

# Fuzzy AHP

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Version 3.2

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## Introduction

The FuzzyAHP is a web application that makes it possible to evaluate alternatives by classical AHP method or its version suitable for the fuzzy environment. Besides solving classical (fuzzy) MCDM (multiple-criteria decision-making) problems, it can be also used for group decision-making and decision-making under risk.

For deriving the priority vector from Saaty matrices, three methods have been implemented:

- Eigenvector method
- Geometric mean method
- The fuzzy method working with triangular fuzzy elements described by Prof. Ramík.

For a brief overview of the mathematical background used in this software, the following paper is recommended:

HOLEČEK P., TALAŠOVÁ, J.: A free software tool implementing the fuzzy AHP method, *Proceedings of the 34th International Conference on Mathematical Methods in Economics 2016*, Liberec, Czech Republic, p. 266 – 271, ISBN 978-80-7494-296-9.

The paper summarizes the used theoretical methods and provides also references to the original literature where you can find more information on the method of interest.

The FuzzyAHP application is freely available at <http://FuzzyMCDM.upol.cz/FuzzyAHP>.

## Main window

The main window contains a header with links for saving, loading, or creating a new project:

- **New project** – Clicking on this link creates a new evaluation project. Before creating a new project, save all your work because all unsaved changes in the currently opened project will be lost.
- **Open project** – It opens a project that you have previously saved into a file.
- **Save project** – It saves the currently opened project into a file that you download on your computer. After clicking on this link, choose the name and location, where you want to save the currently edited project.
- **Load an example** – This item displays a page with a list of examples. You can select one of them and use it to explore the possibilities of the software. By loading the project with the example, the current project is closed. So if you are working on a project, make sure that you have saved all the changes first.
- **Information** – More information on the FuzzyAHP web application can be seen by clicking on this link.

Below the page header, there is a bar making it possible to navigate through the individual step of designing the project. Use the **Next step** button, to move to the next step, or **Previous step** button to go back to the previous step. You can also choose a specific step that from the drop-down list by clicking on it.

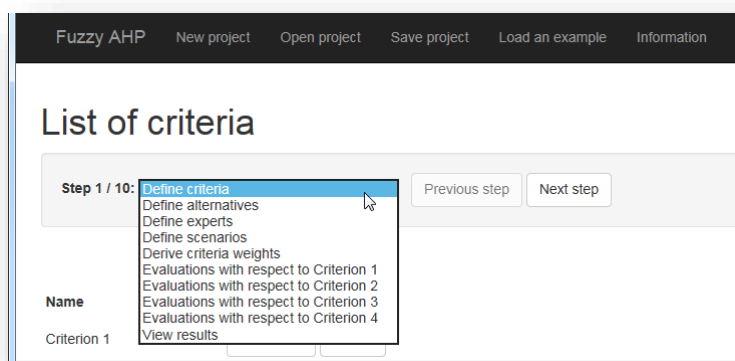


Figure 1 The main window

## The evaluation process

The evaluation process differs depending on the type of the problem. Different types require different pieces of information to be set. In this user-guide, we distinguish following basic types:

- **Multiple-criteria decision-making (MCDM)** – In this basic settings, multiple alternatives are evaluated with respect to multiple criteria. However, the evaluation is done by a single person (there is only one expert) and no randomness is assumed to be present.
- **Group MCDM** – Compared to the classical MCDM, in group MCDM, multiple experts are present (i.e. alternatives are evaluated by multiple people).

- **MCDM under risk** – In this setting, multiple scenarios are defined together with their probabilities. The alternatives are then evaluated for each of the scenarios.

The FuzzyMCDM software is very flexible and even combination of the mentioned basic problem types can be solved in it (e.g. group MCDM under risk).

In the following sections, the evaluation process and the required data will be described for each of the basic problem types.

## Multiple-criteria decision-making (MCDM)

In MCDM, there are multiple criteria, but there is only one expert and only one scenario used.

The solution of such a problem in FuzzyMCDM consists of the following steps:

1. First, the list of criteria is defined.
2. Next, the list of alternatives that should be evaluated is provided.
3. Then, a page with the list of expert appears. Since there is only one expert, you do not have to modify anything and proceed directly to the next step.
4. A page with the list of scenarios appears. In classical MCDM, there is only one scenario, so again proceed directly to the next step.
5. Then the Saaty matrix comparing importances of the criteria is set.
6. For each criterion, the Saaty matrix comparing alternatives with respect to this criterion is provided.
7. Finally, the resulting overall evaluations of the alternatives are calculated.

These steps will be described in more detail in the following text.

### Defining the list of criteria

First, the list of criteria has to be defined. By default, you can see four criteria as in the figure bellow.

The screenshot shows the 'List of criteria' page in the Fuzzy AHP software. At the top, there is a navigation bar with the following options: 'Fuzzy AHP', 'New project', 'Open project', 'Save project', 'Load an example', and 'Information'. Below the navigation bar, the page title is 'List of criteria'. Underneath the title, there is a progress indicator that says 'Step 1 / 10: Define criteria' with a dropdown menu and two buttons: 'Previous step' and 'Next step'. The main content area contains a table with four criteria, each with an 'Edit name' button and a 'Delete' button. At the bottom of the table, there is an 'Add' button and an empty input field for adding a new criterion.

Figure 2 The list of criteria

You can change the name of any criterion by clicking on the **Edit name** button, specifying the new name and confirming the changes by clicking on the **Save** button.

The criteria can be also deleted by clicking on the **Delete** button.

A new criterion is added by writing its name into a text box below the criteria list and by clicking on the **Add** button.

When you have specified all the criteria, proceed to the next step by clicking on the **Next step** button in the navigation bar. You can also move to the criteria list later and add additional criteria, or edit or delete the existing criteria.

### Setting the list of alternatives

The next step is setting of the list of alternatives. The controls on this page are similar as on the previous page for setting the list of criteria. By default you can see three alternatives as on the following figure. Again, you can use Add, Edit or Delete buttons to add an alternative, edit its name, or delete it.

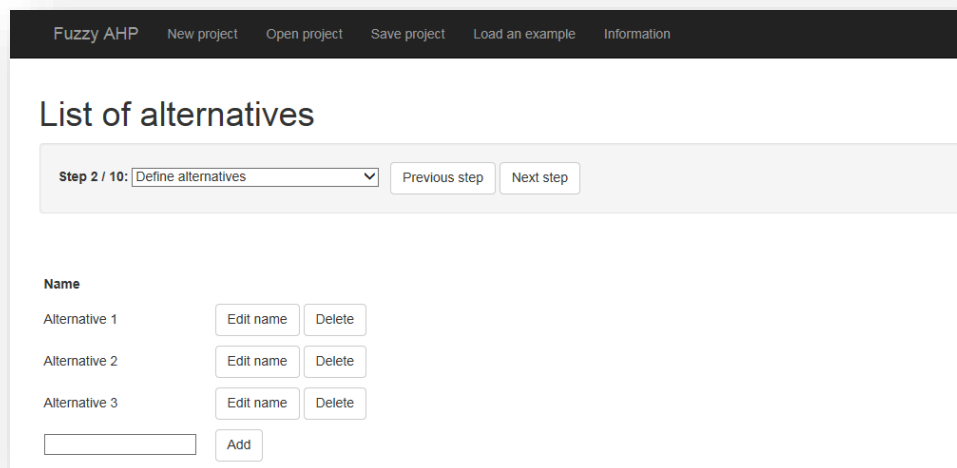


Figure 3 List of alternatives

When you have specified all alternatives that should be compared, proceed to the next step by clicking on the **Next step** button. Again, you can modify the list of alternatives later.

### Editing the Saaty matrix for deriving the criteria weights

The next step is to provide the Saaty matrix, which is used to derive the weights of the criteria. Select an element in the Saaty matrix by clicking on it. Only elements above the main diagonal are editable (they have dark blue color). The other elements are not editable, because they are set automatically (they have light blue color). The currently selected element has green color.

After selecting an element, write its value in the text box below the "Selected value" title. The following format can be used:

- You can write a triangular fuzzy element as three numbers separated by spaces. For example, the element in the first row and the second column in Figure 7 is "1 2 3". This means that the first criterion should be approximately two times more important than the second criterion (it is admitted, that it can be only 1-times or also as much as 3-times more important).
- A dot is used as a separator of decimal places (eg. "0.2 0.25 0.5").

- Instead of writing decimal numbers, you can simply use fractions. For example in the first row and fourth column in Figure 7, there is "1/4 1/3 1/2". This means that the fourth criterion should be approximately three times more important than the first criterion (or the importance of the fourth criterion is only one third of the importance of the first criterion), but it can be also only two times more important or as much as four time more important.
- If no fuzziness is required, you can write just a single number. For example, instead of writing triplet "2 2 2", you can write just "2". This can be seen in the first row and third column in Figure 7, which means that the first criterion should be twice as important as the third one.

Fuzzy AHP   New project   Open project   Save project   Load an example   Information

### Set Saaty matrix

Step 5 / 10: Derive criteria weights   Previous step   Next step

Saaty matrix

	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Criterion 1	1	1 2 3	2	1/4 1/3 1/2
Criterion 2	1/3 1/2 1	1		
Criterion 3	1/2		1	
Criterion 4	2 3 4			1

Selected value

1 2 3   Save   < Previous   Next >

Figure 4 Setting the Saaty matrix for deriving the criteria weights

As soon as all elements of the matrix are set, the resulting weights appear.

### Comparison of alternatives with respect to the individual criteria

For each criterion, the Saaty matrix comparing alternatives with respect to this criterion has to be set. The process is the same as in the previous step.

### Viewing the results

When all Saaty matrices are set, the resulting overall evaluations of the alternatives can be viewed. If some of the matrix elements have not been filled in, the page with results would contain only a warning that some information is missing. In this case, return back to the previous steps and set all the missing elements.

### Group MCDM

In group MCDM, the evaluation is performed by multiple evaluators (experts). Most of the required steps are the same as in solving classical MCDM; however some steps are new.

For solving a group MCDM problem, the following actions are required.

1. First, the list of criteria is defined.
2. Next, the list of alternatives that should be evaluated is provided.
3. The list of experts is provided.
4. Then, a page with the list of scenarios appears. We expect that there is only one scenario, so skip this step and proceed directly to the next one.
5. The Saaty matrix for deriving the importances of each expert should be provided.
6. For each of the experts:
  - a. The Saaty matrix comparing importances of the criteria is set.
  - b. The Saaty matrices comparing alternatives with respect to all of the criteria are provided.
7. Finally, the resulting overall evaluations of the alternatives are calculated.

The required steps for a particular problem with 4 criteria and 2 experts are illustrated in Figure 5.

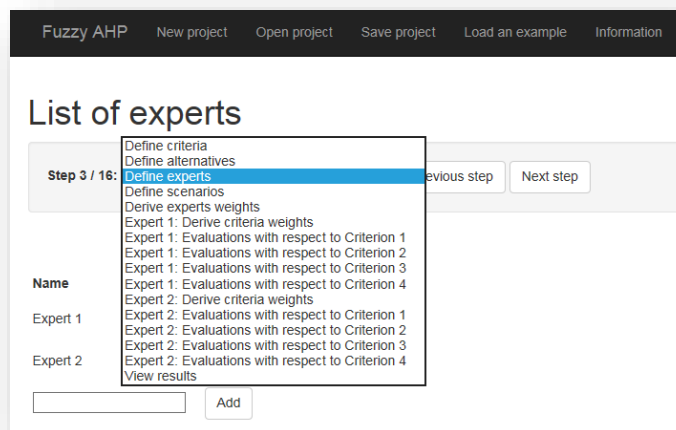


Figure 5 The required steps in group MCDM

The **lists of criteria and alternatives** are defined in the same way as for classical MCDM problems. Description of these steps can be found in the sections *Defining the list of criteria* and *Setting the list of alternatives*.

The **list of experts** should be defined as a next step. It is done again in the same way as defining e.g. the list of criteria. In group MCDM, there is more than one expert (evaluator). Provide the names of these experts (e.g. John, Mark, etc.).

In the next step, the **scenarios** should be defined. Since we assume only one scenario (multiple-scenarios are used in MCDM under risk), you do not have to modify anything and proceed directly to the next step.

In the following step, Saaty matrix for deriving **weights (importances) of the expert** is set. Working with Saaty matrices in general is described in the section *Editing the Saaty matrix for deriving the criteria weights*. The only difference is in the interpretation of the values in the Saaty matrix. If, for example, there is a number 5 in the first row and second column of the matrix, it means that we think that the first expert is five times more important than the second one.

Finally, the **weights of the criteria and evaluations of the alternatives** with respect to all of the criteria are derived from the respective Saaty matrices. In group MCDM, this is however done for each of the expert. Each expert can therefore have different opinion on the importances of the individual criteria and, of course, on the evaluation of the alternatives according to these criteria.

The page with **results** contains the overall results and also the resulting evaluations of the alternatives for each of the experts.

## MCDM under risk

The difference of the MCDM under risk compared to the classical MCDM is the presence of multiple scenarios (states of the world).

The steps for solving such a type of problems are

1. The list of criteria is defined.
2. The list of alternatives is provided.
3. Next, a page with the list of experts appears. We expect that there is only one expert, so skip this step and proceed directly to the next one.
4. The list of scenarios is provided.
5. The Saaty matrix comparing importances of the criteria is set.
6. The Saaty matrix for deriving the probabilities of the individual scenarios is provided.
7. For each criterion and each scenario, the Saaty matrix comparing alternatives with respect to this criterion (under assumption that the particular scenario occurs) is provided.
8. Finally, the resulting overall evaluations of the alternatives are calculated.

The steps that should be performed in the software for a problem with 4 criteria and 2 scenarios are illustrated in Figure 6.

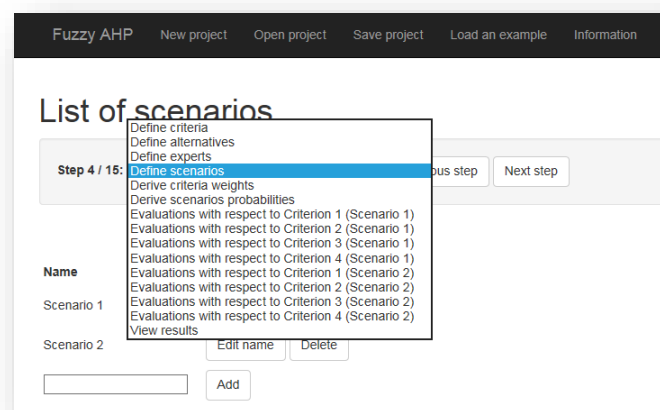


Figure 6 The required steps for MCDM under risk

The **lists of criteria and alternatives** are defined in the same way as for classical MCDM problems. Description of these steps can be found in the sections *Defining the list of criteria* and *Setting the list of alternatives*.

The **list of experts** can be skipped because we assume presence of only one expert.

In the next step, **the list of scenarios** should be defined. This is done in the same way as, for example, the definition of the criteria list. Provide the names of the scenarios that can occur in the future (for example, economic growth, economic decline, no change on the market).

The **criteria weights** are derived from the respective Saaty matrix in the same way as in classical MCDM.

Next, Saaty matrix for deriving **scenarios probabilities** should be set. For more information on setting Saaty matrices in general please refer to the section *Editing the Saaty matrix for deriving the criteria weights*. The difference is however in the interpretation of the elements in the Saaty matrix. If, for example, there is a number 5 in the first row and second column of the matrix, it means that we assume that the first scenario is five times more likely to happen than the second one.

Finally, the **evaluations of the alternatives** with respect to all of the criteria are derived from the respective Saaty matrices. In MCDM under risk, this is however done for each of the scenarios. Notice that only alternatives evaluations differ in each scenario. The criteria weights remain the same.

On the page with the **results**, the overall results can be seen. They are accompanied with the partial results for each of the scenario.

## More complex types of problems

The FuzzyAHP software makes it possible to solve also combinations of the mentioned basic types of problems. For example, the process of solving a (fuzzy) group multiple-criteria decision-making problem under risk with 4 criteria, 2 scenarios and 2 experts is shown in Figure 7. Notice that quite a lot of data have to be provided in this case (the whole process of solving such a problem consists of 26 steps).

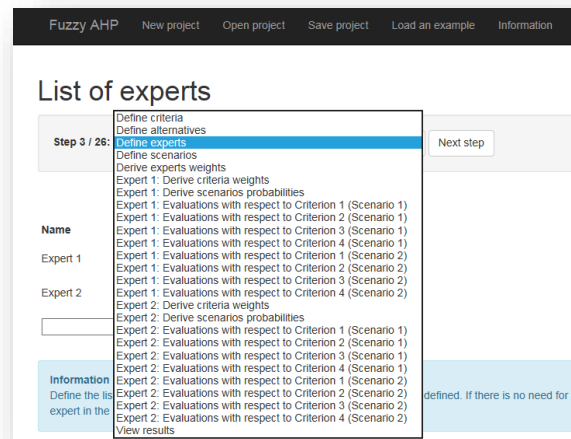


Figure 7 An example of a more complex of problem