Choosing the optimal policies for risk reduction in mine contaminated areas

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Abstract

As regards mine contamination, the Republic of Croatia is one of the ten most contaminated countries in the world. There are almost 1 million mines on mine suspected areas of 4000 km². About 500 km² are covered with minefields, while the rest of the area is contaminated with individual explosive ordnance. Mine suspected areas and minefields are located in 14 of 21 counties. Mine affected areas have not been used for years, they pose a huge economic problem, they obstruct the infrastructure development and reconstruction, return of displaced persons and their reintegration into normal life. They also pose a significant safety problem. In particular, any activities that are carried out in the mine contaminated areas pose a significant risk to human life and to material assets. It is estimated that removing all the mines present in the Republic of Croatia would cost approximately 1,157 billion US$ and would require 10 years of intensive work. Therefore, it is necessary to establish an order of priorities for mine removal, assessing which territories offer the greatest potential benefits if the mines are removed and normal activities can be resumed thereon. Clearly, such territories should be de-contaminated first. This paper describes a model aimed at determining the objective priorities to reduce the risks stemming from mine contamination. The model is based on a combination of GIS analysis and a multicriteria method. Further, the model incorporates the views of all interested parties, i.e. the representatives, whether public or political, of the contaminated territories.
1 Introduction

Croatia, as many other countries around the world, is contaminated with mines, pernicious weapons that go on killing a long time after a war has ended. Mine victims are mainly civilians that become injured or killed many decades after the weapons have become silent. In view of the fact that the number of victims, scale of destruction and costs of solving the problem brought about by mines could be compared to the biggest-scale ecological disaster, mines might be regarded a weapons that leaves behind the most horrible consequences. Antipersonnel mines have been designed in such a way that they do not kill but inflict heavy injuries, causing tremendous suffering to people. In addition to human suffering, mines bring about disastrous humanitarian, social and economic losses. The areas contaminated with mines become unavailable and fertile land remains uncultivated and useless.

The Republic of Croatia, facing this huge problem, has decided to start solving it immediately. Croatia, promoting the ban of use, production, stockpiling and transfer of antipersonnel landmines, has been among the first countries to sign the Ottawa Treaty. It has decided to assist mine victims and to demine its territory, which is the only way to avoid future victims among civilians.

One of the biggest obstacles in demining and mine victims assistance is lack of resources. Demining is extremely time-consuming and expensive, and Croatia, war-torn and full of economic problems, may not carry it out on its own.

The problems of mine contamination in Croatia poses one of the biggest obstacles to the overall economic and other progress. The aim of mine action in Croatia is to return mine suspected areas to their previous use, using existing and future demining technologies, until the year 2010. It is estimated that removing all the mines present in the Republic of Croatia would cost approximately 1,157 billion US$. They also pose a significant safety problem. In particular, any activities which are carried out in the mine contaminated areas pose a significant risk to human life and to material assets.

2 Problem description

Croatia is one of the ten most mine contaminated countries in the world. The realistic estimation is that about 1 million mines have been laid in Croatia. The mine suspected areas are estimated to cover of 4000 km². About 500 km² are covered with minefields, while the rest of the area is contaminated with individual explosive ordnance. Mine suspected areas and minefields are located in 14 of 21 counties. Great problems are caused by the fact that not all minefields are marked or consistent, and a number of mines have unknown locations, they are not registered, they have been planted by non-professionals, or they have moved due to weather conditions and erosion. There is also a big problem with a large number of unexploded ordnance (UXO).

In view of the above mentioned problems caused by mines, it is clear that main goal is to demine the Croatian territory as soon as possible, thus eliminating all present risks.
In the meantime it is necessary to evaluate areas contaminated with mines, which demining will have the biggest positive influence on lowering risk for human life and to material assets, refugees’ return, revitalisation of economic and social life, having, at the same time, less possible costs and more possible safety.

As there were evident interest conflicts and local political pressure, the intention was to develop methodology that would make decision process of the optimal policies for risk reduction more objective and based on real parameters. In order to achieve such objective a pilot project for the most endangered county was launched with the intention of establishing effective methodology and showing the possibility for real application on the other areas.

3 Pilot-project for “Sisacko-moslavacka County”

Regarding available data and actuality of humanitarian demining problem it is decided that pilot project took place in “Sisacko-moslavacka County”, and communities of the County would be treated as homogenous zones (areas) that would be ranged according to the agreed criteria.

According to the available parameters on the area of “Sisacko-moslavacka County” it was registered 640 minefields. By terrain surveying as well as by identification of suspicious areas a digitalised database was created containing all mine contaminated and suspicious areas with 72 polygons on 11 communities in total. Regarding the fact that all aforementioned polygons were not homogenous, and it was not possible to make them homogenous by applying some simple procedure, it was decided that being part of the certain community should be a criteria for polygon joining, i.e. for forming of set of actions (projects) that would be ranked, i.e. analysed by applying multicriteria analysis in order to determine an optimal policies for risk reduction. Such approach is reasonable, because communities are the smallest territorial and political units that are involved in the evaluation of optimal policies for risk reduction.

According to the project demands and in order to ensure all relevant data and enable straightforward generating of more generic data, GIS containing various thematic layers was created. ArcView and some other ESRI tools that enable more complex spatial data analysis were used. Analysing the problem following problem characteristics were evaluated:

- High demining price
- Conflict of interests
- Hierarchic nature of the problem (several solution levels)

Within the project the objectives were defined, too:

- Establishment of more objective criteria for the evaluation of demining priority, i.e. optimal policies for risk reduction
- Gathering of all relevant data
- Modelling of the decision process that is acceptable to the most of the groups which, generally, have conflict interests
- Involvement more groups in the decision process
Figure 1: Position of "Sisacko-moslavacka County" in Croatia and Europe

As the solving methodology the following compromised steps are worked out:

- System approach in problem characteristics definition
- Providing of relevant data for numerical process by Geographic Information System (GIS)
- Modelling of the decision process
- Multicriteria analysis for making objective of the subjective demands (approaches)

According to the fact that during evaluation of the optimal policies for risk reduction, several groups are involved in the decision process, the activities in the process of problem solving were defined:

- Defining of the characteristics, namely, of the set of the activities and set of the criteria (problem scope definition)
• Bringing together the sets of action and criteria with "partners" in the decision process (it is usual to add some of the criteria due to the partner insisting, during the group decision making)
• Definition of the criteria weight and preference types for each criterion
• Bringing together (negotiating) criteria weights in the iterative process
• Definition of the alternative scenarios of the criteria weight assessment, assessing more weight to the certain criteria group
• Model (numerical) problem solving and presenting of numerical and graphical results of ranked actions (of mine contaminated areas) by PROMETHEE method (Preference Ranking Organisation METHod for Enrichment Evaluations)
• Sensitivity analysis, namely, stability checking of the set of the criteria weight scenarios
• Usage of GAIA (Geometrical Analysis for Interactive Aid) method for the visualisation of the problem characteristics via geometrical representation
• Presenting of the multicriteria analysis results to the participants in decision making process, as well as, numerical solving of the additional scenarios (criteria weights variations as the results of negotiation)
• Elaboration of multicriteria analysis results including verbal and graphical interpretation of the obtained ranks

Figure 2 shows a schematic procedure, which contains GIS analysis as a first step, and evaluation of relevant criteria presented as thematic layers. For the criteria that can be spatially presented, using GIS analysis, concrete numerical values as input for multicriteria analysis are being evaluated. For the criteria that cannot be generated by GIS analysis, an expert team evaluation and mathematical estimation are being performed. For example, by using data from 'mine records' from both parties involved in the war conflict, it is estimated that on the territory of this County was posed 30.506 mines, 24.887 of which can be identified on the already known mine fields in 8 communities (Table 1). For 5.623 mines location is not known, so the most possible solution is that they are posed on the territory of 11 mine endangered communities, or less possible on the territories of other communities in the County that, up to date, are not contaminated with mines.

Figure 3 shows a part of the layout displaying density of the identified mines at the polygons that are defined according to their presence in the certain community.

Figure 4 shows the territory that presents possible contact of population and mine explosive ordnance. Obtained area presenting an "objective estimated risk" for domestic population is calculated by multiplying the number of inhabitants of settlement that is within, or on, the border of suspected mine areas with average population density on the study area. Mine accident risk on the present infrastructure is calculated indirectly as well, i.e., around digitalised installation infrastructure a 100m both-sided buffer is determined, and after that by implementation of geoprocessing function an intersection area of mine fields and
infrastructure installation is determined. In the similar manner, for the mine contaminated areas of each 11 analysed communities the values of estimated risk for other criteria are evaluated (roads, agriculture areas, forests, parks of nature, etc.).

**CRITERIA USED IN GIS ANALYSIS:**

- Layout of mine risk in parks of nature, etc.
- Layout of mine risk in forest
- Layout of mine risk of energetic and telecommunication infrastructure
- Layout of mine risk on agriculture fields
- Layout of mine risk of water supply systems
- Layout of mine risk on roads
- Layout of density of located mines
- Population on mine contaminated areas
- Mine contaminated areas
- Communities
- Topology map

Figure 2: Layout of the methodology for optimal policies for risk reduction in mine contaminated areas
During multicriteria analysis for each of the criteria the weights were assigned by stakeholder involved in the decision process. Namely, it is important to involve representatives of social and political associations from the communities' territory, which are included in the priority ranking, in order to obtain results that would be accepted by them as optimal ones.
For the numerical part of multicriteria analysis, namely, methods PROMETHEE and GAIA (Geometrical Analysis for Interactive Aid), "Decision Lab 2000" is used. It is commercial name of software distributed by "Visual Decision" from Canada. Contemporary architecture of this software, based on the "Decision Support System" (DSS) enables very comfort work and very wide support to the decision-making processes.

Large number of information most of which is possible to visualise (graphs, various coloured diagrams) gives a complete insight to the decision-maker into the problem characteristics and possible results of various problem solving scenarios.

Table 2 presents results of the numerical analysis by PROMETHEE method, i.e. evaluated ranks that presented optimal policies for risk reduction in mine contaminated areas (presented results are not final optimal solution).

Achieved synthetic parameter "Phi" presents valorisation of total risk based on defined criteria and weighting coefficients. Table 2 shows that community Slunj is ranked first and represents demining priority, because total risk of 0.5364 dominates after second ranked community Petrinja with Phi value of 0.3077.

Follow the ranks of other communities to the last one, community Gvozd with negative priority value Phi -0.2397.

Figure 5 shows layout of the relations between criteria obtained by GAIA software, namely by application of principal component analysis for Phi values.
for each criteria. Insight into the criteria relations is very important for problem understanding and recognising correlation between different UXO risk parameters.

Table 2

<table>
<thead>
<tr>
<th>COMMUNITIES</th>
<th>Phi Plus</th>
<th>Phi Minus</th>
<th>Phi Net</th>
<th>Ranking</th>
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<tbody>
<tr>
<td>DVOR</td>
<td>0.1830</td>
<td>0.1537</td>
<td>0.0293</td>
<td>4</td>
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<tr>
<td>GLINA</td>
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<td>0.1470</td>
<td>-0.0391</td>
<td>5</td>
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<tr>
<td>DUBICA</td>
<td>0.0657</td>
<td>0.1797</td>
<td>-0.1140</td>
<td>7</td>
</tr>
<tr>
<td>PETRINJA</td>
<td>0.3888</td>
<td>0.0810</td>
<td>0.3077</td>
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</tr>
<tr>
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<td>0.1558</td>
<td>-0.0514</td>
<td>6</td>
</tr>
<tr>
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<td>0.5364</td>
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</tr>
<tr>
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</tr>
<tr>
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<tr>
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<td>0.0547</td>
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<tr>
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<tr>
<td>GVOZD</td>
<td>0.0003</td>
<td>0.2401</td>
<td>-0.2397</td>
<td>11</td>
</tr>
</tbody>
</table>

Figure 5. Geometrical presentation of the relations between criteria is shown by GAIA method.
Multicriteria analysis of humanitarian demining action in the “Sisacko-moslavacka County” pointed out lots of methodological, social and political advantages of this approach to the real and complex problem.

The procedure of choosing the optimal policies for risk reduction in mine contaminated areas using GIS analysis and multicriteria analysis, if it is correctly implemented, demands collaboration of social and political authorities and practically involves all interested parties, which are numerous in the human demining problem. Namely, between "small" farmer, whose backyard is contaminated, and county and community councils, forums and representatives, there are several levels that are directly or indirectly exposed to the mine accident risks. All of them, more or less, expect that their problem should be treated as priority one, so their involvement in the decision process lowers tensions and partly removes frustrations because of problem solving prolongation. On the other side, insight in the priority evaluation procedure, regarding to the objectively evaluated risk level, creates trust climate and firms standpoint that priorities are evaluated properly because they are involved in the process. Transparency of the available data that are base for the analysis is very important because everyone can check whether "his" parameters are correctly evaluated.

Therefore, Decision Lab 2000 software has various options for post-analysis and "what-if" simulation estimation (such as “Walking Weights" option) in order to eliminate subjectivity that is always present during risk evaluation.

References


www.visualdecision.com/PROMETHEE