DEVELOPMENT OF MULTI CRITERIA DECISION ANALYSIS MODEL FOR INTEGRATED WATER RESOURCES MANAGEMENT

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ABSTRACT

Water management in irrigated agricultural has become exceedingly complex at present due to a variety of conflicting criteria. Identifying the best alternative among different alternatives is not an easy job. Multi Criteria decision analysis techniques are useful tools which can help in solving such problems, but these techniques are not easy to understand and needs special background to deal with it.

For that reason, a Multi criteria Decision analysis Model called (MultiDeciMode) has been developed as an easy, quick and practical tool and valid for multi purposes application, which could help Decision Makers (DM) in solving sophisticated problems such as water resources management. The model was developed based on the used of three multi criteria decision analysis methods, the Weighted Summation (WS), Compromised Programming (CP), and ELECTRE-II. A modification in The ELECTRE-II method was suggested to overcome its complexity and to be simpler for the users. A software program for the three MCDA methods, and the interface were developed and written using visual basic programming language and one version for windows was developed.

The MultiDeciMode gives options for the user to apply sensitivity analysis for criteria scores and to calculate the average final ranking due to sensitivity analysis and also gives the coefficient of variation (CV) for the ranking of each alternative. The alternative ranking and the CV can give clear description about the performance of each alternative during the sensitivity analysis.

The technical performance of the model has been tested by applying each of the selected methods to a number of applications published in the literature. All the MCDA methods, gave the same results comparing with that from the literature. The Modified-ELECTRE-II method could be used instead of the ELECTRE-II method, which become simpler, without threshold values, easy to apply and understand and save a lot of calculation especially for the iteration and making the preference graphs. The results of verification proved the applicability of the MultiDeciMode as a useful tool for solving complicated multicriteria problems.
INTRODUCTION

Water management in irrigated agriculture has become exceedingly complex at present due to a variety of conflicting criteria, such as technical performance, economics, social acceptability, environmental impacts, and water availability. Identifying the best alternative (solution) which considers all the mentioned criteria is very difficult and there is no doubt that this type of problem must be considered as a Multi Criteria Decision Making (MCDM) problem.

In the past decade, much attention has been paid to multi-criteria decision analysis techniques to help the decision maker (DM) to determine management alternatives for complex public resources systems (Mahmoud and Garcia 2000). These techniques are methodologies for making management alternatives based on evaluation criteria weighted by the user and for providing a rational methodology for decision making in the face of uncertainty.

To describe a problem in a multi criterion context, evaluation matrix should be constructed. The columns of this matrix represent the different alternatives under consideration, while the rows represent the evaluation criteria. Elements of the evaluation matrix quantify the performance level of each alternative pertained to different criterion. When this matrix is formulated, it is easy to screen, prioritize various alternatives and provide the decision-makers either with the best (optimal) solution of a problem or with a list of alternative solutions ranked according to priorities concerning particular objectives or criteria examined.

In this paper a multi criteria decision analysis model named MultiDeciMode has been developed and verified for multi purposes application, which could help Decision Makers (DM) in solving sophisticated problems such as water resources management.

DESCRIPTION OF MCDA METHODS

Weighted Summation method

This method derives the ranking from the weighted sum of standardized scores. As a first step all effective scores are standardized and a appraisal score is then calculated for each alternative by first multiplying the standardized scores by its appropriate weight and followed by summing the weighted scores of all effects (Elshorbagy 1994).

The standardization method used in equation (1), when the higher is the better (Maximization):

\[
\text{Standardization scores} = \frac{\text{score} - \min \text{raw score}}{\max \text{raw score} - \min \text{raw score}}
\]  

and when the lower is the better (Minimization) equation (2) is used.
The utility of each alternative $U_i$ is determined by the summation of the weighted numerical values of each criterion using equation (3). The alternative, which has the greatest utility, is the best alternative.

$$U_i = \sum_{i=1}^{m} W_i \ast S_{ij}$$

Where $W$ is the weight of each criterion, $S_{ij}$ is the standardized weight of alternative criteria, $U_i$ is the utility of each alternative, and $U_{optimal}$ is the utility of the best alternative:

$$U_{optimal} = Max U_i \quad \text{for all } i$$

Compromised Programming method

Compromised Programming (CP) is a mathematical programming technique for use in a continuous context (Zeleny 1973). A variation of this method has been used in water resources multi-criteria discrete problems (Duckstein and Opricovic 1980). It is used to identify non-dominated solutions that are closest to the ideal solution as determined by some measure of distance. The solutions identified to be closest to the ideal solution are called compromise solutions and constitute the compromise set. The ideal solution is one, which provides the extreme value for each of the criteria considered in the analysis. The distance from the ideal solution for each alternative is measured by what is referred to as the distance metric. Shown in equation (5) is the operational expression used to compute the family of distance metrics ($L_j$) for a set of $n$ criteria and $m$ alternatives.

$$L_j = \left[ \sum_{i=1}^{n} w_i \left( \frac{f^*_i - f_{i,j}}{f^*_i - f_{i,w}} \right)^p \right]^{1/p}$$

where:

$L_j$ is the distance metric;
$f^*_i$ is the optimal value of the $i^{th}$ criteria;
$f_{i,w}$ is the worst value of the $i^{th}$ criteria;
$f_{i,j}$ is the value of the $i^{th}$ criteria for alternative $j$;
$w_i$ are weights indicating decision maker preferences;
$p$ is a parameter ($1 \leq p \leq \infty$);
$i$ is indicates the number of criteria $i = 1, \ldots, n$; and
$j$ is indicates the number of alternatives $j = 1, \ldots, m$.

The rest of the alternatives are ranked is ascending order according to their $L_j$ value. Normally, a compromised solution is determined by solving $L_j$ with $s = 1, 2$ and $\infty$ (Goicoechea et al., 1982).

**ELECTRE-II method**

The method of ELECTRE-II is an extension of ELECTRE-I and was developed by Roy (1968, 1971, 1974, 1975) and Roy and Bertier (1971) (cited by Nachtnebel 1994, b) and offers a complete ordering of the non-dominated alternatives. This ordering is accomplished by the construction of outranking relationships based on the predefined preference of the decision maker. In this method alternatives $i$ is preferred to alternative $j$ (i.e., $i$ outranks $j$) if and only if the concordance condition and the discordance condition are both satisfied. Additionally multiple levels of concordance and discordance are specified and are used to construct two extreme outranking relationships; these are, a strong relationship, $R_s$, and a weak relationship, $R_w$.

**Concordance**

A weight is assigned to each criterion expressing the importance of a specific criterion in comparison to the other criteria. The concordance between any two alternatives $i$ and $j$ is a weighted measured of the number of criteria for which alternative $i$ is preferred to alternative $j$ and is given as:

$$C (i, j) = \frac{W^+ + W^=} {W^+ + W^=}$$

Where $W^+$ is the sum of weights where $a_i > a_j$ for criteria $z_k$

$W^+ = \sum W_k$, for all $K : f_{ik} > f_{jk}$

In the opposite case we obtain: $W^- = \sum W_k$, for all $K : f_{ik} < f_{jk}$

and $W^=$ is the indifferent cases: $W^= = \sum W_k$, for all $K : f_{ik} = f_{jk}$

where $f_{ik}$ are the elements of payoff matrix. Summarizing, the concordance index is based on an ordinal comparison neglecting the degree that $i$ is better than $j$. It is a necessary condition for the outranking and is expressed by the following inequalities:

$$C (i,j) > P$$

$$W^= > W$$

And where $0 < P < 1$ is required minimum level of concordance.

**Discordance**

To compute the discordance an interval scale is first defined for each criterion. The scale is used to compare the discomfort caused between the “worst” and the “best” of each criterion. Each criterion can be assigned a different range $V_{rk}$. The output $f_{ik}$ expressed in any units, is mapped on the scale $V_{rk}$ by:
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\[ V_{ik} = \frac{f_{ik} - f_k^{-}}{f_k^{+} - f_k^{-}} \times V_{rk} \]  \hspace{1cm} (7)

\( f_k^{+} \) stands for the best and \( f_k^{-} \) for the worst possible result with respect to criterion \( k \).

This procedure provides the opportunity to compare criteria expressed in different units. The discordance can be calculated as follows:

\[ D_{(i,j)} = \frac{\text{Max} \ (V_{jk} - V_{ik})}{\text{Max} \ (V_{rk})} \]  \hspace{1cm} (8)

This procedure provides the opportunity to compare criteria expressed in different units. Essentially, ELECTRE-II established a complete ordering on the set of alternatives being considered such that it satisfies:

1. The test of concordance (i.e., the concordance measure is above some minimum level of acceptability, \( p \)).
2. The test of non-concordance (i.e., discordance measure is below some maximum level of allowable discordance, \( q \)).

ELECTRE-II requires two preference graphs representing the strong and weak preferences of the decision maker. These graphs are then used in an iterative procedure to obtain the desired ranking of the alternatives. The ranking procedure is a three-stage process. First a downward ranking \( R \) is obtained. Next, an upward ranking, \( R' \) is obtained and in the last stage the final ranking which is called the median ranking, \( R_0 \), is achieved. It is a blend of the downward and upward rankings. Eight steps described the details of the technique are described by Nachtnebel, 1994b.

**ELECTRE-II method modification**

ELECTRE-II is one of MCDA techniques, which was applied in many different problems, but some authors have reported some of its disadvantage such as it requires from the decision maker to determine weights and threshold values; the concepts of concordance and discordance and the quantification procedure may not be that concrete and appealing to the decision maker; and for a large number of alternatives the preference graphs become complicated and difficult to interpret (Tabucanon 1988) and it is very difficult to understand and apply (Mahmoud and Garcia 2000). For that reasons an attempt to avoid its complexity, especially in making the iteration and preference graphs and to eliminate the effect of changing the threshold values on the final ranking. As in the case of ELECTRE-II method, two indices, the concordance and the discordance, expressed the performance of alternatives with respect to the criteria. The concordance can be calculated as in the ELECTRE-II method from equation (6).
The first modification is to calculate the discordance as follows:

\[
D(i, j) = \frac{\text{Max} (V_{jk} - V_{ik})}{\text{Max} (V_{rk})} \times W_{cr}
\]

(9)

Where \( W_{cr} \) is the criteria weight at which the maximum differences is occurred.

The modification as shown in equation (9) is the including of the criteria weights and in that condition all the measuring scale for the concordance and discordance depends on the criteria weights. Including the criteria weights will provide the opportunity to give discordance differently for each criterion according to the level of preference by the decision maker. In other words the outcomes of two alternatives with 80% and 60% scores for specific criteria would yield a different discordance index than in the case where the outcomes of other two alternatives scores are 80% and 60% for other criteria. The discordance index will depend on the criteria weight. Applying equation (8) will give the same discordance index for those two conditions.

The second modification as shown in equation (10) is to calculate the final utility of the alternative by the difference between the total concordance and the total discordance.

\[
U_{alti} = \sum C_{i, j} - \sum D_{i, j}
\]

(10)

The advantages of this method are that it does not depend on the threshold values for concordance and discordance as in ELECTRE-II method, which can affect the final ranking, there is no need for the iteration and the preference graphs, the final utility in the modified method includes the total performance of each alternative to the other alternatives and now the method became very easy to understand and to apply by the decision makers.

**MODEL DEVELOPMENT**

A Multi criteria Decision analysis Model called (MultiDeciMode) was developed to help the decision makers in water resources management problem, it is based on the used of three multi criteria decision analysis methods, the Weighted Summation (WS), Compromised Programming (CP), and ELECTRE-II as recommended by many authors to use more that one type of MCDM methods when investigating several alternative strategies (Voogd, 1983 and Gates et al 1991). All these techniques were applied before in water resources management problems, the first two methods were selected for there simplicity for the users (Mahmoud and Garcia 2000), and the third method is one of the complicated support techniques and was selected for the users with more experience with MCDA.
The **MultiDeciMode** was developed for specific purposes: 1) to be able to evaluate the different alternatives for integrated water table management and to select the best alternative among them, 2) to the DM in solving sophisticated problems in water resources management, 3) to provide useful tool for the DM, without requiring experience with the MCDA techniques, 4) to have an easy, quick and practical user friendly interface valid for multi purposes application.

A software program for the four MCDA methods, and the interface were developed and written using visual basic programming language and one version for windows was developed. The interface was designed in a simple way to guide step by step the DM who has little computer experience to find solution for his complicated problems and to help users to get the information they need as quickly, as clearly, and as easily as possible. The interface provides graphs for alternatives utilities and ranking and text file for the output from each of the applied methods. Flow chart guide for the use of **MultiDeciMode** has been shown in Figure 1 and the user can follow all program steps easily without the need of any manual.

**Input Data**

The first input data is the problem name in the screen as shown in figure 2 and then another screen will appear asking the user to insert the numbers of criteria and alternatives (Figure 3). Large decision matrices can be cumbersome to manipulate, and it is recommended to eliminate the numbers of criteria $C_n$ and alternatives $A_m$, so that $C_n \times A_m \leq 100$ (Hope, 1996). For that reason the maximum number of criteria is 15, and the maximum number of alternatives is 20.

After entering the criteria and alternatives number, the user will be asked to indicate that if criteria scores which will be given is normalized or it needs to be calculated by the program, also the user must indicate if the maximum and minimum values of scores will be given by him or calculated by the program for each criterion using the equation used in the equation used for normalization (Figure 4). Then the user will be asked to enter the criteria scores of the first alternative and then click on next to insert the criteria scores of the second alternative until to insert the scores of the last alternative (Figure 5).

If the maximum and minimum values of criteria scores will be given by the user, then another screen for that purpose will appear for the user to enter these values for each criteria (Figure 6).The next step after entering the criteria scores and the maximum and minimum values of scores, is to enter the weight and condition for each criterion (Figure 7). The given weight will be normalize by the program by using the following equation

$$ w_{i,n} = \frac{w_i}{\sum w_i} \quad (11) $$

Where $w_{i,n}$ is the normalized weight, and $w_i$ is the given weight for criterion $i$. 
Figure 1 MultiDeciMode Flow Chart
Figure 2 Screen for opening new problem

Figure 3 Screen to insert Criteria & Alternatives Number

Figure 4 Screen for normalization and maximum

Figure 5 Screen for criteria scores and minimum values

Figure 6 Screen for maximum and minimum values for scores
For criteria condition, the user will be asked to select the condition for each criterion with 1 and 2 numbers, condition equal to 1 means that the criterion is maximization and the normalized value will be calculated by using equation 1 and condition equal to 2 means that the criterion is minimization and the normalized value will be calculated by using equation (2).

After that the user can save the input data by clicking save problem form the main menu and the program will save the input data in a file under a directory by the name of the problem and with an extension of *.inp.

**Model Run**

After entering all the input data, a screen contain all the available MCDA methods will be appeared to the user and the user can select one or some or all of the following methods, weighted summation, compromised programming, ELECTRE-II, and modified ELECTRE-II to be applied to the problem (Figure 8). If the user selects ELECTRE-II method, another screen will be appeared asking the user to enter the threshold values of concordance and discordance. Three levels of concordance and two levels of discordance are required and after that the program will apply the selected methods to the data of problem.

**Model Output**

The model saves output file for each MCDA method, the file will be with the name of the problem, and with an extension of *.wts, *.cmp, *.elc, and *.mle for weighted summation, compromised programming, ELECTRE-II, and modified ELECTRE-II, respectively. Each file contains all the calculation steps, and give the final utility and ranking for all alternatives. The user can open the output text file by the Notepad or WordPad programs to see the results and also it can be opened in Excel for deeper analysis.
Another option by the program to view charts for alternatives utilities and ranking for each applied method (Figure 10). An example for the weighted summation charts are shown in Figure 11-a, for alternatives utilities, and in Figure 11-b for alternatives ranking.

![Screen to select technique to run](image1)

**Threshold Values (for ELECTRE-II)**

<table>
<thead>
<tr>
<th>Levels of Concordance</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concord (P1)</td>
<td>0.85</td>
</tr>
<tr>
<td>Concord (P2)</td>
<td>0.75</td>
</tr>
<tr>
<td>Concord (P3)</td>
<td>0.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Levels of Discordance</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discord (q1)</td>
<td>0.4</td>
</tr>
<tr>
<td>Discord (q2)</td>
<td>0.2</td>
</tr>
</tbody>
</table>

![Screen for threshold values for ELECTRE-II method](image2)

![Screen for output charts](image3)

**Figure 8 Screen to select technique to run**

**Figure 9 Screen for threshold values for ELECTRE-II method**

**Figure 10 Screen for output charts**

**Figure 11-a Example for output chart for alternative utility- WS method**

**Figure 11-b Example for output chart for alternatives ranking- WS method**
Sensitivity Analysis

A well-known approach to dealing with uncertainties concerns the sensitivity analysis. This means that, for a given evaluation matrix how change of one criterion score will influence the final result of the evaluation. In this way insight can be gained into the sensitivity of critical scores, which are to some extent responsible for the uncertainty of the final evaluation outcomes (El-Refaie 2000). The MultiDeciMode gives option for the user to apply sensitivity analysis for criteria scores (Figure 12). The user will be asked to give range of change for each criterion consists of minimum, maximum and change step, for example, the change can be –20%, to +20% with a step 5% for one criterion and for another criterion to be –10% to +30% with a step 10%. The model save output file for the sensitivity analysis by each of the MCDA methods, the file will be with the name of the problem, and with an extension of *.Swts, *.Scmp, *.Selc, and *.Smle for weighted summation, compromised programming, ELECTRE-II, and modified ELECTRE-II respectively. Each file contains the final ranking for all alternatives and for each run due to the change in criteria score and at the end of the file the model will calculate the average final ranking due to sensitivity analysis and also give the coefficient of variation (CV) for the ranking of each alternative.

Model Verification

The technical performance of the model has been tested by applying each of the MCDA methods, which included in the MultiDeciMode to a number of applications published in the literature. The purpose of this verification is to be sure that the MCDA methods calculation is written correctly in the model. Two applications will be described briefly for each MCDA method.

Verification of Weighted Summation method

Heyder, et al (1991) have applied the weighted summation method in a case study for improving an irrigation water delivery system in the Alamosa River and La Jara Creek irrigation systems in the San Luis Valley of south-central Colorado. Eleven alternative
planning strategies were explored with respect to five criteria, which are relative cost, social acceptability, institutional acceptability, and environmental impact and water delivery performance. The evaluation matrix \( R \) for the problem is as following:

Two different weights have been applied as following:

\[
R = \begin{bmatrix}
0.60 & 0.70 & 0.90 & 0.95 & 0.50 \\
0.54 & 0.67 & 0.95 & 1.00 & 0.25 \\
0.65 & 0.67 & 0.20 & 1.00 & 0.25 \\
0.57 & 0.00 & 0.60 & 0.70 & 0.20 \\
0.60 & 0.45 & 0.40 & 0.40 & 0.25 \\
0.73 & 0.50 & 1.00 & 0.25 & 0.25 \\
0.90 & 0.45 & 0.75 & 0.25 & 0.50 \\
0.78 & 0.42 & 0.80 & 0.25 & 0.25 \\
0.93 & 0.80 & 0.75 & 0.25 & 0.50 \\
0.77 & 0.47 & 0.00 & 0.00 & 0.25 \\
0.60 & 0.63 & 0.75 & 0.90 & 0.50 \\
\end{bmatrix}
\]

\[
W_1 = \begin{bmatrix}
1.00 & 1.00 & 1.00 & 1.00 & 1.00 \\
\end{bmatrix}
\]

\[
W_2 = \begin{bmatrix}
0.33 & 0.25 & 0.17 & 0.08 & 0.17 \\
\end{bmatrix}
\]

The utilities for all alternatives by applying the weighted summation method for the two weights are as following:

\[
Utilities \ for \ W_1 = \begin{bmatrix}
alt_1 & alt_2 & alt_3 & alt_4 & alt_5 & alt_6 & alt_7 & alt_8 & alt_9 & alt_{10} & alt_{11} \\
0.73 & 0.68 & 0.55 & 0.41 & 0.42 & 0.55 & 0.57 & 0.50 & 0.56 & 0.30 & 0.67 \\
\end{bmatrix}
\]

\[
Utilities \ for \ W_2 = \begin{bmatrix}
alt_1 & alt_2 & alt_3 & alt_4 & alt_5 & alt_6 & alt_7 & alt_8 & alt_9 & alt_{10} & alt_{11} \\
0.69 & 0.63 & 0.54 & 0.38 & 0.45 & 0.60 & 0.64 & 0.56 & 0.63 & 0.42 & 0.64 \\
\end{bmatrix}
\]

The same results have been obtained by applying the MultiDeciMode.

**Verification of Compromised Programming method**

Romero and Rehman (1989) have applied the CP method in agricultural planning problem; three alternatives have been evaluated according to two criteria, which are Net Present Value (NPV) (maximization) and casual labour (minimization). The evaluation matrix \( R \) for the problem is as following:
The authors applied the CP method have applied to the problem using equation (3.5) for \( p=1, 2, \infty \) and the final results were as follows:

\[
L_1 = \begin{bmatrix} 3 \\ 1 \end{bmatrix}
\]

The same results have been obtained by applying the \textbf{MultiDeciMode}.

\textbf{Verification of ELECTRE-II method}

The ELECTRE-II method has been verified in a case study, which applied by - to supply an area in Thailand with water for irrigation. Eleven alternative schemes were generated for this study among a combination of using shallow ground water, buying water, using tube wells, changing plantation, establishing long ponds and constructing reservoir. The process of the problem ended with formulating the final evaluation matrix in an appraisal table (11 alternatives and 6 key criteria) as shown in Table 1.

<table>
<thead>
<tr>
<th>APPRAISAL</th>
<th>ALT 1</th>
<th>ALT 2</th>
<th>ALT 3</th>
<th>ALT 4</th>
<th>ALT 5</th>
<th>ALT 6</th>
<th>ALT 7</th>
<th>ALT 8</th>
<th>ALT 9</th>
<th>ALT 10</th>
<th>ALT 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>0.88</td>
<td>1.0</td>
<td>0.19</td>
<td>1.0</td>
<td>0.99</td>
<td>0.94</td>
<td>0.66</td>
<td>0.53</td>
<td>0.54</td>
<td>0.46</td>
<td>0.0</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.86</td>
<td>0.72</td>
<td>1.0</td>
<td>1.0</td>
<td>0.83</td>
<td>0.89</td>
<td>0.95</td>
<td>0.78</td>
<td>0.67</td>
<td>0.28</td>
<td>0.41</td>
</tr>
<tr>
<td>W.quality</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Ecology</td>
<td>0.67</td>
<td>0.67</td>
<td>0.46</td>
<td>0.46</td>
<td>0.67</td>
<td>0.67</td>
<td>0.57</td>
<td>0.61</td>
<td>0.58</td>
<td>0.57</td>
<td>0.36</td>
</tr>
<tr>
<td>Production</td>
<td>0.67</td>
<td>0.53</td>
<td>0.0</td>
<td>0.0</td>
<td>0.62</td>
<td>0.67</td>
<td>0.4</td>
<td>0.8</td>
<td>0.65</td>
<td>0.78</td>
<td>1.0</td>
</tr>
<tr>
<td>Pub.Accept</td>
<td>0.22</td>
<td>0.11</td>
<td>0.33</td>
<td>0.0</td>
<td>0.43</td>
<td>0.48</td>
<td>0.53</td>
<td>0.82</td>
<td>0.58</td>
<td>0.98</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Two different weights from the five, which applied, by the author were selected for the verification. These weights are:

\[
R = \begin{bmatrix} 62,500 & 163,625 & 166,775 \\ 4,000 & 10,472 & 11,893 \end{bmatrix}
\]
The threshold values used for the analysis for strong and weak relationships are $p = 0.8$, $q = 0.2$ and $p = 0.6$, $q = 0.4$ respectively. The author applied the ELECTRE-II method to case study by using a software called DEFINITE. The final ranking for the eleven alternatives for the first weight is as follows: Alt8, 6 then Alt5, 10, 1 then Alt11 then Alt9 then Alt7, 2 then Alt4 and lastly Alt3, and for the second weight is as following: Alt6 then Alt5, 1 then Alt8 then Alt9 then Alt2, 7 then Alt4 and finally Alt3, 10, 11.

The same results have been obtained by applying the MultiDeciMode.

**Testing of modified ELECTRE-II method**

The modified ELECTRE-II and ELECTRE-II methods were applied to two case studies to test the ability of the modified ELECTRE-II method for ranking the different alternatives comparing to ELECTRE-II method.

The first case study have applied by Goicoechea et al (1982) to evaluate the performance of five divisions in a company based on five criteria, which are Return on investment (maximization), Percentage increase in market scale (maximization), Rate of growth of scale (maximization), Number of employee complaints field (minimization), and Employee turnover ratio (minimization).

The evaluation matrix $R$ for the problem is as following:

$$R = \begin{bmatrix}
0.21 & 0.20 & 0.30 & 0.15 & 0.18 \\
0.10 & 0.21 & 0.07 & 0.20 & 0.11 \\
0.10 & 0.08 & 0.20 & 0.12 & 0.25 \\
0.07 & 0.10 & 0.02 & 0.20 & 0.05 \\
0.10 & 0.08 & 0.09 & 0.12 & 0.12 \\
\end{bmatrix}$$

and the criteria weights are as following:

$$W = \begin{bmatrix}
3 \\
2 \\
2 \\
1.5 \\
1.5 \\
\end{bmatrix}$$
The three levels of concordances $p^*$, $p^0$, $p^-$ are assumed equal to 0.75, 0.65, and 0.6, respectively. Moreover, the two levels of discordance are $q^* = 0.65$ and $q^0 = 0.2$

The Final ranking by applying the ELECTRE-II, and the Modified-ELECTRE-II methods for all alternatives are shown in Table 2.

**Table 2. Ranking the alternatives for case study (Goicoechea et al (1982)) by ELECTRE-II and Modified-ELECTRE-II method**

<table>
<thead>
<tr>
<th>Ranking</th>
<th>ELECTRE-II method</th>
<th>Modified ELECTRE-II method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alt3</td>
<td>Alt3</td>
</tr>
<tr>
<td>2</td>
<td>Alt1</td>
<td>Alt1</td>
</tr>
<tr>
<td>3</td>
<td>Alt5</td>
<td>Alt5</td>
</tr>
<tr>
<td>4</td>
<td>Alt2</td>
<td>Alt2</td>
</tr>
<tr>
<td>5</td>
<td>Alt4</td>
<td>Alt4</td>
</tr>
</tbody>
</table>

As shown in Table 4 the final ranking for all alternatives is the same by applying the modified ELECTRE-II method comparing to ELECTRE-II method.

The second case study applied by (Elshorbagy, 1994), which used for the verification of ELECTRE-II method. Modified ELECTRE-II method was applied to the same problem by using first weights (W1) and the final ranking for the eleven alternatives is as following: Alt6 then Alt 8 then Alt5 then Alt11 then Alt10 then Alt1 then Alt9 then Alt7 then Alt2 then Alt4 and lastly Alt3.

The obtained results by modified ELECTRE-II for this case study are almost the same as obtained from ELECTRE-II method; only alternatives 1 and 11 exchanged their ranking.

The obtained results from the two cases study indicated that the Modified-ELECTRE-II method could be used instead of the ELECTRE-II method, which become simpler, without threshold values, easy to apply and understand and save a lot of calculation especially for the iteration and making the preference graphs.

**SUMMARY AND CONCLUSIONS**

A Multi criteria Decision analysis Model called (MultiDeciMode) has been developed to help the decision makers in water resources management problem, it is based on the used of three multi criteria decision analysis methods, the Weighted Summation (WS), Compromised Programming (CP), and ELECTRE-II. ELECTRE-II method was modified to overcome its complexity and to be more simple for the users.
The **MultiDeciMode** has been developed for a specific purposes: 1) to be able to evaluate the different alternatives for integrated water table management and to select the best alternative among them, 2) to support the DM in solving sophisticated problems in water resources management, 3) to provide useful tool for the DM, without requiring experience with the MCDA techniques, 4) to have an easy, quick and practical user friendly interface valid for multi purposes application. The interface has been designed in a simple way to guide step by step the DM who has little computer experience to find solution for his complicated problems and to help users get the information they need as quickly, as clearly, and as easily as possible. The interface provides graphs for alternatives utilities and ranking and text file for the output from each of the applied methods.

The technical performance of the model has been tested by applying each of the MCDA methods, which included in the **MultiDeciMode** to a number of applications published in the literature. All the MCDA methods, which included in the model, gave the same results comparing with that from the literature and the verification results have proved that the MCDA methods calculation is written correctly in the model. The Modified-ELECTRE-II method could be used instead of the ELECTRE-II method, which becomes simpler, without threshold values, easy to apply and understand and save a lot of calculation especially for the iteration and making the preference graphs.

**REFERENCES**


