

APPLYING THE ANALYTIC HIERARCHY PROCESS IN THE REVITALISATION OF POST-MINING AREAS FIELD

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***Summary:** An application of the AHP in the methodology of designing the revitalisation of post-mining regions has been presented in this article. A hierarchy of factors and the best ways for the regeneration of exploited region were established by experts. There were two groups of experts: the first one included experts related to the revitalised region, while the second one was made up of independent representatives from scientific institutions. Separate results from both groups of experts and the collective results of the judgements are shown in the paper.*

1. Introduction

The processes of revitalisation in the post-mining regions¹ are very complex because they require legal regulation, the securing funds and the carrying out of the identification and analysis of the factors characterising the exploited sites which is the basis for drawing up a conception of a revitalisation.

In order to conduct a revitalisation process in the proper way specialists from many disciplines are necessary: miners, planners, architects, naturalists, sociologists etc. It is necessary involve the revitalisation's investment society, as well, since they can have an influence on the shaping of future functions of the sites under revitalisation and for the success or failure of their functioning.

Designing the revitalisation complexes of the post – mining sites (regions) while taking into account each stage of this process whose aiming to choose an optimal conception of the revitalization was undertaken for the first time in Poland. The origin of the working out of the method of designing the revitalisation of exploited areas with complex profiles is an aspiration for the regeneration of large and diverse exploited regions in a way that all the region is in harmony. A worked out method will allow for easier revitalisation not only for post-mining regions but also for those ones which are destroyed by other then mining industry. Particular stages of the method and their short description is presented in the second point of the article.

One of the most important stages of the revitalisation process is making decisions about the function of the exploited sites. The ways of the reclamation² are proposed by people which are obligated to conduct

¹ A post – mining region (complex of post – mining areas) is defined as many old mining objects including voids, heaps, technical and building infrastructure, as well as, mining terrain that are concentrated in a relatively small areas and encompassed by mining and processing activity.

that process (e.g. mining operators) and it is in their interest to fulfil this commitment as cheaply and simply as possible.

A decision of one person representing local government is the needed to start reclamation process. According to the current laws, ways and conditions of the reclamation are established by local government on the basis of an operator's application. In some cases, a decision about a way of reclamation made by a representative of local government requires the opinions and agreements of other institutions, but there is necessary to mention that, decision body does not need take into account the opinions.

It follows that, a shortcoming of the current functioning procedure concerning approving the ways of reclamation are mainly one - person decision, reflecting interest of those, who are obligated to the reclamation and the supervision of the reclaimed site.

Using the analytic hierarchy process to ensure the making of a proper decision about the way a revitalisation takes into account voices of key actors and rejecting extreme ideas. The analytic hierarchy process was included in the procedure in order to establish an optimal way of revitalising a post-mining region (fig 2.1). According to the AHP assumptions a choice of the best from among the proposed conceptions of revitalisation is made on the basis of opinion experts.

The advantages of the AHP, which decided about its applying to designing of the revitalisation of large and diverse post-mining areas are:

- It brakes down complex problems into simple elements which can be measured,
- It allows a decision to be made by many people instead of only one person,
- It makes it possible to use the numerical and non-numerical elements at the same time, and post-mining areas are described by both of them.

In order to make it easier to understanding the issues included in this article, the method of designing the revitalisation of post-mining regions with a diversified profile is shown in the point 2. Verifying and applying the method in order to determine its usefulness was conducted in the *Krzemionki Podgórskie* region of Cracow.

2. The method of designing the revitalisation of post - mining regions

The method of designing revitalisation for large and diverse post-mining regions aimed at establishing the main and supplemental functions for particular sites in the region. Known and applied earlier methods: the method of architectural – landscape interiors/units (polish abbreviation JARK/WAK) and analytic hierarchy process were included in the method, as well as a new assumptions were conducted. The following stages of the method were shown on the scheme (fig 2.1).

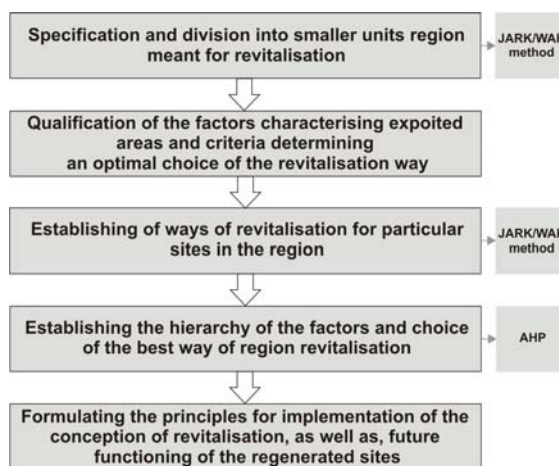


Fig 2.1 The procedure for the revitalisation of large and diverse post-mining regions

The principles of specification of the sites, which are to be revitalised together with their surrounding constitutes the first stage of the method. The need for complex treatment of each exploited site in the region resulting from the necessity of avoiding a

² The laws separate reclamation stages (bringing back the value to the destroyed site) and redevelopment stages (using reclaimed sites for forest, agricultural or recreational purposes) in Poland The expression “revitalisation”, „regeneration” including both stages: reclamation and redevelopment

combination of random ways of revitalisation, not corresponding to each other and making more expensive revitalisation investments. The principles of dividing the region into smaller units in order to conduct valorisation and definition the factors are also included in that stage.

Classification of the essential for the post- mining sites factors (economical, environmental, cultural, social, spatial, technical, formal-legal) constitutes the second stage of the procedure. An analysis of the factors is the basis of establishing the criteria which determines the ways for the regions revitalisation.

Establishing main and supplementing ways of revitalisation of the exploited sites is the third stage of the method. The analysis of the factors characterizing the exploited sites and relevant criteria are the basis for drawing up a conception of revitalisation for the exploited sites.

The choice for the best conception of revitalisation for the post-mining region, which is preceded by a hierarchy of importance for the factors is a crucial element of the method (stage IV). Since designing the revitalisation of the exploited regions with diverse profiles is a complex process the analytic hierarchy process, which makes it easier to solve such problems was applied. From among other heuristic methods the AHP has been chosen as the most useful method for solving complex revitalization problems.

The choice of the optimal way of post-mining region revitalisation is made in the designing process (stages I-IV). In order not to squander results of designing process during the realisation stage, it is necessary to draw up principles of proper realisation for the revitalisation conception, as well as, for the maintenance and success of the regenerated sites in the future (stage V).

Thanks to generalisations, which were applied to the presented method it can be used in a wide range of post-industrial sites that are characterised by complex and diverse structures. The method makes it easier for mining operators, decision bodies, scientists, investors etc. conducting the process of revitalisation in proper way.

3. The factors characterising the *Krzemionki Podgórskie* post – mining region

Verifying and applying the method of large and diverse post-mining sites revitalisation was conducted on *Krzemionki Podgórskie* region in Cracow. *Krzemionki Podgórskie* is located near centre of the city and occupies an area of approximately 300 ha. Many quarries of different sizes remain due to intensive mineral extraction (since the middle ages until the 1980s). Only two of them are regenerated. In spite of large conversion of the region, it is characterised by enormous natural, viewing, cultural, commemorative and recreational virtues.

In order to establish the main and supplemental functions for the particular sites in the exploited region the most characteristic factors for that region were described and analysed. *Krzemionki Podgórskie* - a large and very diversified region - needs wide a characteristic of the factors and criteria determining the choice of the optimal way of the revitalisation. Since space of this article is limited only list of the factors, which were the basis for drawing up conceptions for the *Krzemionki Podgórskie* region regeneration are shown. They are as follows: cultural, environmental, formal-legal, hydrological, social, spatial and technical.

An analysis of the factors was the basis for establishing the criteria for an optimal choice of revitalization ways for the *Krzemionki* region. The diversified characteristic of the region creates many possibilities for its revitalisation. Established criteria shows which functions for the regenerated sites are preferred and which are unacceptable. For example, ways of revitalising a post-mining site which includes memorials in it or in its surrounding limit its future functioning. Creating an optimal proposition for the regeneration of a large and diverse region without detailed characteristics and analysing important factors and without using advanced decision processes could be difficult or even impossible. The assumptions of the proposed method of designing large and diverse post-mining region, which included the analytics hierarchy process in the decision stage allows us to make a proper resolution.

4. A description of the conceptions of the revitalisation

On the basis of characteristic factors related to the *Krzemionki Podgórskie* region and the established criteria determining the choice of an optimal way in the revitalization tree different conceptions of the region revitalisation were drawn up. They are described below.

Ist conception – so called full

The main idea of this conception is cleaning, protecting and popularising places with precious natural and historical meaning, especially memory sites. These places will fulfil cultural, natural and educational functions. The area of the former German concentration camp will be converted into memorial park. Its border will be marked in visible way and some of the camps' objects will be partly rebuild. Some of the quarries and post-mining buildings will be converted into recreational and sports facilities. The main emphasis will be put on the educational function of the region. Many sites and facilities will be used for educational purposes. Besides thematic routes will be created in the region. Those sites which are located in the surroundings of the post-mining areas and are not in use and neglected will be transformed for the service all the region, eg. a car park.

IInd conception – so called zero

The current condition of the region is going to be retained. Economic functioning of some quarries will be continued, regardless of their natural or historic value. The other quarries, as well as, area of the former German concentration camp will be retained without regeneration.

IIIrd conception – so called variant

Social issues will be stressed in the third conception. Propositions for post-mining sites will be directed to the social needs. Quarries, industrial and military buildings will be converted into the following functions:

- Artistic ateliers, young artists can organise various courses (painting, sculpture, theatre course, etc.). They will receive ateliers without any cost and instead they will instruct poor children free of charge.
- Start up and retraining centres. In the start up centre one can set up businesses with the help of professional advisers. In retraining centre, people who have lost their job can learn a new profession.
- Recreational and sports facilities, especially for the quarries and other sites located near school.

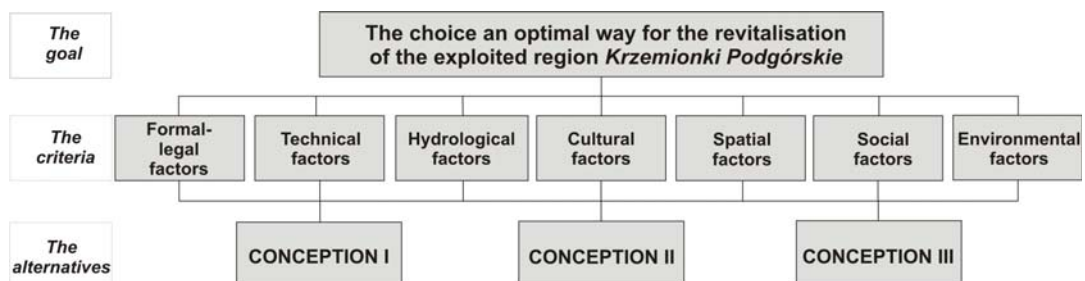
Contemplative character is proposed for the former German concentration camp. With reference to the age of the limestone extraction, the border and the most tragedy sites of the camp as a gate, appeal place or collective graves will be marked with pieces of limestone. Neglected and deserted sites and objects located near by post-mining areas will fulfil a service functions for all the region, e.g. a car park.

A variety of the factors which characterise the *Krzemionki Podgórskie* is included in the tree conceptions of the region revitalisation. The criteria, which were established on the basis of factor analysis were implemented acceptable and unacceptable ways of revitalisation. This is why a hierarchy of factors are important.

5. Hierarchy of the factors and choice of the best conception for post-mining region revitalisation using the analytic hierarchy process

In order for optimal decision making to take place in such complex process as the revitalisation of *Krzemionki Podgórskie* post-mining region, the analytic hierarchy process was applied. AHP made possible the structure of the complex problem into single elements, which is the basis of building the hierarchy decision model (fig 5.1).

According to the assumptions of the analytic hierarchy process, the number of elements on the one level of the hierarchy should not exceed nine, since a comparison more then nine elements can make great



inconsistency (Saaty, 2001). Taking this into account there are seven elements on the second level of the hierarchy (factors) and tree elements on the last level (conceptions).

Fig 5.1 Hierarchy of choosing an optimal way for the revitalisation of the post-mining region

Group of experts established a relationship between the elements of each level of hierarchy by comparing them in pairs. The questionnaire together with a description of the factors and conceptions of the region revitalisation constituted basis for comparison. In the first place experts estimated the importance of the criteria (factors) relative to the goal: the choice an optimal way for the revitalisation of the exploited region. Then, the experts compared the alternatives – tree conceptions of the region revitalisation in relative to the factors. The experts used a verbal scale to their estimation and then numbers were assigned to it.

Two groups of experts were involve at the decision making process. The first group are closely connected to the region and consist of representatives of the local government, local society, cultural and educational institutions located in that region. While the second group was made up of independent representatives from scientific institutions. There were an equal amount of experts in each group.

The interviews were carry out by each experts. During the interview, the experts were familiarized with aim of the decision making process, a description of the factors and conceptions of the revitalisation of the *Krzemionki Podgórskie* region. The experts made estimations of elements included in the hierarchy model and they expressed their opinion concerning particular conception.

Judgements received from experts were subject to mathematical verification using the Expert Choice programme. The weight of particular factors (criteria) reflected their impact into goal, as well as, global priority for alternatives pointed out the best conception of the post-mining region revitalisation were calculated. Separate results for the two groups of experts and collective result of judgements are shown in the following tables: 5.1, 5.2 and 5.3.

Table 5.1 Results of the 1st group of experts – representatives of the *Krzemionki Podgórskie* region

The criteria (factors)	Weight W_i	Conception I		Conception II		Conception III	
		Local priority	Global priority	Local priority	Global priority	Local priority	Global priority
Cultural	0,2862	0,5510	0,1577	0,0597	0,0171	0,3893	0,1114
Environmental	0,2463	0,5527	0,1361	0,0605	0,0149	0,3868	0,0953
Formal-legal	0,1781	0,4642	0,0827	0,0718	0,0128	0,4642	0,0827
Social	0,1144	0,3538	0,0405	0,0566	0,0065	0,5896	0,0674
Hydrological	0,0701	0,3333	0,0233	0,3333	0,0233	0,3333	0,0233
Technical	0,0585	0,5375	0,0314	0,1758	0,0103	0,4043	0,0236
Spatial	0,0469	0,3364	0,0158	0,2643	0,0124	0,3992	0,0187
	1		0,4875		0,0972		0,4225

Weights of the factors calculated on the basis of the comparison matrix created the priority vector:

$$W_f = (0,2862 w_c; 0,2463 w_e; 0,1781 w_{f-l}; 0,1144 w_s; 0,0701 w_h; 0,0585 w_t; 0,0469 w_{sp}) \quad (5.1)$$

The form of the priority vector indicated that for the first group of experts the most important factors influenced the way of post-mining sites revitalisation were regarded: cultural, environmental and formal-legal then social, hydrological, technical and spatial.

Judged the cultural, environmental and formal-legal factors as the most important for the *Krzemionki Region* regeneration influenced on the hierarchy of alternatives. In the experts opinion, the best alternative for the regeneration of the post-mining region is the first conception, which emphasis natural and cultural educational values of the *Krzemionki* region. The global vector for the alternatives is shown in formula 5.2.

$$W_c = (0,4875w_I; 0,4225w_{III}; 0,0972w_{II}) \quad (5.2)$$

Results of the second group of judgement are shown in the table 5.2.

Table 5.2 Results of the 2nd group of experts – representatives from the scientific institutions

The criteria (factors)	Weight W_i	Conception I		Conception II		Conception III	
		Local priority	Global priority	Local priority	Global priority	Local priority	Global priority
Cultural	0,2922	0,4316	0,1261	0,1065	0,0311	0,4619	0,1350
Environmental	0,1979	0,4208	0,0833	0,2156	0,0427	0,3636	0,0719
Technical	0,1707	0,5622	0,0959	0,0714	0,0122	0,3665	0,0625
Spatial	0,1281	0,4955	0,0635	0,1391	0,0178	0,3653	0,0468
Formal-legal	0,0882	0,4663	0,0411	0,1153	0,0102	0,4184	0,0369
Social	0,0880	0,4377	0,0385	0,0725	0,0064	0,4897	0,0431
Hydrological	0,0354	0,2847	0,0101	0,3916	0,0139	0,3237	0,0115
	1		0,4585		0,1342		0,4077

A similar result was achieved by representatives of the second group of experts (representatives from institutions, which are not connected to the region). The hierarchy of the factors established by this group of experts is as follow: cultural and environmental then technical, spatial, formal-legal, social and hydrological (formula 5.3).

$$W_f = (0,2922w_c; 0,1979w_e; 0,1707w_t; 0,1281w_{sp}; 0,0882w_{f-l}; 0,0880w_s; 0,0354w_h) \quad (5.3)$$

Presented in formula 5.3 is the importance of the factors reflected in the form of the priority vector for the alternatives (formula 5.4). According to this vector the best conception is the first one, big acceptance received also the third conception, however the weight of the second conception is considerably lower than other ones. The global vector for the alternatives has a forms as is shown in the formula 5.4.

$$W_c = (0,4875w_I; 0,4077w_{III}; 0,1342w_{II}) \quad (5.4)$$

The analytic hierarchy process does not assume calculating priority vectors for two groups of experts. However, for revitalisation of the *Krzemionki Podgórskie* post-mining region, such comparison has been done. Both groups of experts are in agreement with regard to both the most important factors for the revitalisation of the region and the best conception for its regeneration. This means that the enormous historical and natural values of the *Krzemionki Podgórskie* region and the necessity to protect and promote them are the most important for everyone.

The collective results of two group of experts are presented in table 5.3 and on figures 5.2 and 5.3.

Table 5.3 Collective results of two group of experts

The criteria (factors)	Weight W_i	Conception I		Conception II		Conception III	
		Local priority	Global priority	Local priority	Global priority	Local priority	Global priority
Cultural	0,2892	0,4912	0,1420	0,0831	0,0240	0,4256	0,1230
Environmental	0,2220	0,4867	0,1081	0,1380	0,0306	0,3752	0,0833
Formal-legal	0,1331	0,4652	0,0619	0,0935	0,0124	0,4412	0,0587
Technical	0,1145	0,5498	0,0629	0,1236	0,0141	0,3853	0,0441
Social	0,1011	0,3957	0,0400	0,0645	0,0065	0,5396	0,0545
Spatial	0,0874	0,4159	0,0363	0,2017	0,0176	0,3822	0,0334
Hydrological	0,0527	0,3089	0,0162	0,3624	0,0191	0,3285	0,0173
	1		0,4678		0,1245		0,4146

The influence of particular factors on the way of revitalising the *Krzemionki Podgórskie* region is expressed by vector of priority (formula 5.5) and on the chart (fig 5.2).

$$W_f = (0,2892w_c; 0,2220w_e; 0,1331w_{f-l}; 0,1145w_t; 0,1011w_s; 0,0874w_{sp}; 0,0527w_h) \quad (5.5)$$

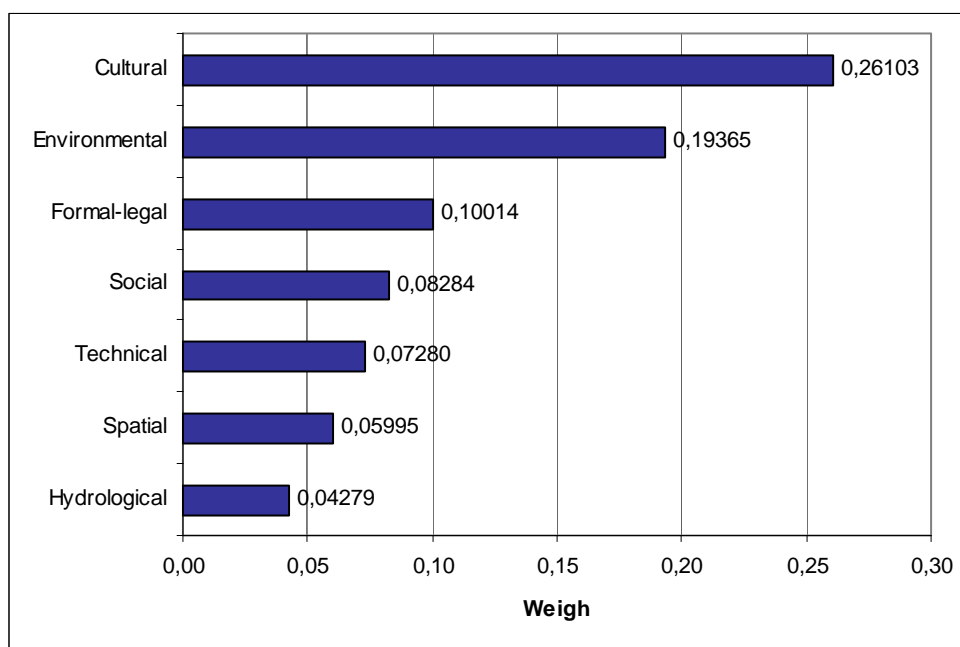


Fig 5.2 Global vector for the criteria – the factors characterising the *Krzemionki Podgórskie* post-mining region

The consistency ratio for all estimated criteria is included in the limits 0,4 – 7 %, which means that experts judgements are consistent.

A collective analysis of the results of both group of experts judgement show, that what is most important for the revitalisation of the *Krzemionki Podgórskie* post-mining region are the cultural (0,2892) and environmental (0,2220) factors. The weight of the formal – legal factors (0,1331) located them in the third place. Among of others, natural protected area and historic monuments are included in the formal-legal factors. Such an estimation reflected the profile of the region, which is dominated by historical and natural features. Industrial heritage, martyrdom sites and other historical objects located near-by post-mining sites such as a military and sacred objects constitute in cultural value. However, natural values

take the form of geological phenomena, which are results of mineral extraction or precious habitat which can be results of the natural succession, as well as landscape, green areas, view points etc.

Technical (0,1145), social (0,1011) and spatial (0,0874) factors are the next in the hierarchy. Hydrological factors (0,0527) are the less important for realisation of the goal. Justification of this situation can be found in fact that the quarries in *Krzemionki Podgórskie* region are not full of water and those factors do not influence the regeneration process.

The assessment alternatives is reflected in the hierarchy of the factors. The values of the priority vector which were calculated for the alternatives are the basis of ordering fuzzy of alternatives and pointing out the best solution (alternative with the highest worth priority vector). A global vector for alternatives has been formed, as is shown in the formula 5.6 and on the chart (fig 5.3).

$$W_c = (0,4678w_I; 0,4146w_{III}; 0,1245w_{II}) \tag{5.6}$$

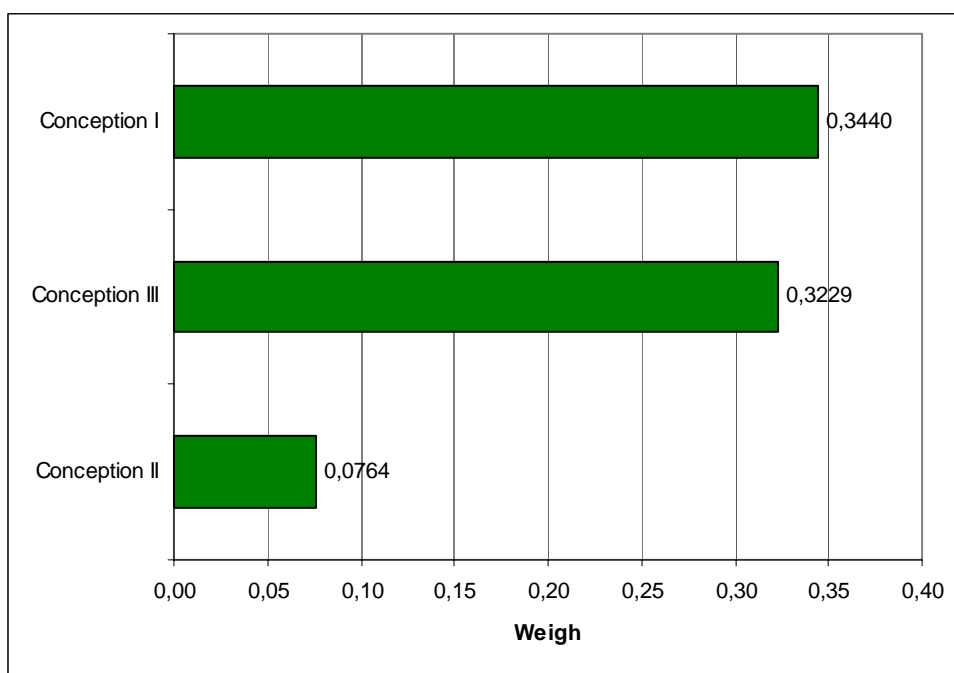


Fig 5.3 Global vector for the alternatives – the conceptions of the *Krzemionki Podgórskie* post-mining region revitalisation

The consistency ratio for all estimated alternatives is included in the limits 0 – 0,8 %, which means that experts judgements are consistent.

The global vector for the alternatives show that the best conception for the *Krzemionki Podgórskie* revitalisation in the opinion of experts is the first one, so called full with the highest priority - 0,4678. The choice of the first conception as the best one, results from the factors hierarchy, where the highest weight received cultural, environmental and formal-legal factors. This conception take into account the natural and historical values of the region in wide range. The best conception is shown in figure 5.4.



Fig 5.4 The way of the Krzemionki Podgórskie revitalisation
 1st CONCEPTION - SO CALLED FULL

The worth of the priority of the third conception is on a very similar level as the first one is, namely 0,4146. Historical and natural places were taken into account within this conception, but the proposed ways of regeneration are directed to social needs. Technical and spatial features of the region were used for social aims. This is a result of the factor estimation, where social, technical and spatial factors are on the next positions after cultural, environmental and formal-legal.

The second conception experts regarded as not adequate with reference to the *Krzemionki Podgórskie* region. The worth of its priority (0,1245) is considerably lower than for the other conceptions.

Choosing the best conception of the *Krzemionki Podgórskie* post-mining region revitalisation can be beginning of realisation process.

Drawing up the conceptions and taking into account the factor analysis and advanced decision making process based on experts judgement is an example of the rational and effective process of the revitalisation.

4. Conclusion

The method of designing the revitalisation is characterised by an innovative and complex approach to the complicated problem with regard to the revitalisation of large and diverse exploited region. The new aspect of the method (among other) is applying the analytic hierarchy process as the most useful experts method for complex problems solving. AHP was used for establishing the hierarchy of the factors which are important for way the region revitalisation and choosing the best conception.

The utility of the method of designing the revitalization of the large and diverse post-mining regions, thus also the choice of the best conception using the analytic hierarchy process were verified on the basis of *Krzemionki Podgórskie* region. Factors, which characterise each post-mining sites in the region, as well as, conceptions of their revitalization were discussed and estimated by experts. A hierarchy of the factors and the best conception were the results of the experts judgments.

The use of both method of designing the revitalisation and the AHP in our study proved to be useful.

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