

# Decision Analysis Module for Excel

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**Abstract**—The Analytic Hierarchy Process is frequently used approach for solving decision making problems. There exists wide range of software programs utilizing that approach. Their main disadvantage is that they are relatively expensive and missing intermediate calculations. This work 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 and displays intermediate calculations. Users can structure their decision models into three levels – scenarios/users, criteria and variants. Items on all levels can be evaluated either by weights or pair-wise comparisons. There are provided three different methods for the evaluation of the weights of criteria, the variants as well as the scenarios – Saaty's Method, Geometric Mean Method and Fuller's Triangle Method. Multiplicative and additive syntheses are supported. The proposed software package is demonstrated on couple of illustrating examples of real life decision problems.

**Keywords**—Analytic hierarchy process, multi-criteria decision making, pair-wise comparisons, Microsoft Excel, Scenarios.

## I. INTRODUCTION

DECISION making in situations with multiple variants is an important area of research in decision theory and has been widely studied e.g. in [2] – [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.mindecider.com>), Make It Rational (<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 or individual entrepreneurs.

Here we introduce a new Microsoft Excel add-in named 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. Users can structure their decision models into three levels - scenarios, 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. There are provided three

different methods for the evaluation of the weights of criteria, the variants as well as the scenarios - Saaty's Method [10], Geometric Mean Method [1] and Fuller's Triangle Method [2].

## II. 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 Fig. 1.

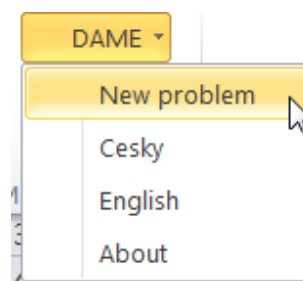


Fig. 1 New problem menu

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

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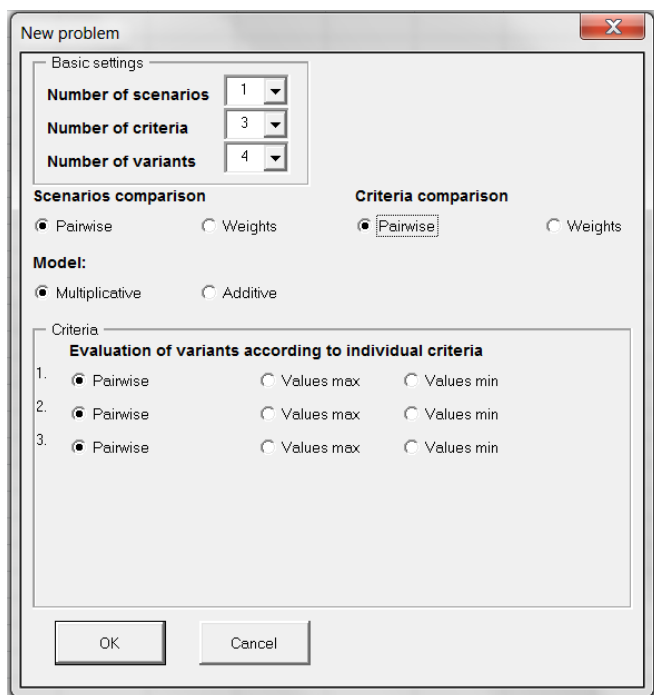


Fig. 2 New problem characteristics

In the top panel there are basic settings: Number of scenarios, criteria and variants. In case a user doesn't want to use scenarios, the number of scenarios should be set to one. In the second panel we can set how we want to compare scenarios and criteria either using pairwise comparison matrix or set weights directly. 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 Fig. 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 (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 (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  $Z$  is given by (3):

$$Z = W_{32} W_{21}, \quad (3)$$

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

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

and  $W_{32}$  is the  $m \times n$  matrix:

$$W_{32} = \begin{bmatrix} w(C_1, V_1) & \dots & w(C_n, V_1) \\ \vdots & \dots & \vdots \\ w(C_1, V_m) & \dots & w(C_n, V_m) \end{bmatrix}, \quad (5)$$

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  $C_i$ .

### III. CASE STUDY

Here we demonstrate the proposed add-in DAME on a decision making situation buying an "optimal" dishwasher with 3 decision criteria and 3 variants. The goal of this realistic 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 scenarios, so number of scenarios will be set to one. Setting of parameters can be seen on the Fig. 4.

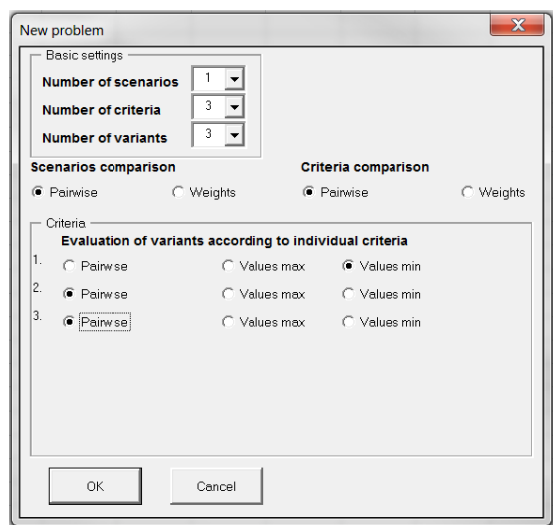


Fig. 4 Case study – setting of parameters

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 Fig. 5.

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

Fig. 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 Fig. 6.

<b>Criteria Comparison:</b>					
<b>Criteria</b>	<b>Price</b>	<b>Efficiency</b>	<b>Design</b>	<b>0.010</b>	<b>Criteria weights</b>
<b>Price</b>	1	2	4		0.558425
<b>Efficiency</b>	0.5	1	3		0.319618
<b>Design</b>	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 Fig. 7.

<b>Evaluation of Variants According to Individual Criteria:</b>						
<b>Price</b>	<b>Value</b>				<b>Variants weights</b>	
Var 1	8				0.405405	0.12202
Var 2	10				0.324324	0.229651
Var 3	12				0.27027	0.648329
						0.333069
<b>Efficiency</b>	<b>Var 1</b>	<b>Var 2</b>	<b>Var 3</b>	<b>0.002</b>		
Var 1	1	1/2	1/5			
Var 2	2	1	1/3			
Var 3	5	3	1			
<b>Design</b>	<b>Var 1</b>	<b>Var 2</b>	<b>Var 3</b>	<b>0.014</b>		
Var 1	1	5	2			
Var 2	0.2	1	1/4			
Var 3	0.5	4	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 Fig. 8 and graphical representation on Fig. 9. We can conclude that the best variant is Var 3 with weight 0.40 followed by Var 1 with weight 0.33 and the last one is Var 2 with weight 0.27.

<b>Czn=</b>	<b>Weight</b>	<b>Rank</b>
Var 1	0.334848	2
Var 2	0.266389	3
Var 3	0.398764	1

Fig. 8 Case study – total evaluation of variants

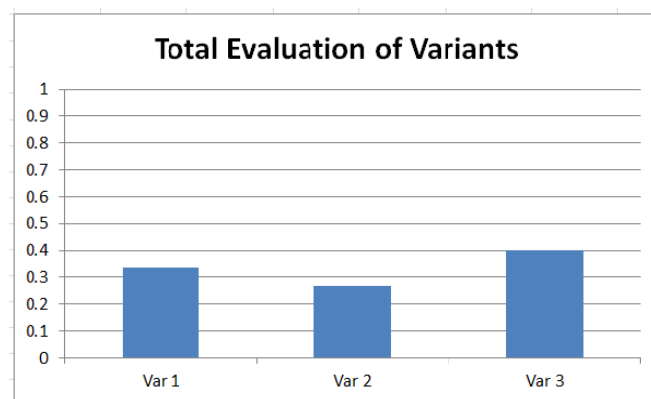


Fig. 9 Case study – total evaluation of variants - graph

#### IV. CASE STUDY WITH SCENARIOS

In real decision situations a decision maker usually faces uncertainty. For example it may happen that price goes up or efficiency is calculated based on special conditions that are far from real ones. That is why our proposed software works also with scenarios. In this case study we assume two scenarios – optimistic and pessimistic. First we must compare both scenarios using pairwise comparison matrix. It can be seen on Fig. 10.

Scenarios	optimistic	pessimistic	0.000	Scenarios weights
optimistic	1	2		0.666667
pessimistic	0.5	1		0.333333

Fig. 10 Case study – scenarios comparison

Optimistic scenario is using exactly the same entries as in the previous case study, so we just need to compare individual criteria and evaluate variants to individual criteria for the second - pessimistic scenario, see Figs. 11 and 12.

Criteria Comparison:					
Criteria	Price	Efficiency	Design	0.030	Criteria weights
Price	1	3	3		0.593634
Efficiency	0.333333	1	2		0.249311
Design	0.333333	0.5	1		0.157056

Fig. 11 Case study – criteria comparison variants – pessimistic scenario

Evaluation of Variants According to Individual Criteria:						
Price	Value	Variants weights				
Var 1	9	0.406332	0.633708	0.157056		
Var 2	11	0.332454	0.191921	0.593634		
Var 3	14	0.261214	0.174371	0.249311		
Efficiency	Var 1	Var 2	Var 3	0.005		
Var 1	1	3	4			
Var 2	0.333333	1	1			
Var 3	0.25	1	1			
Design	Var 1	Var 2	Var 3	0.030		
Var 1	1	1/3	1/2			
Var 2	3	1	3			
Var 3	2	0.333333	1			

Fig. 12 Case study – evaluation of variants – pessimistic scenario

Final evaluation of variants for pessimistic scenario can be seen on Fig. 13.

Zn=	Weight	Rank
Var 1	0.423869	1
Var 2	0.338437	2
Var 3	0.237694	3

Fig. 13 Case study – final evaluation of variants – pessimistic scenario

Finally from both scenarios there is calculated synthesis and total evaluation of variants is shown on Fig. 14.

CZn=	Weight	Rank
Var 1	0.364522	1
Var 2	0.290405	3
Var 3	0.345074	2

Fig. 14 Case study – total evaluation of variants

Comparing to the previous case study without scenarios we can see that final rank of variants has changed. Now the best

variant is Var 1 with weight 0.36, then Var 3 with weight 0.35 and the last one Var 2 with weight 0.29.

## V. CONCLUSION

In this paper we have proposed a new Microsoft Excel add-in DAME for solving decision making problems. Comparing to other decision support programs 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 two realistic case studies we have demonstrated its functionality in individual steps. This add-in 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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