



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

Marko Mladineo

University of Split, Faculty of Electrical Engineering, Mechanical, Engineering
and Naval Architecture

marko.mladineo@fesb.hr

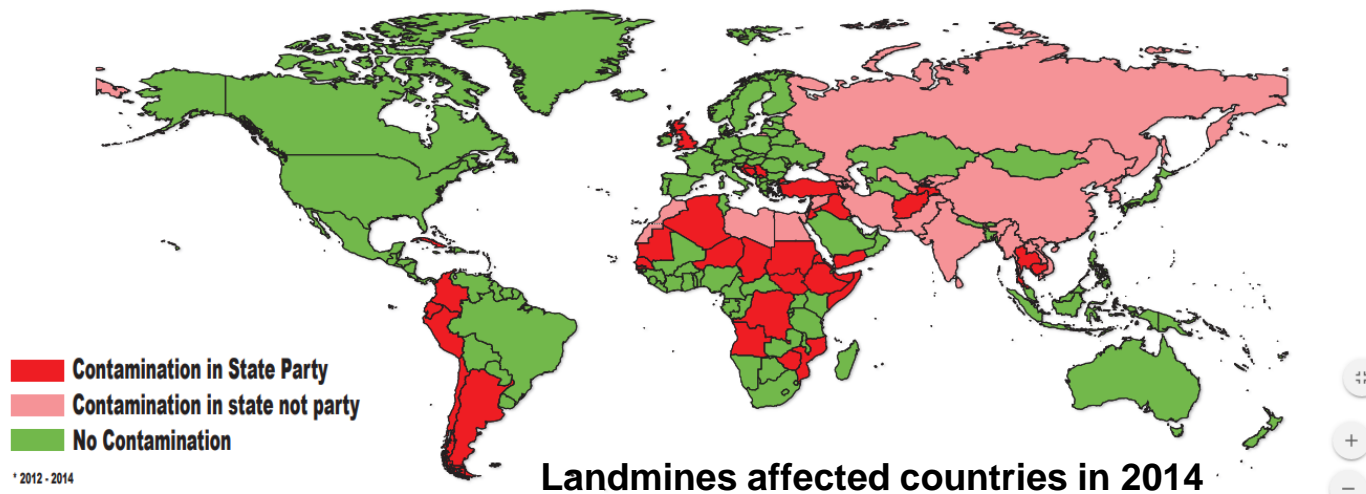
Niksa Jajac, Nenad Mladineo

University of Split, Faculty of Civil Engineering, Architecture and Geodesy

njajac@gradst.hr, mladineo@gradst.hr

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.



Introduction

- It was expected for **Croatia** to become 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!

Minska slika Hrvatske

411,6 km²

minski sumnjivih površina u devet županija, odnosno 60 gradova i općina

39.076 mina

pretpostavlja se da ima na MSP teritoriju u Republici Hrvatskoj



BRODSKO-POSAVSKA *još nije prekontrolirano cijelo područje da se može otpisati, treba biti u siječnju

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



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:

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

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

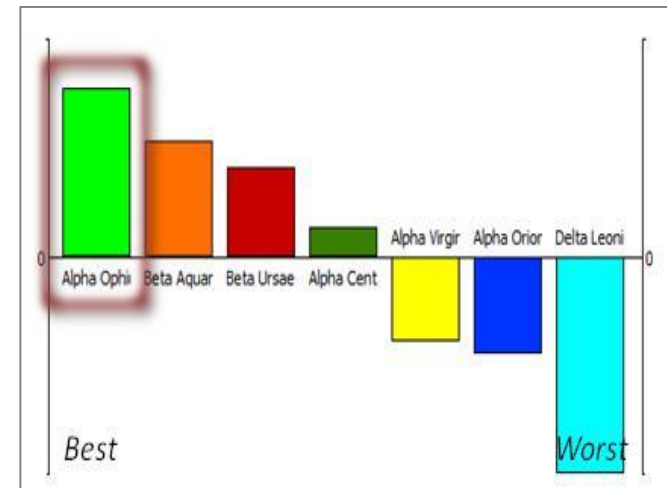
$$\Phi^+(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a, x)$$

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

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

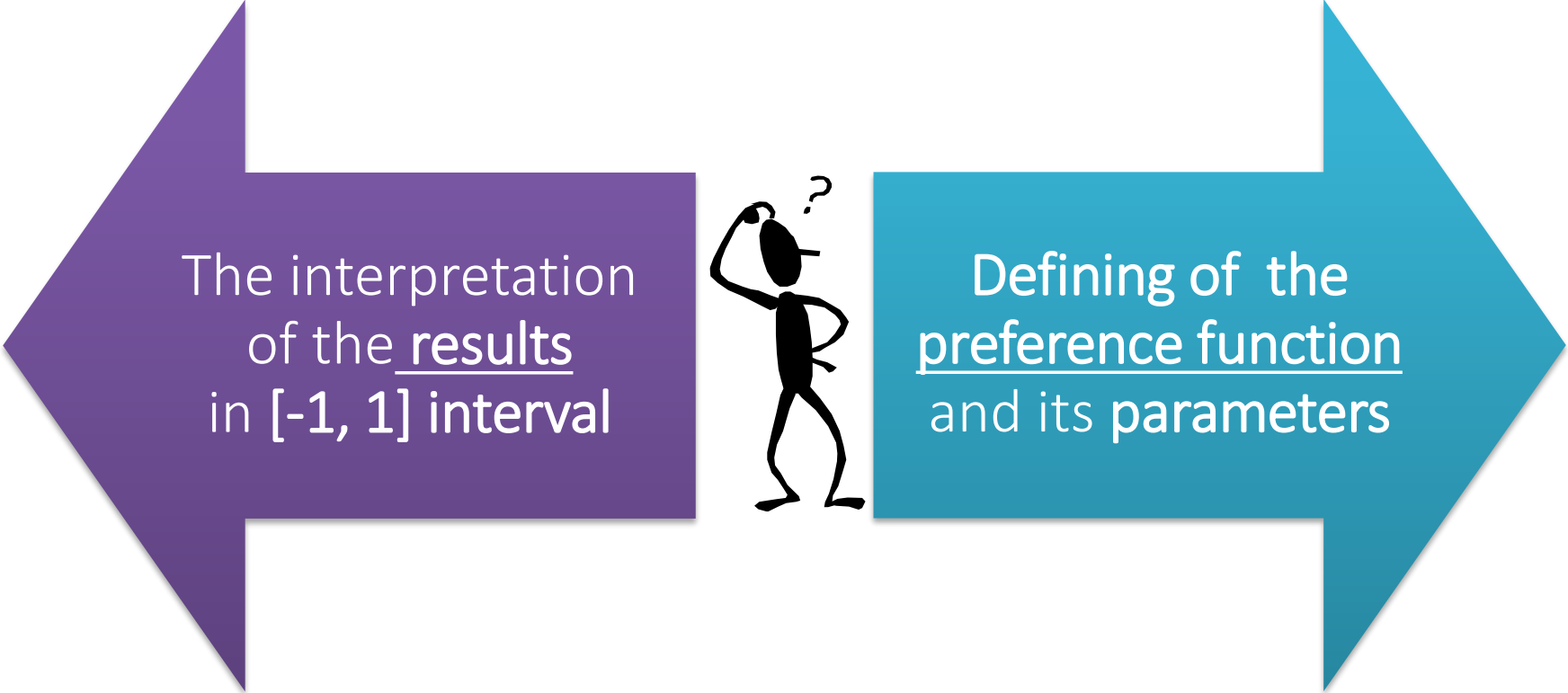
$$\Phi(a) = \Phi^+(a) - \Phi^-(a)$$

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' :

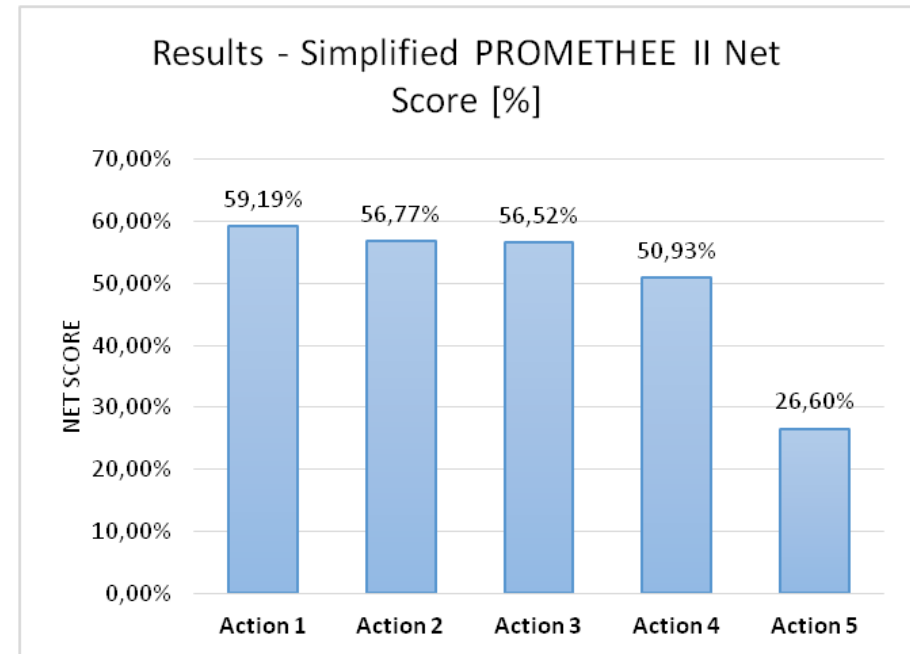
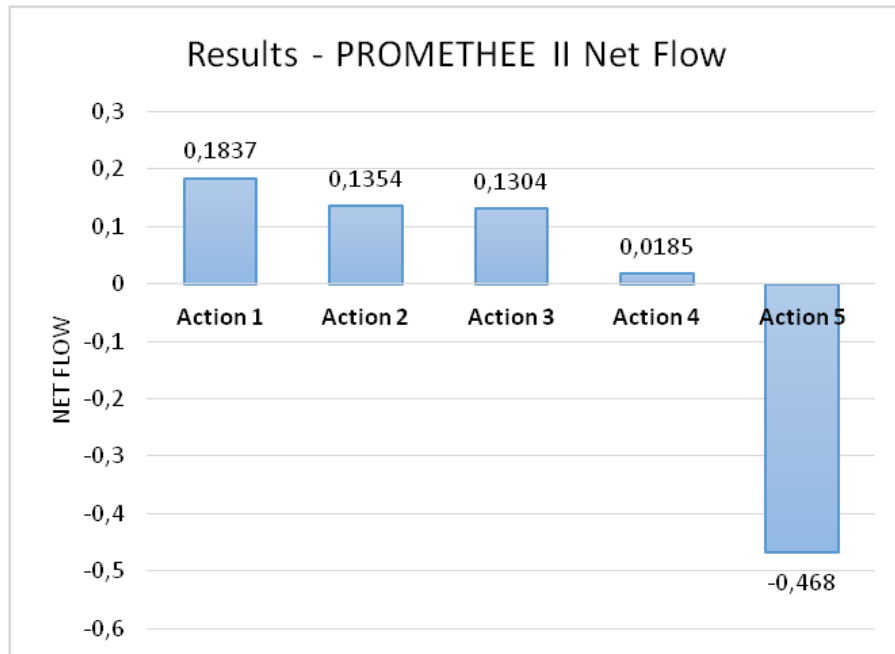
$$\Phi(a) = \Phi^+(a) - \Phi^-(a)$$



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

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

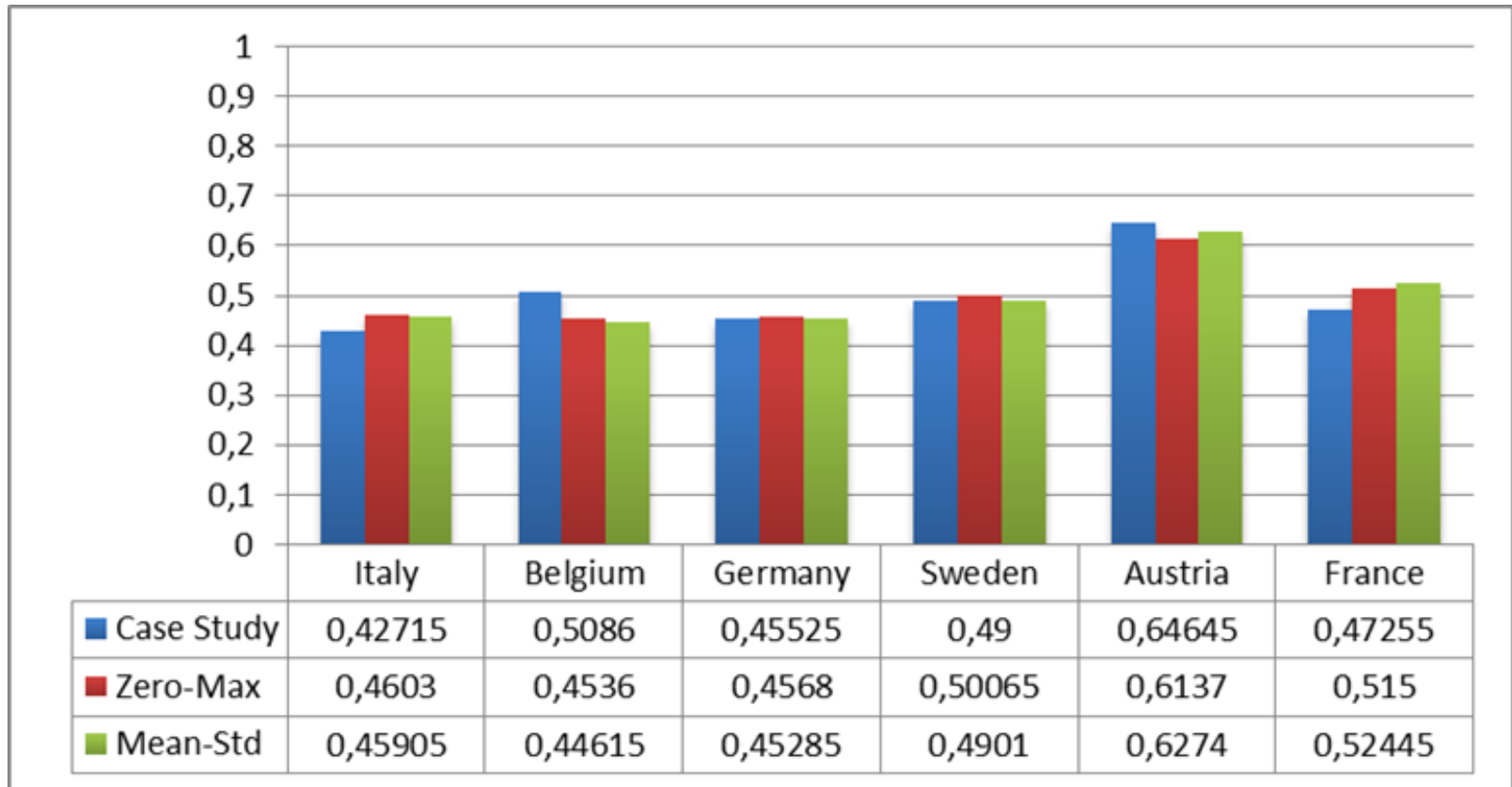
Simplified PROMETHEE method

- Case Study “Power plant location selection” – evaluation matrix:

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

Simplified PROMETHEE method

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



- 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

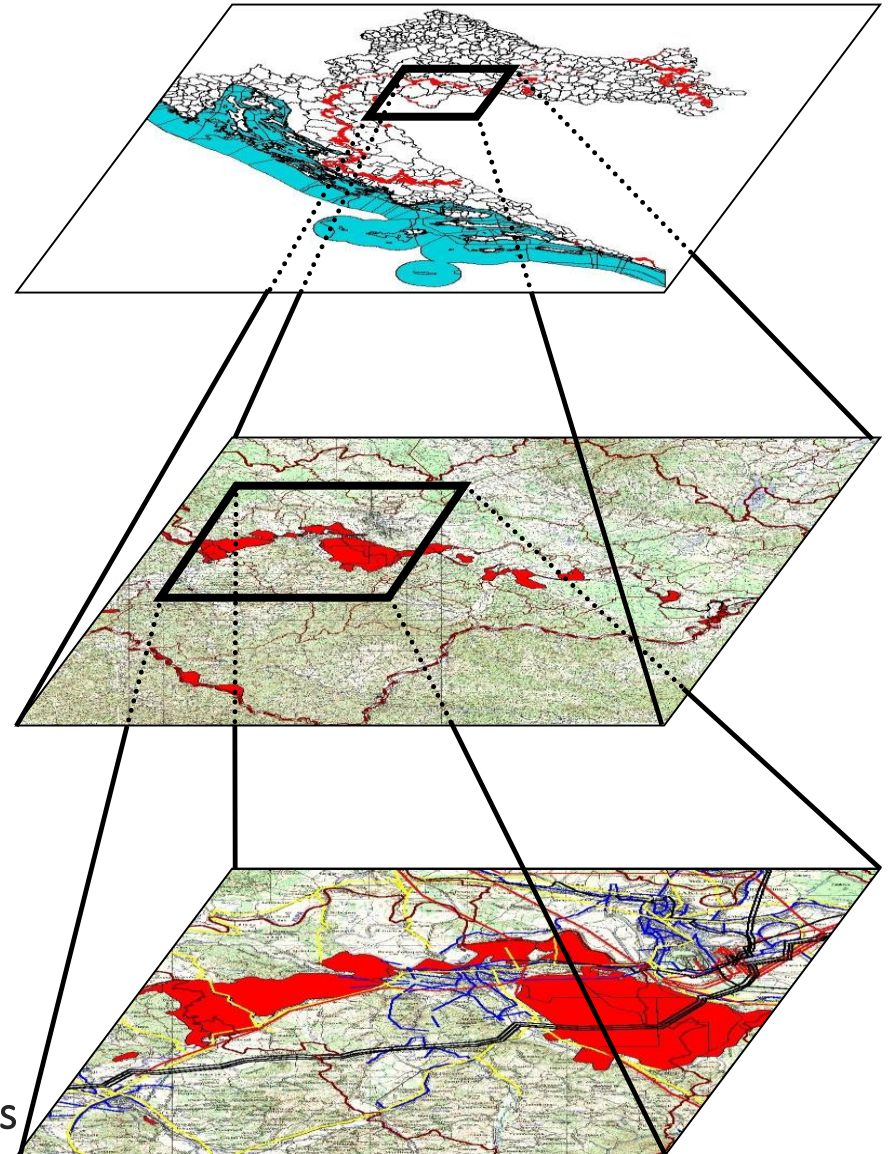
- State level
- Alternatives are **Counties**

Tactical level

- County level
- Alternatives are **Municipalities**

Operative level

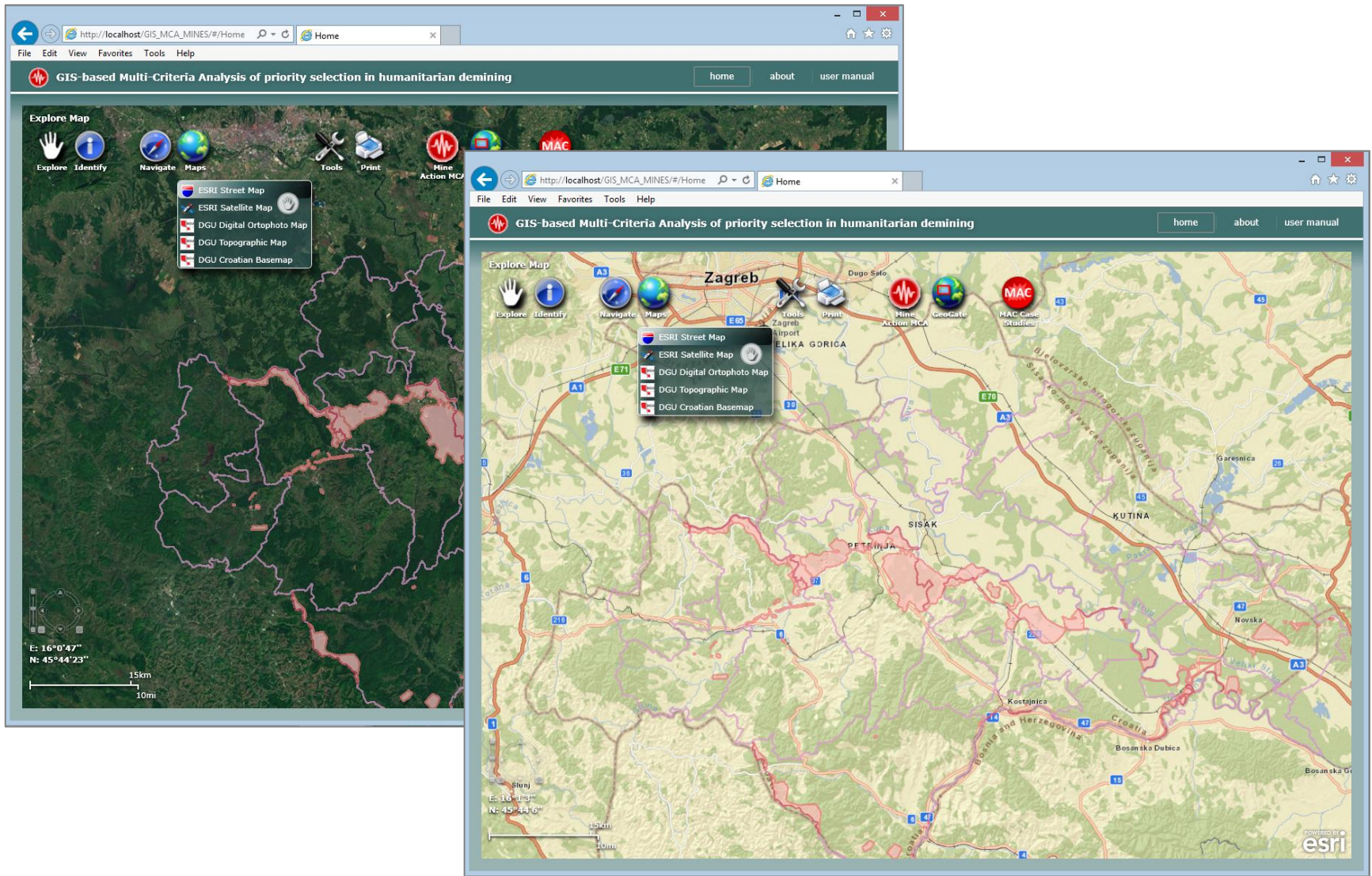
- Municipality level
- Alternatives are **Demining projects**



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: MCA for Case Study in Croatia

The screenshot displays a web browser window with the URL `http://localhost/GIS_MCA_MINES/#/Home`. The application title is "GIS-based Multi-Criteria Analysis of priority selection in humanitarian demining". The interface includes a top navigation bar with "home", "about", and "user manual" links. A toolbar on the left offers "Explore Map" options: Explore, Identify, Navigate, Maps, Tools, Print, Mine Action MCA, and Geo. The main map area shows a satellite view of a region with several colored zones (orange, yellow, white) and circular markers. A central dialog box titled "Demining priority selection for Sisacko-moslavacka County" contains the following text:

Multi-Criteria analysis

Select MCA level (county or municipality level) and click on the 'Run MCA'. After that all suspected minefields in selected county or municipality will be analyzed taking into account 24 different criteria. After that you can run additional MCA using different predefined Scenario, or you can define your Custom scenario using Criteria management. Minefields with highest rank have highest demining priority.

MCA level:

Selected county:

At the bottom left, coordinates are shown as E: 16°52'4" and N: 45°30'32", along with a scale bar for 10km and 5mi. The bottom right corner features the "POWERED BY esri" logo.

Web DSS: Results of MCA for Case Study in Croatia

The screenshot shows a web browser window with the URL `http://localhost/GIS_MCA_MINES/#/Home`. The application title is "GIS-based Multi-Criteria Analysis of priority selection in humanitarian demining".

Map Interface:

- Tools: Explore Map, Identify, Navigate, Maps, Tools, Print, Mine Action MCA, Geoprocessing.
- Map: Aerial view of a region with minefields numbered 1 through 11. Minefield 111 Topusko SM is highlighted with a blue star.
- Pop-up for 111 Topusko SM:
 - Rank: 9
 - Score: 42%
- Coordinates: E: 16°0'12", N: 45°16'3"
- Scale: 15km / 10mi

Demining priority selection for Sisacko-moslavacka County

Multi-Criteria analysis

Select MCA level (county or municipality level) and click on the 'Run MCA'. After that all suspected minefields in selected county or municipality will be analyzed taking into account 24 different criteria. After that you can run additional MCA using different predefined Scenario, or you can define your Custom scenario using Criteria management. Minefields with highest rank have highest demining priority.

MCA level: County level

Selected county: Sisacko-moslavacka

Run MCA Clear MCA results

Selected scenario: Scenario I

Results

Criteria management

Score (%)

Minefield ID	Score (%)
101	50
107	42
106	50
110	70
109	45
105	40
104	45
108	70
102	50
111	42
103	40

POWERED BY esri

Web DSS: Scenario selection for Case Study in Croatia

The screenshot shows a web browser window displaying a GIS-based Multi-Criteria Analysis (MCA) application. The browser address bar shows the URL: http://localhost/GIS_MCA_MINES/#/Home. The application title is "GIS-based Multi-Criteria Analysis of priority selection in humanitarian demining".

The main interface features a map of Sisacko-moslavacka County with several minefield locations marked with numbered circles (1-10). A control panel on the right allows users to configure the MCA process:

- Multi-Criteria analysis** section:
 - MCA level: County level
 - Selected county: Sisacko-moslavacka
 - Buttons: Run MCA, Clear MCA results
- Selected scenario:** Scenario III
- Results** section (Criteria management):
 - Impact of terrain characteristics and infrastructure: 5 stars
 - Economic impact of mine clearance: 2 stars
 - Social welfare impact: 3 stars
 - Impact of land-mine risk reduction: 4 stars
- Pie Chart** showing the distribution of results across the four criteria.

The pie chart data is as follows:

Criteria	Rank	Color
Impact of terrain characteristics and infrastructure	5	Green
Economic impact of mine clearance	2	Blue
Social welfare impact	3	Yellow
Impact of land-mine risk reduction	4	Red

The application is powered by ESRI, as indicated by the logo in the bottom right corner.

Web DSS: MCA Tool for Mine Action Community

Criterion 1:

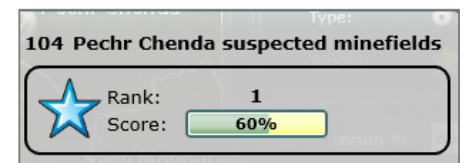
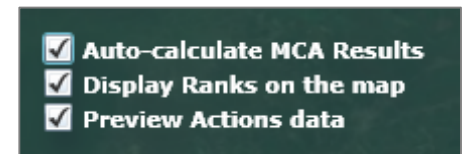
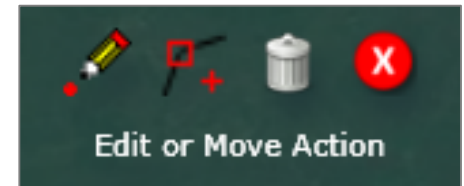
Type: Maximize Minimize

Weight: ★★★★★

Criterion 2:

Type: Maximize Minimize

Weight: ★★★★★



MCA Files

MAC Case

You can save your MCA data, i.e. actions and criteria data to MCA File on your computer. You can also import MCA data from already existing MCA File on your computer.

Pechr Chenda

Web DSS: MCA Tool for Mine Action Community

The screenshot shows a web browser window displaying a GIS-based Multi-Criteria Analysis (MCA) tool. The browser address bar shows the URL: `http://localhost/GIS_MCA_MINES/#/Home`. The page title is "GIS-based Multi-Criteria Analysis of priority selection in humanitarian demining".

The main interface features a map of Cambodia with several suspected minefields marked with orange circles. The map includes a toolbar with icons for Explore, Identify, Navigate, Maps, Tools, and Print. The map shows locations such as Sambour, Kracheh, Pechr Chenda, Kaev Seima, Snoul, and Chhloung. A scale bar indicates 30km and 20mi. The coordinates for the map are E: 106°39'44" and N: 11°42'33".

Overlaid on the map is the "MCA - Multi-Criteria Analysis" dialog box, which is currently in the "Criteria Setup" tab. It lists five criteria for analysis:

- Criterion 1:** Demining Cost (million \$). Type: Maximize Minimize. Weight: 3 stars.
- Criterion 2:** Mines and UXOs Victims (number of people). Type: Maximize Minimize. Weight: 5 stars.
- Criterion 3:** Economical Impact (1-5 scale). Type: Maximize Minimize. Weight: 3 stars.
- Criterion 4:** Social Impact (1-5 scale). Type: Maximize Minimize. Weight: 3 stars.
- Criterion 5:** CS. Type: Maximize Minimize. Weight: 3 stars.

Below the map is a table showing the results of the MCA for four selected minefields:

ID	Action name	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Criterion 11	Criterion 12
101	Kaev Seima suspected minefields	1.6	24	4	4	0	0	0	0	0	0	0	0
102	Kracheh suspected minefields	2.5	33	3	3	0	0	0	0	0	0	0	0
103	Snoul suspected minefields	0.8	12	3	4	0	0	0	0	0	0	0	0
104	Pechr Chenda suspected minefields	2.2	18	5	5	0	0	0	0	0	0	0	0

At the bottom of the interface, there is a record navigation bar showing "Record: << < 4 > >> Records (1 out of 4 Selected) Options...".

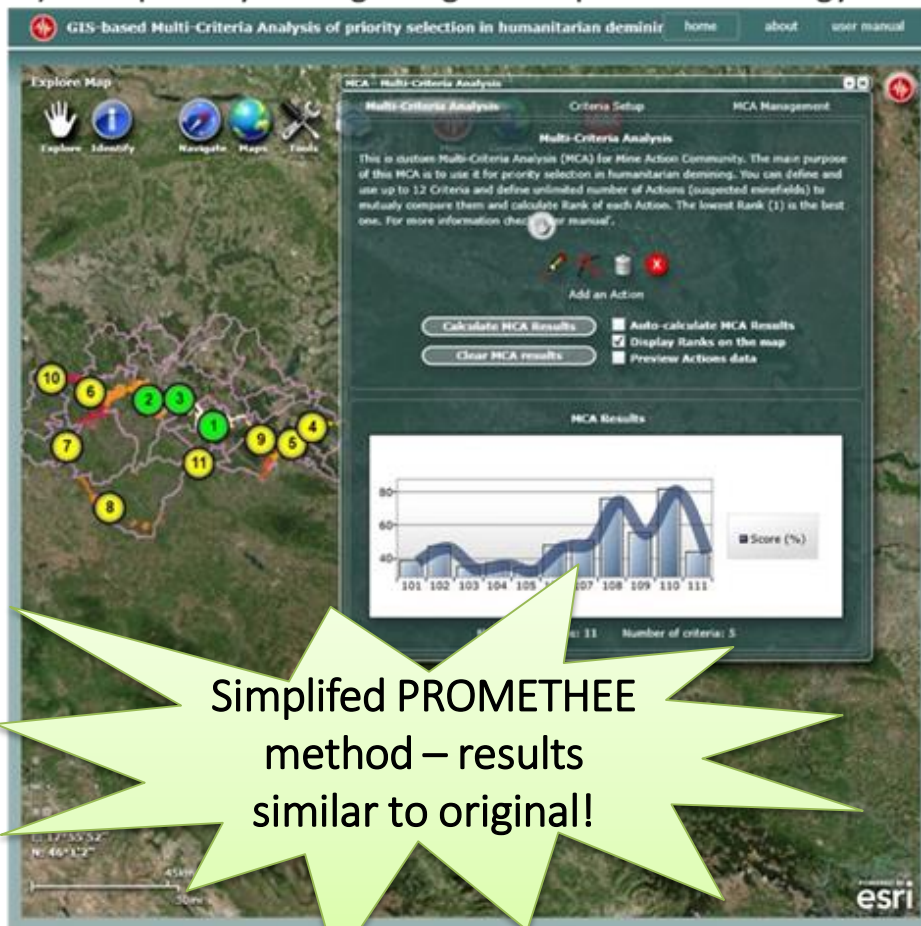
Web DSS: MCA Tool (simplified PROMETHEE) validation

- 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



Simplified 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, were tackled in this research.
- The **simplified 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)

