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ANP shortcuts or how to utilize MDAHP technique

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Abstract:

Aim: Multi-Dominant Analytic Hierarchy Process (MDAHP) was devised to solve particular decision-making problems. The same problems may be solved by means of a more universal technique, namely Analytic Network Process (ANP). The originators of MDAHP authoritatively state that both tools could be applied interchangeably with success. The authors' experience, however, shows that this is not the case. The issue of substitutability of one technique for another is therefore critically discussed in the paper.

Design / research method: The paper presents the comparison of the outcomes of the ANP and MDAHP application to solve a decision-making problem.

Conclusions / findings: The comparison of the effects of utilizing both techniques proves that there are differences as to their actual purpose. These differences make them complement each other perfectly in addressing the same decision-making problem. It also shows that the application of MDAHP is more time consuming.

Originality / value of the article: A critical discussion on the interchangeable application of ANP and MDAHP is presented in the paper.

Keywords: MDAHP, ANP, application, usefulness, substitutability.
JEL classification codes: C02, C44, C65.

1. Introduction

The MDAHP method was proposed by Kinoshito and Nakanishi (1999) and represents the embodiment of the idea of linking pins by Schoner et al. (1993). Its purpose is to solve particular

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issues which involve the presence of interactions between ranked objects and their attributes. A concept characteristic for MDAHP is the dominant alternative. It is to be understood as an object evaluated which provides the context through which the influence of the object evaluation criteria is perceived. It can be identified with the way the influence of attributes on the evaluation of objects is perceived by expert using, for this purpose, the dominant alternative. A detailed outline of this method can be found in the paper by Dytczak and Ginda (2013).

Identical decision-making issues can be tackled employing a more universal method, it being Saaty's Analytic Network Process (1996). The originators of MDAHP see this method as an equivalent alternative for ANP (Kinoshita 2010, Kinoshita et al. 2013). However, they do not provide convincing evidence that would confirm this view. Thus, it should be seen as a hypothesis that still requires to be tested as to its being true. The above thesis finds, however, no confirmation even in the outcomes of not much complex analyses carried out using the two methods. Further on in the paper, such example illustrating the differences between the methods was used. They provided the basis for drawing practical conclusions as to the usefulness and application scope of both methods.

2. Illustration of differences between MDAHP and ANP

2.1. An illustrative example

In order to illustrate the differences between the methods, we will use a calculation example involving choosing a product – a mobile phone model. Suppose, we make our choice based on the recommendations provided by three experts. Let's mark these models with the following symbols: M1, M2 and M3. They make up a set of decision alternatives (choice alternatives) A:

$$A = \{M1, M2, M3\}. \quad (1)$$

For assessing the mobile phone models two basic features were used:

1. Function (convenient to use) U.
2. Form (attractive look) W.

They make up set C:

$$C = \{U, W\}. \quad (2)$$

Suppose that each expert recommends a different model of the mobile phone and within the context of this model weighs subjectively the influence of its features. We also assume that we can specify our initial preferences in terms of the individual models in the context of each of their features, and thus, the initial sub-priorities of the models. For defining the weights of the feature influence and initial priorities of the models one can use any tools, e.g. pairwise comparison (Ginda 2015). In further calculations we will use sets of standardized (summed to unity) influence weights of features presented in Table 1 and the levels of initial sub-priorities of the models included in Table 2.

2.2. Calculation characteristics

ANP and MDAHP calculation mechanisms were implemented by using GNU Octave (Eaton 2002), a widely available environment for numerical computations.

Table 1. The set of standardized influence weights of features [–]

Feature	Evaluation context		
	M1	M2	M3
W	0.4	0.7	0.2
U	0.6	0.3	0.8
Sum:	1	1	1

Source: self-reported data.

Table 2. Initial priorities of the mobile phone models [–]

Model	W	U
M1	1	1
M2	2	$\frac{1}{2}$
M3	3	$\frac{1}{6}$
Sum:	6	$1\frac{2}{3}$

Source: self-reported data.

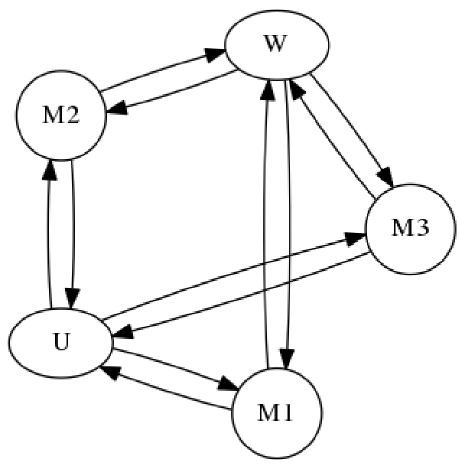
The calculations are iterative in their nature. They end when the required absolute accuracy in terms of determining final priorities and influence weights of the features of the mobile phone models are achieved, with the accuracy being accepted at the following level:

$$\Delta = 0.001. \quad (3)$$

2.3. ANP application

The structure steering the ANP analysis corresponding to the issue discussed is presented in Figure 1. In conducting calculations using the ANP method one has to bring the set of the initial priorities regarding the models of the mobile phone, presented in Table 2, to the standardized form showed in Table 3.

Figure 1. The structure steering ANP



Source: self-reported data.

Table 3. Standardized initial priorities of the mobile phone models [–]

Model	W	U
M1	$\frac{1}{6}$	0.6
M2	$\frac{1}{3}$	0.3
M3	$\frac{1}{2}$	0.1
Sum:	1	1

Source: self-reported data.

Based on the standardized sets of the initial priorities of the models (Table 3) and influence weights of the features (Table 1), we build the ANP main matrix which we denote with symbol **S** (4). Its subsequent rows and columns correspond to features W, U and the phone models M1, M2, M3. According to the ANP principles, the elements of the rows of matrix **S** express information on influence weights of features and priorities of models given in the context of the features and models to which the individual matrix columns correspond.

$$\mathbf{S} = \begin{bmatrix} 0 & 0 & 0.4 & 0.7 & 0.2 \\ 0 & 0 & 0.6 & 0.3 & 0.8 \\ \frac{1}{6} & 0.6 & 0 & 0 & 0 \\ \frac{1}{3} & 0.3 & 0 & 0 & 0 \\ \frac{1}{2} & 0.1 & 0 & 0 & 0 \end{bmatrix}. \qquad (4)$$

Since matrix (4) has stochastically a left-sided form, the sequence of subsequent powers of the matrix is convergent. The boundary of convergence is limit matrix $\mathbf{S}_{\text{lim}}$, which was obtained by raising the matrix to the 9th power:

$$\mathbf{S}_{\text{lim}} = \mathbf{S}^9 = \begin{bmatrix} 0 & 0 & 0.439 & 0.439 & 0.439 \\ 0 & 0 & 0.561 & 0.561 & 0.561 \\ 0.410 & 0.410 & 0 & 0 & 0 \\ 0.315 & 0.315 & 0 & 0 & 0 \\ 0.276 & 0.276 & 0 & 0 & 0 \end{bmatrix}. \qquad (5)$$

The content of matrix (5) shows that using ANP leads to the standardization of the set of priorities as regards the phone models (Table 4) and the set of total influence weights of features (Table 5). Both sets have a standardized nature.

Table 4. The overall priorities and ranking of the phone models (ANP) [–]

Model	Overall priority [−]	Rank
M1	**0.410**	**1**
M2	**0.315**	**2**
M3	**0.275**	**3**
Sum:	1	1

Source: self-reported data.

Table 5. The uniformed total influence weights of features (ANP) [–]

Feature	Weight [−]
W	0.439
U	0.561
Sum:	1

Source: self-reported data.

The results obtained using ANP suggest that by far the best choice is model M1. Among the other models, slightly worse is M3. The total influence weights of features, on the other hand, show that the best model recommendation corresponds to the total functionality influence slightly overweighing the look of the phone. The information on the total influence of features may help in the final acceptance of the recommendation or its rejection in the case there is no acceptance of the results stemming from weighing this influence.

2.4. MDAHP application

The function of dominant alternatives is played by the phone models recommended by the individual experts. Unlike ANP, the MDAHP method uses directly non-standardized priorities of the models presented in Table 2. The results of the application of the method are compiled in Tables 6 and 7.

Table 6. Overall priorities and ranking of mobile phones (MDAHP)

Model	Context			Standardized priority[−]	Rank
	M1	M2	M3		
M1	1	1.303	1.488	**0.410**	**1**
M2	0.768	1	1.142	**0.315**	**2**
M3	0.672	0.876	1	**0.275**	**3**
Sum:	2.440	3.179	3.630	1	

Source: self-reported data.

Table 7. The sets of total influence weights of features (MDAHP) [−]

Feature	Conetxt		
	M1	M2	M3
W	0.178	0.465	0.796
U	0.822	0.535	0.204
Sum:	1	1	1

Source: self-reported data.

The second, third and fourth columns of Table 6 present the raw sets, i.e. non-standardized priorities of the individual phone models. They result directly from the calculations and correspond to the context of the individual dominant alternatives. By standardizing each of these sets we obtain, however, a uniform set of priorities marked in bold in the penultimate column of Table 6. This is the same set that we obtained using ANP (compare with Table 4).

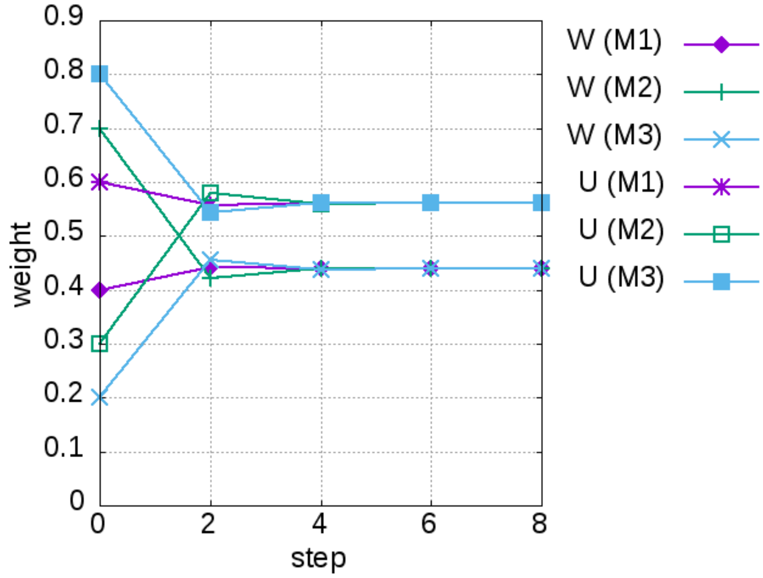
The outcome of the MDAHP application is that we obtain independent sets of total influence weights of features associated with the individual dominant alternatives. Their standardized forms are presented in Table 7.

2.5. Comparing the effects of using both methods

Despite its simplicity, the calculation example clearly illustrates the essential similarities and differences between the results obtained while applying both methods. The two methods employ different calculation mechanisms. However, in using them we still obtain an identical standardized set of the total priorities of objects. Attention should also be drawn to the different form of the evaluation as regards the total influence of the features of objects. This attests to the diversification of specific application goals of both methods. The uniform nature of the set of total influence weights of features suggests that the case of ANP involves searching for a consensus between experts. Moreover, the different sets of total influence weights of features in MDAHP suggest that what is sought here is a compromise between experts.

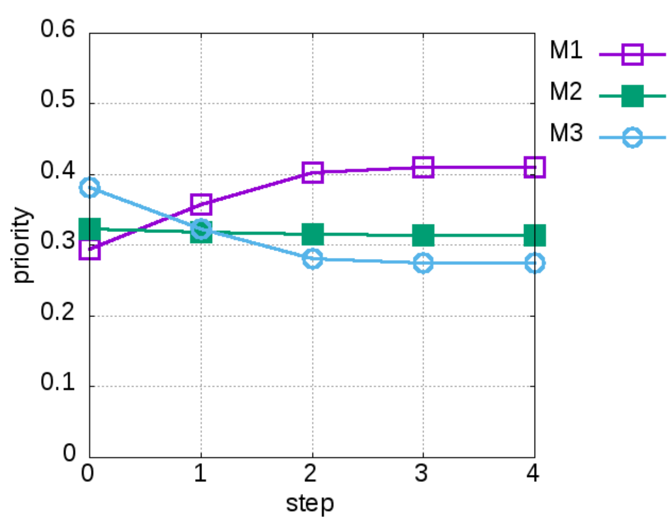
While comparing the application of the two methods, it is worth emphasizing the context of time-consumption of the calculations. Based on the results of the calculations conducted, it can be concluded that in comparison to ANP, the substantial advantage of MDAHP is its convergence which is twice as good in terms of the number of necessary calculation steps. This is reflected by comparing Figures 2-5 with Figures 6-7. Yet, MDAHP clearly loses to ANP in terms of the time spent on the calculations. The results coming from the multiple repeated measurements of time that is needed to carry out the calculations show that calculations conducted using MDAHP are much more time-consuming (four or even five times more). This fact is depicted in Figure 8.

Figure 2. The depiction of convergence of the weighing process of total influence of features in the context of the influence of different dominant alternatives (MDAHP)



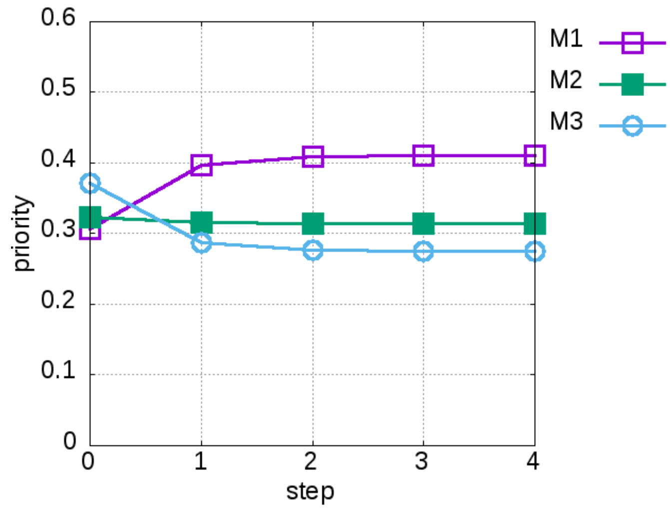
Source: self-reported data.

Figure 3. The depiction of convergence of the process determining total priorities of the phone models in the context of the influence of dominant alternative M1 (MDAHP)



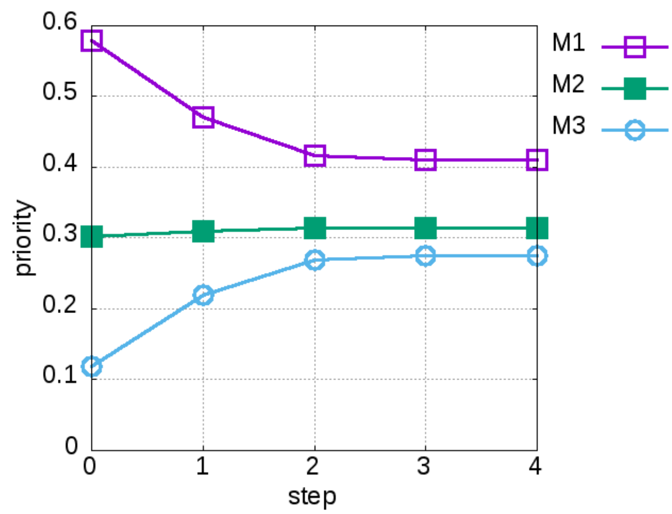
Source: self-reported data.

Figure 4. The depiction of convergence of the process determining total priorities of the phone models in the context of the influence of dominant alternative M2 (MDAHP)



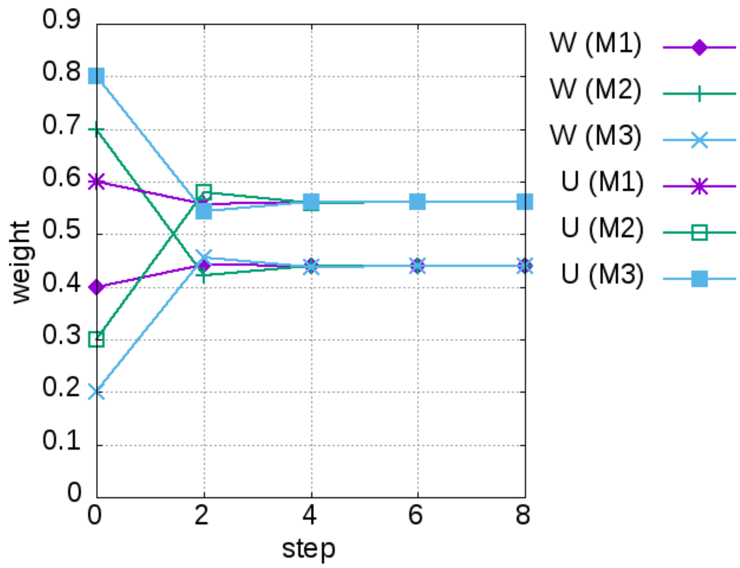
Source: self-reported data.

Figure 4. The depiction of convergence of the process determining total priorities of the phone models in the context of the influence of dominant alternative M3 (MDAHP)



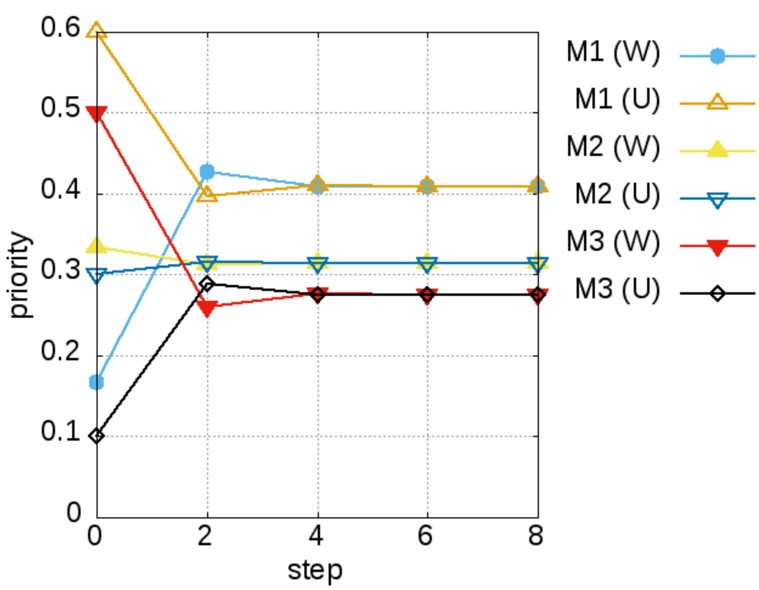
Source: self-reported data.

Figure 6. The depiction of convergence of the process determining total influence weights of features in the context of the influence of different dominant alternatives (ANP)



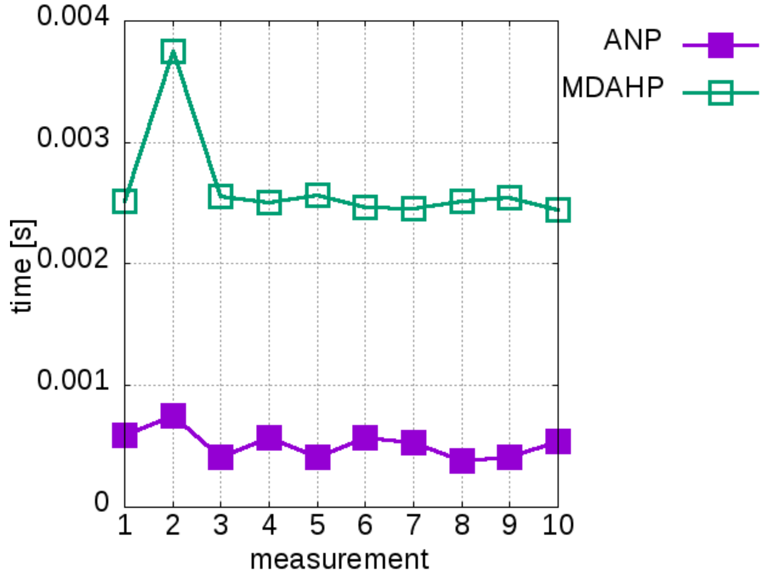
Source: self-reported data.

Figure 7. The depiction of convergence of the process determining total priorities of the phone models in the context of the influence of different features (ANP)



Source: self-reported data.

Figure 8. The depiction of time-consumption of calculations conducted by ANP and MDAHP methods



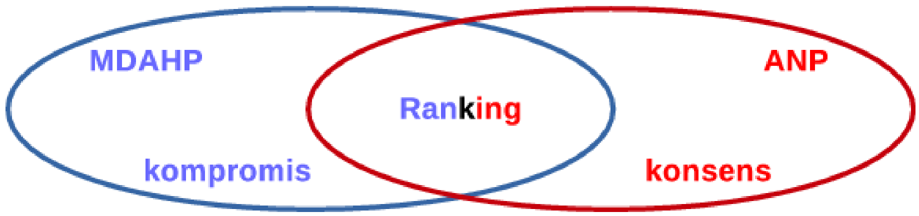
Source: self-reported data.

3. Summary and findings

The findings of the illustrative analysis suggest that MDAHP and ANP are not equivalent methods for solving particular decision-making problems, as illustrated by the subject taken as example. The differences in a substantial portion of results obtained through the application of the two methods indicate that the methods should be viewed as mutually complementary rather than as competing (cf: Figure 9). Therefore, with a view to improve the results of analyses conducted using these methods, we propose their simultaneous application. This allows for supporting the decision-making that is based on accounting for the two, very different in their underpinnings, solutions of issues relating to seeking a consensus or compromise between experts in the context of the perception of the influence exerted by the features of the objects. Moreover, considering that calculations conducted by MDAHP are much more time-consuming, the recommendation to limit the application of the method on its own to the search for a compromise between experts seems reasonable.

Given the primary aim of the paper, the differences between the results stemming from the application of both methods were illustrated using a not too much complex issue. Therefore, we intend to employ more complex subjects in the future to verify the findings presented in the paper.

Figure 9. The depiction of the complementary nature of ANP and MDAHP



Source: self-reported data.

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