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A Modified AHP for Large-scale MCDM: a Case of Power Station Construction Project Selection

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ABSTRACT

This article proposes a novel technique to alter the analytic hierarchy process (AHP) to deal with large-scale multi-criteria decision-making. Since the AHP has been a fruitful tool for decades, it has been advised that up to seven aspects should be considered. However, realistically, real-world decision problems very often have more than that. We propose assigning a significant scale from 1 to 9, like a survey questionnaire; then, we present the relative criteria scoring and modify the way of constructing the relative criteria scoring matrix. It is called the large- scale AHP. To illustrate the performance of the novel method, we conducted the experimental study by working with a regional electricity provider. The problem was deciding on selecting the power station construction project with 10 choices and 7 criteria. The result was compared with the classical AHP with a clustering technique. The outcome showed that both approaches yielded the same decision and chose the same alternative A_8. Furthermore, both methods yielded the same order on weighted criteria. However, the new technique could save decision-making time by 77.08%.

Keywords: Analytical hierarchy process; Multi-criteria decision; Site selection

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1. Introduction

Electricity is one of the essential infrastructures and a primary factor in communication, transportation, agriculture, and industry. The demand for access to electricity and electricity stability is higher as time goes by.

It is the responsibility of electricity providers to be involved in the planning of new power stations and the distribution and management of electricity to ensure equal access and stability of electricity to the communities within the area of construction, as well as on the construction site.

Each year, the electricity provider is in charge of extending the scope of the electricity distribution system to ensure an adequate amount of electricity for all users. It is their obligation to be involved during the planning stage and to prioritize each project as to where and when the project contractors can move forward using criteria such as weather forecasts and expert advisory. These criteria and their weight are not yet visible in concrete numbers.

The decision-making process is only concerned with benefits and overlooking the cause of basis. Direct and indirect effects after the decision have been made can lead to failed judgment due to the inadequate amount of information received and the pressure the decision-makers have to undergo. The authority should foresee the opportunities and possibilities using their own experiences [1, 2]. When we make a decision, our decision is based mainly on our instinct and ordinary senses [3]. Complex judgment should be made under systematic and logical thinking procedures and other appropriate supporting methods because, in making a difficult decision, there are criteria that need to be kept in consideration, such as technical criteria, concepts, and methodologies of Multiple Criteria Decision Making (MCDM) which are considered important [4-6].

MCDM consolidates alternative assessments and compares possible alternatives in different criteria. The comparisons of each option are measured by assessing their appeal according to each criterion and prioritizing the reliability in ranking to determine the weight of each criterion [7].

Analytic Hierarchy Process (AHP) is one of the MCDM's tools developed by Thomas L. Saaty in 1970. AHP uses pairwise comparisons, depending on the decisions of experts to derive priority scales, and serves the purpose of classifying the problem into more minor criteria. Then, it evaluates the elements hierarchically using mathematics and psychology principles that are related to the ranking of crucial factors and the comparison of a pair of clusters [8]. AHP is used to hierarchically weigh each element in number according to each element's ranking [9]. AHP has an extensive variety of applications, such as resource allocation of businesses or public policy, strategic planning, source selection, program selection, and task priority [10]. Garbuzova-Schlifter et al. [11] present an AHP-based risk analysis of energy efficiency projects in Russia with eight main criteria. The analysis had 28 pairwise comparisons and 29 sub-criteria pairwise comparisons; resulting in errors because of confusion.

In this study, we put the AHP technique into use in classifying and analyzing the factors and alternatives in the decision-making of constructing a power station. Our goal is to find the best and most relevant factors and alternatives to help stabilize the amount of electricity distributed. Regarding the methodology, the classical Analytic Hierarchy Process is used in the calculation, and there are seven main criteria. In the case of parallel comparison, the experts must conduct the comparison 21 times. For 10 elected alternatives of each criterion, the experts must conduct the comparison 315 times. In total, 336 comparisons are required. The classic AHP is a measurement through pairwise comparisons and depends on the decisions of experts to derive priority scales, which is a bit complex and hard to achieve. To solve this matter, we require the experts to grade the importance from 1 to 9 for seven criteria and rank 10 alternatives of power station construction projects for their convenience. The method is called Large-scale AHP.

2. Methodological framework

The assumptions of this research are the same as those of researchers using the basic AHP model, except for a scaling score method for extensive criteria decision-making problems. Let the criteria be a set of properties or attributes concerning which elements in the goal are compared. We will refer to the elements of criteria as C.

Let C be a criterion with $C_1, C_2, C_3, \ldots, C_n$. C_n be a scaling scoring with 1, 2, 3, 4, 5, 6, 7, 8, 9. Note that 1 means extremely less important, and 9 means extremely more important, as shown in Table 1.

Table 1. The scaling scoring of importance.

Verbal Judgments	Intensity of Importance
Lowest	1
Weakly	3
Moderate	5
Very strongly	7
Extreme	9
Intermediate values between the two adjacent judgments	2, 4, 6, 8

$$\begin{matrix} C_1-C_1, & C_1-C_2, & C_1-C_3, & \ldots, & C_1-C_n \\ C_2-C_1, & C_2-C_2, & C_2-C_3, & \ldots, & C_2-C_n \\ C_3-C_1, & C_3-C_2, & C_3-C_3, & \ldots, & C_3-C_n \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ C_n-C_1, & C_n-C_2, & C_n-C_3, & \ldots, & C_n-C_n \end{matrix},$$

where

$$C_{ij} = \begin{cases} C_i - C_j \geq 0, & \text{then } C_{ij} = (C_i - C_j) + 1, \\ C_i - C_j < 0, & \text{then } C_{ij} = \dfrac{1}{-[(C_i - C_j) - 1]}. \end{cases} \tag{2.1}$$

Then the judgment matrix A, which contains the comparison value C_{ij} for all $i, j \in \{1, 2, \ldots, n\}$, relative criteria scoring, which is given by Eq. (2.2) [12].

$$A = \begin{bmatrix} C_{11} & C_{12} & C_{13} & \cdots & C_{1n} \\ \dfrac{1}{C_{21}} & C_{22} & C_{23} & \cdots & C_{2n} \\ \dfrac{1}{C_{31}} & \dfrac{1}{C_{32}} & C_{33} & \cdots & C_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \dfrac{1}{C_{n1}} & \dfrac{1}{C_{n2}} & \dfrac{1}{C_{n3}} & \cdots & \dfrac{1}{C_{nn}} \end{bmatrix}. \tag{2.2}$$

For multiple decision makers, let h be the number of the decision maker and C_{ij}^k be the comparison value of criteria i and j given by the decision maker k, where $k = 1, 2, \ldots, h$. Then by using the geometric mean of the C_{ij}^k conducted by each decision maker, we have a new judgment matrix with the element given by Eq. (2.3).

$$\begin{aligned} C_{ij} &= \left(C_{ij}^1 \times C_{ij}^2 \times C_{ij}^3 \times \cdots C_{ij}^k \times \cdots C_{ij}^h\right)^{1/h} \\ &= \left(\textstyle\prod_k^h C_{ij}^k\right)^{1/h}. \end{aligned} \tag{2.3}$$

Step 1: Normalize each column to get a new judgment, matrix A.

$$A' = \begin{bmatrix} C'_{11} & C'_{12} & C'_{13} & \cdots & C'_{1n} \\ C'_{21} & C'_{22} & C'_{23} & \cdots & C'_{2n} \\ C'_{31} & C'_{32} & C'_{33} & \cdots & C'_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C'_{n1} & C'_{n2} & C'_{n3} & \cdots & C'_{nn} \end{bmatrix} = \begin{bmatrix} \frac{C_{11}}{\sum_{i=1}^n C_{i1}} & \frac{C_{12}}{\sum_{i=1}^n C_{i2}} & \frac{C_{13}}{\sum_{i=1}^n C_{i3}} & \cdots & \frac{C_{1n}}{\sum_{i=1}^n C_{in}} \\ \frac{C_{21}}{\sum_{i=1}^n C_{i1}} & \frac{C_{22}}{\sum_{i=1}^n C_{i2}} & \frac{C_{23}}{\sum_{i=1}^n C_{i3}} & \cdots & \frac{C_{2n}}{\sum_{i=1}^n C_{in}} \\ \frac{C_{31}}{\sum_{i=1}^n C_{i1}} & \frac{C_{32}}{\sum_{i=1}^n C_{i2}} & \frac{C_{33}}{\sum_{i=1}^n C_{i3}} & \cdots & \frac{C_{3n}}{\sum_{i=1}^n C_{in}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{C_{n1}}{\sum_{i=1}^n C_{i1}} & \frac{C_{n2}}{\sum_{i=1}^n C_{i2}} & \frac{C_{n3}}{\sum_{i=1}^n C_{i3}} & \cdots & \frac{C_{nn}}{\sum_{i=1}^n C_{in}} \end{bmatrix}. \tag{2.4}$$

Step 2: Sum up each row of normalized judgment matrix A to get weight vector V.

$$V=\begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix}=\begin{bmatrix} \sum_{j=1}^{n} C'_{1j} \\ \sum_{j=1}^{n} C'_{2j} \\ \vdots \\ \sum_{j=1}^{n} C'_{nj} \end{bmatrix}. \qquad (2.5)$$

Step 3: Define the final normalization weight vector W.

$$W^T=\begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}=\begin{bmatrix} \frac{v_1}{\sum_{i=1}^{n} v_1} \\ \frac{v_2}{\sum_{i=1}^{n} v_1} \\ \vdots \\ \frac{v_n}{\sum_{i=1}^{n} v_1} \end{bmatrix}. \qquad (2.6)$$

In the next step, we use the consistency-checking method developed by Thomas L. Saaty. He determined the Consistency Ratio (CR) in the following equations [13].

$$CI=\frac{(\lambda_{\max}-n)}{n-1}, \qquad (2.7)$$

$$CR=\frac{CI}{RI}, \qquad (2.8)$$

where CI is the consistency index, n is the dimensions of the matrix, RI is the random index, and CR is the consistency ratio. The consistency ratio must be less than or equal to 0.10, and the decision maker's judgments consistent enough to give useful estimates of the weights for the objective function.

When $\lambda_{\max}$ is the largest eigenvalue of a matrix, n is the dimension of the matrix and the random index that depends on n, as shown in Table 2 [14]. The decision is acceptable if the consistency ratio is less than or equal to 0.10. However, if it is not, the analyst must redo the process [15].

Final step: the criteria are arranged in decreasing order. The most important criterion has the most significant weight. On the other hand, the least important criterion has the most negligible weight.

Table 2. Random index [14].

n	3	4	5	6	7	8	9	10	11	12	13
RI	0.58	0.89	1.12	1.24	1.33	1.40	1.45	1.49	1.51	1.54	1.56

3. A Case of Power Station Construction Project Selection

3.1 Problem details

A regional electricity provider needed to select a power station construction project site from 10 alternatives. There are 10 decision-makers in this study. They set up a group of experts from the relevant department. The team proposed seven criteria to assess: expected income (C_1), electricity consumption (C_2), system problems (C_3), number of electricity users (C_4), forecast of power shortage (C_5), the establishment of transmission electricity lines (C_6), and community acceptance (C_7). The structure of this multi-criteria decision analysis is shown in Fig. 1.

As mentioned earlier, there are seven criteria. In pairwise judgment, the experts must conduct the comparison 21 times. For 10 elected alternatives of each criterion, the experts must guide the comparison 315 times. If we combine the comparisons, 336 will be required. Furthermore, as the number of decisions made by a decision maker increases, the results obtained can be expected to be less reliable.

Accordingly, we applied our proposed method to solve such a large-scale decision problem. By deploying our technique, the decision-makers needed to make only 77 comparisons.

In this large-scale AHP method, the researcher collected data using the workshop method to summarize the scoring, which reduced data variation and missing data.

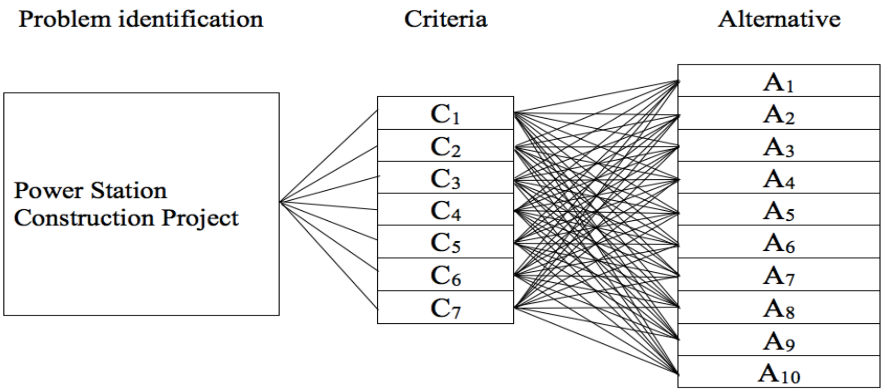

Fig. 1. Structure of AHP model for the power station construction project site selection.

3.2 Results and analysis

We first show the result of the criteria scores. They are shown in Table 3. We, then, use Eqs. (2.1)-(2.2) to calculate the relative criteria scoring, C_{ij}. Some examples of the relative criteria scoring calculation are shown as $C_{12} = 7 - 9 = -2,$ then $C_{12} = \frac{1}{-[(7-9)-1]}$; thus, $C_{14} = 7 - 6 = 1 \geq 0,$ then $C_{14} = (7-6)+1,$ thus $C_{14} = 2.$ The matrix A is shown in Fig. 2.

$$A = \begin{bmatrix} 1 & 1/3 & 1/2 & 2 & 1/3 & 4 & 5 \\ 3 & 1 & 2 & 4 & 1 & 6 & 7 \\ 2 & 1/2 & 1 & 3 & 1/2 & 5 & 6 \\ 1/2 & 1/4 & 1/3 & 1 & 1/4 & 3 & 4 \\ 3 & 1 & 2 & 4 & 1 & 6 & 7 \\ 1/4 & 1/6 & 1/5 & 1/3 & 1/6 & 1 & 2 \\ 1/5 & 1/7 & 1/6 & 1/4 & 1/7 & 1/2 & 1 \end{bmatrix}$$

Fig. 2. Matrix *A* of the case study.

By using Eqs. (2.3)-(2.8), the weight of each criterion is shown in Table 3.

Table 3. A score of criteria by experts.

Criterion	9	8	7	6	5	4	3	2	1
C_1 : expected income			✓						
C_2 : electricity consumption	✓								
C_3 : system problem		✓							
C_4 : number of electricity users				✓					
C_5 : forecast of power shortage	✓								
C_6 : establishment of transmission electricity lines						✓			
C_7 : community acceptance							✓		

Table 4. Weighted criteria and consistency ratio.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	Weight (%)
C_1	1.00	0.33	0.50	2.00	0.33	4.00	5.00	11.83
C_2	3.00	1.00	2.00	4.00	1.00	6.00	7.00	27.74
C_3	2.00	0.50	1.00	3.00	0.50	5.00	6.00	17.80
C_4	0.50	0.25	0.33	1.00	0.25	3.00	4.00	8.04
C_5	3.00	1.00	2.00	4.00	1.00	6.00	7.00	27.74
C_6	0.25	0.17	0.20	0.33	0.17	1.00	2.00	4.00
C_7	0.20	0.14	0.17	0.25	0.14	0.50	1.00	2.85
CR	0.0242 < 0.10							

From Table 4, the most important criteria are C_2 (electricity consumption) and C_5 (forecast of the power shortage), with a weight of 27.74%, followed by C_3 (system problem), with a weight of 17.80%. The C_1 (expected income) is ranked third in importance, with a weight of 11.83%.

We then use the same technique, the relative criteria scoring Eq. (2.1), to assess the weight of each construction site according to the decision criteria. Table 5 shows the experts' scores assigned to each construction project based on each decision criterion. We then calculate the weight and consistency ratio using Eqs. (2.3)-(2.8).

Some examples of the relative criteria scoring calculation according to criteria C_1 are shown as: $A_{12} = 9 - 7 = 2,$ then $A_{12}^{C_1} = (9-7)+1,$ thus $A_{12}^{C_1} = 3; A_{28}^{C_1} = 7-9 = -2,$ then $A_{28}^{C_1} = \dfrac{1}{-[(7-9)-1]},$ thus, $A_{28}^{C_1} = \dfrac{1}{3}.$ The matrix A^{C_1} is shown in Fig. 3.

Table 5. A score of alternatives based on criteria by experts.

Alternatives/Sites	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	9	8	5	7	9	5	5
A_2	7	7	5	6	9	5	5
A_3	5	5	7	4	9	5	5
A_4	1	1	6	2	8	5	5
A_5	2	2	5	3	9	5	5
A_6	3	3	9	5	9	5	5
A_7	4	4	5	1	9	5	5
A_8	9	9	8	9	9	5	5
A_9	9	9	8	9	8	5	5
A_{10}	6	6	5	8	9	5	5

$$A^{C_1} = \begin{bmatrix} 1 & 3 & 5 & 9 & 8 & 7 & 6 & 1 & 1 & 4 \\ 1/3 & 1 & 3 & 7 & 6 & 5 & 4 & 1/3 & 1/3 & 2 \\ 1/5 & 1/3 & 1 & 5 & 4 & 3 & 2 & 1/5 & 1/5 & 1/2 \\ 1/9 & 1/7 & 1/5 & 1 & 1/2 & 1/3 & 1/4 & 1/9 & 1/9 & 1/6 \\ 1/8 & 1/6 & 1/4 & 2 & 1 & 1/2 & 1/3 & 1/8 & 1/8 & 1/5 \\ 1/7 & 1/5 & 1/3 & 3 & 2 & 1 & 1/2 & 1/7 & 1/7 & 1/4 \\ 1/6 & 1/4 & 1/2 & 8 & 3 & 2 & 1 & 1/6 & 1/6 & 1/3 \\ 1 & 3 & 5 & 9 & 8 & 7 & 6 & 1 & 1 & 4 \\ 1 & 3 & 5 & 9 & 8 & 7 & 6 & 1 & 1 & 4 \\ 1/4 & 1/2 & 2 & 6 & 5 & 4 & 3 & 1/4 & 1/4 & 1 \end{bmatrix}$$

Fig. 3. Matrix A^{C_1} of the case study.

Table 6. Weighted alternative according to C_1 and consistency ratio.

Alternative	$A_1^{C_1}$	$A_2^{C_1}$	$A_3^{C_1}$	$A_4^{C_1}$	$A_5^{C_1}$	$A_6^{C_1}$	$A_7^{C_1}$	$A_8^{C_1}$	$A_9^{C_1}$	$A_{10}^{C_1}$	Weight (%)
$A_1^{C_1}$	1.00	3.00	5.00	9.00	8.00	7.00	6.00	1.00	1.00	4.00	21.55
$A_2^{C_1}$	0.33	1.00	3.00	7.00	6.00	5.00	4.00	0.33	0.33	2.00	11.06
$A_3^{C_1}$	0.20	0.33	1.00	5.00	4.00	3.00	2.00	0.20	0.20	0.50	5.72
$A_4^{C_1}$	0.11	0.14	0.20	1.00	0.50	0.33	0.25	0.11	0.11	0.17	1.55
$A_5^{C_1}$	0.13	0.17	0.25	2.00	1.00	0.50	0.33	0.13	0.13	0.20	2.08
$A_6^{C_1}$	0.14	0.20	0.33	3.00	2.00	1.00	0.50	0.14	0.14	0.25	2.89
$A_7^{C_1}$	0.17	0.25	0.50	4.00	3.00	2.00	1.00	0.17	0.17	0.33	4.07
$A_8^{C_1}$	1.00	3.00	5.00	9.00	8.00	7.00	6.00	1.00	1.00	4.00	21.55
$A_9^{C_1}$	1.00	3.00	5.00	9.00	8.00	7.00	6.00	1.00	1.00	4.00	21.55
$A_{10}^{C_1}$	0.25	0.50	2.00	6.00	5.00	4.00	3.00	0.25	0.25	1.00	7.98
CR	0.0346 < 0.10										

The matrix A^{C_1} is the scaling of alternative comparison based on criteria C_1. We calculated all matrices: $A^{C_1}, A^{C_2}, ...,, A^{C_7}$ for criteria $C_1, C_2, ..., C_7$, respectively. We then calculated the weight of each alternative according to the criteria by using Eqs. (2.3)-(2.8); the weight of each alternative based on the criteria C_1 is shown in Table 6.

The weighted alternatives based on seven criteria are calculated. Fig. 4 shows the weight of alternative i corresponding to criteria j. Thus entry $A_{11} = 21.55$ is the weight of alternative 1 based on criteria 1. And from the weight of criteria, we found $w = [11.83 \;\; 27.74 \;\; 17.80 \;\; 8.04 \;\; 27.74 \;\; 4.00 \;\; 2.85]$, shown in Table 3. We multiply matrix A_{ij}^{C} by vector w; we then receive the score of all alternatives, as shown in Fig. 5. It also can be illustrated as a bar chart, as shown in Fig. 6.

$$A_{ij}^{C} = \begin{bmatrix} 21.55 & 16.32 & 4.20 & 11.60 & 11.11 & 10.00 & 10.00 \\ 11.06 & 11.60 & 4.20 & 8.28 & 11.11 & 10.00 & 10.00 \\ 5.72 & 5.90 & 11.37 & 4.18 & 11.11 & 10.00 & 10.00 \\ 1.55 & 1.58 & 7.28 & 2.12 & 5.56 & 10.00 & 10.00 \\ 2.08 & 2.12 & 4.20 & 2.96 & 11.11 & 10.00 & 10.00 \\ 2.89 & 2.96 & 25.77 & 5.90 & 11.11 & 10.00 & 10.00 \\ 4.07 & 4.18 & 4.20 & 1.58 & 11.11 & 10.00 & 10.00 \\ 21.55 & 23.53 & 17.28 & 23.53 & 11.11 & 10.00 & 10.00 \\ 21.55 & 23.53 & 17.28 & 23.53 & 5.56 & 10.00 & 10.00 \\ 7.98 & 8.28 & 4.20 & 16.32 & 11.11 & 10.00 & 10.00 \end{bmatrix}$$

Fig. 4. Matrix A_{ij} of the large-scale AHP.

$$x = A_{ij}^{C} \times w^{T} = \begin{bmatrix} 21.55 & 16.32 & 4.20 & 11.60 & 11.11 & 10.00 & 10.00 \\ 11.06 & 11.60 & 4.20 & 8.28 & 11.11 & 10.00 & 10.00 \\ 5.72 & 5.90 & 11.37 & 4.18 & 11.11 & 10.00 & 10.00 \\ 1.55 & 1.58 & 7.28 & 2.12 & 5.56 & 10.00 & 10.00 \\ 2.08 & 2.12 & 4.20 & 2.96 & 11.11 & 10.00 & 10.00 \\ 2.89 & 2.96 & 25.77 & 5.90 & 11.11 & 10.00 & 10.00 \\ 4.07 & 4.18 & 4.20 & 1.58 & 11.11 & 10.00 & 10.00 \\ 21.55 & 23.53 & 17.28 & 23.53 & 11.11 & 10.00 & 10.00 \\ 21.55 & 23.53 & 17.28 & 23.53 & 5.56 & 10.00 & 10.00 \\ 7.98 & 8.28 & 4.20 & 16.32 & 11.11 & 10.00 & 10.00 \end{bmatrix} \times \begin{bmatrix} 11.83 \\ 27.74 \\ 17.80 \\ 8.04 \\ 27.74 \\ 4.00 \\ 2.85 \end{bmatrix} = \begin{bmatrix} 12.52 \\ 9.71 \\ 8.44 \\ 4.32 \\ 5.59 \\ 9.99 \\ 6.28 \\ 17.81 \\ 16.27 \\ 9.07 \end{bmatrix}$$

Fig. 5. Weighted alternatives of the large-scale AHP.

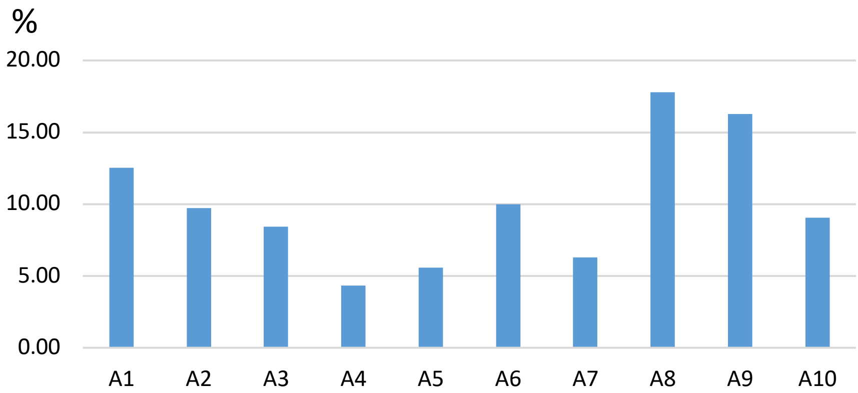

Fig. 6. The weight of the alternative power station project.

From Figs. 5-6, it can be stated that using the large-scale AHP, alternative 8 is likely to be chosen and is the most beneficial one.

We then adopted the suggestion of [16] to use multiple decision makers, a clustering technique, each of which pays attention to a particular area of the hierarchy; this approach would necessitate fewer individual judgments and logically produce more reliable evaluation from any one individual. This allowed us to compare our findings with the classical AHP.

Thus, we divided the group of experts into three subgroups. The first group is the top management level in which there are three decision-makers. The second group is the managers and supervisors in which there are three decision-makers. And the third group is the managers and supervisors in which there are four decision-makers. We assigned the first group to decide the weight of the criteria. The second group is responsible for the pair-wise comparison of 10 alternatives on C_1 to C_3. Finally, the third group is responsible for the pairwise comparison of 10 alternatives on C_4 to C_7.

Fig. 7 shows the outcome of the classical AHP. Fig. 8 is the outcome comparison between the large-scale AHP and the classical AHP.

$$x = A_{ij}^{C} \times w^{T} = \begin{bmatrix} 12.85 & 11.53 & 8.38 & 9.15 & 13.51 & 10.02 & 9.97 \\ 11.02 & 9.96 & 5.30 & 7.40 & 12.55 & 9.41 & 7.10 \\ 10.14 & 7.87 & 10.28 & 5.41 & 11.81 & 12.30 & 16.51 \\ 2.06 & 1.82 & 8.87 & 2.34 & 3.97 & 5.47 & 3.79 \\ 2.23 & 2.31 & 4.48 & 2.69 & 8.05 & 4.68 & 4.05 \\ 2.94 & 2.90 & 27.44 & 5.89 & 11.72 & 8.94 & 6.96 \\ 2.33 & 4.14 & 4.58 & 1.71 & 12.47 & 4.87 & 3.39 \\ 24.72 & 25.22 & 13.29 & 22.77 & 11.50 & 17.16 & 17.32 \\ 24.05 & 24.60 & 13.29 & 24.91 & 3.43 & 15.94 & 18.57 \\ 7.67 & 9.66 & 4.10 & 17.73 & 10.99 & 11.19 & 12.36 \end{bmatrix} \times \begin{bmatrix} 8.02 \\ 26.36 \\ 22.79 \\ 7.23 \\ 26.36 \\ 4.61 \\ 4.61 \end{bmatrix} = \begin{bmatrix} 11.13 \\ 9.32 \\ 10.06 \\ 4.31 \\ 4.53 \\ 11.50 \\ 6.11 \\ 17.93 \\ 15.74 \\ 9.36 \end{bmatrix}$$

Fig. 7. Weighted alternatives of the classical AHP.

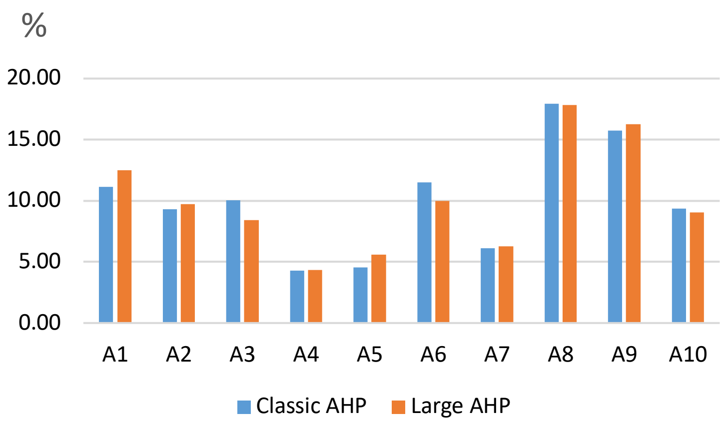

Fig. 8. The comparison of weighted alternatives.

From Fig. 8, interestingly, construction project number 8 is chosen by both decision-making approaches. Precisely, the large-scale AHP yielded the difference between the first and the second rank, A_8 and A_9, of $17.81 - 16.27 = 1.54\%$. Besides, the classical AHP yielded the difference between the first and the second rank, A_8 and A_9, of $17.93 - 15.74 = 2.19\%$. The outcome-changing threshold of the classical AHP is a little bit larger than the large-scale AHP. This means that the pairwise comparison approach is more robust. Nevertheless, the large-scale AHP is more applicable in real practice. It gives the same result as the classical AHP while demanding less effort. While the classical AHP needs 336 decisions, the large-scale needs only 77 decisions which reduces the effort of the decision-makers by 77.08%. To express bold evidence, suppose each decision-making needs 1 minute to discuss and make a judgment, 336 decisions expect around 5 hours and a half to conduct. Nonetheless, the large-scale AHP needs only 1.28 hours to finish with the same result.

4. Conclusion

AHP is the most well-known multi-criteria decision analysis. The procedure entails a hierarchical breakdown of the main evaluation problem into more manageable and evaluable sub problems. Given that AHP takes into account any expressed preferences at each phase, there is no need to explicitly estimate a utility function. The drawback of AHP is it needs a huge number of pair-wise comparisons even on a medium-size problem; say 7 alternatives and 5 criteria. However, in real-world problems, we may face up to 20 alternatives with 10 criteria. It is impossible to employ the AHP in such cases.

We proposed a novel technique by borrowing the idea of the Likert scale but employing a 1 to 9 scale. The modified ones are the concept of the relative criteria scoring and the matrix of the relative criteria scoring. Our approach's performance was then assessed in the large-scale multi-criteria decision analysis of a power station construction project selection. There were 10 alternatives and 7 criteria to get through the course of the decision. In this case, the criteria with most weight are C_2 (electricity consumption) and C_5 (forecast of the power shortage). Station A_8 should be constructed first among all alternatives; it is considerably a justified decision making process.

When comparing the proposed method with the classical AHP with a clustering technique, the proposed method yielded the same conclusion as the classical AHP while requiring significantly less effort. Furthermore, the threshold of decision changing was not a substantial discrepancy.

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