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Hybrid expert system aiding design of post-mining regions restoration

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ABSTRACT

Reclamation as one of the stages in the life cycle of a mine is realized using different techniques and technology adapted to the unique characteristics for any given mining institution. Restoration of terrain from open-cast mining is influenced by many factors and processes; the results are open to interpretation and are not predictable. Most of the aforementioned factors have qualitative characteristics. The number and complex connections among these factors make the analysis of post-mining terrain restoration expensive and time-consuming. Therefore the automation of the decision making is desirable. In this paper, a fuzzy decision support system design is proposed for the restoration of post-mining regions. The system was applied to the testing of decision making concerning the direction of revitalization in an open-cast mining institution in Zator community, southern Poland. The considered gravel mine has worked since 1951 and belongs to the Cracow Aggregate Exploitation Company.

1. Introduction

The mining of mineral materials affects the environment in special ways – degrading or destroying the scenery, altering and changing the terrain and removing considerable areas of agricultural soil and forest. Open-cast mines excavate the soil to exploit the natural resources, giving rise to the problem of either redevelopment or restoration of the excavations when the exploitation is complete.

Numerous papers provide guidelines on land reclamation methods for modern open-cast sites (Coppin and Bradshaw, 1982; Glen, 1994; Ricks, 1995; Prach et al., 1999; Schaaf, 2001; Sklenička and Lhota, 2002). The development of the reclamation strategy, after-use possibilities and the constraints to plant growth and soil development, taking environmental problems into account, are discussed by Andres and Mateos (2006). Details concerning reclamation procedures and techniques available are considered as are the practical guidelines for each (Hancock, 2004). These details vary regionally, so each region has its own specificity, such as the USA (Brown, 2005), South America (Parrotta and Knowles, 2001), U.K. (Cloke et al., 1996), continental Europe (Hendrychová, 2008; Prach et al., 1999; Sklenička et al., 2004; Wiegleb and Felinks, 2001), Asia (Agarwal and Shanker, 2004) and Australia (Bell, 2001). Alternative details for various climatic regions should be taken into consideration by combining local knowledge with the general details and criteria.

Reclamation, as one of the stages in the life cycle of a mine, is realized using different techniques and technology, adapted to the unique characteristics for any given mining institution. It is influenced by many factors and processes so the results are hard to predict. Therefore, it is extremely important to have tools aiding decisions concerning the revitalization of regions, the more so because most of the experts are educated in specialized fields – hydrologists, geologists, ecologists, economists.

According to Polish law, the person or institution responsible for the destruction of the environment is obliged to obtain agreement on the restoration required and perform the repairs. There is no detailed legal description for redevelopment except for the definition. Currently, the definition for executing basic reclamation is to return the terrain to the same use as the local surrounding terrain. Companies are required to take account of the complexity and many alternative revitalization processes that characterize post-mining terrain restoration.

Realizing the difficulty of making decisions for the future functions of a post-exploitation area, the authors present and test an algorithmic aid for an analysis of the optimum choices for revitalization. Since some factors characterizing excavation sites have a qualitative character, they cannot be expressed numerically. Therefore, the inference tree, being the decision-making algorithm description, is aided by fuzzy inference moduli.

This paper is organized in the following way. The systematization of factors characterizing excavation sites, objects and

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post-industrial areas are presented in Section 2. The implemented expert system, a hybrid rule system with fuzzy moduli, is introduced in Section 3. The introduced system is tested in the process of making a decision about revitalization direction in an open-cast mining institution in southern Poland – see Section 4.

2. The problem description

The decision process concerning the optimum form of reclamation and redevelopment is an essential component of the terrain restoration after the open-cast mining of natural resources. It should be characterized by the most important factors and criteria of the revitalization. The exact analysis and profile of environmental protection factors should include cultural values, traditions and societal expectations. The practical basis for reclamation should take into consideration both economic issues and social acceptability.

The process of making choices in directions for the redevelopments of terrains post-exploitation is preceded by inventorying of the characteristic factors for a given region. This enables us to specify and analyse a profile of factors and to create a criterion that defines the limitation and choice for the form of revitalization.

The factors characterizing the excavation, objects and terrains post-exploitation, as well as the criteria for selecting the optimum direction of reclamation and redevelopment are presented on the

Table 1
Classification of factors characterising open-cast mining excavation sites, objects and post-industrial areas and criteria determining a choice of an optimal mode of reclamation and redevelopment.

Factors	Possible factors characterizing excavations and commentary	Admissible general directions of reclamation
Economical	The direction of reclamation and development depends on the level of predicted expenses to be incurred in liquidation and reclamation, as well as later maintenance of the post-mining areas. The costs determine the function of natural resource post-mining region. The correct choice of direction in reclamation decisions, based on analysed factors in projecting phases of the exploitation, shapes the final excavation form, along with the bingstead or wastes.	The minimization of expenses on liquidation by mining institutions, assumes the inclusion of all the below mentioned factors.
Social	The demography of a local community, its wealth, level of education, traditions and customs, social preferences and needs will be considered in case of commercial ventures, in planning demand on products, or services. The optimal choice could be, therefore, a local opinion poll of community and council to discover their preferences for the utilization of the post-mining terrains.	Agricultural Forest Natural Economic Water Cultural
Formal-legal	These are: obligation to conduct reclamation and development forms of protection for example the protection of nature, relics, structure of property of soils, and the local plan of spatial development.	Agricultural Forest Natural Economic Water Cultural
Environmental	This includes geological formations, landscape and indigenous plants and animals. The value placed on specific natural resources should determine relevant environmental protection policies such as: maintenance of ecological processes, stability of ecosystems, maintaining biodiversity, habitat, geological heritage and the education of the local community.	Natural
Spatial	The degree of the terrain urbanization, shape of the communication infrastructure, distance to protected terrains, distance to industrial institutions and the possibility of the individual commuting using private or public transport.	Agricultural Forest Natural Economic Water Cultural
Hydro geological	The presence or absence of water on the bottom of an excavation, water quality, the depth of underground water, thickness of impermeable geological layers as well as the hydro geological connections.	Agricultural Water
Geological-engineering	Measurement and description of an excavation post-mining: The base – type of rock, penetrability of the base, tectonic phenomena (offsets and fissures) and karst and the morphology. The slopes – type of rock and stability, angle of inclination. These factors include type of excavation, shape, depth and surface, quantity of groundwater exploitation, size of external and internal bingstead, type of stored material, shape and inclination of the final slopes. The objects of industrial infrastructure – type, technical shape, cubature and possibility of adaptation and the surface area of the above-mentioned objects.	Agricultural Forest Natural Economic Water Cultural
Cultural	The objects of technique and material culture, for example: the old mines, buildings, workshops, constructions, tools, machines, transportation, illustrating technical progress. Also included are historical and spiritual monuments, for example: places of martyrdom, tombs, and extermination camps.	Cultural