RISK MANAGEMENT TOOL TO SUPPORT SPOIL DUMPS REVITALIZATION

NARZĘDZIE DO ZARZĄDZANIA RYZYKIEM WSPIERAJĄCE REWITALIZACJĘ ZWAŁOWISK POGÓRNICZYCH

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The paper features the results of Łukasiewicz – EMAG's team work within the SUMAD project. The focus has been put on how to use the developed SUMAD Risk Management Tool (SUMAD RMT) which supports the revitalization process of a post-mining heap. The tool enables the following:

- *to identify and reduce risk factors related to the heap and to the revitalization process,*
- *to estimate financially the revitalization process,*
- *to monitor non-financial like political, environmental, social, etc. factors which are very important because they can positively or negatively shape the social and political reception of the whole revitalization process.*

The paper describes shortly the methodology based on three pillars (three kinds of analyses):

- *RRA – Risk Reduction Assessment (risk management),*
- *CBA – Cost–Benefit Assessment (estimation of financial factors),*
- *QCA – Qualitative Criteria Assessment (estimation of non-financial factors).*

The methodology has an iterative character and its main steps are the following:

1. *Identification of the heap to be revitalized and preliminary revitalization activities,*
2. *Preliminary RRA, CBA, QCA analyses,*
3. *Composing the revitalization alternatives,*
4. *Alternative assessment with respect to risk (RRA), financial (CBA) and non-financial (QCA) factors,*
5. *Decision making based on the acquired aggregated data.*

The methodology was illustrated by examples from the revitalization process.

Słowa kluczowe: *revitalization process, risk factors, post-mining heaps*

Artykuł przedstawia wyniki pracy zespołowej w Instytucie Łukasiewicz – EMAG w ramach projektu SUMAD. Skupiono się na wykorzystaniu opracowanego Narzędzia Zarządzania Ryzykiem SUMAD (SUMAD RMT), które wspomaga proces rewitalizacji hałdy pogórniczej. Narzędzie to umożliwia:

- *rozpoznanie i ograniczenie czynników ryzyka związanych z hałdą i procesem rewitalizacji,*
- *finansowe oszacowanie procesu rewitalizacji,*
- *monitorowanie czynników pozafinansowych, które są bardzo ważne, ponieważ mogą pozytywnie lub negatywnie kształtować odbiór społeczny i polityczny całego procesu rewitalizacji.*

W artykule pokrótce opisano metodykę opartą na trzech filarach (trzy rodzaje analiz):

- *RRA – Ocena Redukcji Ryzyka (zarządzanie ryzykiem),*
- *CBA – Ocena Kosztów i Korzyści (oszacowanie czynników finansowych),*
- *QCA – Ocena Kryteriów Jakościowych (oszacowanie czynników pozafinansowych).*

Metodologia ma charakter iteracyjny, a jej główne etapy są następujące:

1. *Identyfikacja hałdy przeznaczonej do rewitalizacji oraz wstępne działania rewitalizacyjne,*
2. *Analizy wstępne RRA, CBA, QCA,*
3. *Tworzenie i analiza alternatywnych rozwiązań rewitalizacyjnych,*
4. *Ocena alternatywnych rozwiązań w odniesieniu do czynników ryzyka (RRA), finansowych (CBA) i niefinansowych (QCA),*
5. *Podejmowanie decyzji w oparciu o zebrane zagregowane dane.*

Metodykę zilustrowano przykładami z procesu rewitalizacji.

Keywords: *proces rewitalizacji, czynniki ryzyka, hałdy pogórnicze*

Introduction

The paper falls within the topic of the EU RFCS SUMAD (Sustainable Use of Mining Waste Dumps) project. The objective of the project is to explore the possibilities of reusing areas with coal-mining spoil with respect to geotechnical, sustainability, environmental, socio-economic, and long-term management challenges. To achieve this objective, there were several methods applied, such as risk management and physical or numerical modelling to different revitalization schemes. The essence of these operations was to estimate technical viability of the spoil dump for the development of renewable energy infrastructure. The input came from heap operators, developers, and authorities involved in the project.

The spoil dumps produced by the mining activity cause ecological degradation of areas and objects, and rise risks to human health, natural environment and economy. The heap revitalization takes time and money and requires a coordinated and multidirectional approach. Not only the risk mitigation is important, but also financial and non-financial issues. The revitalization budget is usually limited and stakeholders expect certain benefits in the future as well. The revitalization process should consider many diversified non-financial factors as well, e.g. social, environmental, technological, political, which positive or negative impact should be considered too. The planning of the revitalization process is complicated and requires consideration of many diversified issues, sometimes with the opposite effects. To elaborate input data for the decision maker, who ought to select the most advantageous revitalization option, software may be helpful. The software is able to perform complicated analyses, to manage huge amount of data and to support the decision maker. For this reason the SUMAD Risk Management Tool (SUMAD RMT) was developed by the Łukasiewicz – EMAG project team supported by the other project partners.

The tool enables the following:

* to identify and reduce risk factors related to the heap and to the revitalization process,
* to estimate financially the revitalization process,
* to monitor non-financial factors which are very important because they can positively or negatively shape the social and political reception of the whole revitalization process,
* to provide the aggregated results of different revitalization options to the decision-makers.

SUMAD RMT has three main modules responsible for:

* RRA – Risk Reduction Assessment (risk management),
* CBA – Cost–Benefit Assessment (estimation of financial factors),
* QCA – Qualitative Criteria Assessment (estimation of non-financial factors).

These modules are supported by others, allowing to specify heap properties, to compose different revitalization options called here revitalization alternatives, to register incidents relevant to heaps, to present results of the RRA, CBA, QCA analyses to the decision maker and finally to generate the revitalization plan.

Apart from this short introduction, the paper includes Section 2 presenting the current research status and research motivation and Section 3 showing the general architecture and functionality of SUMAD RMT. Section 4 includes an example of the tool use in the planning of the revitalization process. Section 5 concludes the research leading to the SUMAD RMT development.

Current research, motivation and objectives

The interdisciplinary research leading to the SUMAD RMT development embraces risk management, especially its application in ecology and post-industrial revitalization, cost-benefits assessment, assessment of social, environmental, political, and other soft factors in the decision process.

The extensive literature review dealing with the paper domain was provided in the paper [1]. Here it will be supplemented and summarized.

The methodology implemented in SUMAD RMT is based on EMAG's earlier EU projects concerning different security aspects [2], [3]. Both of them were also based on three pillars (RRA, CBA, QCA), but the domain of application considered in these projects, such as the security of public mass event, public mass transportation, air transportation/airport, communal security planning, cyber security, and critical infrastructure protection, required a quite different approach comparing to the SUMAD RMT.

There are several papers related:

* to the risk management and environmental management methods focused on a broader range of ecological issues [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15],
* to the geotechnical risk issues [16], [17], [18],
* to the Multi-Criteria Decision-making Methods (MCDM), and similar used to support revitalization or rehabilitation processes [19],
* to the specific methods focused on a certain revitalization issue: coal mining and processing [20], waterfronts [21], ANP-based (Analytic Network Process) and PEST-based (Political, Economic, Social and Technological) method for urban areas [22], methods for urban areas [23], PEST-based method for surface coal mining areas[24], AHP-based (Analytic Hierarchical Process) and TOPSIS-based (Technique for Order of Preference by Similarity to Ideal Solution) method for surface lignite mines [25], AHP based method for post-mining areas [26].

However, among the reviewed approaches, there is not a single one that would consider three kinds of factors: mixed-risk, financial, and non-financial factors. What is more, none is focused on the revitalization of the post-mining waste dumps. The most similar toolset to SUMAD RMT is SMARTe, but it does not deal with the very specific domain of heap revitalization. Ecological and geotechnical methodologies, research, and experiments carried out by the SUMAD consortium will provide domain data for the tool to predefine threats, vulnerabilities, scenarios, risk measures, and revitalization techniques.

The research motivation is to solve heap specific revitalization issues and facilitate the heap revitalization planning process.

The paper objective is to develop a dedicated tool supporting the heap revitalization planning process based on the experts' knowledge and experiences.

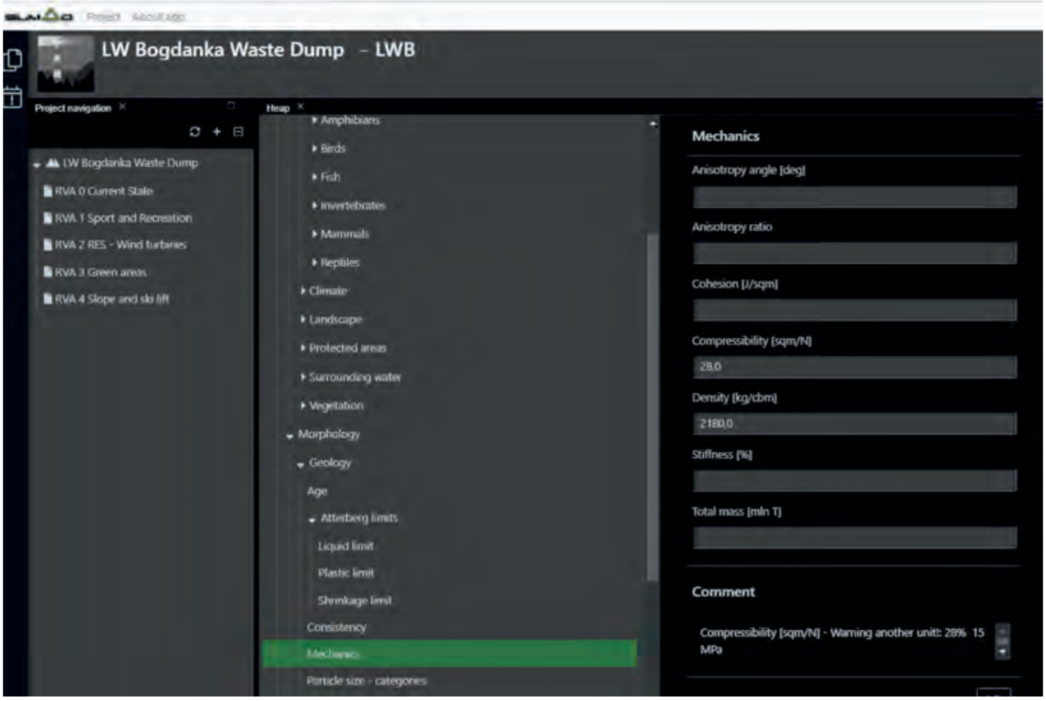

Fig. 1. Heap specification example in SUMAD RMT
Rys. 1. Przykład specyfikacji zwałowiska w SUMAD RMT

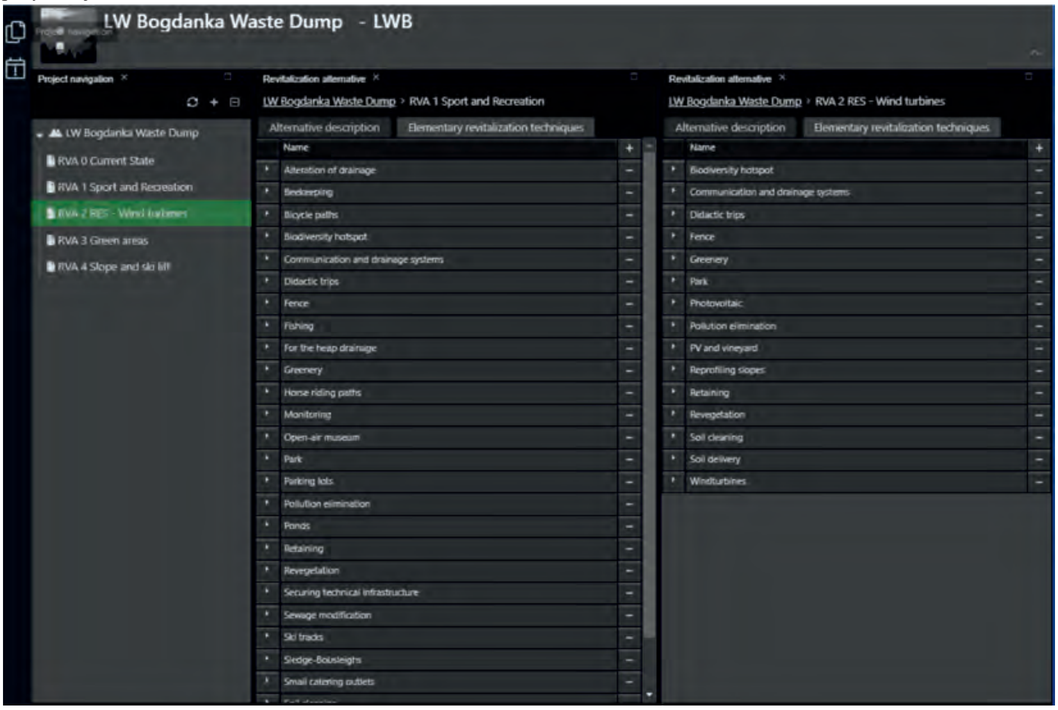

Fig. 2. Examples of revitalization alternatives
Rys. 2. Przykładowe alternatywy rewitalizacji

Development of the specialized SUMAD Risk Management Tool (SUMAD RMT)

Apart from the auxiliary modules managing program users, managing predefined data and registering historical heap-related incidents, SUMAD RMT embraces modules which directly support the planning process of revitalization activities for a given heap:

• The heap specification module which to elaborate the structurized and detailed specification of the considered object; the specification includes administrative records containing the heap owner, localization, etc., geometrical parameters, including area height, volume, shape, geological parameters, including age, critical water contents of fine-grained soil, consistency, particle size, compressibility, stiffness, cohesion, structure, kind of heap material, technical conditions, surface usability, pollutants related to ignitability, corrosivity, radioactivity, reactivity, toxicity, littering, including bulky waste as well as biodegradable and non-degradable materials, heap environment records, including landscape profile, climate parameters, air pollution status, vegetation and animals (especially protected ones), surrounding water, protected areas such as culture heritage or nature, and auxiliary information, like legal restrictions, available financial, technical, and operational resources; this specification is used as the input for any other operations;

• The revitalization alternatives composer; each revitalization alternative (RVA) consists of several elementary revitalization techniques (ERTs); RVAs are subject of RRA, CBA and

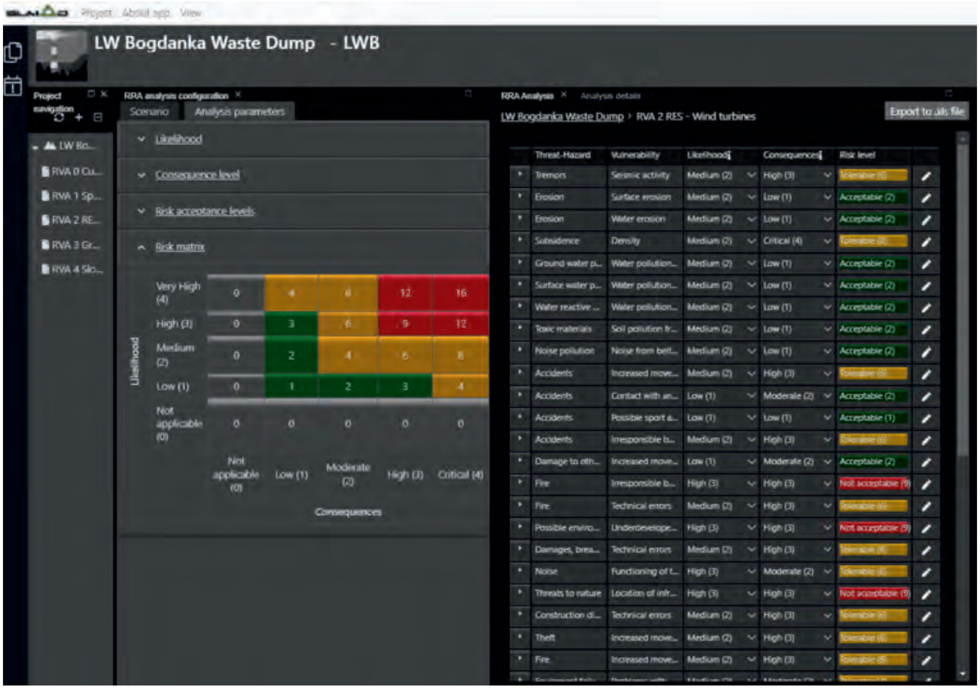

Fig. 3. RRA configuration and analysis
Rys. 3. Konfiguracja i analiza RRA

Fig. 4. CBA-OPEX matrix
Rys. 4. Macierz CBA-OPEX

QCA analyses, whose results allow the decision maker to select one RVA for implementation; risk parameters are expressed by predefined enumeration scales;

• RRA requires the identification of risk scenarios, i.e. pairs: <threat/hazard-vulnerability>, and for each of them the assessment of likelihood (L) and consequences (C); risk values is represented by their product (R=L*C); comparing the obtained values with the reference levels all scenarios are classified as acceptable, tolerable or unacceptable; the last one should be mitigated by adding additional ERTs to the assessed alternative; CBA parameters are expressed in currency units;

• The CBA framework includes three separate matrices for: CAPEX (CAPital EXpenditure), OPEX (OPerating EXpenditure) and BENEFITS; their rows include configurable groups of categories and subcategories; the columns represent particular years of the analysis time span, e.g. planning time span may be 20 years; the analyst plans costs/benefits and as the result he/she obtains financial parameters (indices), like NPV (Net Present Value), DPBT (Dynamic Payback Time);

• The QCA module allows to assess all positive or negative impacts of different "soft factors", like social, political, environmental, technological, etc. factors on the given RVA implementation; the QCA framework is pictured as a matrix; the rows represent groups of criteria and criteria which are assessed by the analyst; the groups and the criteria within the groups have weights assigned; the analyst makes use of predefined assessment scales; Utility functions (UF), assigned individually to the criteria, are used to transform the enumerative value

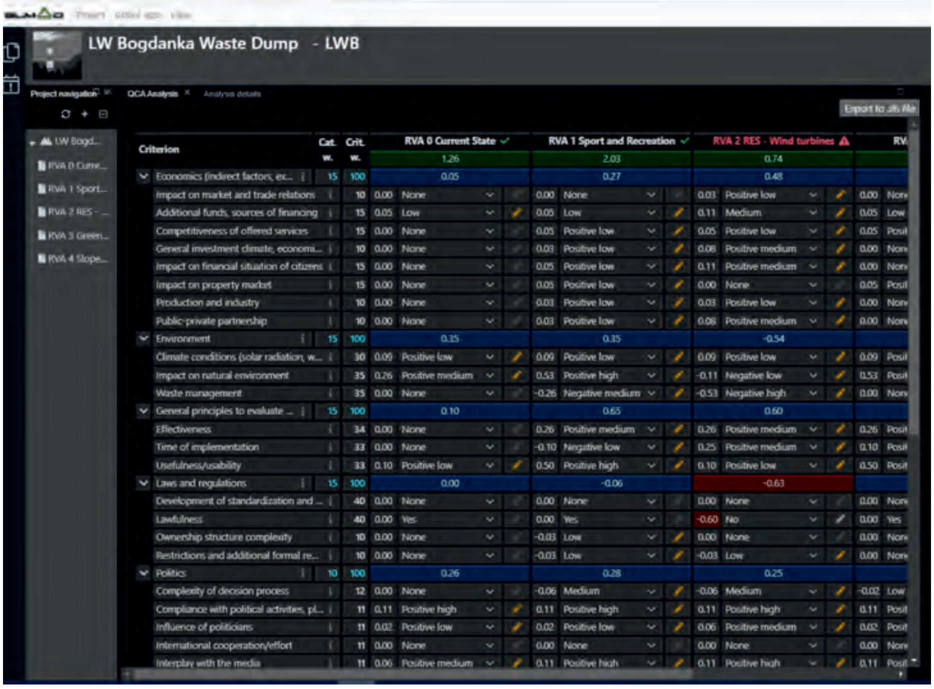

Fig. 5. QCA analysis for alternatives
Rys. 5. Analiza QCA dla alternatyw

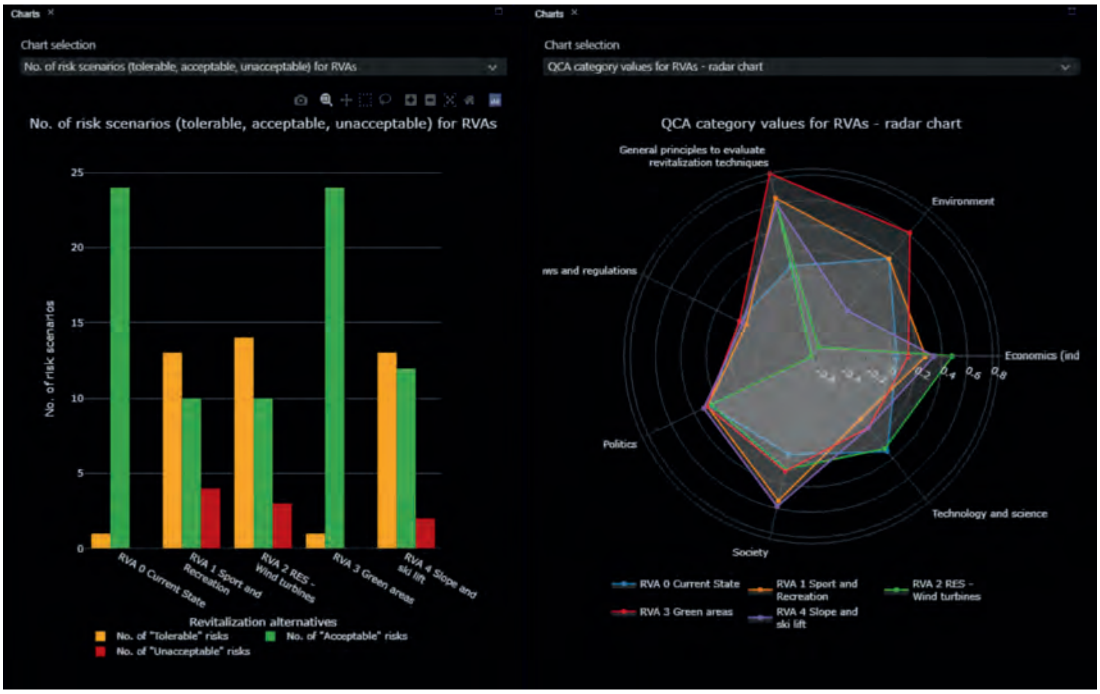

Fig. 6. RRA and QCA charts examples
Rys. 6. Przykłady wykresów RRA i QCA

given by the analyst to the output value; this way the character of a criterion is modelled (a certain curve of impact);

• The DMAV (Data Management, Aggregation, and Visualization) software module is responsible for the presentation of the analyses results (tables, graphs) and generating the revitalization planning report; the results are presented online, and reports can be generated on request (html, pdf, xlsx).

SUMAD RMT is equipped with the knowledge base called the PDM (Predefined Data Manager) which includes different categories of the predefined data items relevant to the different kinds of heaps and their revitalization processes, such as: threats, vulnerabilities, ERTs, impact categories, CBA categories, QCA categories used by the software. The user can select them directly for the revitalization project or can define some specific items manually.

The operation of these modules is exemplified in the next section.

Support spoil dumps revitalization planning with the use of SUMAD RMT

The most extensive validation of the SUMAD RMT methodology and tool was performed on the LWB Bogdanka heap managed by the project partner LWB. During the several workshops LWB, KOMAG, GIG and EMAG project teams identified input data (heap properties, possible revitalization activities), performed RRA, CBA and QCA analyses, and proposed modification of predefined items.

DMAV summary

Criteria	RVA 0 Current State	RVA 1 Sport and Recreation	RVA 2 RES - Wind turbines	RVA 3 Green areas	RVA 4 Slope and ski lift
Risk-related parameters					
No. of identified risk scenarios	25	27	27	25	27
No. of "Unacceptable" risks	0	4	3	0	2
No. of "Tolerable" risks	1	13	14	1	13
No. of "Acceptable" risks	24	10	10	24	12
Max. risk value	4	9	9	4	9
Total risk value	36	115	130	36	99
Average risk value	1.44	4.26	4.81	1.44	3.67
Cost-benefit parameters					
Total investment cost (CAPEX)	0.00	32920000.00	40738000.00	765000.00	3075000.00
Total operational cost (OPEX)	0.00	7120000.00	4912000.00	2688000.00	5020000.00
Total benefits	0.00	0.00	21840000.00	4000000.00	10400000.00
NPV (Net Present Value)	0.00	-37427142.20	-29384294.16	91780.97	409104.71
DPBT (Dynamic Payback Time)				4y, 189d	4y, 202d
Qualitative assessment parameters					
QCA aggregated value	1.26	2.03	0.74	2.27	1.73
Killing criterios					
Lawfulness	-	-	Active	-	-
Economics (indirect factors, externali...	0.04	0.27	0.48	0.14	0.34
Environment	0.35	0.35	-0.54	0.61	-0.17
General principles to evaluate revitali...	0.10	0.65	0.60	0.85	0.60
Laws and regulations	0.00	-0.06	-0.63	0.00	-0.03
Politics	0.26	0.28	0.25	0.28	0.31
Society	0.17	0.54	0.29	0.30	0.58
Technology and science	0.33	0.00	0.30	0.09	0.09

Summary

Fig. 7. Comparing alternatives
Rys.7. Porównywanie rozwiązań alternatywnych

The revitalization project starts with the establishment of the project team and the configuration of analytical parameters (scales for L and C, risk matrix, weights, etc).

At the beginning of the revitalization project the heap should be specified. The heap specification has the tree structures of multiple levels of categories ending with the elementary data container (numerical value, enumerative value, textual).

Figure 1 presents a part of the tree structure (middle panel) with data representing mechanical parameters (right panel). The left panel presents the considered alternatives for this heap – discussed later.

At this stage the historical revitalization activities are identified too as the "zero" alternative (RVA0) being the reference point for the planned revitalization alternatives.

In the LWB Bogdanka heap example the following activities were identified (RVA0 Current state):

• ERT1: Decreasing the heap volume by ca. 10% and using this material for levelling the external degraded areas and for concrete production,
• ERT2: Partial afforestation,
• ERT3: Partial soil cleaning,
• ERT4: Hydrological improvement.

The heap with RVA0 is the subject of the RRA (identification of the risk picture) and the QCA (identification of intangible constraints and chances) analyses. CBA (planning) is not relevant for past activities and can be used to register financial categories approximately as lump sums.

The obtained results allow to compose several RVAs representing different revitalization directions focused on different applications. Each RVA embraces a certain number of ERTs focused on the risk mitigation and planned applications.

Figure 2 presents the RVA0 and four planned (RVA1-RVA4) revitalization options (left panel) and details related to RVA1 Sport and recreation and RVA2 RES – Wind turbines. Please note the ERTs of these alternatives.

All alternatives are analyzed again with the use of RRA, QCA and CBA.

Figure 3 exemplifies the risk assessment. The middle panel presents the RRA configuration tab. Please note the risk matrix configured for all risk analyses performed for alternatives. The right panel shows examples of risk scenarios identified for RVA2 with results. All unacceptable cases should be mitigated by adding additional ERTs to the alternative. Tolerable risk cases are usually monitored, but can be mitigated too.

Figure 4 features a sample CBA/OPEX analysis for RVA2. Please note different financial categories and values planned for years 3, 4, 5, and the total values.

Figure 5 exemplifies the QCA analysis for revitalization alternatives. Please note qualitative criteria ordered by groups, their weights (marked light blue) and the input values, e.g. for the criterion: "Impact on natural environment" (weight within group 35%) belonging to the "Environment" group (group weight 15%), the analyst places the value "Negative low" for RVA2, transformed by the utility function and weights to the result "-0.11". RVA2 obtains the assessed value 0.74, but it cannot be accepted as the final result, due to the "killer criterion". This criterion called "Laws and regulation/Lawfulness" should be unconditionally satisfied, but the analyst found some issues in this matter and gives verdict "No", which implies warning (marked red).

The decision-maker can generate about 20 different charts and a table summarizing the most important results. He/she can compare different values before selecting the given alternative for implementation.

The left panel of Figure 6 characterizes a risk picture of each of the considered alternatives at the given project stage. RVA1 has the biggest number of unacceptable risks. RVA0 and RVA3 are low-risk, but they are less useful. The right panel shows the QCA group values for the considered alternatives. Please note that for the "Environment" group the most advantageous is RVA3 (value 0.6), while the worst is RVA2 (ca. -0.5).

Figure 7 presents key results obtained from the RRA, CBA and QCA analyses. Please note that the "Lawfulness killer criterion" for RVA2 is not satisfied. It means that the RVA2 project cannot be accepted at this stage and needs additional effort.

At any project stage a revitalization plan can be issued (html/pdf).

Conclusions

SUMAD RMT embraces all revitalization planning stages, from the heap properties specification to the assessed options proposed to the decision-maker. The planning process is based on very detailed and diversified input data and produces aggregated results.

The planning is based on the risk management, financial and non-financial assessments. This process allows to consider factors related to the planned revitalization application. It is important, because applied ERTs introduce quite new risks for the revitalized object. For example, new risks related to wind turbines, PV installation, even a huge number of heap visitors are easily considered by the tool. The comprehensive assessment of intangible pros and cons for the alternatives are reached. QCA allows to identify different hidden or side effects, easily omitted and causing surprising negative effects during the implementation and use. The PDM knowledge base representing the domain data raises the projects reusability. The RRA, CBA, QCA analytic modules provide a unified picture of all revitalization options supporting the decision-maker.

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