GIS-based concept for multi-criteria approach in the management of the landmines and UXO clearance

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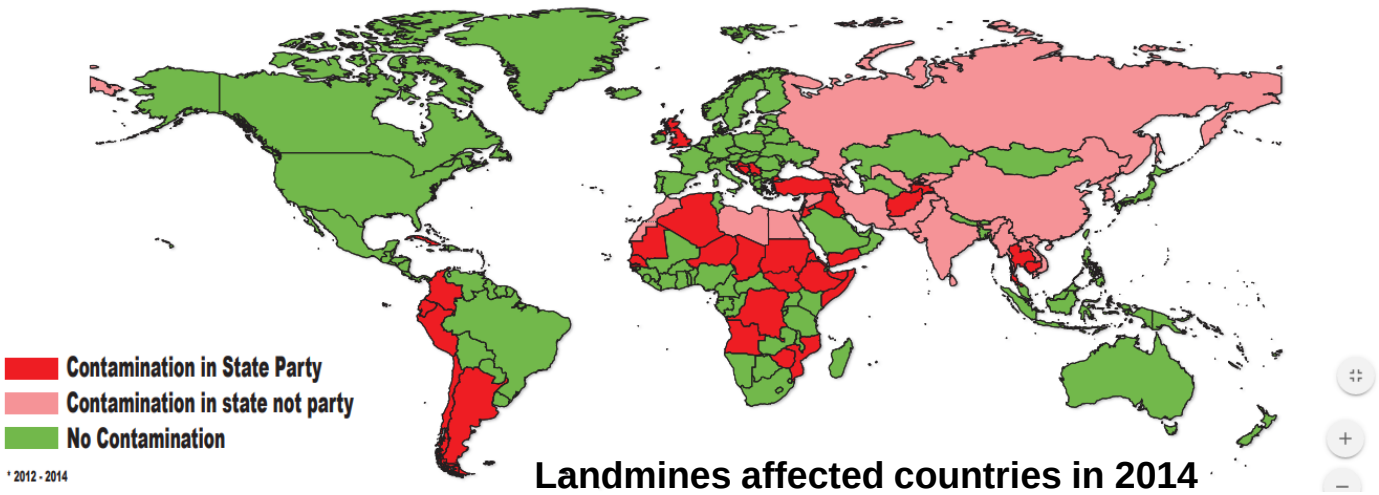
Introduction

- Today, the **landmines and unexploded ordnance (UXO) still represent a daily threat** in some parts of Afghanistan, Angola, Bosnia, Cambodia, Croatia, Iraq, Mozambique, Nicaragua, Somalia, and other countries.
- These devastating post-war effects are **terrible as a war itself**.
- The **agriculture, infrastructure, industry** and even a **tourism are suffering** due to threat of landmines and UXO.



Landmines affected countries in 2014

Introduction

- It was expected for **Croatia** to became the landmines-free country till 2019, but now this has been **prolonged till 2028**!

- **412 km²** are still mine suspected areas with about **39.000 landmines**!
- In 2016, three people working in demining projects were killed by deadly bouncing mine PROM-1.
- Most of the landmines in Croatia are bouncing mines!

Mine Action research

- **Mine Action programs** represent efforts to raise mine awareness, i.e. to educate population, to have effective mine survey and **prioritization of the areas for clearance programs**, and to successfully manage the mine clearance programs.
- The financial shortage usually triggers a **need for priority setting** in the management of the Mine Action programs.
- In this research prioritization of mine action projects using **Multi-Criteria Analysis (MCA)** based on **Geographic Information System (GIS)** and **simplified PROMETHEE method** is presented.
- GIS is used to **create spatial homogenous zones** which represent mine affected areas for priority selection.
- A specialized **tool for customized MCA** has been developed and validated, as a part of **FP7 Project TIRAMISU**.

Mine Action research in Croatia

- In Croatia, over the past fifteen years, a priority setting **using Multi-Criteria Analysis (MCA) coupled with Geographic Information System (GIS)** has been deployed in mine-action management
- While using MCA two issues have been noticed as a problematic:
  - **Problem of collecting the input data** – some of the data are spatial data (area, terrain characteristics, vegetation, infrastructure, etc.) and some of the data are non-spatial data (cost, number of victims, socio-economic impact, etc.)
  - **Problem of defining criteria set** – represents broad number of issues like defining criteria set (economical, technical, social, etc.), decision-maker's preferences (some kind of thresholds or reference points), and criteria weights

PROMETHEE method

- In this research, **PROMETHEE method** was chosen for Multi-Criteria Analysis (MCA)
  - An input for PROMETHEE method is a matrix consisting of set of potential alternatives (actions) A, where each a element of A has its $f(a)$ which represents evaluation of one criteria
  - Method PROMETHEE I ranks actions by a partial pre-order
  - PROMETHEE II method which **ranks the actions by total pre-order** calculating net flow

PROMETHEE method

Input → Black box → Output

An input is a matrix consisting of set of **potential alternatives** (actions) A, where each a element of A has its $f(a)$ which represents evaluation of one criteria:

	$f_1(.)$	$f_2(.)$	.....	$f_j(.)$	.....	$f_k(.)$
a_1						
a_2						
...						
a_i				$f_j(a_i)$		
...						
a_n						

Method **PROMETHEE I** ranks actions by a **partial pre-order**, with the following dominance flows:

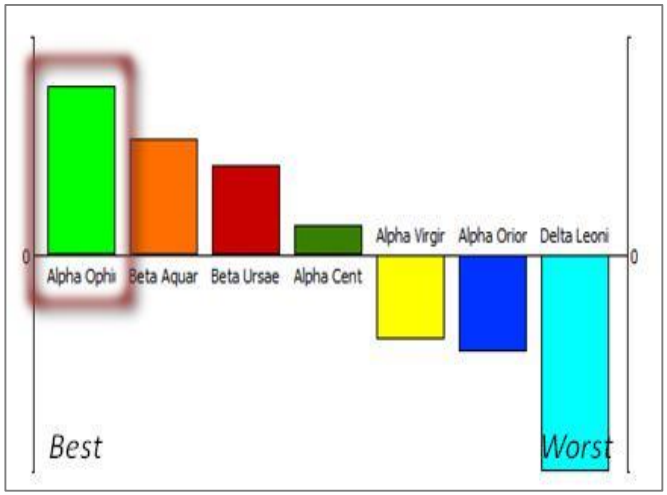
$$\Phi^+(a) = \frac{1}{n-1}\sum_{x\in A}\pi(a,x)$$

$$\Phi^-(a) = \frac{1}{n-1}\sum_{x\in A}\pi(x,a)$$

Method **PROMETHEE II** ranks the actions by **total pre-order**:

$$\Phi\ (a) = \Phi^+(a) - \Phi^-(a)$$

An output is set of **ranked alternatives** (i.e. demining priorities):



Simplified PROMETHEE method

- There are two issues that make PROMETHEE method **hard to understand for non-expert users**:

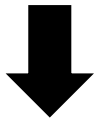
The interpretation of the **results** in **[-1, 1] interval**

Defining of the preference function and its **parameters**

Simplified PROMETHEE method

- However, **net flow** Φ of PROMETHEE II method can be a little bit modified to produce **the output in [0, 1] interval**, instead of [-1, 1] interval
- It is a, so-called, **net score** Φ':

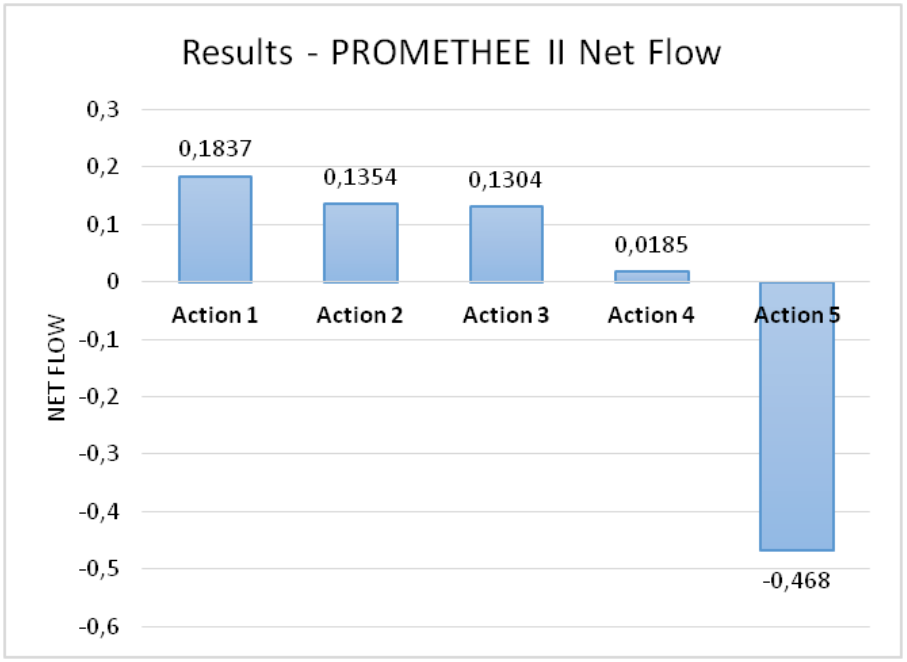
$$\Phi\ (a) = \Phi^{+}(a) - \Phi^{-}(a)$$

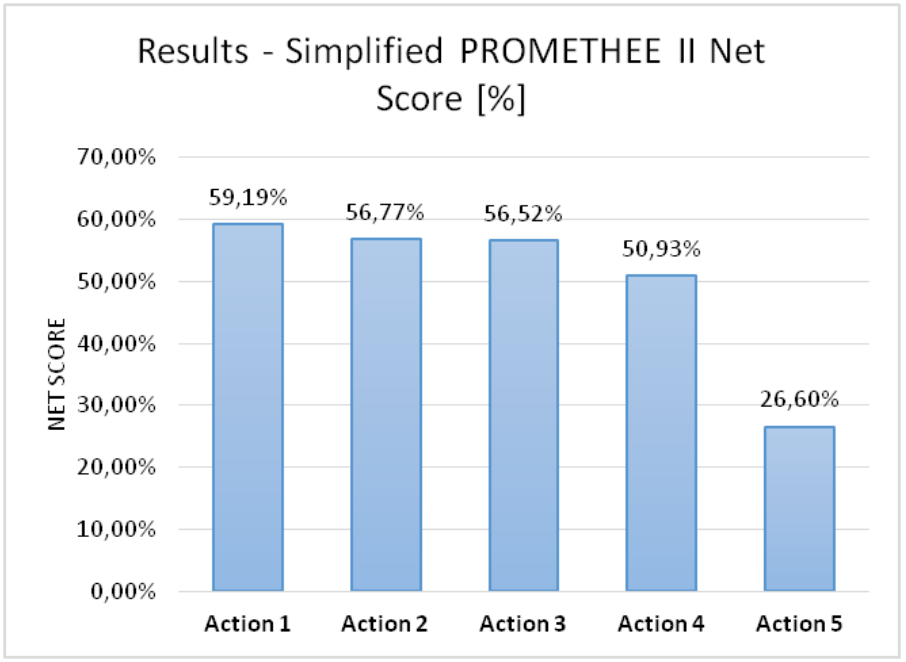


$$\Phi^{'}(a) = \frac{\Phi^{+}(a) + (1 - \Phi^{-}(a))}{2}$$

Simplified PROMETHEE method

- A comparison of the **net flow** Φ and the **net score** Φ' [%]:





- *Note:* **Action 5** with a **negative net flow** has a **net score below 50%**, which is also a synonym for a negative grade (at least in the education system)

Simplified PROMETHEE method

- Next step is to **automatically calculate preference function thresholds**
- It can be achieved by using the linear preference function and two different approaches for thresholds calculation:
  - **'Zero-Max' approach** – set indifference threshold to zero and set maximal difference between criterion evaluations as preference threshold
  - **'Mean-Std' approach** – set difference between mean value and standard deviation as indifference threshold, and set sum of mean value and standard deviation as preference threshold, i.e. mean +/- standard deviation
- The results of simplified PROMETHEE method are **presented on a Case Study** from 'Visual PROMETHEE' software

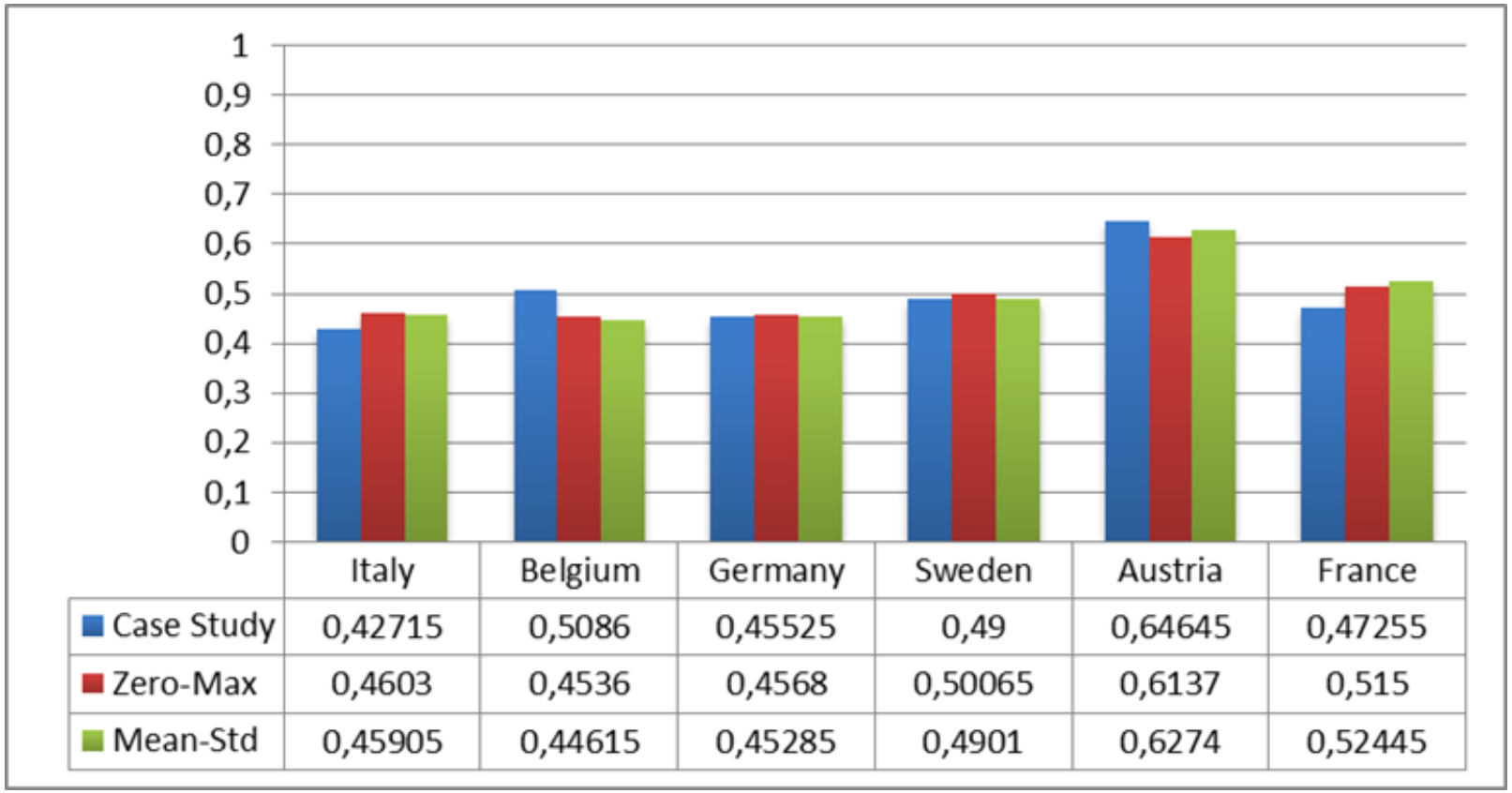
Simplified PROMETHEE method

- Case Study "Power plant location selection" – evaluation matrix:

Criteria name	***Manpower***	***Power***	***Investment***	***Operation***	***Villages***	***Safety***
Criteria weight	1.00	1.00	1.00	1.00	1.00	1.00
Criteria type	*Min*	*Max*	*Min*	*Min*	*Min*	*Max*
'Case Study' preference function	*U-shape* *q = 10*	*V-shape* *p = 300*	*Linear* *q = 50* *p = 500*	*Level* *q = 1* *p = 6*	*Usual*	*Gaussian* *s = 5*
'Zero-Max' preference function	*Linear* *q = 0* *p = 54*	*Linear* *q = 0* *p = 380*	*Linear* *q = 0* *p = 800*	*Linear* *q = 0* *p = 7.7*	*Linear* *q = 0* *p = 7*	*Linear* *q = 0* *p = 9*
'Mean-Std' preference function	*Linear* *q = 14* *p = 39*	*Linear* *q = 107* *p = 299*	*Linear* *q = 202* *p = 528*	*Linear* *q = 1.9* *p = 5.4*	*Linear* *q = 2* *p = 5*	*Linear* *q = 2* *p = 6*
Unit	*personnel*	*MW*	*M€*	*M€*	*villages*	*level*
Italy	80	900	600	5.4	8	5
Belgium	65	580	200	9.7	1	1
Germany	83	600	400	7.2	4	7
Sweden	40	800	1000	7.5	7	10
Austria	52	720	600	2.0	3	8
France	94	960	700	3.6	5	6

Simplified PROMETHEE method

- Case Study results (net score is also used):



	Italy	Belgium	Germany	Sweden	Austria	France
Case Study	0,42715	0,5086	0,45525	0,49	0,64645	0,47255
Zero-Max	0,4603	0,4536	0,4568	0,50065	0,6137	0,515
Mean-Std	0,45905	0,44615	0,45285	0,4901	0,6274	0,52445

- In all three approaches, the **results are very similar**!

Simplified PROMETHEE method

- The conclusions for the simplified PROMETHEE method are:
  - **Usage of net score Φ'** – it is completely all right to use it, since it only interprets PROMETHEE II results in a different interval. The action with a negative net flow has a net score below 50%, which keeps the logic of the "bad" action.
  - **Usage of 'Zero-Max' and 'Mean-Std' approaches** – from mathematical and scientifically point of view, it is completely wrong to use them. However, from a real-world or practical point of view, they are applicable most of the time. The reason is that in the nature there is a harmony and nature likes Gaussian distribution: if the car is fast, it's gas consumption is high; if the product is cheap, it's usually has a bad quality, etc. These facts, together with robustness of PROMETHEE, produce good results with these approaches!

GIS-based concept

- GIS **spatial homogenous zones** on the different levels:

Strategic level

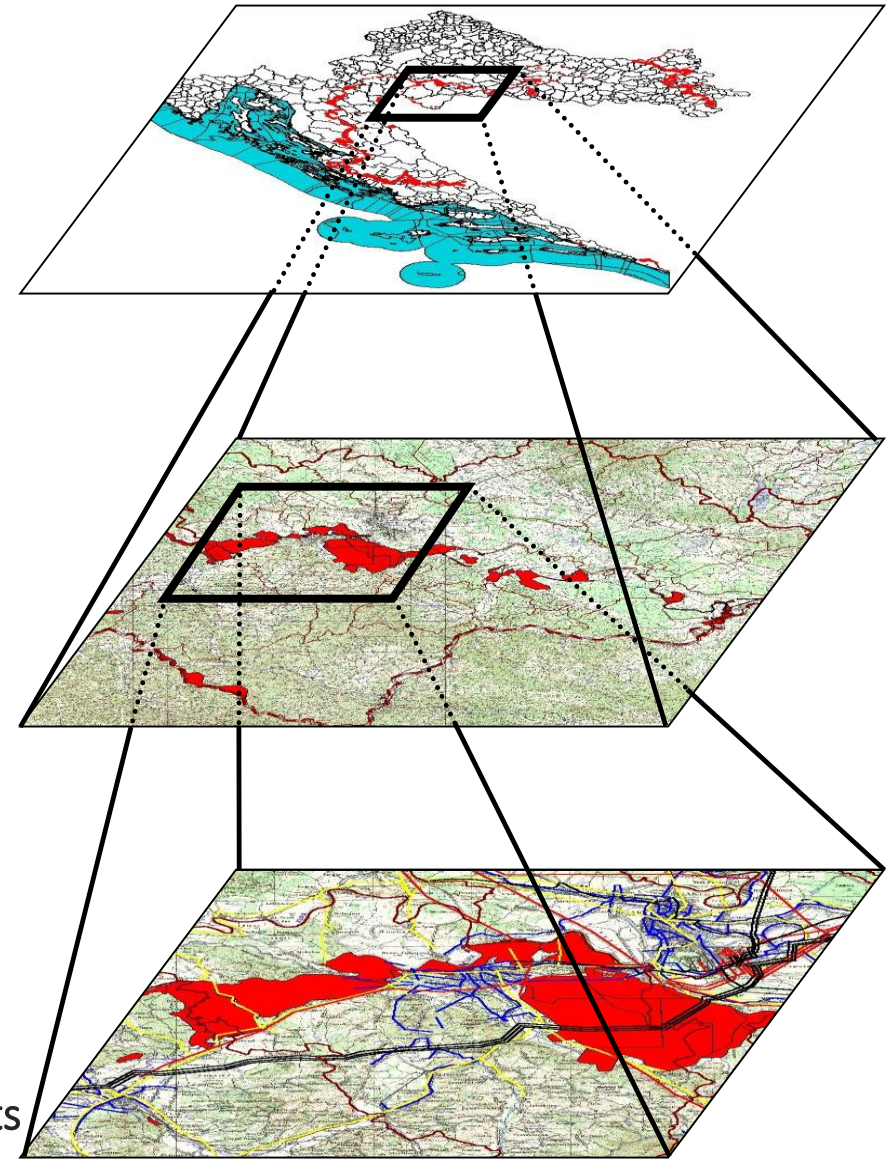
- State level
- Alternatives are **Counties**

Tactical level

- County level
- Alternatives are **Municipalities**

Operative level

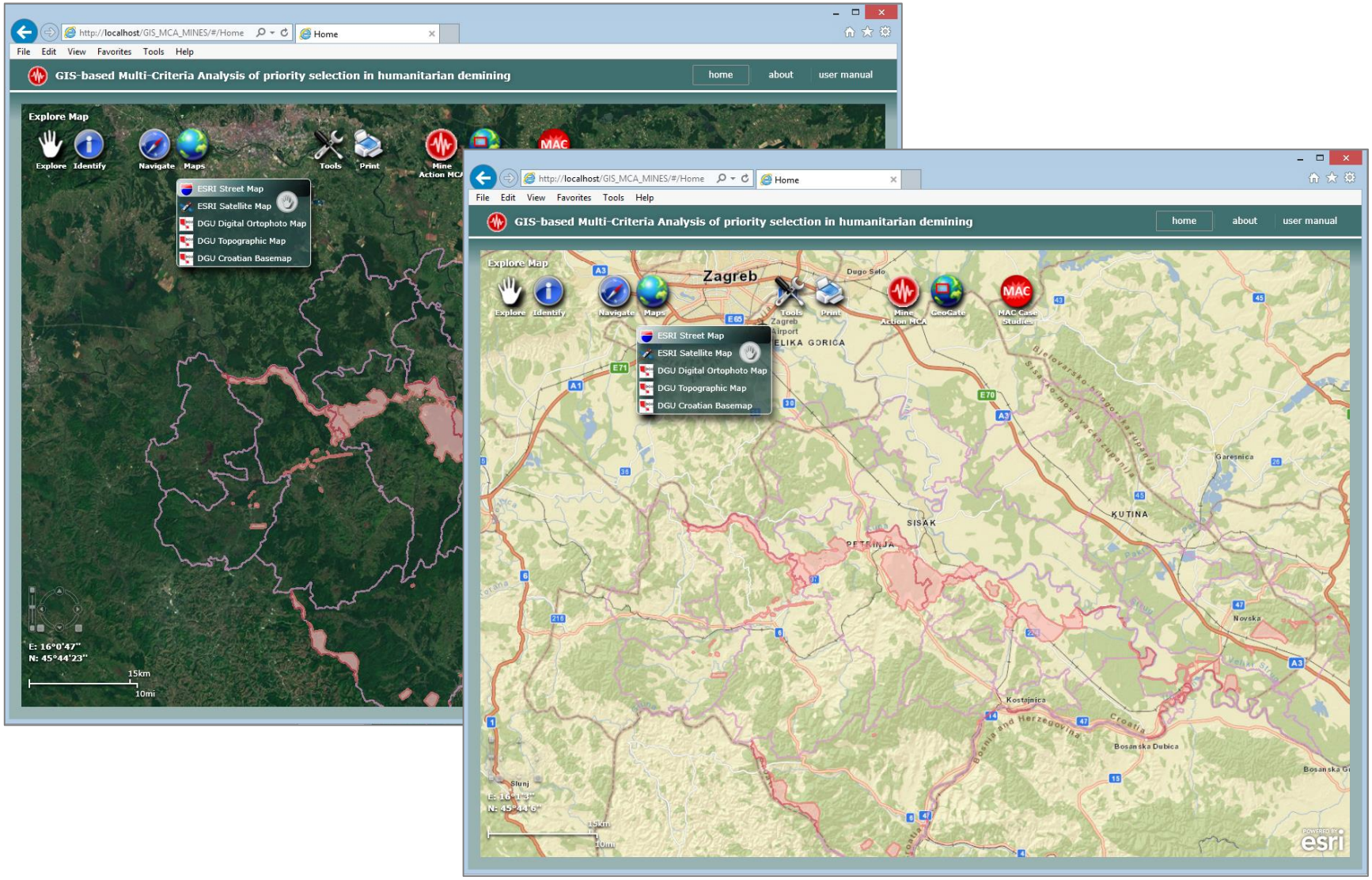
- Municipality level
- Alternatives are **Demining projects**



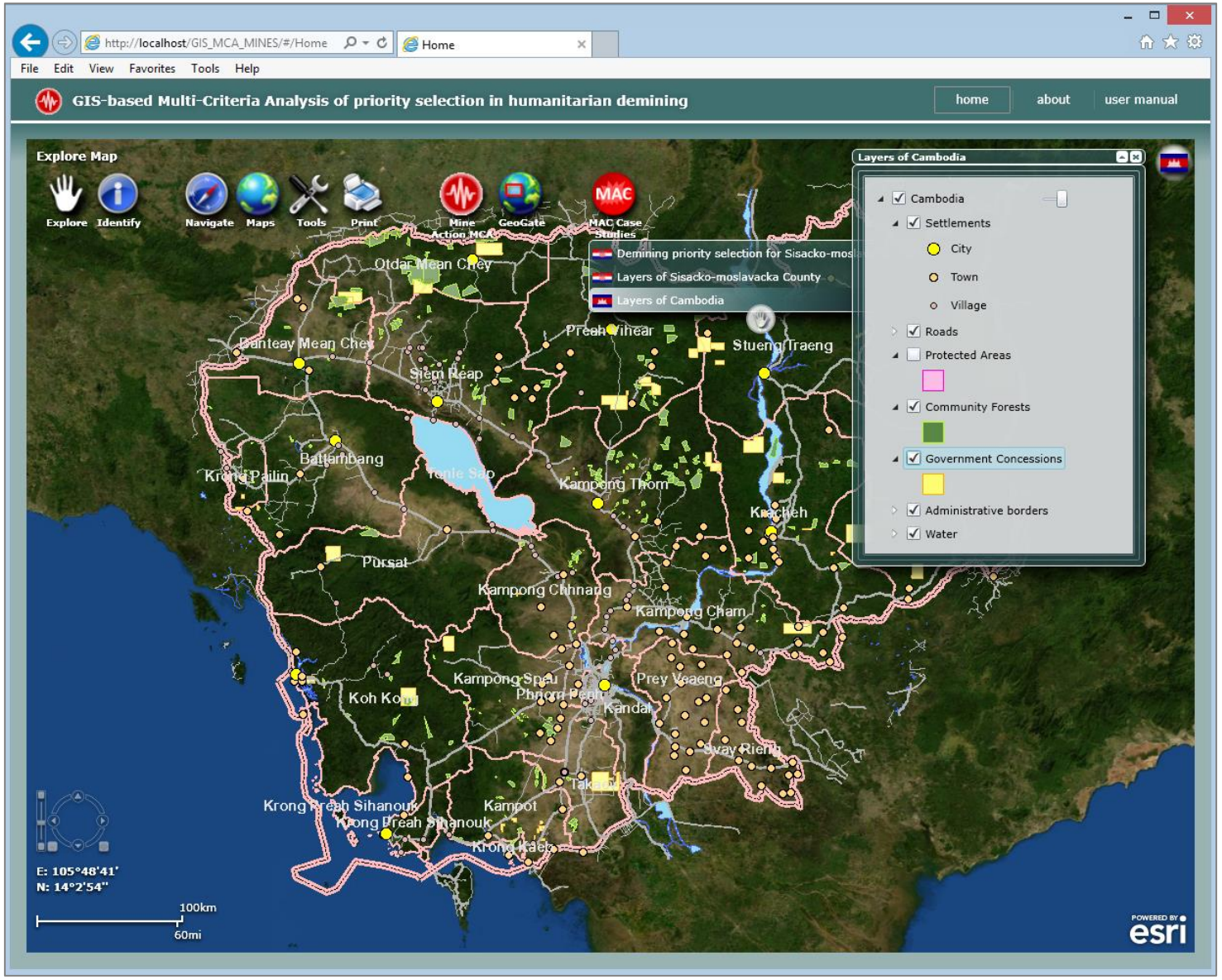
Result: Web-based Decision Support System

- Since several stakeholders, usually dislocated, are included in the priority setting process, a new **Web-based Decision Support System (Web DSS)** has been developed as Web application, as a part of **FP7 Project TIRAMISU**.
- It couples **GIS thematic layers and MCA** making it accessible via friendly user interface to different stakeholders
- Using developed Web DSS **priority setting has become fully transparent** since stakeholders and donors are able to actively join decision making process using on-line Web application
- Additionally, **specialized MCA tool for Mine Action Community** has been developed, based on the **simplified PROMETHEE method**

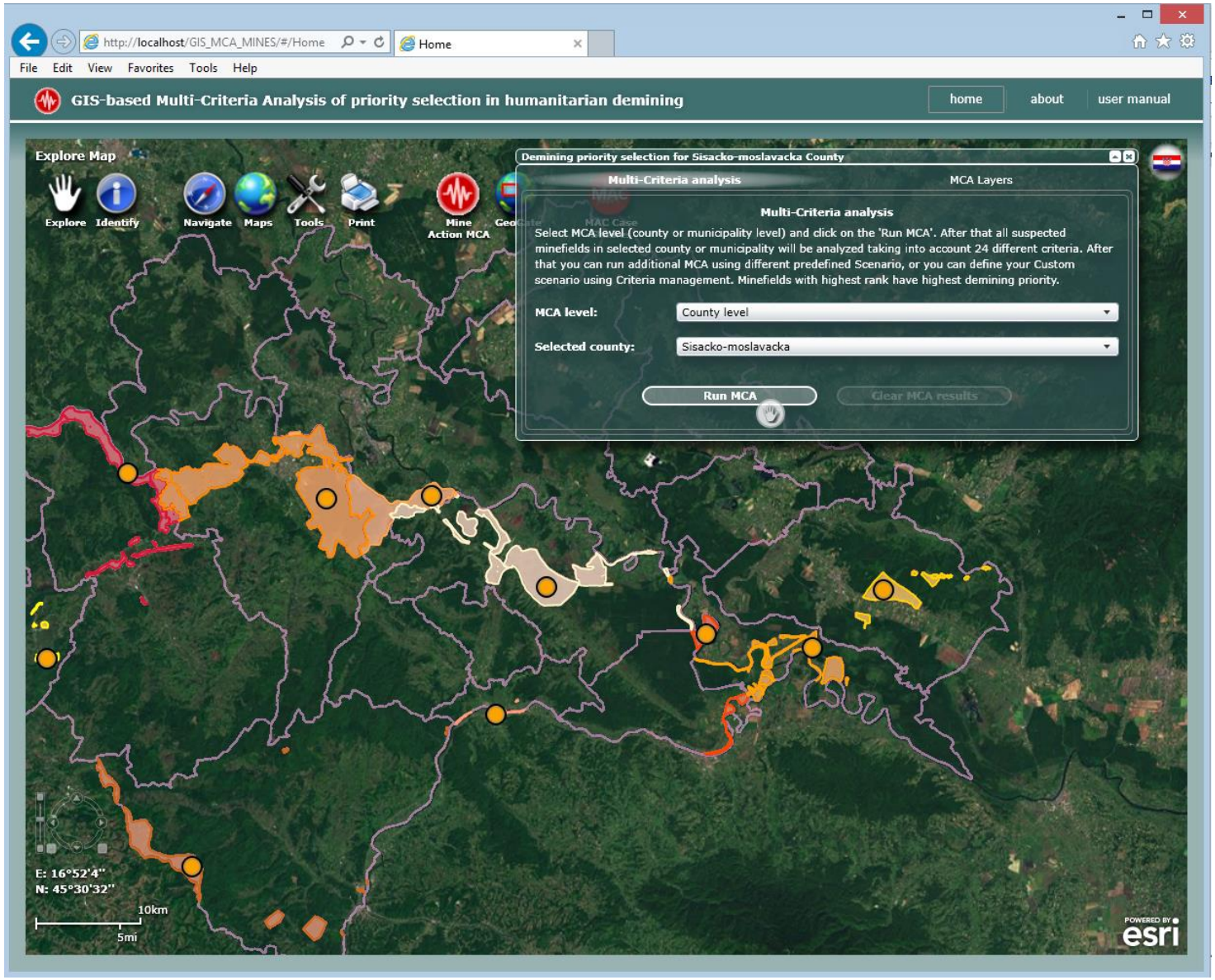
Web DSS: Geographic-Information-System-based



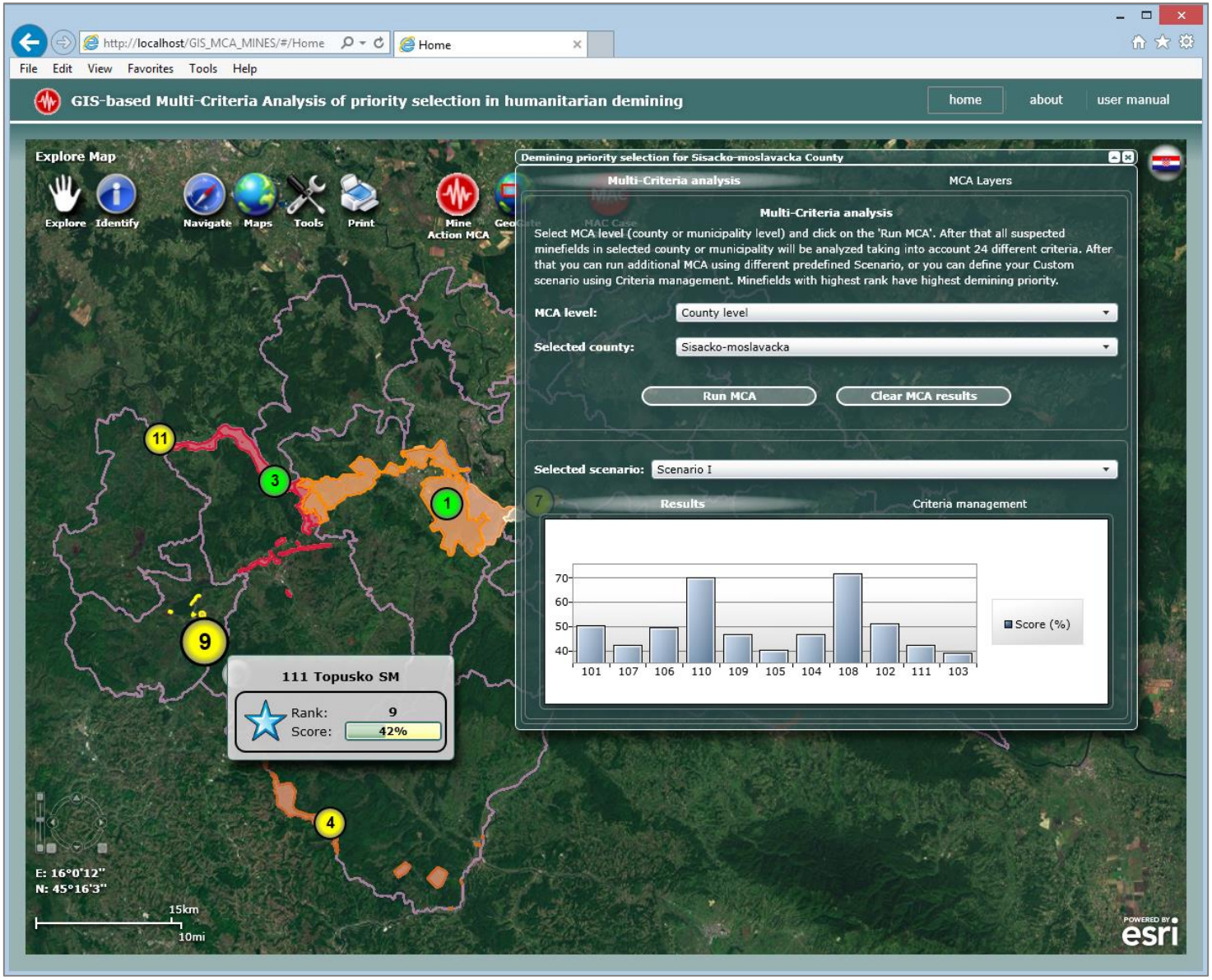
Web DSS: Mine Action Community Case Studies



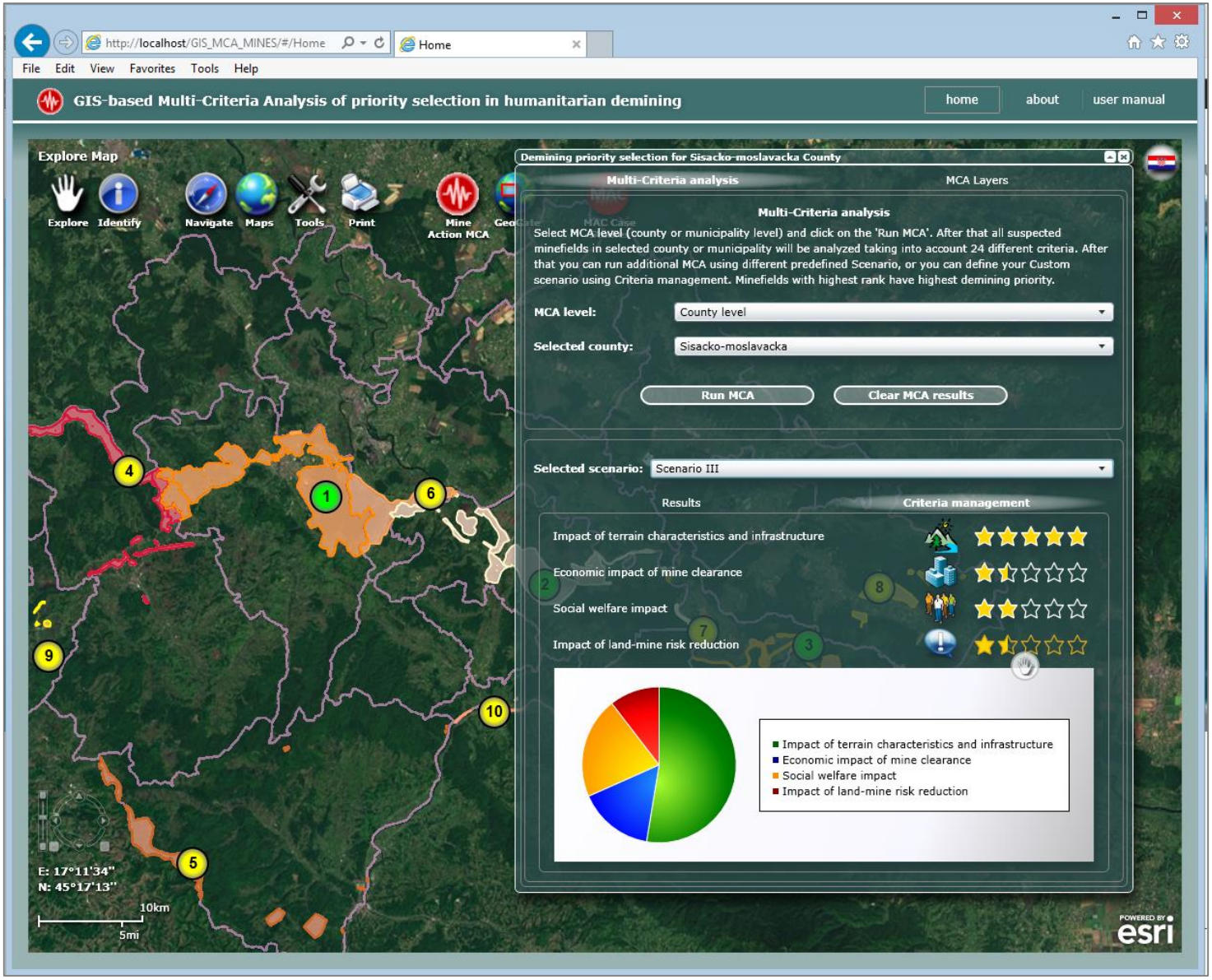
Web DSS: MCA for Case Study in Croatia



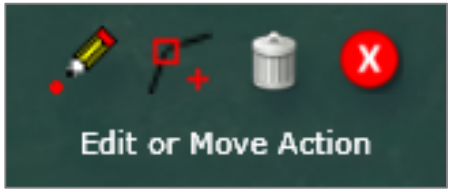
Web DSS: Results of MCA for Case Study in Croatia

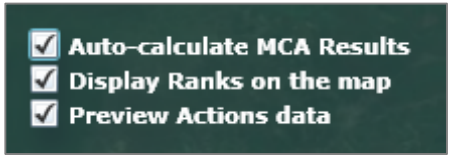


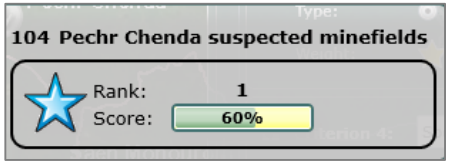
Web DSS: Scenario selection for Case Study in Croatia



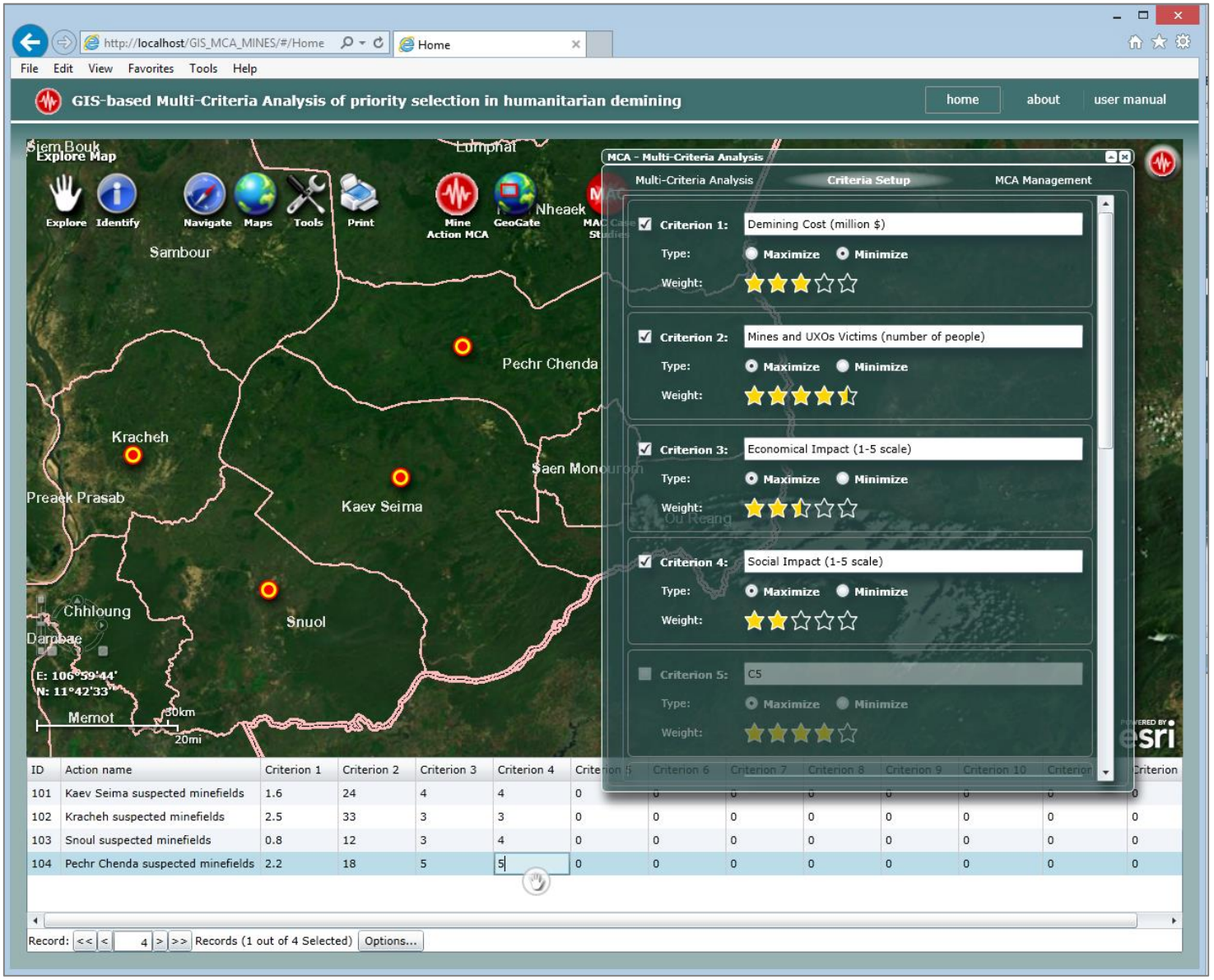
Web DSS: MCA Tool for Mine Action Community







Web DSS: MCA Tool for Mine Action Community



Web DSS: MCA Tool (simplified PROMETHEE) validation

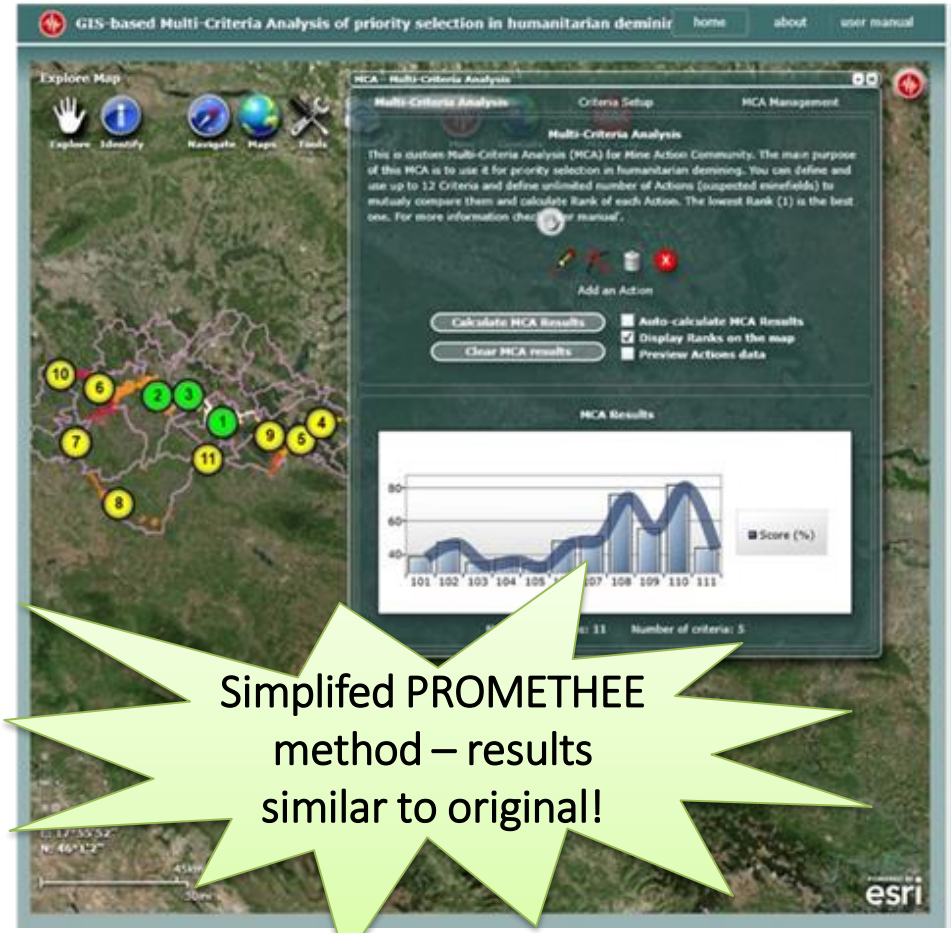
- To validate MCA Tool, i.e. simplified PROMETHEE method, a **historical Case Study** of priority setting is taken.
- The actions from historical Case Study and their evaluations are used as an input to simplified PROMETHEE method.
- The linear preference functions with **'Zero-Max' approach** are used for all criteria.
- New priority setting is made by using developed MCA Tool.
- The **results of the new priority setting** and **historical Case study** are mutually **compared**.
- Although the ranking is a slightly changed, **the results** (net flow and net score) **are very similar**!

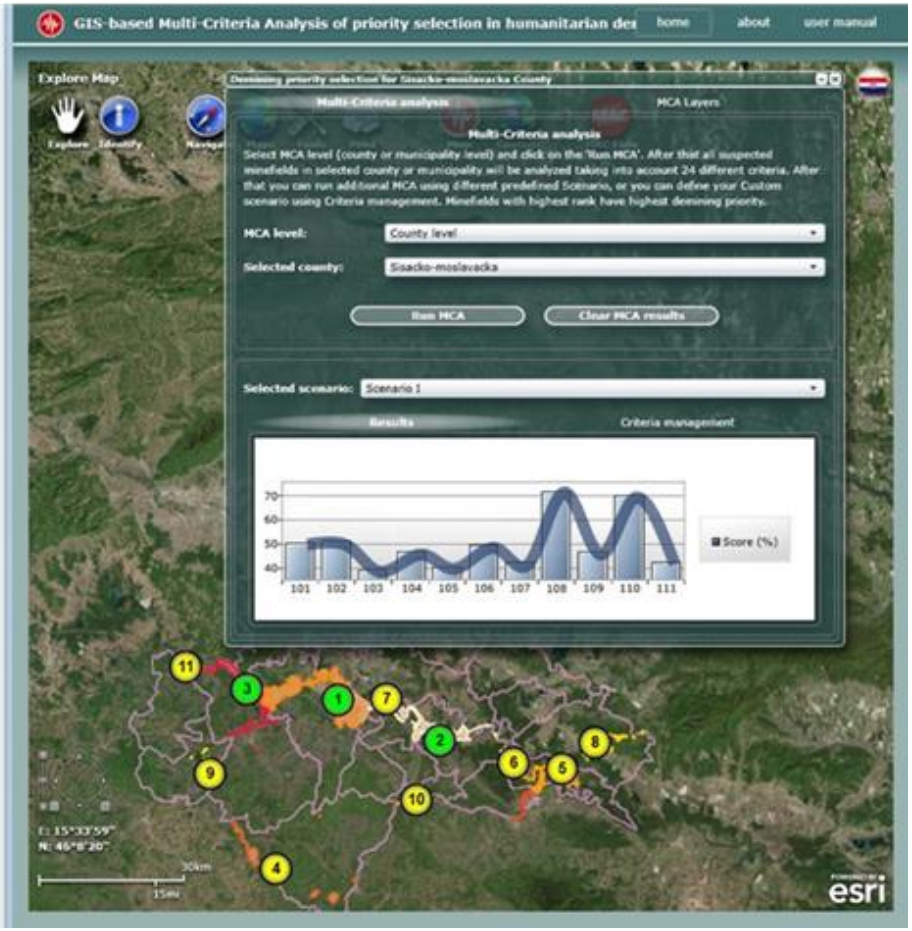
Web DSS: MCA Tool (simplified PROMETHEE) validation

- MCA Tool validation – comparison to historical Case Study:

a) New priority setting using developed methodology

b) Historical Case Study of priority setting





Simplifed PROMETHEE method – results similar to original!

Conclusion

- The **main problems of priority setting** in the management of mine action projects, like defining criteria set, using MCA method, and estimating criteria evaluations, where tackled in this research.
- The **simplifed PROMETHEE method** made MCA understandable **for the non-expert users**.
- General conclusion is that **ranking** of actions (demining projects) **cannot be taken as granted**, but scores of alternatives should also be taken into analysis.
- At the end, scores, not the ranking, could **be used for distribution of demining funds**.
- The further research will be based on tool validation on **more historical case studies** and criteria weights sensitivity analysis.

Acknowledgments

- Research and development of Web DSS “GIS-based Multi-Criteria Analysis of priority selection in humanitarian demining” have been made by **University of Split** in collaboration with the **Croatian Mine Action Center - Center for Testing, Development and Training Ltd**. (HCR-CTRO d.o.o.)
- Developed Web DSS (*http://tiramisu.maps.arcgis.com*) was supported by **FP7 Project TIRAMISU** in the period 2012-2016.
- More than 15 years of research have been published as a book “**Multi-Criteria Analysis for Priority-setting in Mine Action**” (*N. Mladineo, M. Mladineo, S. Knezic; De Gruyter – Sciendo, 2018*)

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