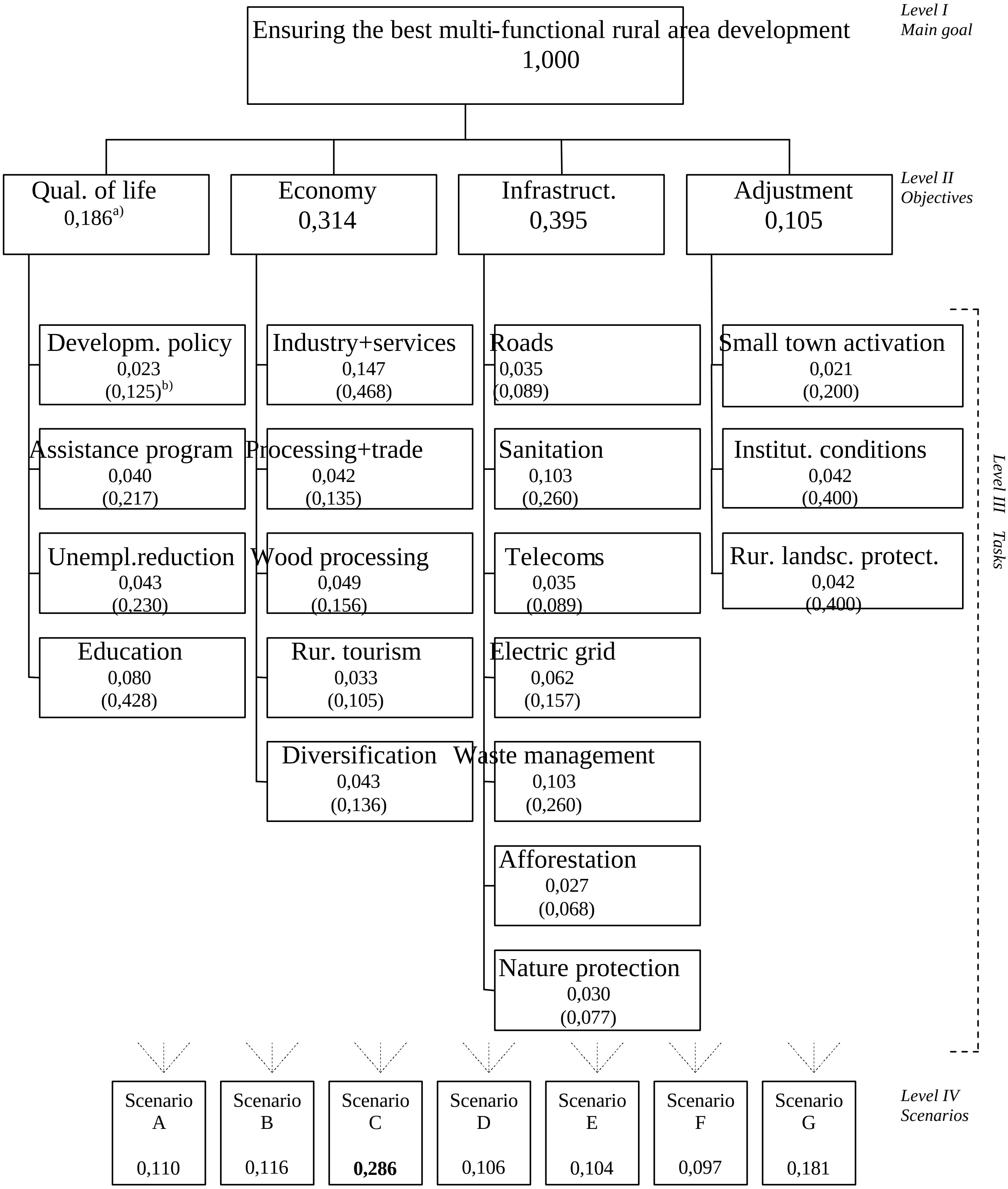
The standardised eigenvectors of comparison matrixes which were calculated defined the relative importance of decision-making criteria at every hierarchy level (i.e. local priorities). Local priorities at levels II – III indicate the contribution of a given decision-making criterion to achieving a criterion at the next higher level. Global priorities at a given level represent the contribution of each decision-making element to achieving the main goal. When local priorities of the third level are multiplied by the global priorities of the higher level, the result defines the preferences of the decision-maker (global priorities) for achieving the main goal. For example: the local priority of the development policy task is 0.125 (Figure 2) and means that this task has a 12.5% contribution to achieving the first objective – quality of life. The global priority of the development policy task is 0.023[9]. This tells us that the contribution of this task to the achievement of the main goal, which is to ensure the best multi-functional development of rural areas, is 2.3% (Stage III, step 4).

Global priorities at the task level, expressed in percentage contributions, form the basis for calculating the indices of intensity with which economic activities should be undertaken in particular sub-regions. The following elements were taken into account in their calculation:

- eliminating the impact of task quantity on the intensity of their performance by changing the scale of global priority values for tasks;
- standardising the intensity values obtained so that the total of standardised values for every sub-region would equal 100;
- the following weights define the intensities with which tasks should be implemented in rural areas of sub-regions: I = 0.50, II = 1.00, III = 1.00, IV = 1.00, V = 1.25, VI = 1.25.

[9] The global priority at level III (tasks) is calculated by multiplying the global priority of the quality of life criterion (0.186) by the local priority of the development policy task (0.125).

Figure 2. Local and global priorities of criteria affecting rural area development in sub-region I



[a] Global priority – the sum of all global priorities at every hierarchy level equals 1.

[b] Local priority – the sum of local priorities of tasks calculated in relation to the objective to which they contribute equals 1.

Source: Own study on the basis of *Strategia rozwoju rolnictwa i obszarów wiejskich w Wielkopolsce. Poznan 2000.*

Table 2. Implementation intensity indices of tasks for rural areas of sub-regions

Task	Sub-region					
	I	II	III	IV	V	VI
	Intensity indices and task importance hierarchy [a)]					
Objective I. Ensuring the best possible quality of life for rural inhabitants						
1. Development policy	0.9	1.9	5.5	5.2	5.4	6.3
2. Assistance programme	1.5	6.1	6.4	5.2	5.4	5.3
3. Unemployment reduction	1.6	6.1	7.9	3.9	11.1	11.4
4. Education	2.9	6.5	6.2	7.6	10.7	7.7
Objective II. Achieving the highest possible level of economy in rural areas						
1. Industry and services	6.9	7.4	6.1	2.2	11.0	6.0
2. Food processing and trade	2.0	12.8	4.6	3.1	5.4	2.4
3. Wood processing	2.3	3.5	2.6	4.4	2.2	10.3
4. Tourism	1.5	1.7	2.6	11.6	2.2	10.8
5. Diversifying farm activity	2.0	12.1	5.2	9.4	5.8	6.0
Objective III. Significant improvement of productive area quality and increased internal integration						
1. Roads	2.3	6.3	7.5	5.1	5.5	10.2
2. Sanitation	6.6	7.2	7.8	6.9	14.9	10.1
3. Telecommunication	2.3	6.8	4.7	6.0	8.4	3.1
4. Electric grid	4.0	4.0	3.5	3.2	5.8	5.1
5. Waste management	6.6	5.5	8.3	5.9	9.5	5.1
6. Afforestation	1.8	3.2	9.5	5.6	3.4	10.4
7. Nature protection	1.9	2.9	6.7	10.5	12.2	8.8
Objective IV. Adjustment to challenges of the 21st century						
1. Small town activation	0.5	2.0	1.3	1.1	1.6	2.0
2. Institutional conditions	1.2	2.0	2.0	1.4	2.5	2.0
3. Rural landscape protection	1.2	2.0	1.6	1.7	2.0	2.0
S	50.0	100.0	100.0	100.0	125.0	125.0

[a)] Task (activity) importance hierarchy according to the intensity index scoring:

- more than 10 points – the most important task (black)
- between 5 and 10 points – a task of medium importance (grey)
- less than 5 points – a task which needs not be implemented (white).

Source: own calculations.

For the first sub-region, which is characterised by the highest economic development, no economic activity which should be implemented with a high intensity was detected (all tasks for this sub-region have weights of less than 10 points). In the second sub-region, there are activities which require intensifying (more than 10 points), namely food processing, agricultural trade and diversification of farm activity. The third sub-region requires the majority of activities to be conducted with a medium intensity (between 5 and 10 points). In sub-region IV, the most important activities (more than 10 points) are related to tourism and nature protection. It is notable that in the last two sub-regions there are many tasks which should be implemented with a great intensity (more than 10 points). This stems from the poor development of these areas. Thus, the following tasks are deemed very important for sub-region V: unemployment reduction, education, industry and services, sanitation and nature protection; and the following are very important for the last sub-region: unemployment reduction, wood processing, tourism, roads, rural area sanitation and afforestation. On the other hand, no task belonging to the main goal of adjusting to the challenges of the 21st century needs to be urgently implemented in any sub-region (less than 5 points).

Global priorities of scenarios are calculates just like at the higher levels. One starts by comparing scenarios in relation to particular tasks, and thus obtains the contributions of particular scenarios to the implementation of a given task (local priorities). Then the local priorities obtained are multiplied by their corresponding global priorities of tasks to obtain component global priorities. When these component global priorities are totalled for a given scenario, the global priority of this scenario is obtained. The best scenario is the one with the highest global priority (stage III, step 5).

In the first sub-region, the one best developed in functional terms, the industry and service scenario should be implemented (importance weight 0.286). However, this sub-region can develop in a natural way, and any non-stimulated activity will further improve its appeal.

Table 3. Importance weights of rural area development scenarios by sub-region

Scenario symbol	Scenario	Type – Sub-region					
		I	II	III	IV	V	VI
		economically integrated	intermediate, dominated by farming	intermediate, of varied structure	intermediate, tourist function	peripheral, farming-dominated	peripheral, with forest-dominated landscape
A	Single-functional agricultural development	0.110	0.238	0.141	0.187	0.190	0.048
B	Multi-functional development by supporting agribusiness, trade and services	0.116	**0.317**	0.090	0.084	0.089	0.056
C	Multi-functional development by supporting industry and services	**0.286**	0.085	**0.345**	0.082	0.107	0.048
D	Multi-functional development by supporting non-framing activity	0.106	0.131	0.120	0.130	**0.343**	0.049
E	Multi-functional development including rural and farm tourism	0.104	0.089	0.102	**0.335**	0.105	0.271
F	Multi-functional development by supporting wood and forest product processing	0.097	0.074	0.107	0.103	0.095	**0.485**
G	Multi-functional development using housing and service functions	0.181	0.066	0.095	0.079	0.071	0.049
	?	1.000	1.000	1.000	1.000	1.000	1.000

Source: Own calculations.

For the second sub-region, the most appropriate scenario turns out to be the agribusiness development scenario (importance weight 0.317). The principal activity here would be to create an effective agricultural sector (competitive on the domestic market) and modernising the food processing industry. These activities require significant intensification (task importance weights greater than 10 points).

The third sub-region requires the promotion of a multi-functional development by supporting industry and services (importance weight 0.345). The potential of cities with developed industry and *gminas* (smallest local authority units) located close to important transport links are advantageous for the development of industry and services. What hinders development in these areas is the generally low level of labour qualifications, so at present only industries and services which do not require highly qualified employees can be located here. Such businesses include construction (roads, houses, commercial buildings) and transport, and among services - restaurants.

The fourth sub-region appears to possess characteristics that make it suitable for the development of tourism and rural tourism (particularly seasonal holidays). These types of business would take advantage of its natural beauty (forests, lakes, historic landscapes). Here, the most important activities (more than 10 points) are tourism and natural protection. The specific character of these rural areas is confirmed by the scenario selected for them: multi-functional development including tourism and farm tourism (importance weight 0.335).

What is notable in sub-region V is the relatively large number of tasks that should be implemented with a high intensity (more than 10 points). This stems from the poor development of these areas.

Consequently, the following tasks are deemed to be very important: unemployment reduction, education, industry and services, sanitation and nature protection. This sub-region requires multi-functional development through supporting non-farm activities (importance weight 0.343).

The last sub-region should develop taking advantage of its rich forests (importance weight 0.485). Rich forest resources offer opportunities for developing rural tourism as well as wood and forestry product processing. Additional assets for developing rural tourism include: the appealing land relief, presence of historic landscapes, preserved elements of folk culture and some tourist infrastructure. The essence of all activities in these areas is to reduce unemployment and improve quality of life by intensifying and modernising their economic development.

Summary

Empirical research conducted has confirmed the suitability of the proposed method for preparing rural area development scenarios. Taxonometric methods were used to develop a typological classification of *powiats* in the Wielkopolskie Voivodship, which is the basic premise for constructing development scenarios. Two methods turned out to be useful: selection of the most appropriate number of clusters using the Xie-Beni, Kosko and F&H indices and the fuzzy clustering method based on the Dunn-Bezdek algorithm, which determined to what extent particular units (*powiats*) belong to each identified functional type. Types were identified on the basis of characteristic features identified using the test of mean differences in a population and in fuzzy clusters as well as the general, theoretical classification of rural areas adopted by OECD.

Saaty's analytic hierarchy process (AHP) method turned out to be a particularly suitable tool for building rural area development scenarios. It was applied to every sub-region in order to assess the intensity of economic activities which should be undertaken to support rural area development and select the most appropriate development scenario. Saaty's method facilitates the selection of the best rural area development scenario (from all those proposed), because the selection is made by comparing the importance of every pair of strategic objectives for rural area development and of every pair of activities supporting this development. This is in contrast to the classical approach to scenario-writing, where the intuition and personal preferences of scenario authors play a greater role.

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