

DAME - Microsoft Excel add-in for solving multicriteria decision problems with scenarios

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Abstract. The main goal of every economic agent is to make a good decision, especially in economic environment with many investment alternatives and evaluation criteria. The Analytic Hierarchy Process (AHP) is widely used approach for solving decision making problems. There exists wide range of computer programs that are able to help decision makers to make good decisions. 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.

This paper introduces 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, Geometric Mean Method and Fuller's Triangle Method. All calculations are instant so users can easily see what happen if value of any input is changed. Apart from the final ordering of the variants there are also shown all intermediate results, so it is clearly seen how the synthesis was produced. The results of the decision model are depicted by a bar chart. Capabilities of the proposed software package are 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.

JEL Classification: C44

AMS Classification: 90C15

1 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], [3], [5], [7], [9], [10], [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 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].

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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.

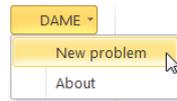


Figure 1 New problem menu

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

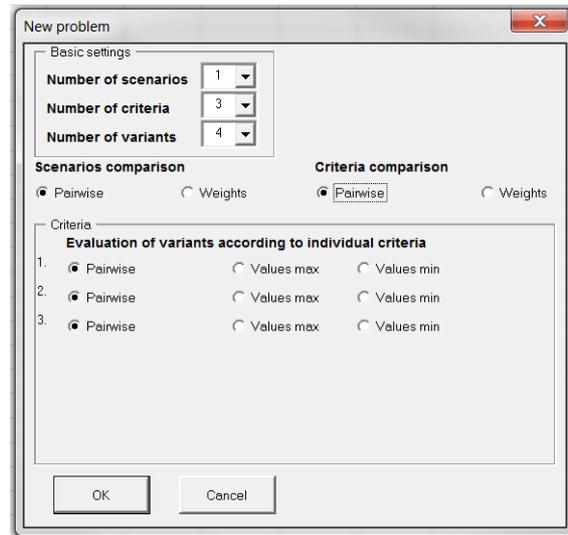


Figure 2 New problem characteristics

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 chose 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

Figure 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” car 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 figure 4.

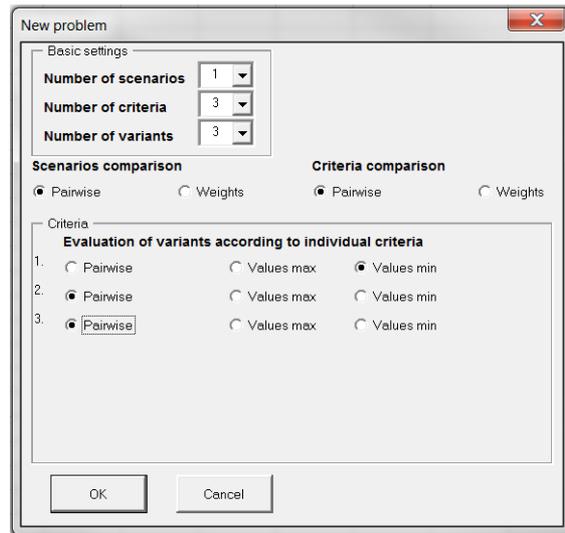


Figure 4 Case study – setting of parameters

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.

Names of criteria:		
price	efficiency	design
Names of variants:		
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.

Criteria	price	efficiency	design	0.005	Criteria weights
price	1	2	3		0.539615
efficiency	0.5	1	2		0.296961
design	0.333333	0.5	1		0.163424

Figure 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	260				0.292405	0.625013	0.167656
Var 2	220				0.34557	0.238487	0.483604
Var 3	210				0.362025	0.1365	0.348739
efficiency				0.010			
Var 1	1	3	4				
Var 2	0.333333	1	2				
Var 3	0.25	0.5	1				
design				0.076			
Var 1	1	1/2	1/3				
Var 2	2	1	2				
Var 3	3	0.5	1				

Figure 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.

CZn=	Weight	Rank
Var 1	0.37079	1
Var 2	0.336328	2
Var 3	0.292882	3

Figure 8 Case study – total evaluation of variants

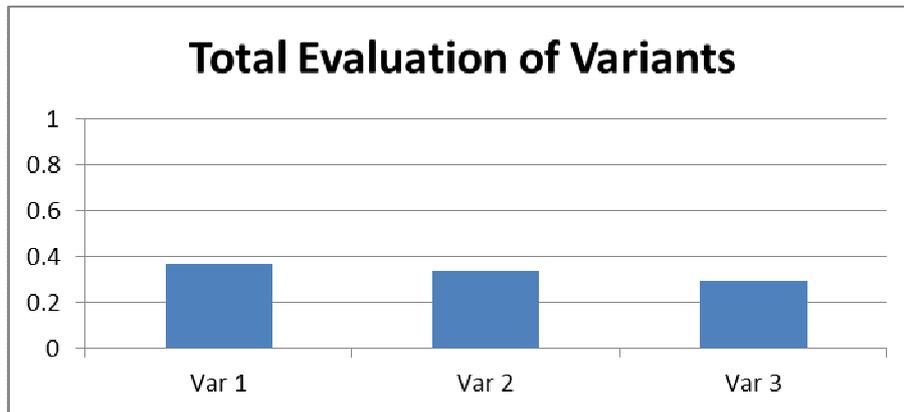


Figure 9 Case study – total evaluation of variants - graph

4 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 figure 10.

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

Figure 10 Case study – scenarios comparison

Optimistic scenario 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 - pessimistic scenario, see figure 11.

price	Value	Variants weights		
Var 1	320	0.276753	0.412599	0.124306
Var 2	240	0.369004	0.32748	0.517134
Var 3	250	0.354244	0.259921	0.35856

efficiency	Var 1	Var 2	Var 3	0.030
Var 1	1	1	2	
Var 2	1	1	1	
Var 3	0.5	1	1	

design	Var 1	Var 2	Var 3	0.060
Var 1	1	1/3	1/4	
Var 2	3	1	2	
Var 3	4	0.5	1	

Figure 11 Case study – evaluation of variants – pessimistic scenario

Final evaluation of variants for pessimistic scenario can be seen on figure 12.

Zn=	Weight	Rank
Var 1	0.2921803	3
Var 2	0.3808808	1
Var 3	0.3269389	2

Figure 12 Case study – final evaluation of variants – pessimistic scenario

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

CZn=	Weight	Rank
Var 1	0.3445867	2
Var 2	0.3511792	1
Var 3	0.3042341	3

Figure 13 Case study – total evaluation of variants

Comparing to the previous case study without scenarios we can see that final rank of variants was changed. Now the best variant is Var 2 with weight 0.35, then Var 1 with weight 0.34 and the last one Var 3 with weight 0.30.

5 Conclusions

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. The new add-in could be used mainly by students, scientists and small companies.

Acknowledgements

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References

- [1] Aguaron, J., Moreno-Jimenez, J.M.: The geometric consistency index: Approximated thresholds. *European Journal of Operational Research* 147 (2003), 137-145.
- [2] Fishburn, P. C.: A comparative analysis of group decision methods, *Behavioral Science* (16), 1971, 538-544.
- [3] Gass, S.I., Rapcsák, T.: Singular value decomposition in AHP. *European Journal of Operational Research* 154 (2004), 573–584.
- [4] Horn, R. A., Johnson, C. R.: *Matrix Analysis*, Cambridge University Press, 1990.
- [5] Mazurek, J., Fiedor, J.: The Decision Tool for the Ordinal Consensus Ranking Problem. In: *Conference Proceedings of the International Scientific Conference ICT for Competitiveness 2012*. Silesian University, School of Business Administration, Karvina, 2012, 184-189.
- [6] Ramík, J., Korviny, P.: Inconsistency of pair-wise comparison matrix with fuzzy elements based on geometric mean. *Fuzzy Sets and Systems* 161 (2010), 1604–1613.
- [7] Ramik, J., Perzina, R.: Fuzzy ANP – a New Method and Case Study. In: *Proceedings of the 24th International Conference Mathematical Methods in Economics 2006*, University of Western Bohemia, 2006.
- [8] Ramík, J., Vlach, M.: *Generalized concavity in optimization and decision making*. Kluwer Publ. Comp., Boston-Dordrecht-London, 2001, 305 p.
- [9] Saaty, T.L.: Exploring the interface between hierarchies, multiple objectives and fuzzy sets. *Fuzzy Sets and Systems* 1, 1978, 57-68.
- [10] Saaty, T.L.: *Multicriteria decision making - the Analytical Hierarchy Process*. Vol. I., RWS Publications, Pittsburgh, 1991.
- [11] Saaty, T.L.: *Decision Making with Dependence and Feedback – The Analytic Network Process*. RWS Publications, Pittsburgh, 2001.

Solver is a Microsoft Excel add-in program you can use for what-if analysis. Use Solver to find an optimal (maximum or minimum) value for a formula in one cell " called the objective cell " subject to constraints, or limits, on the values of other formula cells on a worksheet. Solver works with a group of cells, called decision variables or simply variable cells that are used in computing the formulas in the objective and constraint cells. To save your decision variable cell values as a scenario that you can display later, click Save Scenario in the Solver Results dialog box, and then type a name for the scenario in the Scenario Name box. Step through Solver trial solutions. After you define a problem, click Options in the Solver Parameters dialog box. The following is a comparison of various add-in packages available to do Monte Carlo probabilistic modeling and risk analysis. Add-ins covered are for Microsoft Excel on Windows. Mac software and tools for other platforms, such as R or Matlab are not included. Decision-making software is reviewed separately.

Spreadsheet. Probability. Add-in. Iman, R. L. and Conover, W. J., (1982). 'A Distribution-Free Approach to Inducing Rank Order Correlation Among Input Variables', *Commun Statist-Simula Computa* 11... [7] Ramik, J., Perzina, R.: DAME - Microsoft Excel Add-in for Solving Multicriteria Decision Problems with Scenarios. In: *Proceedings of the 30th International Conference Mathematical Methods in Economics 2012*, University of Western Bohemia, 2012. [8] Ramák, J., Vlach, M.: *Generalized concavity in optimization and decision making*. Kluwer Publ. Comp., Boston-Dordrecht-London, 2001, 305 p. [9] Saaty, T.L.: Exploring the interface between hierarchies, multiple objectives and fuzzy sets. *Fuzzy Sets and Systems* 1, 1978, 57-68. [10] Saaty, T.L.: *Multicriteria decision making - the Analytical Hierarchy Process*. Vol. I., RWS Publications, Pittsburgh, 1991. [11] Saaty, T.L.: *Decision Making with Dependence and Feedback - The Analytic Network Process*.