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## Microsoft Excel as a tool for solving multicriteria decision problems

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### Abstract

The main goal of every agent is to make a good decision. The Analytic Hierarchy Process is frequently used approach for solving decision making problems. There exists wide range of software programs utilizing that approach. Main disadvantage of those software products is that they are commercial and relatively expensive and thus it prevents them to be used by small companies, students or researchers.

This contribution introduces a Microsoft Excel add-in called DAME – Decision Analysis Module for Excel. Comparing to other computer programs DAME is free, can work with scenarios or multiple decision makers, allows for easy manipulation with data, utilizes capabilities of Microsoft Excel and displays all intermediate calculations. Decision makers can structure their decision models into three levels – scenarios/users, criteria and variants. Elements on all three levels can be evaluated either by direct values or pair-wise comparisons. For each pair-wise comparison matrix there is calculated an inconsistency index. There are provided three different methods for the evaluation of the weights of criteria, the variants as well as the scenarios/users – Saaty's Method, Geometric Mean Method and Fuller's Triangle Method. Multiplicative and additive syntheses are supported. All calculations are instant so users can easily see what happen if anything is modified. Bar chart is used for final ordering representation. The proposed software package is demonstrated on couple of illustrating examples of real life decision problems.

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*Keywords:* analytic hierarchy process; multi-criteria decision making; pair-wise comparisons; Microsoft Excel; Geometric Mean Method.

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### 1. Introduction

Decision making in situations with multiple variants, multiple criteria and multiple decision makers is an important area of research in decision theory and has been widely studied e.g. in [1], [2], [4], [6], [9], [10],

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[11]. There exists wide range of computer programs that are able to help decision makers to make good decisions, e.g. Expert Choice (<http://www.expertchoice.com>), Decisions Lens (<http://www.decisionlens.com>), Mind Decider (<http://www.minddecider.com>), MakeItRational (<http://makeitrational.com>) or Super Decisions (<http://www.superdecisions.com>). Main disadvantage of those programs is that they are commercial and relatively quite expensive and thus it prevents them to be used by small companies, students or researchers.

Here we introduce a new Microsoft Excel add-in called DAME – Decision Analysis Module for Excel. Comparing to other software products for solving multicriteria decision problems, DAME is free, able to work with scenarios or multiple decision makers, allows for easy manipulation with data and utilizes capabilities of widespread spreadsheet Microsoft Excel. On the contrary to similar packages it is very important that our new add-in is not just a black box but it displays all intermediate calculations. From this feature will benefit especially students when they learn decision making methods. Important feature is also using Geometric Mean Method which is very fast comparing to Saaty's Method and therefore all calculations are instant.

Users can structure their decision models into three levels – scenarios/users, criteria and variants. Standard pair-wise comparisons are used for evaluating both criteria and variants. For each pair-wise comparison matrix there is calculated an inconsistency index to indicate consistency of their pair-wise comparisons. There are provided three different methods for the evaluation of the weights of criteria, the variants as well as the scenarios/users – Saaty's Method [11], Geometric Mean Method [12] and Fuller's Triangle Method. Multiplicative and additive syntheses are supported.

## 2. Software description

DAME works with all current versions of Microsoft Excel from version 97. It consists of four individual files:

- DAME.xla – main module with user interface, it is written in VBA (Visual Basic for Applications),
- DAME.dll – it contains special functions used by the application, it is written in C#,
- DAME.xll – it contains library for linking C# modules with Excel called Excel-DNA (<http://exceldna.codeplex.com>),
- DAME.dna – configuration file for Excel-DNA module.

All four files must be placed in the same folder and macros must be permitted before running the module (see Excel documentation for details). DAME itself can be executed by double clicking on the file DAME.xla. After executing the add-in there will appear a new menu item “DAME” in the Add-ins ribbon (in older Excel versions the menu item “DAME” will appear in the top level menu). A new decision problem can be generated by clicking on “*New problem*” item in the main DAME menu, see figure 1.

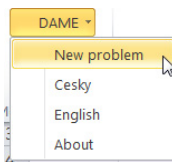


Fig. 1. New problem menu

Then there will be shown a form with main problem characteristics, see figure 2.

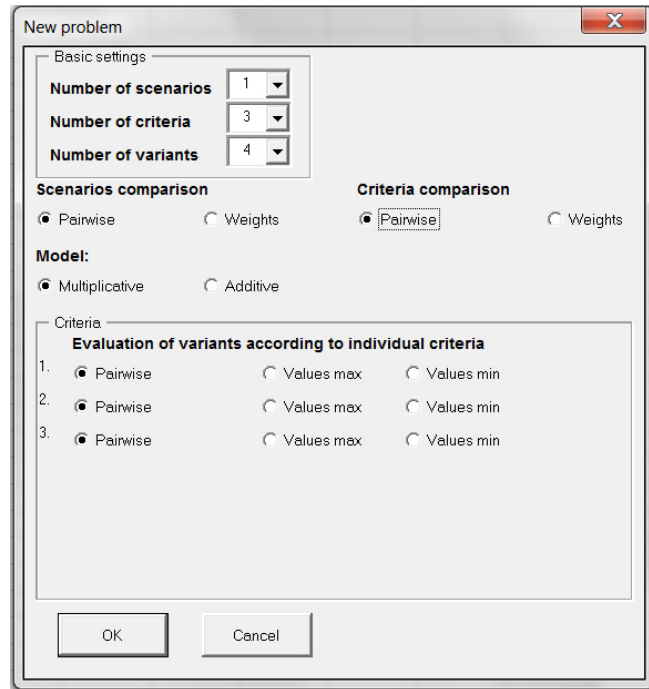


Fig. 2. New problem characteristics

In the top panel there are basic settings: Number of scenarios, criteria and variants. In case a user doesn't want to use scenarios or there is just a single decision maker, the number of scenarios should be set to one. In the second panel we can set how we want to compare scenarios/users and criteria either using pairwise comparison matrix or set weights directly. Here we also choose multiplicative or additive synthesis model. In the last panel users can choose how they want to evaluate variants according to individual criteria. There are three options: Pairwise – each pair of variants is compared individually, Values max – indicates maximization criterion where each variant is evaluated by single value, e.g. price and Values min – indicates minimization criterion where each variant is evaluated by single value, e.g. costs. When user confirms his options a new Excel sheet with forms is created, where user can set names of all elements and evaluate criteria and variants using pairwise comparison matrices as shown on figure 3.

| Criteria | Crit 1 | Crit 2 | Crit 3 | 0.000 | Criteria weights |
|----------|--------|--------|--------|-------|------------------|
| Crit 1   | 1      |        |        |       | 0.333333         |
| Crit 2   | 0      | 1      |        |       | 0.333333         |
| Crit 3   | 0      | 0      | 1      |       | 0.333333         |

Fig. 3. Pairwise comparison matrix

In the pairwise comparison matrix users enter values only in the upper triangle. The values in the lower triangle are reciprocal and automatically calculated. If criterion (variant) in the row is more important than the criterion (variant) in the column user enters values from 2 to 9 (the higher the value is the more important is the criterion in the row). If criterion (variant) in the row is less important than the criterion (variant) in the column user enters values from 1/2 to 1/9 (the less the value is the less important is the criterion in the row). If criterion (variant) in the row is equally important to the criterion (variant) in the column user enters value 1 or leaves it

empty. In the top right corner there is calculated inconsistency index which should be less than 0.1, if it is greater we should revise our pairwise comparisons, so that they are more consistent. In the very right column there are calculated weights of individual criteria (variants) based on the values in the pairwise comparison matrix and selected evaluation method. The weights  $w_k$  based on geometric mean method are calculated using the equation (1).

$$w_k = \frac{\left( \prod_{j=1}^n a_{kj} \right)^{1/n}}{\sum_{i=1}^n \left( \prod_{j=1}^n a_{ij} \right)^{1/n}}, \quad k = 1, 2, \dots, n \quad (1)$$

where  $w_k$  is weight of  $k$ -th criteria (variant),  $a_{ij}$  are values in the pairwise comparison matrix, and  $n$  is number of criteria (variants).

The inconsistency index is calculated using the formula (2).

$$GCI = \frac{2}{(n-1)(n-2)} \sum_{i < j} \log^2 \left( a_{ij} \cdot \frac{w_j}{w_i} \right) \quad (2)$$

When we are entering values in individual pairwise comparison matrices all weights are being instantly recalculated, so we can see immediate impact of our each individual entry. Matrix and graph with total evaluation of variants is then shown at the bottom of the sheet. The resulting vector of weights of the variants  $\mathbf{Z}$  is given by the formula (3).

$$\mathbf{Z} = \mathbf{W}_{32} \mathbf{W}_{21}, \quad (3)$$

where  $\mathbf{W}_{21}$  is the  $n \times 1$  matrix (weighing vector of the criteria), i.e.

$$\mathbf{W}_{21} = \begin{bmatrix} w(C_1) \\ \vdots \\ w(C_n) \end{bmatrix}, \quad (4)$$

and  $\mathbf{W}_{32}$  is the  $m \times n$  matrix:

$$\mathbf{W}_{32} = \begin{bmatrix} w(C_1, V_1) & \cdots & w(C_n, V_1) \\ \vdots & \cdots & \vdots \\ w(C_1, V_m) & \cdots & w(C_n, V_m) \end{bmatrix}, \quad (5)$$

where  $w(C_i)$  is weight of the criterion  $C_i$ ,  $w(V_r, C_i)$  is weight of variant  $V_r$  subject to the criterion  $C_i$ .

### 3. Case study

Here we demonstrate the proposed add-in DAME on a decision making situation buying an “optimal” washing machine with 3 decision criteria and 3 variants. The goal of this decision situation is to find the best variant from 3 pre-selected ones according to 3 criteria: price (minimization criterion), efficiency (pairwise) and design

(pairwise). At this stage we don't use multiple decision makers, so the parameter Number of scenarios will be set to one. Setting of all parameters can be seen on the figure 4.

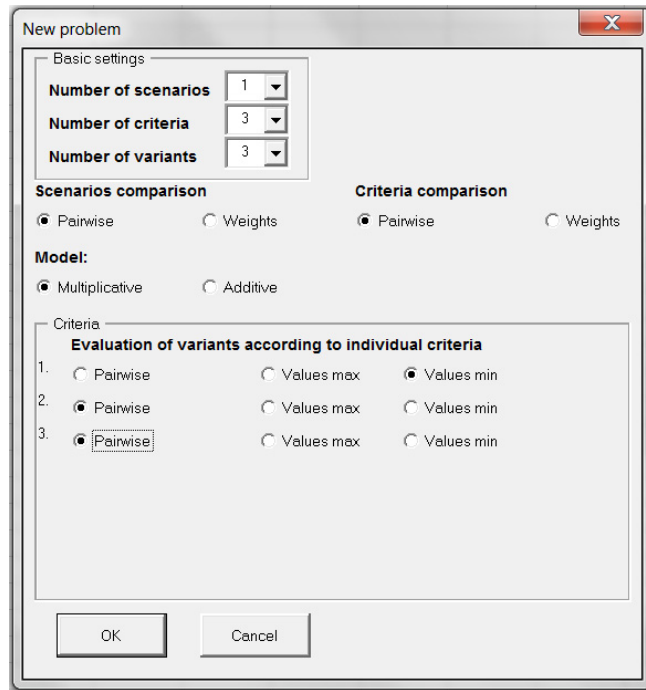


Fig. 4. Case study – setting of parameters

When we submit the form a new sheet is generated. First we set names of criteria and variants, for simplicity we use default names for variants (Var 1, Var 2 and Var 3), see figure 5.

|                           |            |        |
|---------------------------|------------|--------|
| <b>Names of criteria:</b> |            |        |
| Price                     | Efficiency | Design |
| <b>Names of variants:</b> |            |        |
| Var 1                     | Var 2      | Var 3  |

Figure 5 Case study – names of criteria and variants

Next step is comparison of individual criteria using pairwise comparison matrix with elements saying how much more important is criterion in the row than the criterion in the column, see figure 6.

| <b>Criteria Comparison:</b> |       |            |        |       |                  |
|-----------------------------|-------|------------|--------|-------|------------------|
| Criteria                    | Price | Efficiency | Design | 0.010 | Criteria weights |
| Price                       | 1     | 2          | 4      |       | 0.558425         |
| Efficiency                  | 0.5   | 1          | 3      |       | 0.319618         |
| Design                      | 0.25  | 0.333333   | 1      |       | 0.121957         |

Fig. 6. Case study – criteria comparison

We can see that inconsistency index is less than 0.1 therefore we can say that our pairwise comparisons are consistent. In the very right column we can see calculated weights of individual criteria.

Final step is evaluation of variants according to individual criteria. Variants according the first criterion (price) will be evaluated by actual price and variants according the other two criteria (efficiency and design) will be evaluated using pairwise comparisons), see figure 7.

| Price             | Value |          |       |       | Variants weights |          |          |
|-------------------|-------|----------|-------|-------|------------------|----------|----------|
| Var 1             | 11    |          |       |       | 0.28777          | 0.581552 | 0.117221 |
| Var 2             | 10    |          |       |       | 0.316547         | 0.308996 | 0.614411 |
| Var 3             | 8     |          |       |       | 0.395683         | 0.109452 | 0.268369 |
| <b>Efficiency</b> |       |          |       |       |                  |          |          |
|                   | Var 1 | Var 2    | Var 3 | 0.002 |                  |          |          |
| Var 1             | 1     | 2        | 5     |       |                  |          |          |
| Var 2             | 0.5   | 1        | 3     |       |                  |          |          |
| Var 3             | 0.2   | 0.333333 | 1     |       |                  |          |          |
| <b>Design</b>     |       |          |       |       |                  |          |          |
|                   | Var 1 | Var 2    | Var 3 | 0.041 |                  |          |          |
| Var 1             | 1     | 1/4      | 1/3   |       |                  |          |          |
| Var 2             | 4     | 1        | 3     |       |                  |          |          |
| Var 3             | 3     | 0.333333 | 1     |       |                  |          |          |

Fig. 7. Case study – evaluation of variants

As we can see both pairwise comparison matrices are consistent, because their inconsistency indexes are less than 0.1. In the top right matrix we can see calculated weights of all variants (rows) according to individual criteria (columns). At this stage synthesis is calculated and we can see total evaluation of variants in the last table on figure 8 and graphical representation on figure 9. We can conclude that the best variant is Var 1 with weight 0.36 followed by Var 2 with weight 0.35 and the last one is Var 3 with weight 0.29.

| CZn=  | Weight   | Rank |
|-------|----------|------|
| Var 1 | 0.360868 | 1    |
| Var 2 | 0.35046  | 2    |
| Var 3 | 0.288672 | 3    |

Fig. 8. Case study – total evaluation of variants

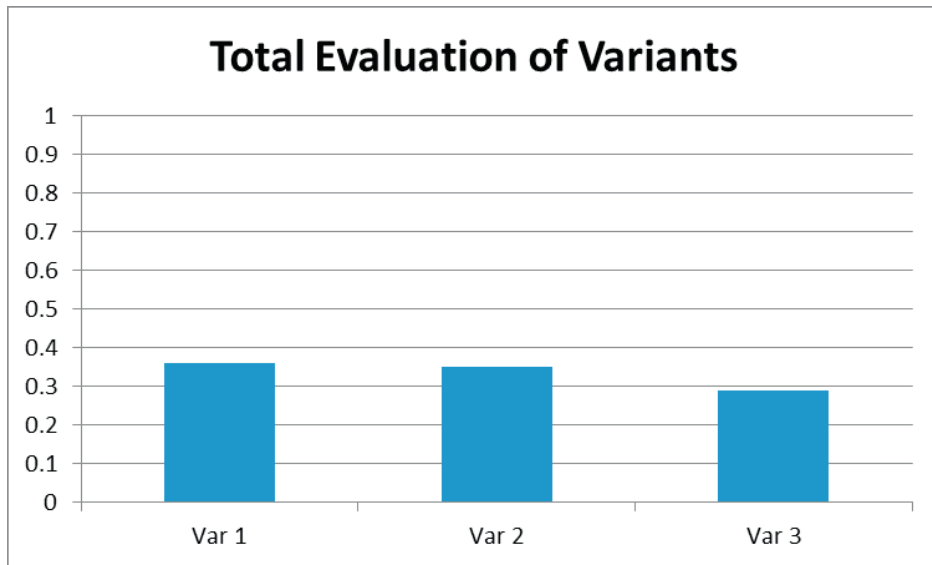


Fig. 9. Case study – total evaluation of variants - graph

#### 4. Case study with multiple decision makers

In real world people have different opinion on the same decision situation. That is why our proposed software works also with multiple decision makers. In this case study we assume two decision makers – User A and User B. First we must compare both decision makers using pairwise comparison matrix. We believe that evaluations of user B are slightly more relevant than evaluations of user A. The pairwise comparison matrix can be seen on figure 10.

| Scenarios | User A | User B | 0.000 | Scenarios weights |
|-----------|--------|--------|-------|-------------------|
| User A    | 1      | 1/2    |       | 0.333333          |
| User B    | 2      | 1      |       | 0.666667          |

Fig. 10. Case study – decision makers comparison

User A is using exactly the same entries as in the previous case study, so we need to just evaluate variants to individual criteria for the second user B, see figure 11.

|               |              |              |              |       |                         |          |          |
|---------------|--------------|--------------|--------------|-------|-------------------------|----------|----------|
| <b>Crit 1</b> | <b>Value</b> |              |              |       | <b>Variants weights</b> |          |          |
| Var 1         | 11           |              |              |       | 0.28777                 | 0.47423  | 0.163424 |
| Var 2         | 10           |              |              |       | 0.316547                | 0.376397 | 0.539615 |
| Var 3         | 8            |              |              |       | 0.395683                | 0.149373 | 0.296961 |
| <b>Crit 2</b> | <b>Var 1</b> | <b>Var 2</b> | <b>Var 3</b> | 0.030 |                         |          |          |
| Var 1         | 1            | 1            | 4            |       |                         |          |          |
| Var 2         | 1            | 1            | 2            |       |                         |          |          |
| Var 3         | 0.25         | 0.5          | 1            |       |                         |          |          |
| <b>Crit 3</b> | <b>Var 1</b> | <b>Var 2</b> | <b>Var 3</b> | 0.005 |                         |          |          |
| Var 1         | 1            | 1/3          | 1/2          |       |                         |          |          |
| Var 2         | 3            | 1            | 2            |       |                         |          |          |
| Var 3         | 2            | 0.5          | 1            |       |                         |          |          |

Fig. 11. Case study – evaluation of variants – User B

Final evaluation of variants for user B can be seen on figure 12.

| Zn=   | Weight   | Rank |
|-------|----------|------|
| Var 1 | 0.314727 | 3    |
| Var 2 | 0.366502 | 1    |
| Var 3 | 0.318771 | 2    |

Fig. 12. Case study – final evaluation of variants – User B

Finally from both users there is calculated synthesis and total evaluation of variants is shown on figure 13.

| CZn=  | Weight   | Rank |
|-------|----------|------|
| Var 1 | 0.330108 | 2    |
| Var 2 | 0.361155 | 1    |
| Var 3 | 0.308738 | 3    |

Fig. 13. Case study – total evaluation of variants

Comparing to the previous case study with a single decision maker we can see that final rank of variants was changed. Now the best variant is Var 2 with weight 0.36, then Var 1 with weight 0.33 and the last one Var 3 with weight 0.31.

### 5. Conclusions

In this paper we have proposed a new Microsoft Excel add-in called DAME for solving decision making problems. On two realistic case studies its functionality was demonstrated in individual steps. The main advantages of the add-in are that it is free, it can work with scenarios or multiple decision makers, displays all intermediate calculations, allows for easy manipulation with data and utilizes capabilities of widespread spreadsheet Microsoft Excel. DAME is used by hundreds of students in the course Decision Analysis for Managers at the School of Business Administration in Karvina, Silesian University in Opava. It can be recommended also for other students, researchers or small companies.

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