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Decision-Making Approach Based on Mean Absolute Deviation (MAD) Weighting Method and Maut Method for the Android Phone Selection Problem

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Abstract
Determining criteria weights is a problem that arises frequently in many multi-criteria decision-making (MCDM) techniques. This paper provides an overview of Mean Absolute Deviation (MAD) weighting methods applicable to multi-criteria optimization techniques. The weights of criteria in multi-criteria decision-making (MCDM) problems are essential elements that can significantly affect results. Taking into account the fact that the weights of criteria can significantly influence the outcome of the decision, it is important to pay particular attention to the objectivity factors of the criteria weights. Accordingly, several methods to determine criteria weights had been developed and presented by researchers. Weighting methods could be Objective, Subjective, Integrated (combined). This study introduces a weighting method, called Mean Absolute Deviation (MAD) method, to determine criteria objective weights. After introducing the method systematically, we present a computational analyses to confirm the efficiency of the Mean Absolute Deviation (MAD) method in the Android Phone selection problem. The procedure of the Mean Absolute Deviation for calculation of weights of criteria is firstly observed. Secondly, MAUT MCDM ranking method was applied to rank alternatives of Android phones to select the best android phones from the weights provided by the MAD weighting method. The conducted analyses demonstrate that Mean Absolute Deviation (MAD) is efficient enough to determine objective weights of criteria of android mobile phones.
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1. Introduction

There is a wide range of Android Phones available in the market with unique features and attributes. Based on different demands of the customer, manufacturers have to provide different variety of the product with different attributes and features. Customers have difficulty in selecting the best product from the ranges of Android phones available in the market. Multi criteria decision making method provides ranking solution to differentiate the range on the basis of product feature and product attributes. In this paper, Multi Criteria Utility Theory (MAUT) is applied on different brands of android phones to choose the best option among the different alternatives after determining the relative importance (weight) of each criterion by using the proposed Mean Absolute Deviation (MAD) weighting technique. The specifications of the products that will be taken under study are with significant attributes; Cost, Random Access Memory (RAM), Internal Storage (ROM (Read Only Memory)), Camera resolution (megapixel (MP)), Battery capacity, and Android version, later in this research. A little detail to each significant criterion under study is discussed as follows:

Cost: Price of goods sold, also known as cost of sales or cost of services, is how much it cost to produce a business's products or services. Cost is a non-beneficial criterion, i.e. a customer selecting a product favours a low cost to a high cost of products that serves the same purposes.

RAM (Random Access Memory): Ram is a superfast but volatile type of storage, faster than the phone's ROM (Internal memory storage), where the apps (set of software), photos, videos, and music live, and it helps the android phone (smart phone) work and feel fast. When a phone is turn on, and an app is open for the first time, the phone pulls the operating system (OS) and app's data from the phone's slower internal storage (main storage) and stores the bulk of that OS and app data in to the phone's faster RAM so that it will enable the users to use different elements and features of the OS and app quickly.

Essentially, apps used are kept running in the background while other apps are on use. Switching between apps and picking up right where it is left off is often called "multitasking". If a phone is said to multitask well, it's because it makes good use of RAM or simply has a ton of it. Indeed, a smart phone with more RAM means the phone can store more of the OS data and apps that are often use for quick access.

Device with more RAM can run more complex software and multiple applications at the same time without the phone slowing down operation or malfunctioning. The more the RAM, the efficient is the functions.

Internal Storage (ROM (Read Only Memory)): In Android phones (smart phones) or mobile devices as they are called, ROM is referred to as internal storage because this is where all kinds of data are stored and accessed constantly, and is actually a flash based storage solution called SSD (Solid State Device). They don't use the spinning HDDs like the computer do. "ROM" on a phone is called 'Internal storage' and is used to store the OS and user data. The Android phone (smart phone) operating system, App codes, App data and all the personal data is placed in storage. Since the phone processor frequently needs to fetch the data or write new one to the storage (Apps can't always remain in RAM), the quality and quantity of storage have a profound impact on the overall smart phone experience.

Little more than a year ago, we saw Android (version one) phones manage surprisingly well with just 4GB of Internal storage. So, exactly how much storage does one need? Or how much minimum storage do I need? That largely depends on your individual needs. More of Internal storage is always a good thing. Besides quantity, quality of internal storage matters a lot. The quality of storage is almost never advertised, so we haven't got much to choose from this regards.

Battery capacity (mAh): The battery capacity of smart phones (Android) is generally measured in mAh. mAh (short for 'milli ampere per hour') is the unit of electric charge. Let's say that an Android phone has a battery capacity of 4000mAh. It means that the phone's battery can supply 4000mA for one hour or 2000mA for 2 hours or 40mA for 100 hours, and so on, depending on its usage. The high the battery capacity, the longer the duration function of an android phone.

Camera Resolution (Megapixel (MP)): What's important to realize is that when it comes to image quality, it's not just a raw numbers game. The higher the camera resolution, the more the advantages it serves. Zooming in, a higher megapixel (MP) photo down to a lower megapixel equivalent has more advantages. For example; if the photo of a bird that was flying far away in the sky was taken, one shot only might be gotten with 16MP camera. That gives a shot with 4,920 by 3,264 pixels in it, but the bird might be the actual point of interest in the shot, with a lot of blue sky that's not actually wanted. On a traditional camera with optical zoom, you'd simply zoom in to make the bird more of a focal point. Using digital zoom, on the other hand, we might cut down the image to say 3008 by 2000 pixels, making the bird much more of the focus of the shot and ending up with what is effectively a 6MP photo from your 16MP original. Crop in closer say, 2048 by 1536, and we'd have even closer shot of the bird at 3MP resolution. It's entirely feasible that even with so much cropping, the results image could be reasonably pleasant, although it will obviously not pack quite so much detail as of the initial resolution.

Where this becomes a bigger issue is if you're using a phone with a less-powerful camera. On a 3MP camera, for example, cropping in would bring the resolution much further down, leaving you with a blurry bird shot, which is not useful for print purposes.

Android versions: Here is the summary of a fast-paced tour of Android version highlights from the platform's birth to present.

Android version 1.0 to 1.1 (The early days): Android made its official public debut in 2008 with Android 1.0. A release so ancient, no codename, things were basic back then. The only significant suites of early Google apps are Gmail, Maps, Calendar, and Youtube.

Android version 1.5 (Cupcake): Version 1.5 was released in early 2009. It include the first on – screen keyboard, it also provided the platform's first ever video recording.

Android version 1.6 (Donut): It was released in the fall of 2009. It gives ability for OS to operate on variety of different screen sizes and resolution. Android's universal search box made its first appearance in android 1.6.

Android version 2.0 and 2.1 (Éclair): Couple of months later, Éclair brought life wall papers, the platform's first speech-to-text function, and once-ios-exclusive pinch-to-zoom capability into Android.

Android version 2.2 (Froyo): Four months after 2.1, Froyo focus on performance improvements and voice actions functions; by getting direction or speaking a command.

Android version 2.3 (Gingerbread): In 2010, Gingerbread started its slow march toward distinctive design with black and green seeped all over the UI i.e. colour of android mascot

Android version 3.0 to 3.2 (Honeycomb): 2011's Honeycomb software was the first to use on–screen buttons for android main navigational commands. Re-image UI for Android.

Android version 4.0 (Ice cream sandwich): It was released in 2011, it brought the ICS home screen and app- switching interface, making swiping a more integral method of getting around operating system.

Android version 4.1 to 4.3 (Jelly Bean): In 2012 and 2013, Jelly Bean brought about our first taste of google now, quick setting panel, and placing widget on lock screen.
Android version 4.4 (KitKat): Late 2013, KitKat was released. It helps in lighter background, the lightened KitKat home screen and its dedicated Google now panel.
Android version 5.0 and 5.1 (Lollipop): It was released in the fall of 2014. It gives a material design, notifications, which now showed up on the locked screen for at-a-glance access.
Android version 6.0 (Marshmallow): Marshmallow was released in 2015. It introduces the screen search feature, the evolution of Apps permission, finger print readers etc.
Android version 7.0 and 7.1 (Nougat): In 2016, Nougat introduced the new native split mode, which enabled users to access two or more applications to be operated with ease.
Android version 8.0 and 8.1 (Oreo): In 2017, Android Oreo added a new picture – in – picture mode. It also added a notification snoozing option and notification channels that offer the controls over how apps can alert you.
Android version 9 (Pie): In August 2018, Android introduced its hybrid gesture/button navigation system, power and screen brightness management, and battery saver mode.
Android version 10: New privacy permissions model version 10 adds some much needed nuance into the realm of location data.
Android version 11: In September 2020, Android version 11 revolves around privacy. It let you grant an app permission to see your location or access your camera or microphone only for a single session of use.

2. The New Combined Decision Making Approach

The new combined decision making approach starts with identification of the problem and the selection of decision makers. Then the criteria and alternatives associated with the problem are determined and necessary data are gathered. The MAD and MAUT methods are applied for determining the weights of the criteria and determining the ranking of the alternatives respectively.

2.1 MAD (Mean Absolute Deviation) Method

The Mean Absolute Method is proposed to determine the criteria weights in a multi-criteria decision making problem. This method is in the category of objective weighting methods for obtaining criteria weights. In this method, we should define a performance measure for the alternatives first. This weighting technique reflects the difference between the overall alternatives' performance.

The following steps are used to calculate objective weights by Mean Absolute Deviation (MAD) weighting method.

Step 1: The decision matrix X which shows the performance value of different alternatives with respect to various criteria is formed.

$$X = [x_{ij}]_{m\times n} = \begin{bmatrix} x_{11} & x_{12} & \dots x_{1n} \\ x_{21} & x_{22} & \dots x_{2n} \\ x_{m1} \vdots & x_{m2} \vdots & \ddots \; x_{mn} \vdots \end{bmatrix} \quad (i = 1,2,\dots,m; j = 1,2,\dots,n) \qquad (1)$$

x_{ij} represents the performance value of i^{th} alternative on j^{th} criterion.

Step 2: The decision matrix is normalized. Beneficial (maximization) and non-beneficial (minimization) criteria are normalized by $Eq. 2$ and $Eq. 3$ respectively. To have the performance measures comparable and dimensionless, all the entries of the decision matrix are linear normalized using the following two equations:

$$r_{ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})} \quad i = 1,2,\dots,m \text{ and } j = 1,2,\dots,n \qquad (2)$$

$$r_{ij} = \frac{\max(X_{ij}) - X_{ij}}{\max(X_{ij}) - \min(X_{ij})} \quad i = 1,2,\dots,m \text{ and } j = 1,2,\dots,n \qquad (3)$$

Step 3: Mean Absolute Deviation (MAD) values (M_j) are determined for each criterion.

$$M_j = \frac{1}{m}\sum_{i=1}^{m} |r_{ij} - \bar{r_j}|$$

Where $\bar{r_{ij}}$ is the average value of each criterion data set, and M_j is the MAD value

Step 4: Mean Absolute Deviation (MAD) weights (W_j) are calculated.

$$W_j = \frac{M_j}{\sum_{j=1}^{n} M_j}$$

Where W_j is the MAD weight

2.2 MAUT (Multi Attribute Utility Theory) METHOD

Multi Attribute Utility Theory (MAUT) methods are the parts of the Multi Attribute Decision Making methods (MADM). MAUT was largely developed by Keeney and Raiffa (1976) (Gomez – Limon et al., 2003). The underlying idea of MAUT is that in any decision problem there is a real valued function or utility which has to be maximized (Zietsman et al., 2006). Due to MAUT, the decision makers can compare all alternatives simultaneously (Wang et al., 2010). The decision maker's preferences are reflected in the form of the utility function which is defined over a set of criteria. Utility value derived from single attribute utility function is the performance of alternatives in MAUT (Pohekar and Ramachandran, 2004; Nikou, 2011). After computing the integrated utility of each alternative, the decision maker ranks the alternatives completely. Integrated utility functions can be either additively separable or multiplicatively separable with respect to single attribute utility (Pohekar and Ramachandran, 2004).

MAUT is a simple and intuitive approach for the decision makers. Moreover it allows the decision maker to allocate relative weights to the various criteria (Zietsman et al., 2006). So in the literature MAUT has been applied a wide range of decision making problems. Wang et al. (2002) presented a decision support system based on MAUT for dewatering systems selection. Seven main parameters were analyzed in the selection process. Loetscher and Keller (2002) developed a decision support system which was called SANEX. It operated in two steps. The second step was related with MAUT. In this step a model derived from MAUT used technical, socio-cultural and institutional criteria for decisions. Gomez-Limon et al. (2003) performed MAUT for computing relative and absolute risk aversion coefficients of farm systems. Ananda and Herath (2005) determined societal risk preferences on public forest land-use attributes using MAUT.

Zietsman et al. (2006) performed MAUT for presenting decision making process concerning transportation programmes and projects in the context of sustainable transportation. Konidari and Mavrakis (2007) performed AHP, MAUT and the Simple Multi-Attribute Ranking Technique (SMART) for evaluating climate change mitigation policy instruments. Kim et al. (2007) evaluated decommissioning scenarios with MAUT method. Canbolat et al. (2007) performed MAUT method to solve for the global manufacturing facility selection problem. Wang et al. (2010) compared MAUT and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) methods. Briefly the relationships between the thresholds of the preference and the risk attitude of the utility function were discussed. Kailiponi (2010) presented an evacuation process for emergency managers. In this study levels of risk at which point evacuation actions should be taken by emergency managers in a storm surge scenario were identified with MAUT method. Freitas et al. (2013) compared AHP and MAUT methods by applying them to the raw materials selection problem in Brazil. Alp et al. (2015) analyzed the corporate sustainability performance of an international company operating in the chemical industry. In the study entropy method was used for determining the weights of the criteria and MAUT was used for assessment of corporate sustainability performance. Ömürbek et al. (2016) analyzed the performances of automotive companies traded on Istanbul Stock Exchange. The weights of the performance criteria were derived from entropy method and automative companies' performances were ranked with MAUT and SAW methods.

The underlying idea of MAUT is that in any decision problem there is a real valued function or utility which has to be maximized (Zietsman et al., 2006). The application steps of MAUT method are presented in the following:

Step 5: The utility function for each criterion is assessed. The value of 1 is assigned to the highest level of satisfaction for a given criterion. On the other hand the value 0 is assigned to the lowest one. Intermediate values may be calculated by the normalization procedure (Freitas et al., 2013). Eq. (6) and Eq. (7) are performed for the beneficial and non-beneficial criteria respectively:

$$U_j(r_{ij}) = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})} \quad i = 1, 2, \dots, m \text{ and } j = 1, 2, \dots, n \qquad (6)$$

$$U_j(r_{ij}) = \frac{\max(X_{ij}) - X_{ij}}{\max(X_{ij}) - \min(X_{ij})} \quad i = 1, 2, \dots, m \text{ and } j = 1, 2, \dots, n \qquad (7)$$

$U_j(r_{ij})$ is the normalised criteria values determined from single-attribute utility functions on normalised scales.

Step 6: After assessing the utility function for each criterion, the integrated utility of each alternative is computed. Additive utility function shown in Eq. (8) is the simplest model in MAUT. In this model the combined utility of the multiple objectives is the sum of the single utility functions multiplied by a scaling constant that reflects the importance of each objective within the decision context (Kailiponi, 2010).

$$U(A_i) = \sum_{j=1}^{n} W_j \, U_j(r_{ij}) \qquad (8)$$

$U(A_i)$ denotes the utility of alternative i; W_j denotes the weight of the criterion j, and $U_j(r_{ij})$ denotes the normalised criteria values determined from single-attribute utility functions on normalized scales. The decision makers should consider the alternative with the highest integrated utility value (Wang et al., 2010).

3. Application

Android phone selection problem is considered using the two proposed methods. The aim is to select the best Android phone that gives the best utility function from among existing diverse alternatives. To purchase an Android phone (smart phone), firstly, a customer consider 6 significant criteria affecting their selection decision. The criteria are; Cost of product, random access memory (RAM), Internal storage (ROM), camera resolution (MP), battery (mAh), and android version. Among these criteria, the RAM, ROM, MP, battery and android version are the beneficial criteria where higher values are desirable; cost of product is a non-beneficial criterion where smaller value is always preferred.

Considering these criteria, a customer decided to purchase an android mobile phones from a set of available 10 alternatives of Android phones (A1, A2, A3, A4, A5, A6, A7, A8, A9, A10). After making necessary analysis the decision matrix table for the android phones selection problems is form. Table 3.1 shows the decision matrix.

Table 3.1: Decision matrix

	COST	RAM	ROM	MP	BATTERY	VERSION
A1	32000.00	1	16	16	3000	9
A2	42990.00	2	32	8	5000	10
A3	30000.00	1	16	8	3500	8
A4	45500.00	2	32	13	5000	10
A5	36000.00	2	32	8	4000	9
A6	27500.00	1	16	8	2400	8
A7	48990.00	2	16	13	4000	7
A8	25790.00	1	16	5	4000	9
A9	27990.00	1	16	5	3020	10
A10	49999.00	2	32	13	5000	9

3.1 Application of MAD (Mean Absolute Deviation) Method

In this section the weights of each criterion are determined by the MAD method. Firstly, the decision matrix is normalized by using Eq. (2) and Eq. (3) for beneficial and non-beneficial criteria respectively and shown in Table 3.2.

Table 3.2: Normalized decision matrix

	COST	RAM	ROM	MP	BATTERY	VERSION
A1	0.7435	0.0000	0.0000	1.0000	0.2308	0.6667
A2	0.2895	1.0000	1.0000	0.2727	1.0000	1.0000
A3	0.8261	0.0000	0.0000	0.2727	0.4231	0.3333
A4	0.1858	1.0000	1.0000	0.7273	1.0000	1.0000
A5	0.5783	1.0000	1.0000	0.2727	0.6154	0.6667
A6	0.9294	0.0000	0.0000	0.2727	0.0000	0.3333
A7	0.0417	1.0000	0.0000	0.7273	0.6154	0.0000
A8	1.0000	0.0000	0.0000	0.0000	0.6154	0.6667
A9	0.9091	0.0000	0.0000	0.0000	0.2385	1.0000
A10	0.0000	1.0000	1.0000	0.2727	1.0000	0.6667

The MAD values (M_j) are determined for each criterion and the MAD weights (W_j) are calculated by using Eq. (4) and Eq. (5). The Mean absolute deviation (MAD) values (M_j) and weights (W_j) of each criterion is as shown in Table 3.3.

Table 3.3: MAD values and Criteria weights

Criteria	COST	RAM	ROM	MP	BATTERY	VERSION
$\bar{r}_j$	0.5503	0.5000	0.4000	0.4273	0.5739	0.6333
M_j	0.3369	0.5000	0.4800	0.2946	0.2806	0.2467
W_j	0.1575	0.2338	0.2244	0.1377	0.1312	0.1153

According to Table 3.3, the RAM is the most important criterion with the highest MAD weight (W_j). ROM, Cost, MP, Battery, and android version follow this criterion respectively.

3.2. Application of MAUT (Multi Attribute Utility Theory) Method

MAUT method is used for finding the rank order of the Android phones alternatives. Firstly, the utility function for each criterion is assessed. Intermediate values are calculated by the normalization $[U_j(r_{ij})]$ procedure. Eq. (6) and Eq. (7) are performed for the beneficial and non-beneficial criteria respectively. The results are presented in Table 3.4.

Table 3.4: The utility function of each criterion

	COST	RAM	ROM	MP	BATTERY	VERSION
A1	0.7435	0.0000	0.0000	1.0000	0.2308	0.6667
A2	0.2895	1.0000	1.0000	0.2727	1.0000	1.0000
A3	0.8261	0.0000	0.0000	0.2727	0.4231	0.3333
A4	0.1858	1.0000	1.0000	0.7273	1.0000	1.0000
A5	0.5783	1.0000	1.0000	0.2727	0.6154	0.6667
A6	0.9294	0.0000	0.0000	0.2727	0.0000	0.3333
A7	0.0417	1.0000	0.0000	0.7273	0.6154	0.0000
A8	1.0000	0.0000	0.0000	0.0000	0.6154	0.6667
A9	0.9091	0.0000	0.0000	0.0000	0.2385	1.0000
A10	0.0000	1.0000	1.0000	0.2727	1.0000	0.6667

After assessing the utility function for each criterion, the integrated utility $(U(A_i))$ of each alternative is computed by Eq. (8). The criteria weights derived from MAD method is utilized for these calculations. Finally, the integrated utility of each alternative is shown in Table 3.5.

Table 3.5: The integrated utility of each alternative

	COST	RAM	ROM	MP	BATTERY	VERSION	$U(A_i)$	RANK
A1	0.1171	0.0000	0.0000	0.1377	0.0303	0.0769	0.36202	6
A2	0.0456	0.2338	0.2244	0.0376	0.1312	0.1153	0.78792	2
A3	0.1301	0.0000	0.0000	0.0376	0.0555	0.0384	0.26163	9
A4	0.0293	0.2338	0.2244	0.1002	0.1312	0.1153	0.83420	1
A5	0.0911	0.2338	0.2244	0.0376	0.0807	0.0769	0.74450	4
A6	0.1464	0.0000	0.0000	0.0376	0.0000	0.0384	0.22239	10
A7	0.0066	0.2338	0.0000	0.1002	0.0807	0.0000	0.42126	5
A8	0.1575	0.0000	0.0000	0.0000	0.0807	0.0769	0.31515	7
A9	0.1432	0.0000	0.0000	0.0000	0.0313	0.1153	0.28983	8
A10	0.0000	0.2338	0.2244	0.1002	0.1312	0.0769	0.76649	3

Ranking the decision matrix of performance measure for 10 alternatives, we result to Table 3.6.

Table 3.6: Ranking of alternatives

	COST	RAM	ROM	MP	BATTERY	VERSION	RANK
A1	32000.00	1	16	16	3000	9	6
A2	42990.00	2	32	8	5000	10	2
A3	30000.00	1	16	8	3500	8	9
A4	45500.00	2	32	13	5000	10	1
A5	36000.00	2	32	8	4000	9	4
A6	27500.00	1	16	8	2400	8	10
A7	48990.00	2	16	13	4000	7	5
A8	25790.00	1	16	5	4000	9	7
A9	27990.00	1	16	5	3020	10	8
A10	49999.00	2	32	13	5000	9	3

According to Table 3.5 and Table 3.6, the ranking of Android mobile phone alternatives is A4 – A2 – A10 – A5 – A7 …, in that order. For this problem A4 is the best alternative with the highest utility value of the highest integrated utility $(U(A_i))$ value of 0.83420 (see Table 3.5) and A6 is the worst alternative with the lowest utility value of the lowest integrated utility value of 0.22239 (see Table 3.5).

4. Conclusion

In this paper the android phone selection problem has been solved with the MAD and MAUT methods. After making necessary operations of these methods the best android mobile phone is determined. The MAD method is used to determine the criteria weights and the MAUT method is used to obtain complete ranking of alternatives. The MAD and MAUT methods provide some advantages to the decision makers. MAD method measures or reflects the differences between the overall alternatives' performance to the decision maker. This method determines the weights of criteria objectively without considering the decision makers' preferences. According to the resulting weights of each criterion acquired through the MAD weighting method from decision making setting is one of the determinants of accuracy and reliability of decision making problem. MAD weighting method is therefore a very good weighting estimator when it is applied to different cases of assessment or evaluation in different decision making process. On the other hand, the MAUT method calculates the best and worst utility for each alternative by estimating the integrated utility of each alternative.

After assessing the utility function for each criterion, the integrated utility of each alternative is computed. Additive utility function shown in Eq. (8) is the simplest model in MAUT. In this model the combined utility of the multiple objectives is the sum of the single utility functions multiplied by a scaling constant that reflects the importance of each objective within the decision context (Kailiponi, 2010). The decision makers considered the alternative with the highest integrated utility value (Wang et al., 2010).

Both methods are based on evaluation matrix and they can simultaneously consider any number of criteria and alternatives. So complex decision problems can be organized and solved in a consistent manner. They handle the beneficial and non-beneficial criteria in the problem separately. They contain simple computational procedure. So they are easy to apply to various conflicting criteria both qualitative and quantitative. The combination of these two methods enables taking advantages of their strengths.

This paper shows that the MAD and MAUT methods are efficiently performed for the android mobile phone selection problem. In future studies, a proposed combined approach may also be applied to other selection problem. The number of the evaluation criteria and the alternatives may be changed (varied) according to the needs of the customer. The weights of the criteria may be derived from different weighting methods. The ranking of the alternatives may be performed with other MCDM methods and the result obtained may be compared.

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