

Web map with combined risks exposure for HR pilot site

Web map with combined risks exposure for HR pilot site with seismic-flood-extreme sea waves

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Work Package Title	Assessment of multi-hazard exposure in coastal and urban areas
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Activity Title	Assessment of combined flood-seismic hazards Assessment of combined seismic-flood-extreme sea waves hazards
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List of abbreviations and terms

GIS – Geographic Information System

MCA – Multi-Criteria Analysis

MHA – Multi-Hazard Risk

Abstract/Executive Summary

This Deliverable presents application which enables visualization of the flood, extreme waves and seismic single risks; and procedure for calculation and visualization of combined risks at the HR test site through the Web maps for single and combined risks.

Introduction

EU Interreg IT-HR project “Preventing, Managing and Overcoming Natural-Hazards Risks to mitiGATE economic and social impact (PMO-GATE)” needed support for data visualization through Geographic Information System (GIS) and multi-criteria analysis (MCA), to support the risk assessment and risk management, in the same software.

These issues were addressed through development of Windows Application “MHR-MCA for PMO-GATE (Multi-Hazard Risk Assessment based on Multi-Criteria Analysis for PMO-GATE project)”. It is a specialized application which supports mapping through GIS interface and multi-criteria analysis based on the PROMETHEE method. It results with KML/KMZ layers which are suitable for the Web maps.

This application enables visualization of the flood, extreme waves and seismic single risks as well as calculation and visualization of combined risks at the HR test site through the Web maps for single and combined risks.

Main characteristics:

Name: **MHR-MCA for PMO-GATE**

Operating System: **Windows 10**

Devices: **PC, Tablet**

Application Type: **Microsoft Store App**

GIS platform: **ESRI ArcGIS Runtime 100.4**

Current version: **v1.0**

Release date: **September 2020**

Download link:

<https://pmo-gate.maps.arcgis.com/home/item.html?id=a29ed75c42044217bf089f84be03c2c0>

Windows Application “MHR-MCA for PMO-GATE”

The capabilities of the Windows Application “MHR-MCA for PMO-GATE (Multi-Hazard Risk Assessment based on Multi-Criteria Analysis for PMO-GATE project)” can be grouped into two main modules (Figure 1):

- **Mapping capabilities** – provided through Geographic Information System (GIS) platform *ESRI ArcGIS Runtime*. The GIS module supports mapping through adding local layers and simple spatial analysis.
- **Decision-making capabilities** – provided through Multi-Criteria Analysis (MCA) module based on the PROMETHEE method. The MCA module supports evaluation of alternatives, determination of decision-maker’s preferences, MCA calculation and results visualization.

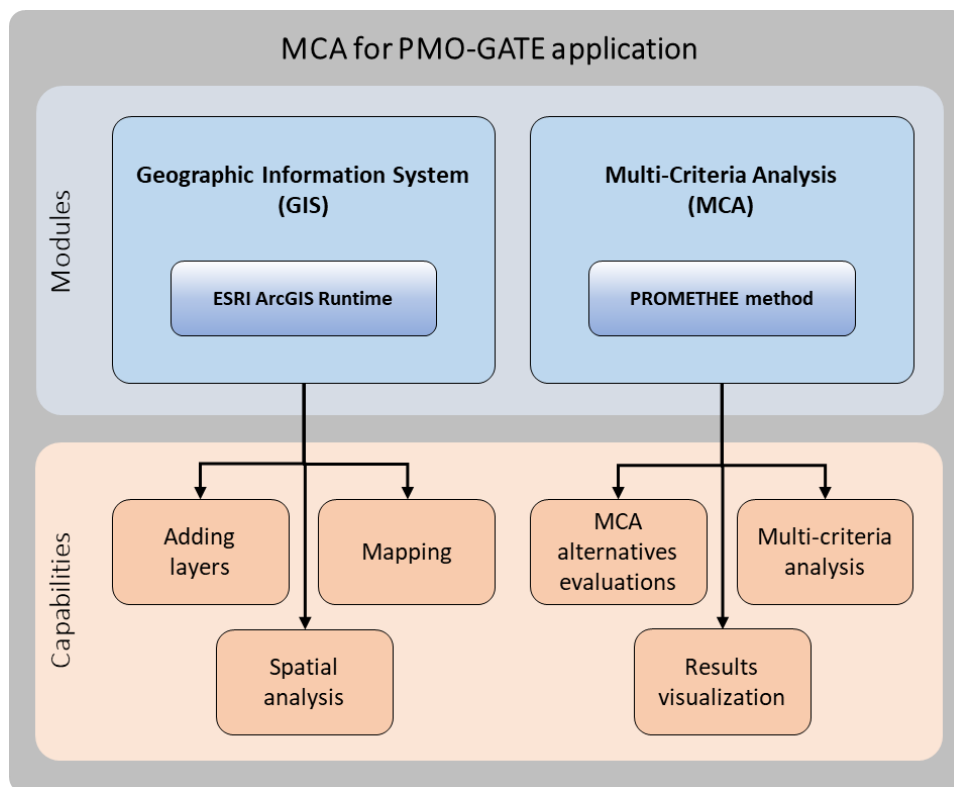


Figure 1. Modules and capabilities of “MHR-MCA for PMO-GATE” application

The GIS and MCA module represent two main parts of the main window of the application (Figure 2). The main menu bar allows user to create a *New* project, *Open* existing one, or *Save* the current one. The default project is always open on the application start.

The projects are saved in *Open Geospatial Consortium* KML/KMZ format file, which is one of the GIS standards. A structure of the file was extended to support the MCA data (Figure 3). KMZ file format allows

the projects to be viewed in any KML/KMZ viewer, for instance in: *Google Earth*, *ArcGIS Earth*, or similar. However, in these applications there is no possibility to edit the MCA input data or results. Multi-criteria analysis must be made in the “MHR-MCA for PMO-GATE” application.

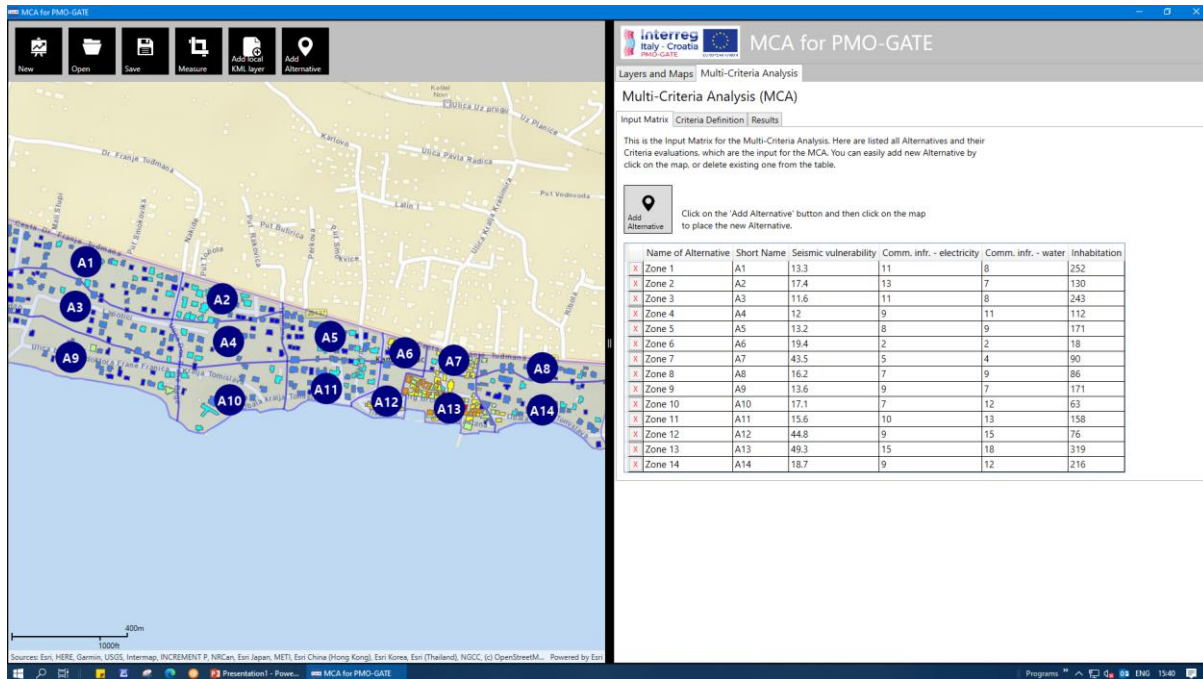


Figure 2. Main window of “MHR-MCA for PMO-GATE” application

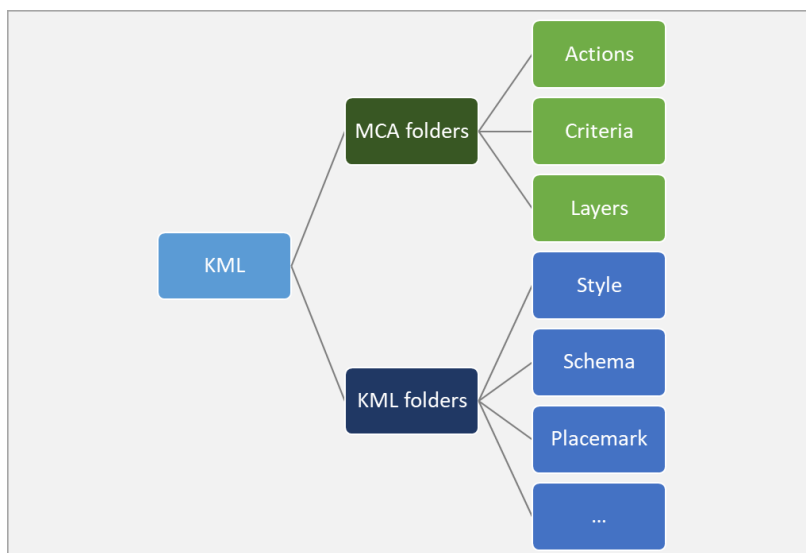


Figure 3. A structure of the project KML/KMZ file

Geographic Information System (GIS) module

The Geographic Information System (GIS) module (Figure 4) enables the mapping capabilities by using the local KML layers (KML/KMZ file) and by providing the online *Basemaps* from *ESRI: Streets map, Imagery map, Ocean map*, etc. Additionally, *Offline Basemap* can be loaded for the work without internet connection.

The alternatives (actions) for multi-criteria analysis are also input on the map by simple click/touch on the map. Automatically the placemark for the alternative is created on the map and alternative is added to the MCA table.

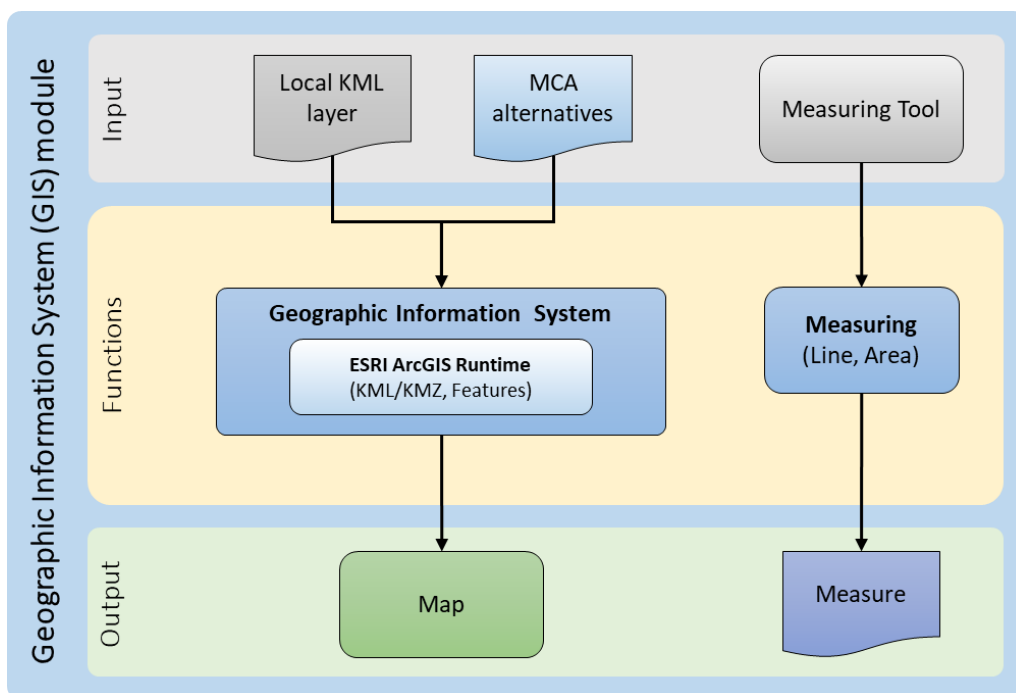


Figure 4. The GIS module of “MHR-MCA for PMO-GATE” application

Additionally, GIS module allows some simple spatial analysis by using the Measuring tool for measuring the distance or area. The measures can be used as an input to MCA table. For instance, a criterion can be a distance of the alternative from some important object, and the *Measuring tool* can be used to evaluate that criterion.

The GIS module is based on the platform *ESRI ArcGIS Runtime*, thus providing the fast and smooth navigation of the map, and excellent performance even in case of huge number of layers and features on the map.

Multi-Criteria Analysis (MCA) module

The Multi-Criteria Analysis (MCA) module provides support for decision-making based on the PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations) method. The PROMETHEE

method represents *a priori* approach to multi-criteria decision-making which means that decision-maker's preferences are known.

In "MHR-MCA for PMO-GATE" application, the decision-maker's preferences are defined through criteria definition and criteria weights parameters. The criteria number is not limited, although it is well known that criteria number shouldn't exceed few dozens. The number of alternatives (actions) is not limited, as well. Although analysis and ranking of more than several hundred alternatives doesn't make sense, because the differences among them will be too small. So, alternatives, criteria and criteria weights represent input to Multi-Criteria Analysis which results with the rank of alternatives and their PROMETHEE net flow and net score (Figure 5).

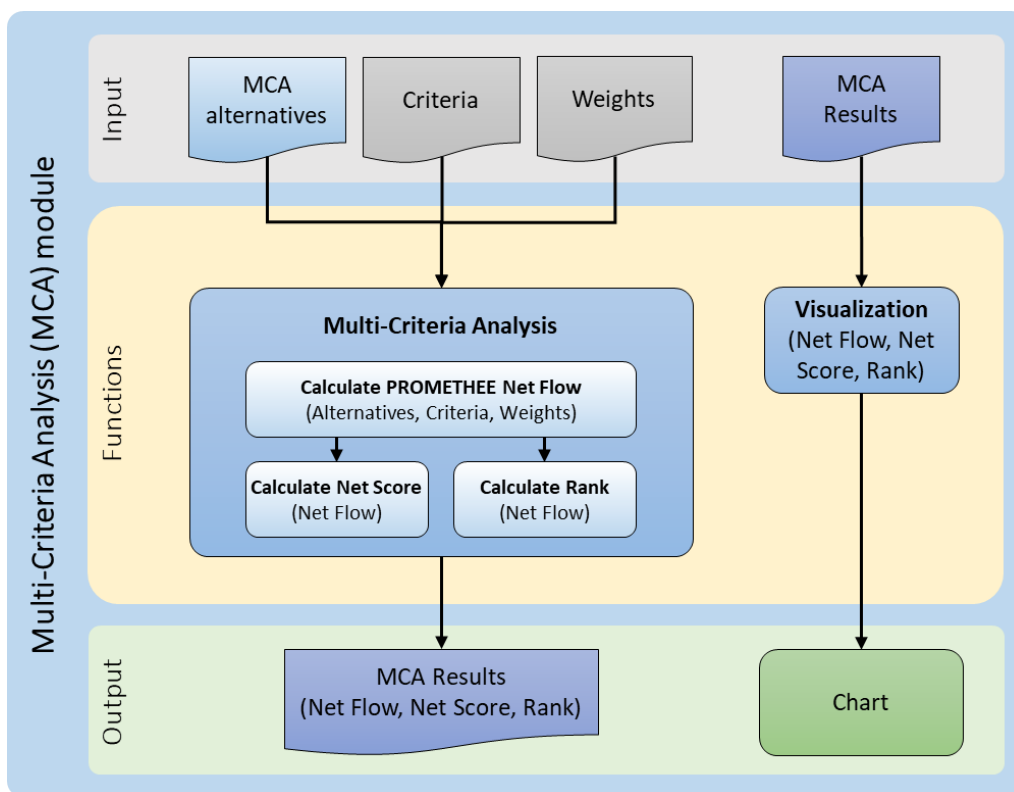
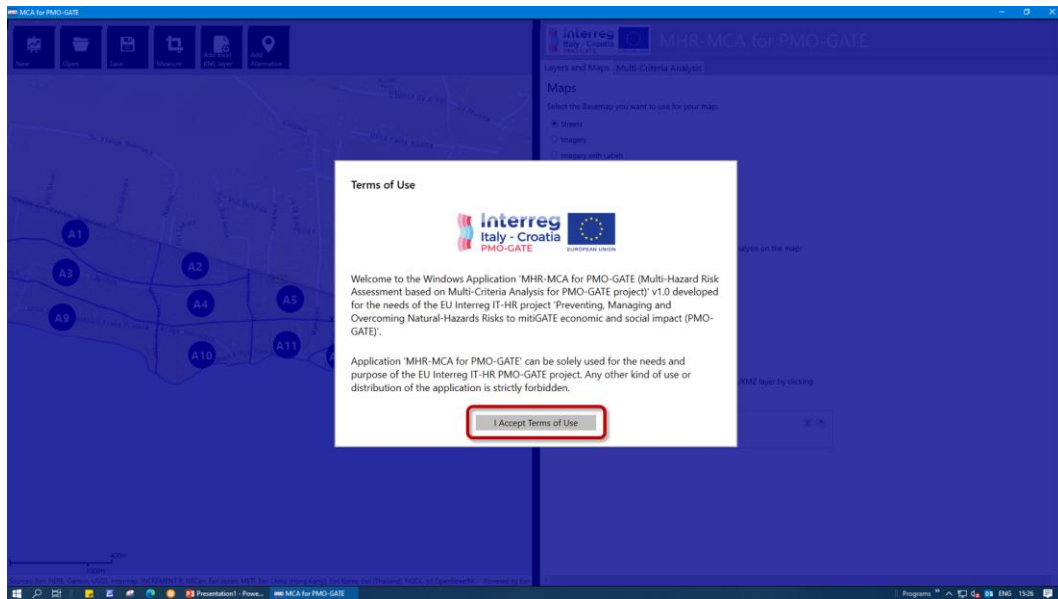


Figure 5. The MCA module of "MHR-MCA for PMO-GATE" application

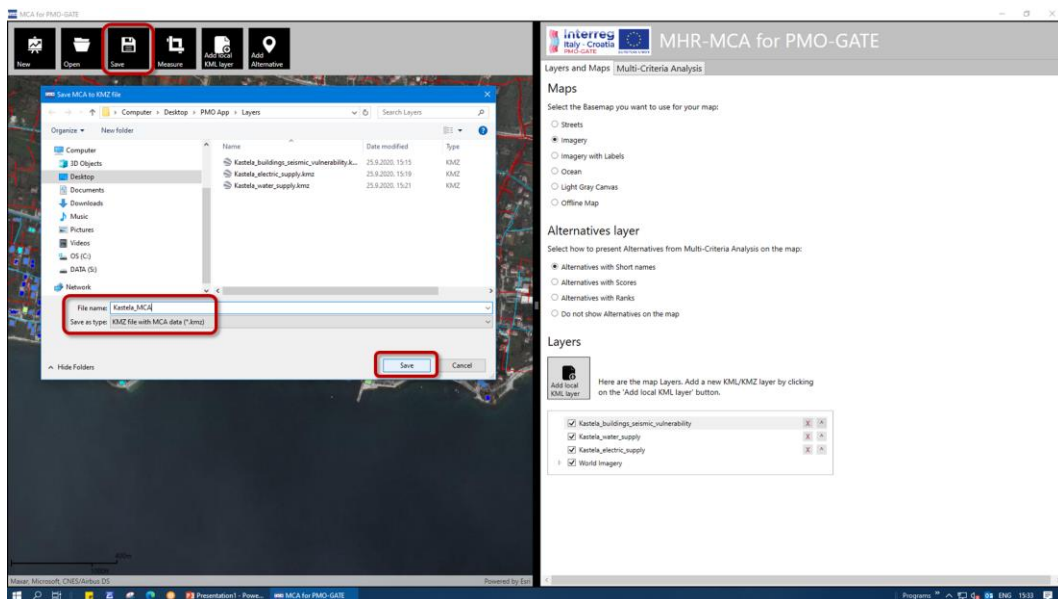
Additionally, the application itself have visualization capabilities to present the MCA results in form of bar chart, column chart, or in table. In combination with the GIS module, it also presents MCA results on the map.

Risk analysis by using “MHR-MCA for PMO-GATE” application

Windows Application “MHR-MCA for PMO-GATE” starts with the window with “Terms of Use”. Since, the application can be solely used for the needs and purpose of the PMO-GATE project and any other kind of use or distribution of the application is strictly forbidden, User must accept these “Terms of Use” in order to work in application:



The application opens the Default Project as an example, but User can choose to *Open* existing project or start the *New* one, and later *Save* the project as the KMZ file:

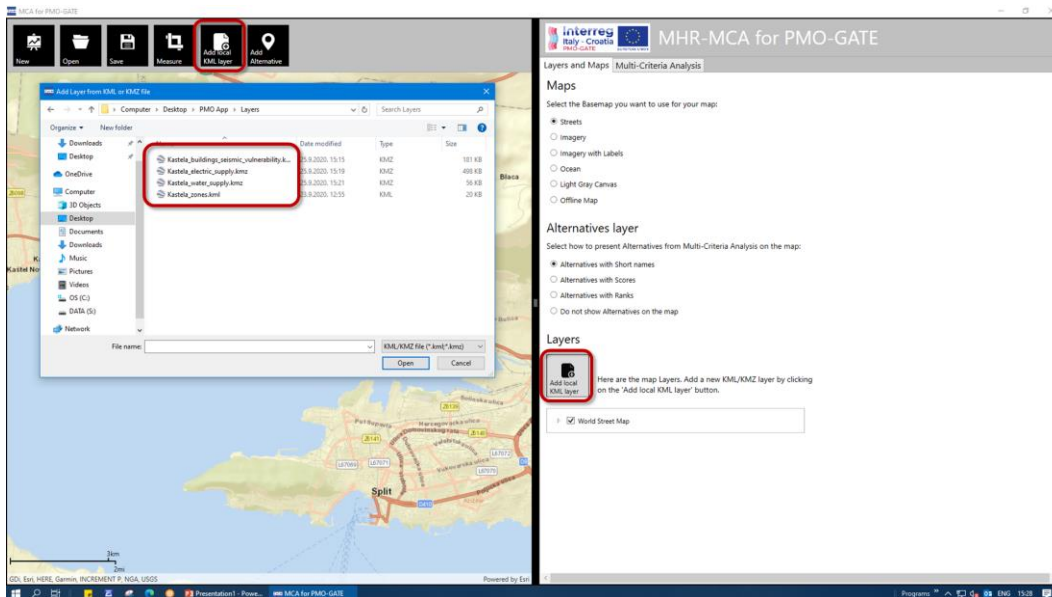


GIS: Maps and Layers

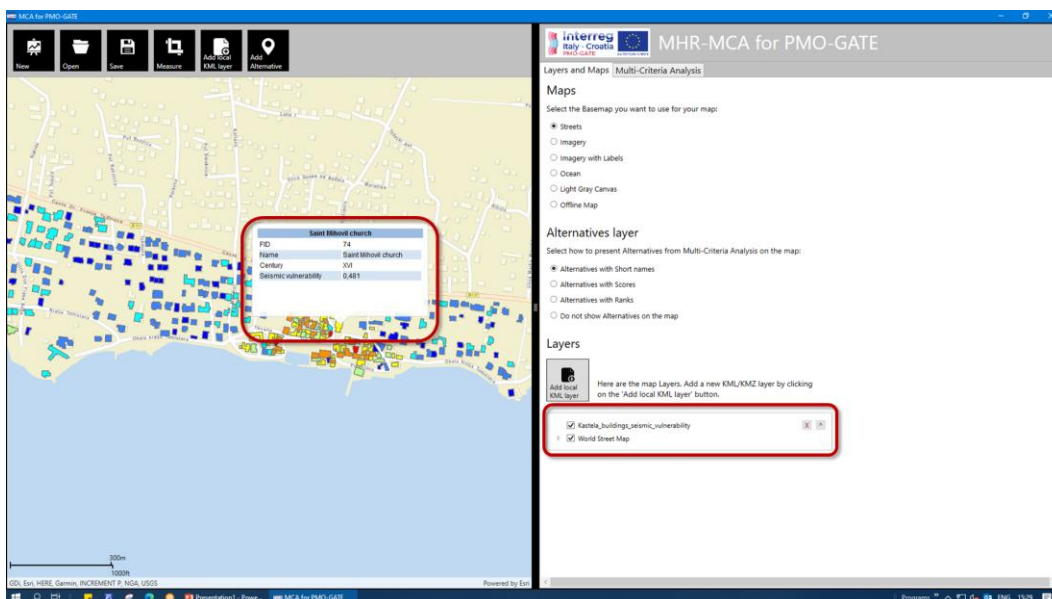
The GIS (Geographic Information System) module of the application consists of the *Maps*, i.e. the *Basemaps*, and *Layers*. There are six Basemaps available with world-wide coverage: *Streets*, *Imagery*, *Imagery with Labels*, *Ocean*, *Light Gray Canvas*, and *Offline Map* (for work without internet connection). User can easily select the *Basemap* and change it at any time:



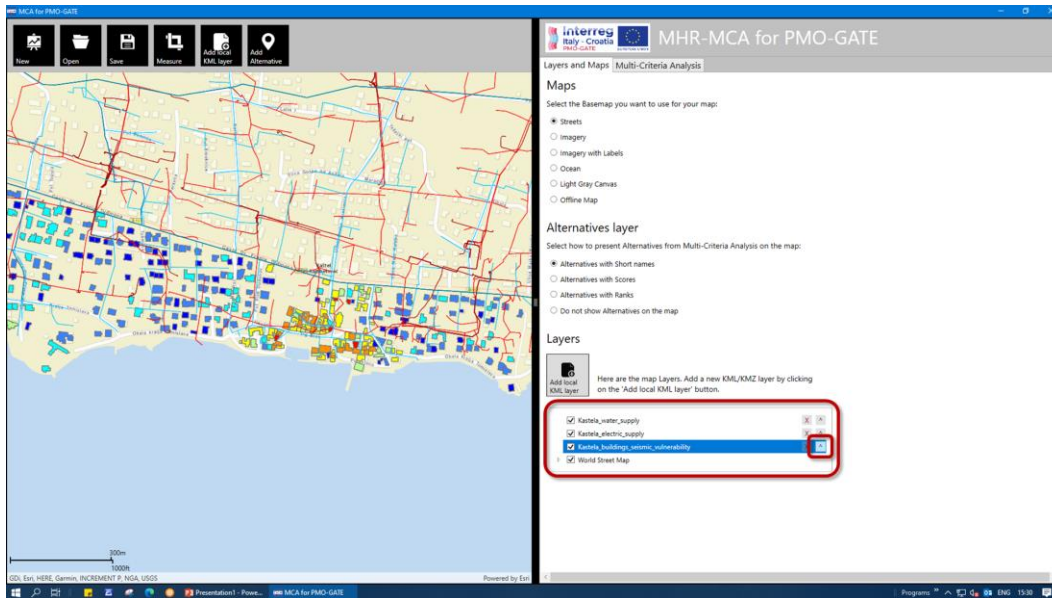
All online *Basemaps* are the *ESRI Web services* available 24-7 for free use. However, for work in the environment without internet connection, the *Offline Map* is available, which is a simple vector map with world-wide coverage. Except *Basemaps*, important GIS aspects are the *Layers*. The supported *Layers* are those in the *Open Geospatial Consortium KML/KMZ* format. Any KML or KMZ file from the PC or Tablet can be added to the map by using the 'Add local KML layer' button:



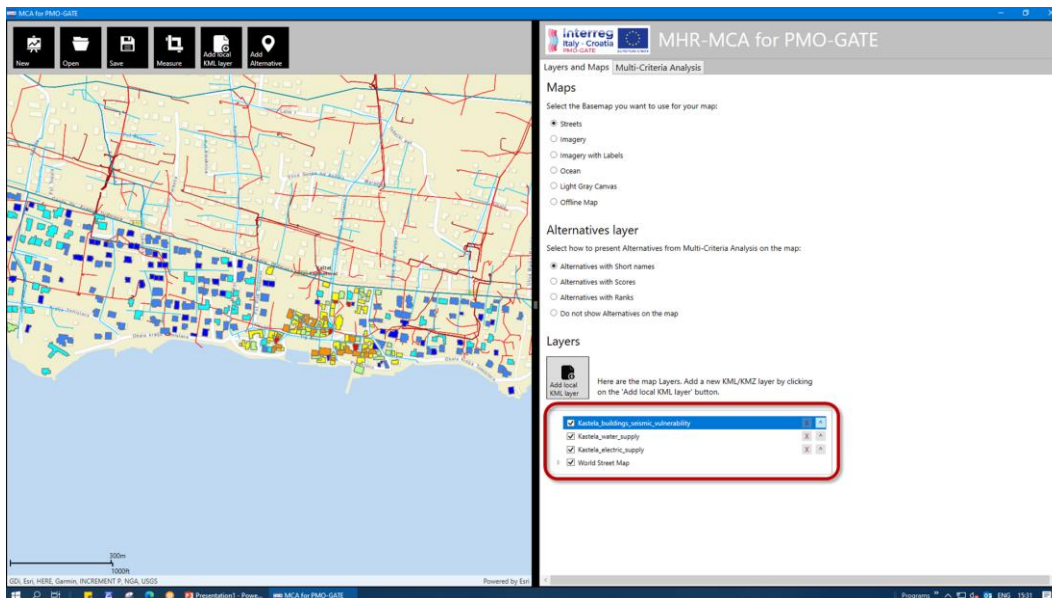
When the *Layer* is loaded, it is added to the *Layers list*, but information about its features can be retrieved by clicking or tapping the *Feature* on the map:



Additionally, *Layers list* can be reordered, i.e. a *Layer* can be promoted on the list by clicking on the button with up-arrow mark:

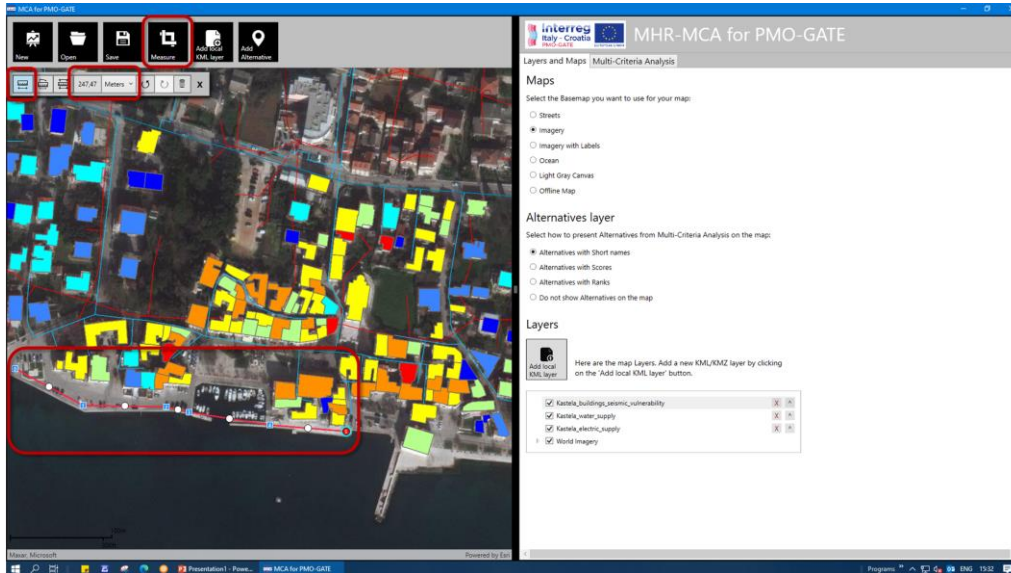


Because, the first *Layer* will be on top of all other layers on the map:

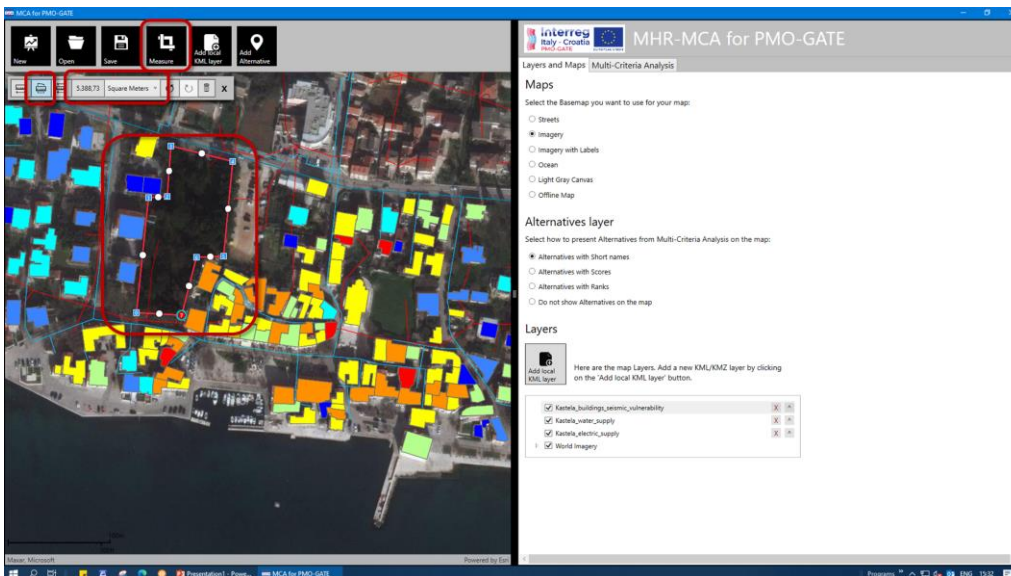


It is the reason why the *Layers'* order is important. So, the *Basemap* is always on the bottom of the list, because it is always beneath all *Layers*. *Layers* added to the map will be saved into the KML file of the project, which means they will also be available when the project is opened in some other KML/KMZ

viewer. The GIS module has a *Measuring tool* available, which can be used for simple spatial analysis. Both the distance and they are can be measured by using this tool. By clicking on the 'Measure' button, a *Measuring toolbar* is activated. The line measure or distance can be easily calculated:



The *Area measuring* can be made as well:

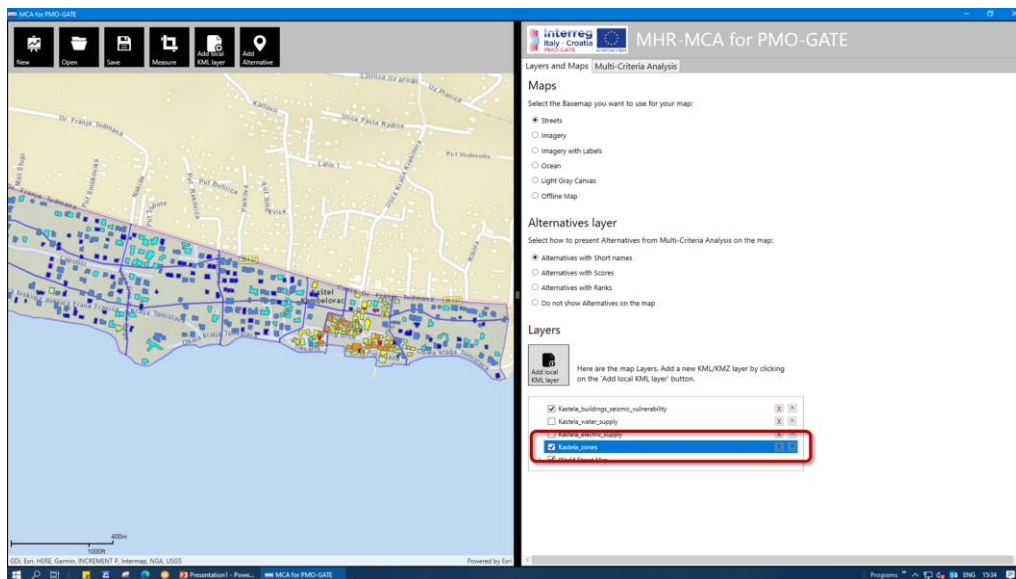


As mentioned, the measuring can be used as an input to MCA table. For instance, a criterion can be a distance of the alternative from some important object, and the *Measuring tool* can be used to evaluate that criterion.

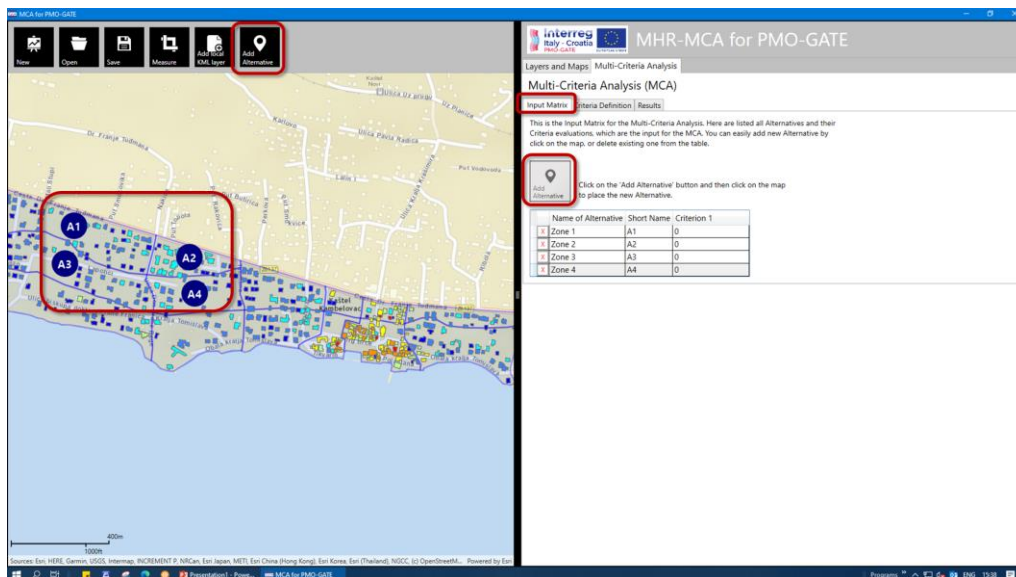
MCA: Alternatives, Criteria and Results

The MCA (Multi-Criteria Analysis) module represents decision-making support based on the PROMETHEE method. First of all, the *Alternatives* must be defined. *Alternatives* can be any set of features (buildings, zones, municipalities, counties, etc.) which will be mutually compared and ranked. They represent the input matrix for the PROMETHEE method.

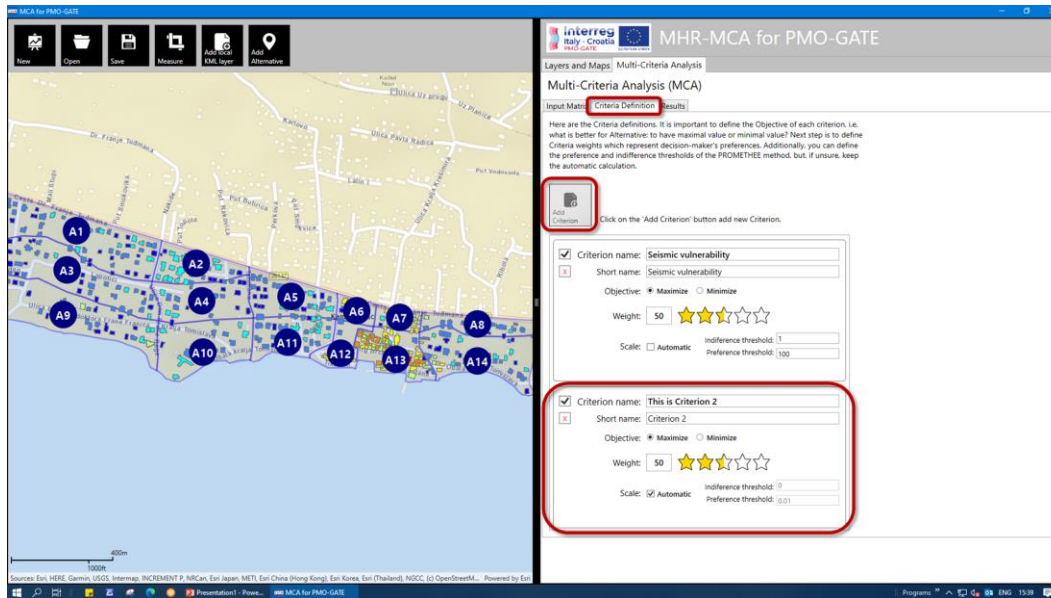
In this example, 16 homogenous zones will be used as *Alternatives* for MCA:



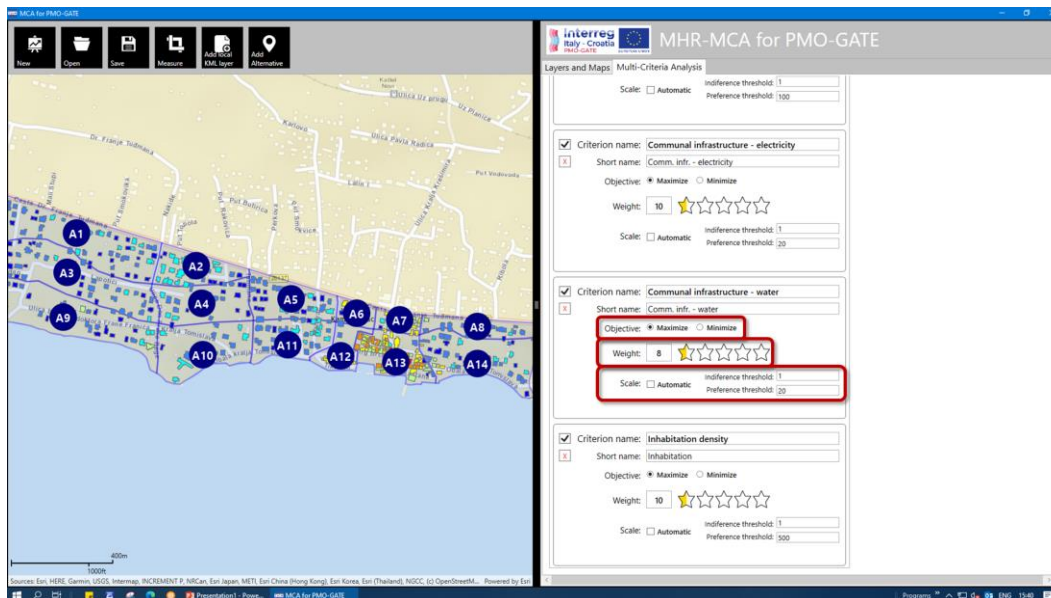
An *Alternative* is added on the map and the table by using the “Add alternative button”:



After all the *Alternatives* have been added, *Criteria* need to be defined. By using the *Criteria Definition* tab and 'Add Criterion' button, User can add as much *Criteria* as he wants:



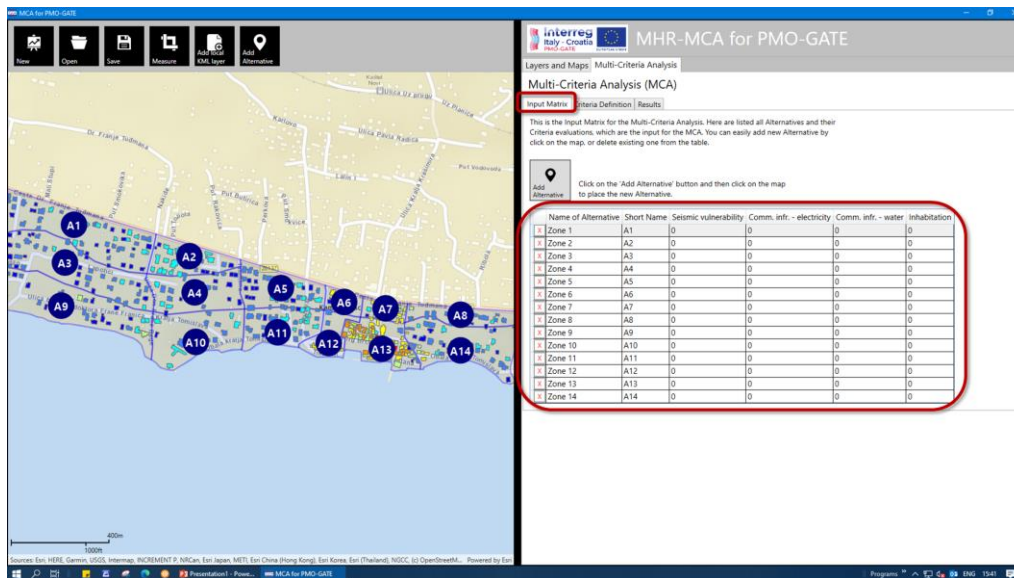
Except *Criterion* name and short name, the *Objective*, *Weight* and *Scale* must be defined for each *Criterion*:



The *Weights* represent decision-maker's preferences and they can be result of the single opinion of the decision-maker or they can be compromise of a group of decision-makers. The *Objective* defines if the *Criterion* should be minimized or maximized. For instance, *Criterion 'Price'* is usually minimized, which

means the cheaper is better, but *Criterion 'Quality'* is usually maximized, which means the higher quality is better. And, at the end, *Scale* must be defined and it represents the perception of scale of the decision-maker. Namely, the PROMETHEE method supports different scale units and ranges for different *Criteria*, therefore the scale is defined through indifference and preference thresholds of the linear type preference function. But, if the User doesn't know how to define these threshold, automatic values will be assigned based on the statistical analysis.

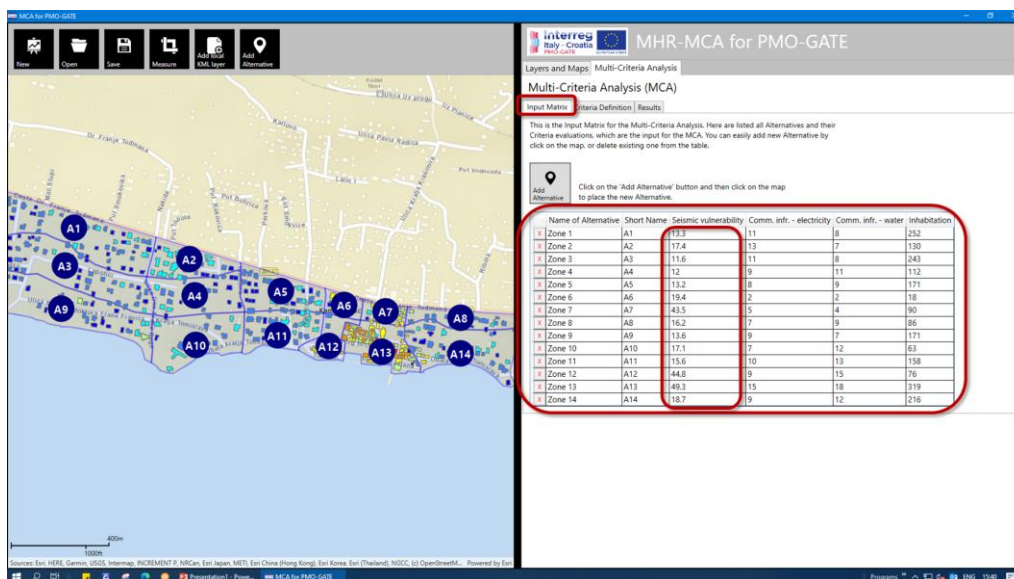
After *Criteria Definition*, the *Input Matrix* is empty:



The screenshot shows the 'MHR-MCA for PMO-GATE' interface. On the left is a map with 14 zones labeled A1 to A14. On the right, the 'Input Matrix' table is empty, with the following structure:

Name of Alternative	Short Name	Seismic vulnerability	Comm. infr. - electricity	Comm. infr. - water	Inhabitation
Zone 1	A1	0	0	0	0
Zone 2	A2	0	0	0	0
Zone 3	A3	0	0	0	0
Zone 4	A4	0	0	0	0
Zone 5	A5	0	0	0	0
Zone 6	A6	0	0	0	0
Zone 7	A7	0	0	0	0
Zone 8	A8	0	0	0	0
Zone 9	A9	0	0	0	0
Zone 10	A10	0	0	0	0
Zone 11	A11	0	0	0	0
Zone 12	A12	0	0	0	0
Zone 13	A13	0	0	0	0
Zone 14	A14	0	0	0	0

Therefore, *Criteria* evaluations for each *Alternative* must be filled into the matrix:

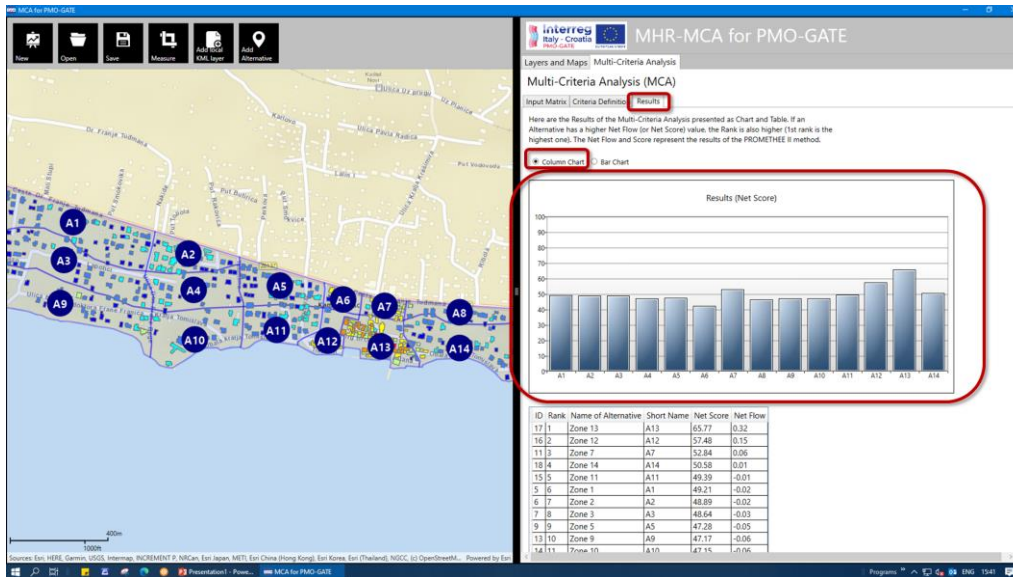


The screenshot shows the same software interface, but the 'Input Matrix' table is now populated with numerical values for each criterion across the 14 zones:

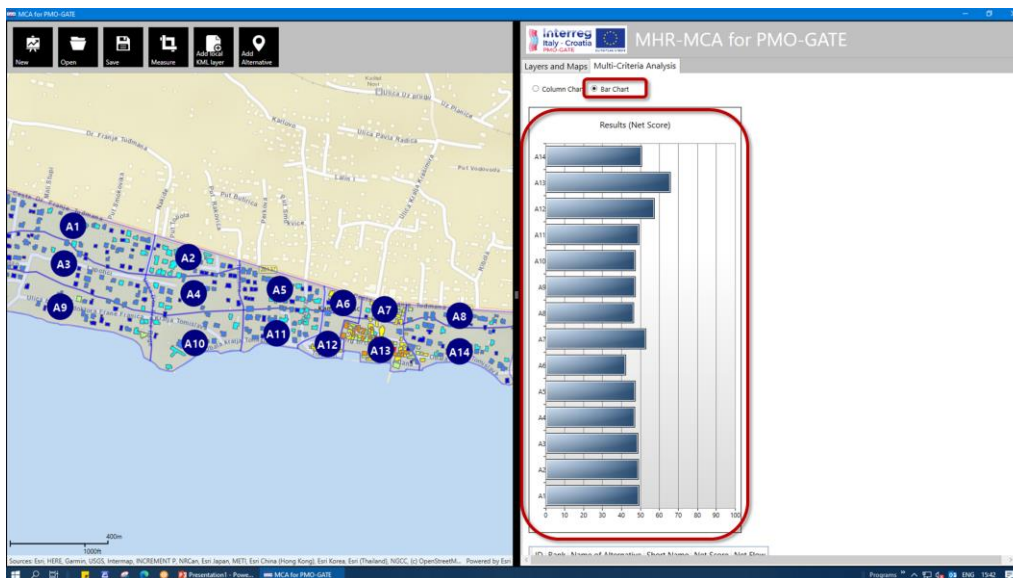
Name of Alternative	Short Name	Seismic vulnerability	Comm. infr. - electricity	Comm. infr. - water	Inhabitation
Zone 1	A1	113.3	11	8	252
Zone 2	A2	117.4	13	7	130
Zone 3	A3	111.6	11	8	243
Zone 4	A4	12	9	11	152
Zone 5	A5	13.2	8	9	171
Zone 6	A6	19.4	2	2	18
Zone 7	A7	43.5	5	4	90
Zone 8	A8	16.2	7	9	86
Zone 9	A9	13.6	9	7	171
Zone 10	A10	17.1	7	12	63
Zone 11	A11	15.6	10	13	158
Zone 12	A12	44.8	9	15	76
Zone 13	A13	49.3	15	18	319
Zone 14	A14	18.7	9	12	216

After filling all the data into the *Input Matrix*, the PROMETHEE method is automatically run, and *Results* are ready for presentation. The *Results* can be presented as the table, charts and on the map.

The *Results* can be presented as a *Column Chart*:

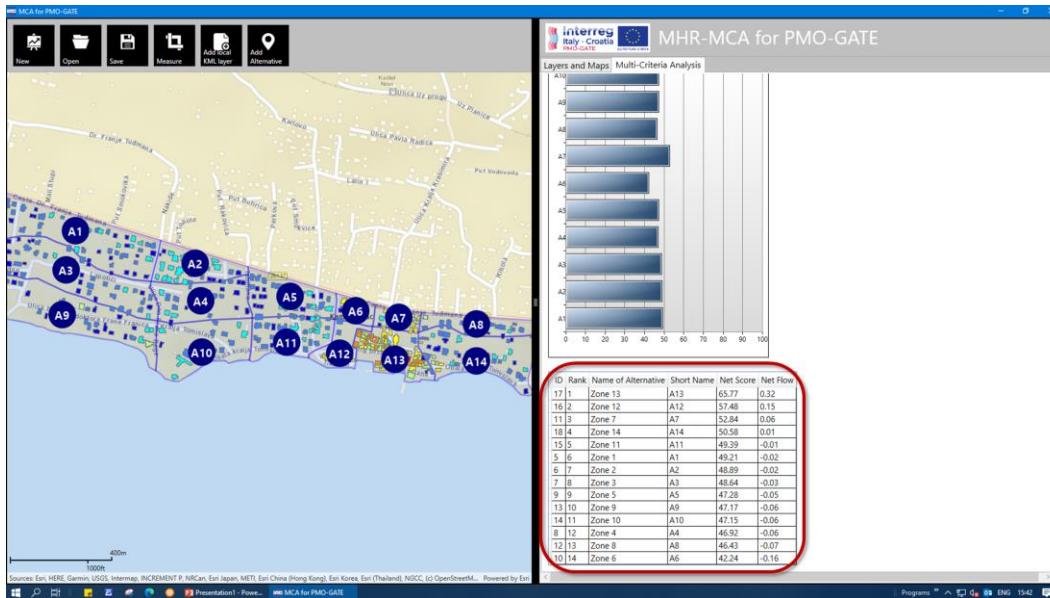


Or as the *Bar Chart*:

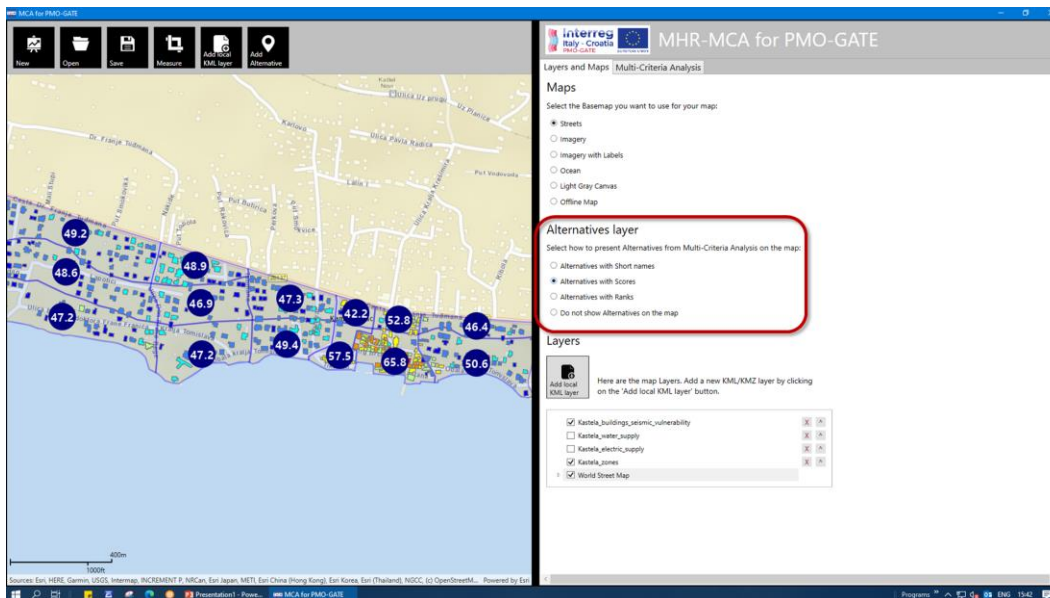


It is important to note that main value used for the *Results* presentation is the *Net Score*. It is a special case of the PROMETHEE II, in which the *Result* for one action is between 0 and 100. In the following figure,

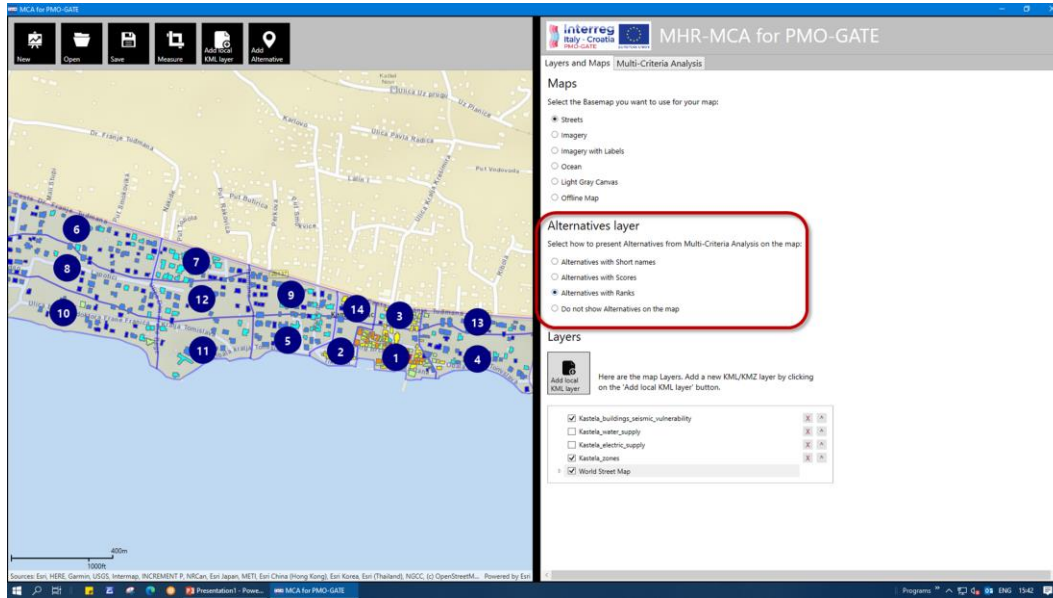
the *Results* are presented in the table with all important PROMETHEE data: the *Ranks*, the *Net Score*, and the *Net flow*.



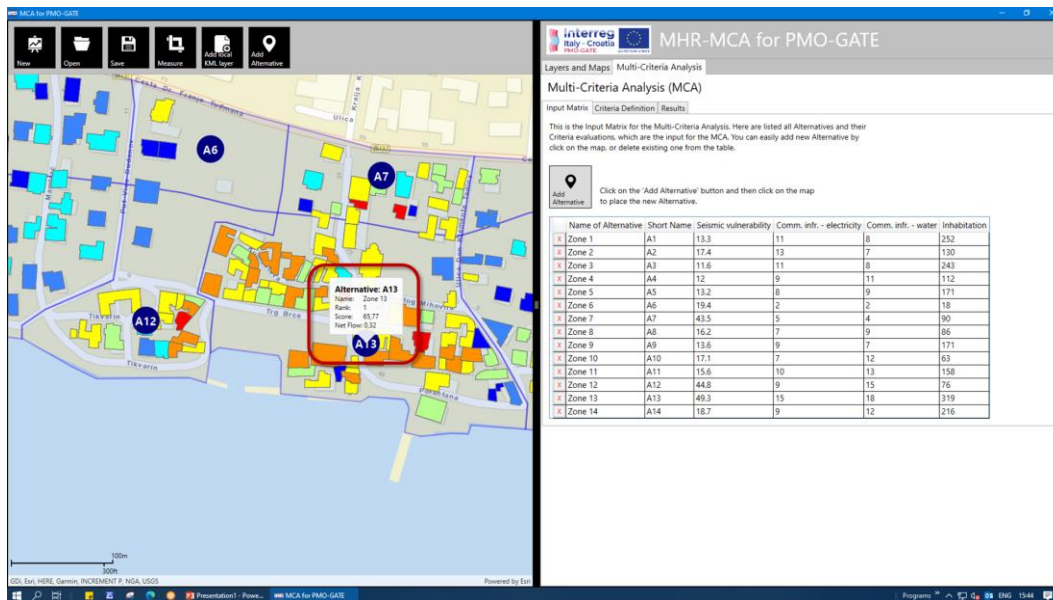
Furthermore, the *Results* can be presented on the map, as well. One option is to present *Results* in the form of the *Net Score* as *Alternatives layer* label:



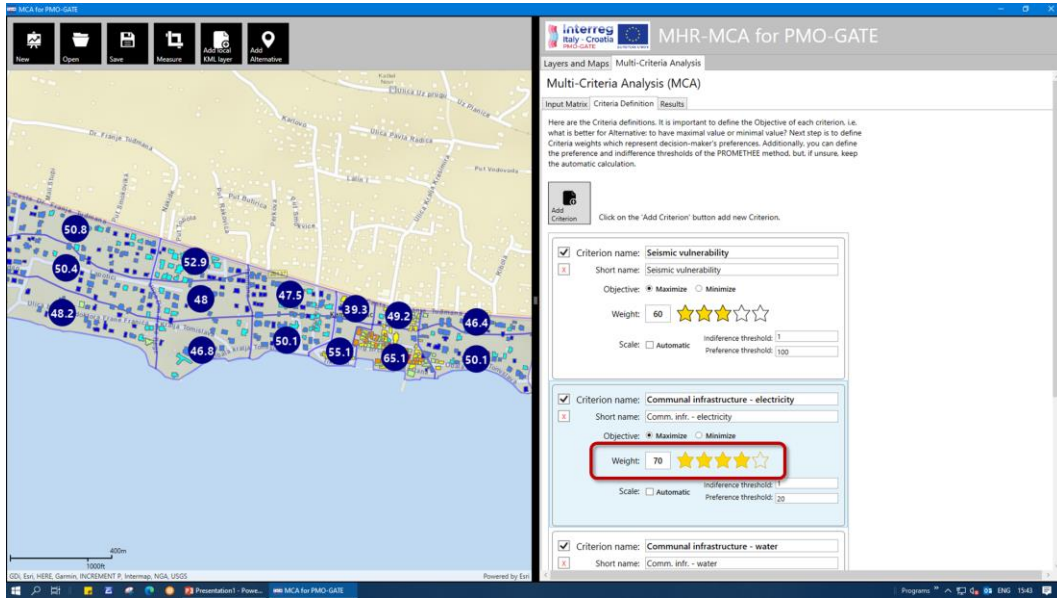
In the *Layers and Maps* tab there is *Alternatives layer* which is used to define what to show on the map as *Result*. Except the *Net Score*, the *Ranks* can be presented as well:



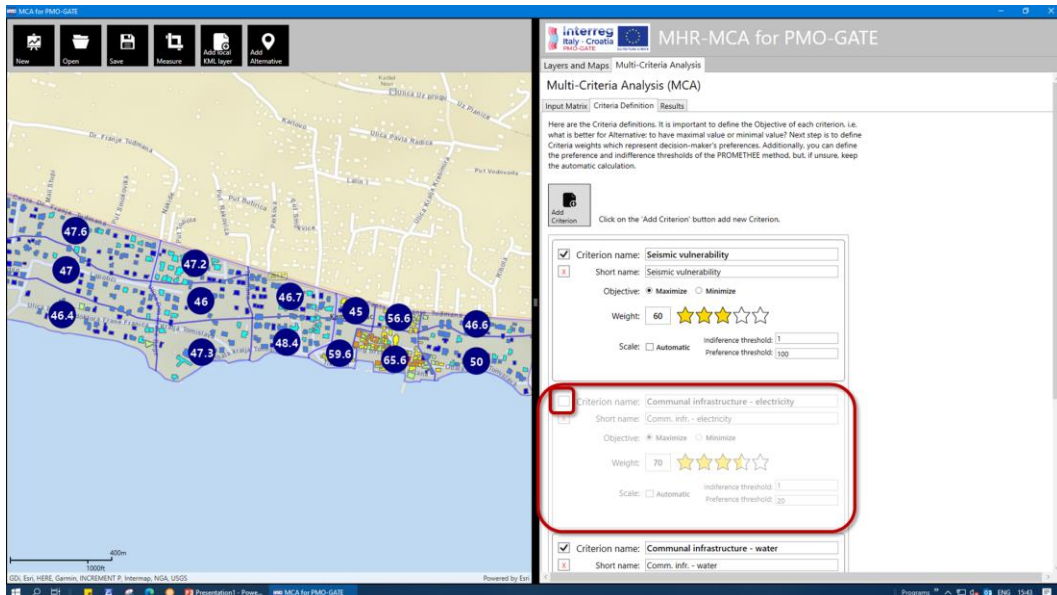
And *Results* can be retrieved for each particular *Alternative* by clicking on it on the map:



One of the main features of the PROMETHEE method is, so called, *Walking Weights* option. In this application, this feature can be also achieved by redefining the *Criteria Weights* by using simple scale in form of *Stars* or precise numerical scale:

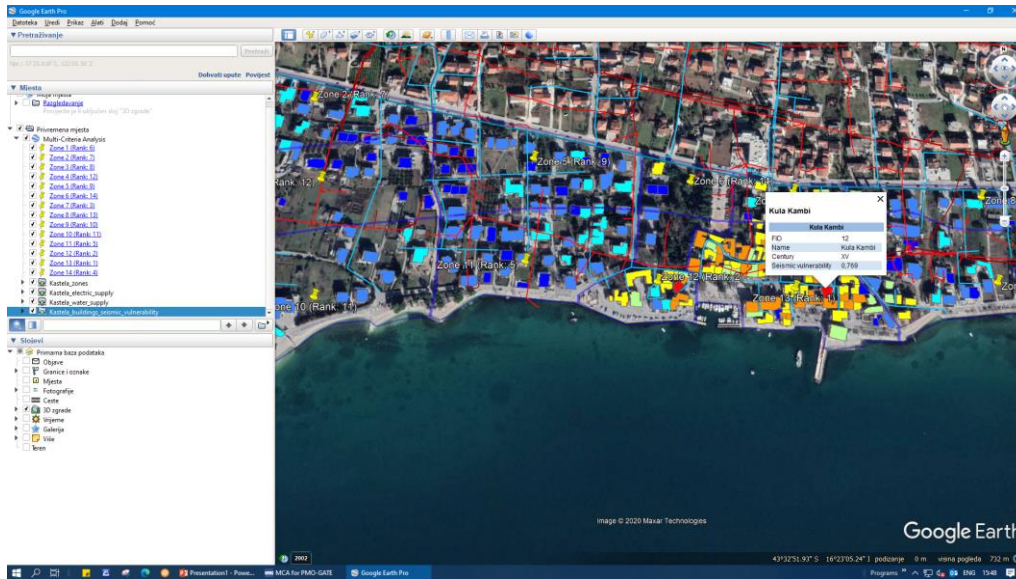


Additionally, the *Criterion* can be switched-off, i.e. it can be temporarily removed from the MCA calculation, without deleting it completely:

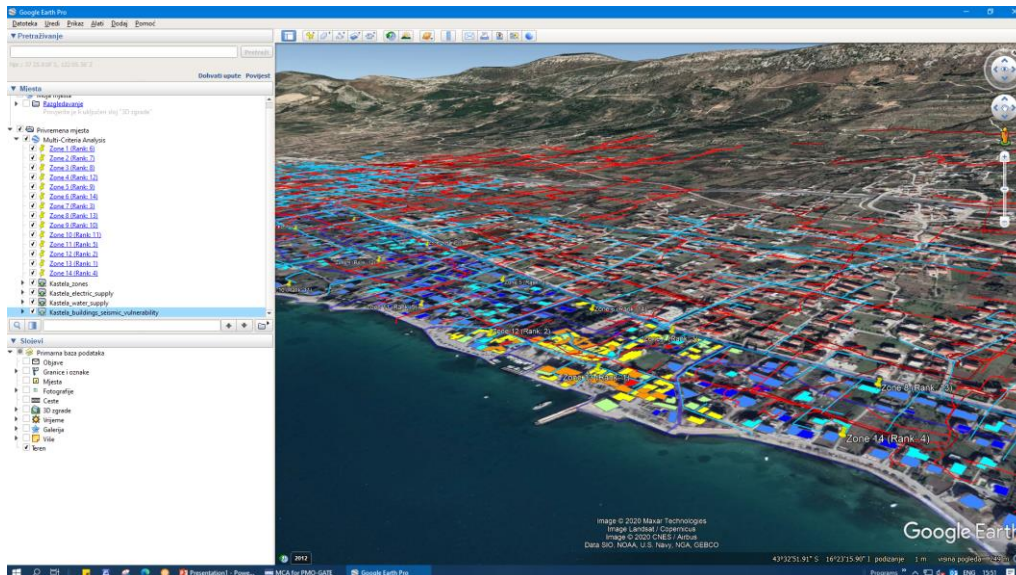


Compatibility with other software

Since the projects are saved in KMZ file format, and all the *Layers* are copied into the project file, the project can be viewed in some other KML/KMZ viewer. The most famous Earth viewer, for which the KML format was developed, the *Google Earth* can easily open the project file:



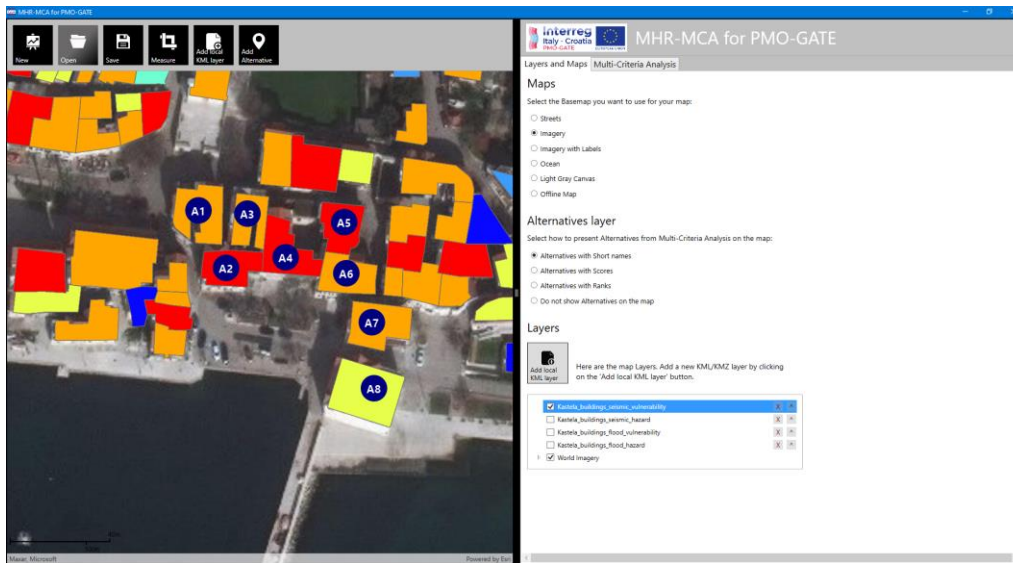
In the *Google Earth*, the 3D model of terrain and 3D buildings are available and can be used for additional analysis:



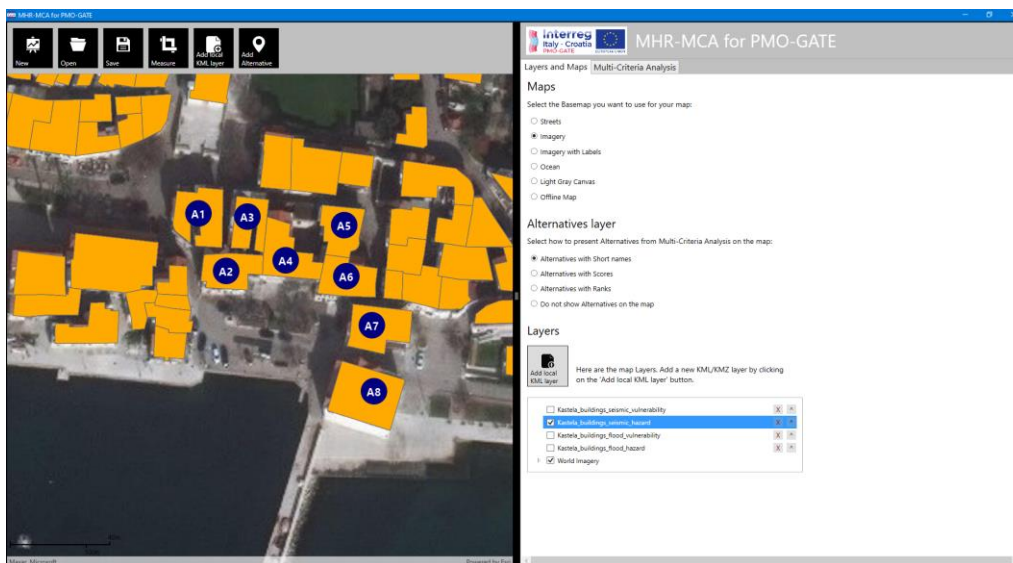
Risk assessment of combined flood-seismic hazards in “MHR-MCA for PMO-GATE”

Vulnerability and hazard maps as input data

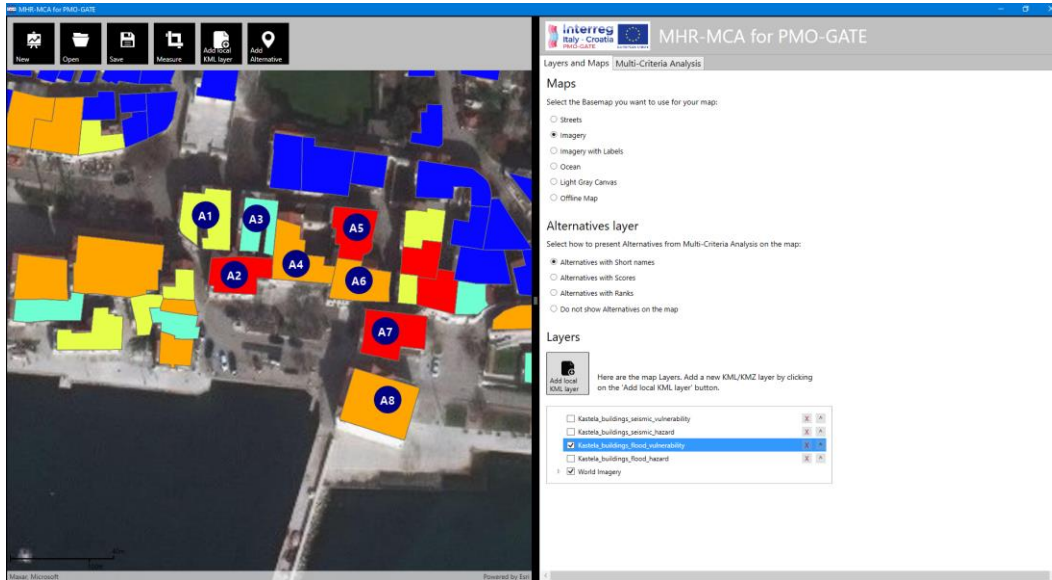
The Risk assessment of combined flood-seismic hazards is presented here on the small example with 8 alternatives, i.e. with 8 buildings in this case on buildings level. The input data consists of the seismic vulnerability map:



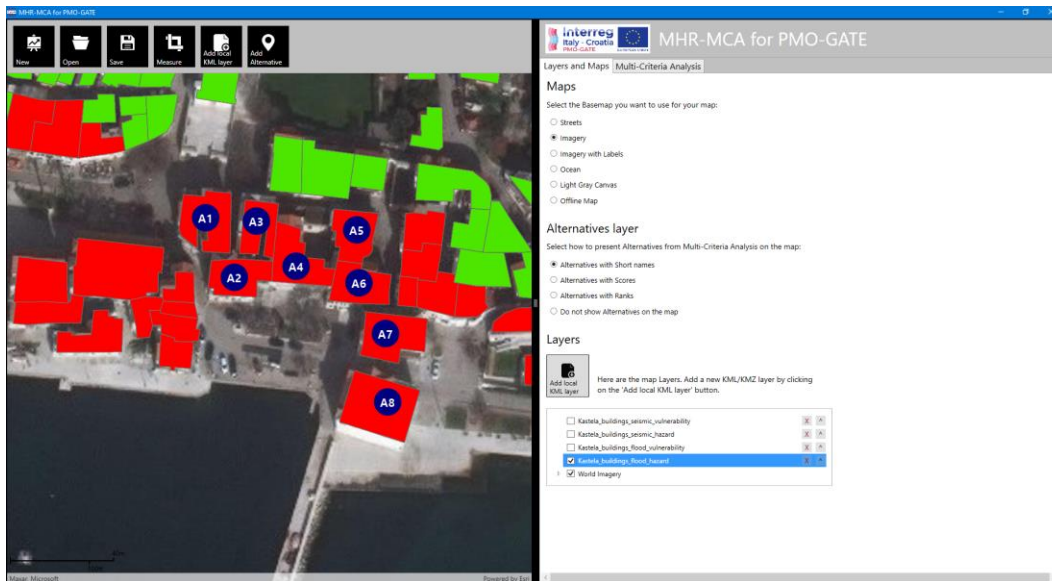
The seismic hazard map:



The flood vulnerability map:



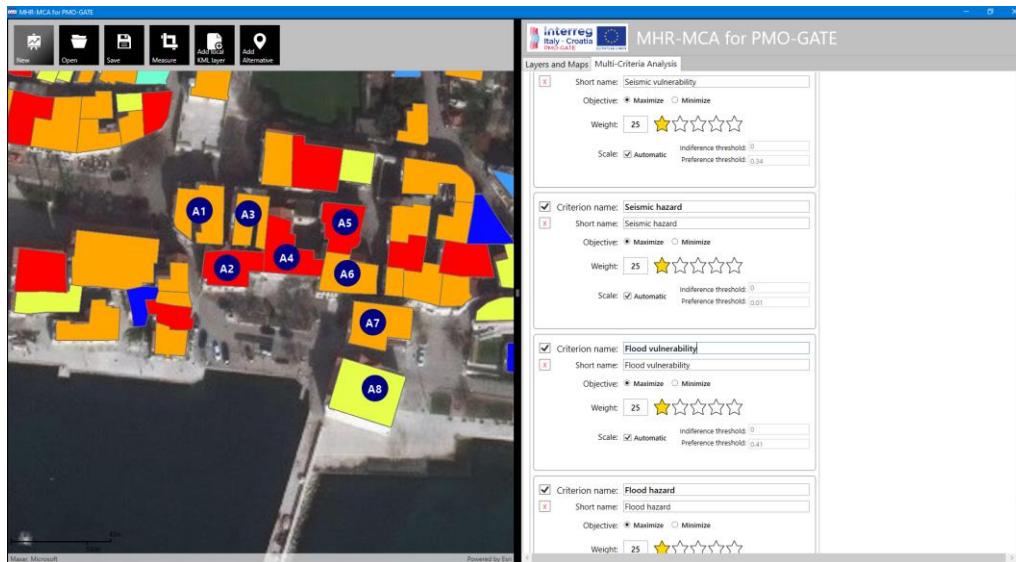
The flood hazard map:



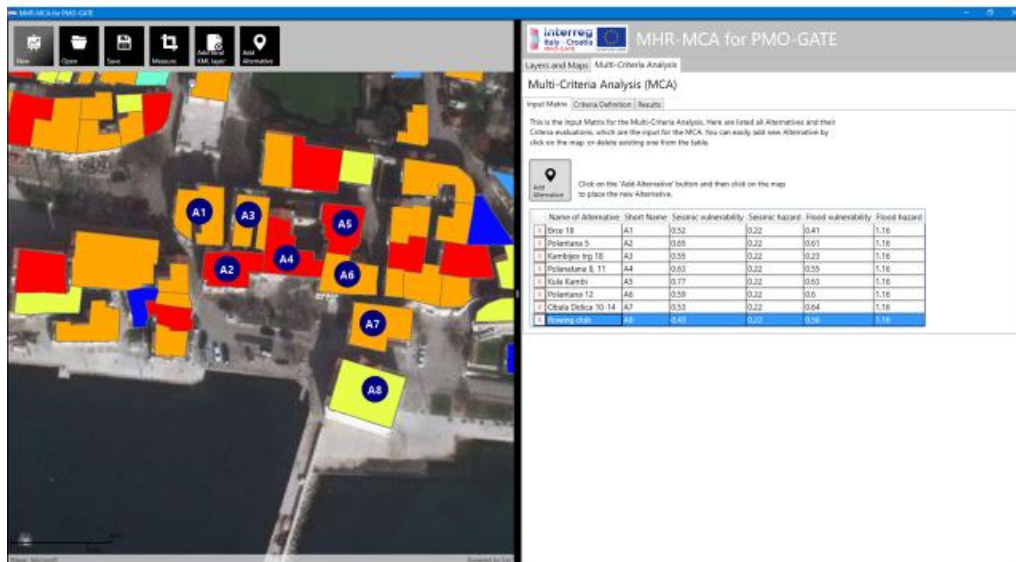
These four maps represent four different indexes for each building and, they will be used as an input data for MHR-MCA.

Criteria and alternatives evaluations as input for MHR-MCA

First of all, four criteria have been defined representing the seismic vulnerability index, seismic hazard index, flood vulnerability index and flood hazard index of the building. Equal weights are given to criteria:



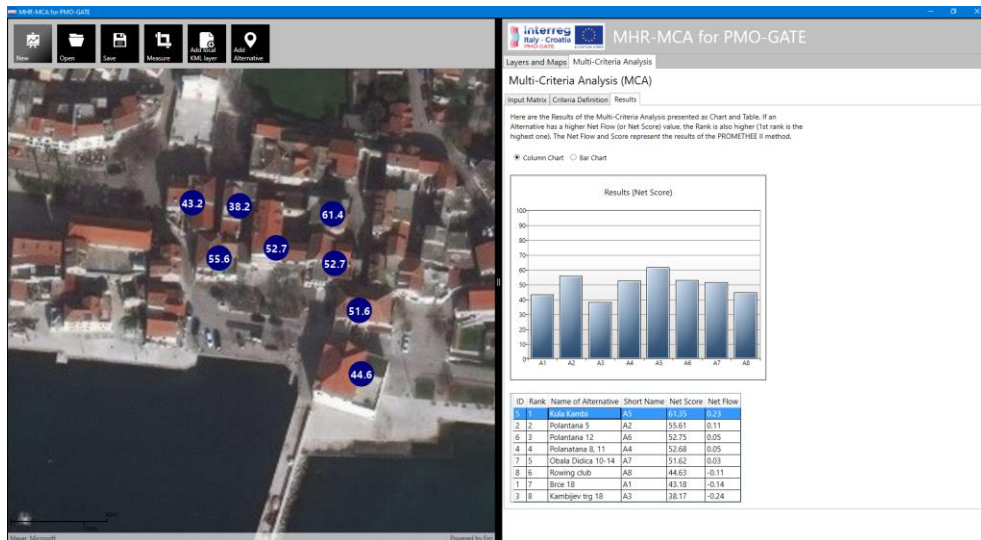
For each criterion, an evaluation represents a particular index for particular building:



These input data are submitted to Multi-Criteria Analysis based on the PROMETHEE method.

The results of the MHR-MCA

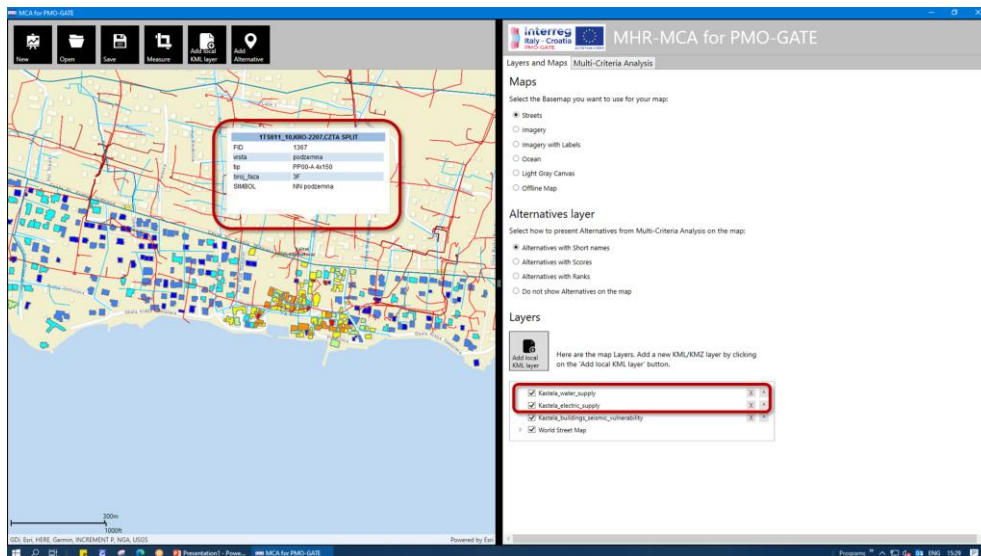
The results of this Multi-Criteria Analysis show that “Kula Kambi” has the highest combined flood-seismic hazard risk, followed by “Polantana 5” on the second place:



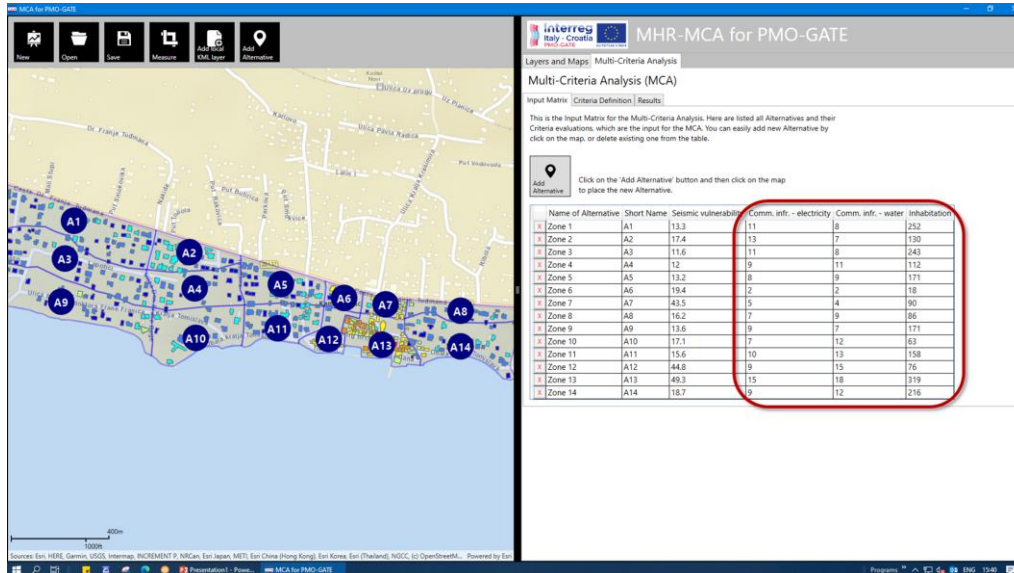
Building “Kambijev trg 18” has the smallest combined flood-seismic hazard risk, in this case. This is just an example of analysis for Risk assessment of the combined flood-seismic hazards.

MHR-MCA based on homogenous zones and additional criteria

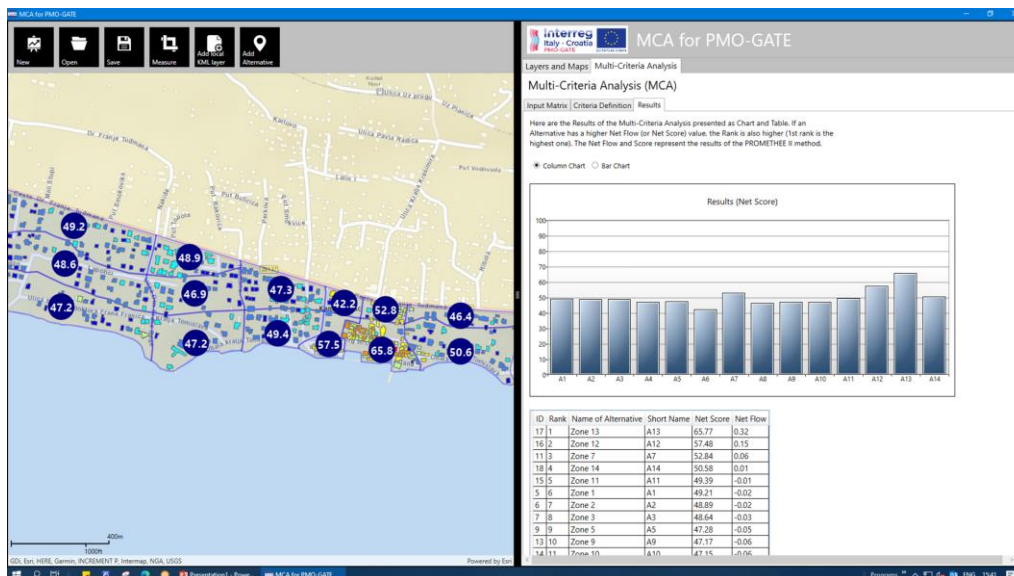
As mentioned, MCA allows adding of dozens of additional criteria, which can enhance the risk assessment. The best way is to have criteria presented as map layers. In this case, additional criteria are *Electric* and *Water supply*:



For this kind of analysis, it is more suitable to use homogenous zones as alternatives. For each zone an average vulnerability and hazard must be calculated, together with evaluations for additional criteria. In this case, the evaluations are made for criteria *Electric supply*, *Water supply* and *Inhabitation density*:



The MHR-MCA resulted with following results:



Homogenous zones A13, A12 and A7, which represent the old part of town, have highest risk priority. On the other hand, zones with modern buildings and with no important electrical and water supply infrastructure resulted as ones with the lowest risk priority (A6, A4 and A8).

Conclusions

Windows Application “MHR-MCA for PMO-GATE (Multi-Hazard Risk Assessment based on Multi-Criteria Analysis for PMO-GATE project)” allows input of map layers, presentation of hazard and vulnerability for particular hazard (seismic, flood, extreme sea waves) on buildings level and homogenous zone level.

Input data used in examples in this documents can be a subject of the change, especially the flood vulnerability data whose evaluations are not yet finished. Further steps also include the defining of criteria weights, especially for combined risk assessment.

References

- [1] Deliverable 4.1.1. Methodology for provision assessment indexes based on Spatial Multi-Criteria Decision Making, PMO-GATE project, 2022.
- [2] Deliverable 4.2.1. Methodology for provision assessment indexes based on Spatial Multi-Criteria Decision Making for seismic-flood-meteo-tsunamis, PMO-GATE project, 2022.