Ahmed M. Agwa[1,2], Shaaban M. Shaaban[1,3]

Northern Border University (1), Al-Azhar University (2), Menoufia University (3), Egypt

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Siting hydropower plant by rough set and combinative distance-based assessment

***Abstract**. Each power plant (PP) is solo entity whose construction site is determined by different criteria in accordance with some physical rules. Latterly, great importance is provided to siting PP in inexact surroundings. Multiple-criteria decision-making for the proper location of the PP construction is relevant. The objective of this research is to create a model for decision-makers to rank available sites for installing hydropower plant (HPP) in accordance with multiple-criteria attributes e.g. accessibility to electrical grid, power potential, economical respects, environmental influence, topography, and natural hazards. In this research, a novel application of a hybrid approach that employs rough set theory (RST) and combinative distance-based assessment (CODAS) method is proposed to prioritize available locations for installing HPP. Firstly, the strength of RST is adopted to get minimal attributes reduction set. Secondly, the relative weights of minimal attributes are determined using RST. Finally, CODAS technique is utilized to calculate the rank of alternatives. The comparison between the proposed method-based results and the results without attributes reduct, proves that the proposed method saves the time and energy.*

***Streszczenie.** Zaproponowano nowatorskie zastosowanie podejścia hybrydowego, które wykorzystuje teorię zbiorów przybliżonych (RST) i metodę oceny kombinowanej opartej na odległości (CODAS) w celu ustalenia priorytetów dostępnych lokalizacji do zainstalowania elektrowni wodnej (HPP) zgodnie z atrybutami wielokryterialnymi, np. dostępność do sieci elektrycznej, potencjał energetyczny, aspekty ekonomiczne, wpływ środowiska, topografia i zagrożenia naturalne.* (*Planowanie u**sytuowania elektrowni wodnej metodą wstępną i kombinowanąocena na podstawie odległości)**.*

Keywords: Hydropower plant, site selection, multiple-criteria decision-making, rough set, combinative distance-based assessment
Słowa kluczowe: Elektrownia wodna, wybór miejsca, podejmowanie decyzji według wielu kryteriów, zgrubny zestaw, kombinowana ocena oparta na odległości

Introduction

Global warming has caused by the increase in industrial activities and unrestrained usage of fossil fuels. Consequently, the climate of several places is unforeseeable nowadays and has turned into unusual. Therefore, the hydropower importance arises as one from the best sources of renewable energy which is distinguished as environmentally friendly, safe, sustainable, and economical [1, 2].

Selecting the best site for installing hydropower plant (HPP) is a tremendously complex procedure as various and contradictory criteria need to be studied in detail. In general, the dependence of the feasibility of installing a power plant (PP) on location, results in a multiple-criteria decision-making (MCDM) problem. During the procedure of siting PP, there are quantifiable and epistemic uncertain criteria. The uncertain criteria associated can be modeled correctly by means of an algorithm which imitates natural intelligence.

Throughout installing industrial locations like PPs, numerous hurtful elements that are dangerous to environment and living organisms will augment due to reducing the area of large forests in erection stage and pollutants. Moreover, hurtful gases may be emitted owing to the combustion of fuel in the thermal PPs. Our already highly polluted environment will deteriorate by irresponsibly and improperly siting the PP construction. Consequently, environment influence evaluation (EIE) is habitually executed after determining possible site for installing an industrial plant. EIE procedures act as a strict requirement in siting for long time and have presently attracted researchers' interests.

Criteria e.g. accessibility to electrical grid and economical respects also act significant roles in siting PPs. During siting HPP, water flow rate and watery head are important criteria since the output power of HPP is directly proportional to them.

Numerous researchers have aimed to prioritize available locations for installing PPs by means of several approaches. Particularly, geographical information system (GIS) [3-9], ordered weighted averaging accompanied by linear weighted averaging [10], artificial neural networks learned by genetic algorithm [11], neuro-fuzzy structure [12], technicality of ordering preference using similarities to ideal solution (TOPSIS) accompanied by vlše kriterijumska optimizacija kompromisno rešenje (VIKOR) (which can be translated from Bosnian to English, better criterion optimization compromise solution) [13], and analytic hierarchy process (AHP) [14].

Other approaches like fuzzy logic (FL) [15,16], FL accompanied by TOPSIS [17-19], FL accompanied by both of AHP and TOPSIS [20, 21], expert system [22], and linear programming [23], were applied to rank available sites for installing PPs.

In addition to the above approaches there are others have been utilized to grade available locations for installing PPs such as graph theory accompanied by matrix method [24], multi-attribute choquet integral [25], hierarchical decision model [26], resources spatial and temporal conjunction [27], and rough set theory (RST) accompanied by multi-objective programming [28].

With reference to the above brief survey, it is still a room for ranking available sites for installing HPP. In this regard, the research will address RST and combinative distance-based assessment (CODAS), which was designed in 2016 [29], in order to grade available locations for installing HPP since published results of RST and CODAS are hopeful and verify their preference over other methods.

RST

RST can be utilized to draw out knowledge from a scope in a brief manner while preserving the content of the information [30]. In RST, distinguishing two objects acts a critical role for choosing a feature [31].

Knowledge Systems

Assume an information system (OB, ATT, VAL, f), where OB – a non-empty group of objects and ATT – a non-empty group of limited attributes, VAL – a group of values of attributes, f – a mapping which from OB to VAL, and $f_a(x)$ means the value of attribute a of object x.

Indistinguishability Relation

In RST, an equivalence relation R_A is the base of sorting procedure and it can be stated w.r.t. to A (where $A \subseteq ATT$) as stated in (1).

(1) $$\mathbf{R_A} = \{(\mathbf{x}, \mathbf{y}) \in \mathbf{OB} \times \mathbf{OB} \mid \mathbf{f_a}(\mathbf{x}) = \mathbf{f_a}(\mathbf{y}), \mathbf{a} \in \mathbf{A}\}$$

If $(x, y) \in R_A$, then it is said that x and y are indistinguishable using attributes from A. Equivalence classes created by equivalence relation R_A are called as categorization $[x]_A$.

Approximations of Sets

Upper and lower approximations of $X \subseteq OB$, are stated as below:

(2) $$\mathbf{R_A} \uparrow \mathbf{X} = \{\mathbf{x} \in \mathbf{OB} \mid [\mathbf{x}]_\mathbf{A} \subseteq \mathbf{X}\}$$

(3) $$\mathbf{R_A} \downarrow \mathbf{X} = \{\mathbf{x} \in \mathbf{OB} \mid [\mathbf{x}]_\mathbf{A} \cap \mathbf{X} \neq \emptyset\}$$

Rough set is the ordered pair ($R_A \downarrow X$, $R_A \uparrow X$).

Dependency of Attributes

An evaluation of dependency of two attributes sets A, $B \subseteq ATT$ is presented in RST. The evaluation is called a degree of dependence of A on B ($\gamma_B(A)$) and stated in (4).

(4) $$\boldsymbol{\gamma}_\mathbf{B}(\mathbf{A}) = \frac{\mathbf{card}(\mathbf{POS_B}(\mathbf{A}))}{\mathbf{card}(\mathbf{OB})}$$

(5) $$\mathrm{POS_B}(\mathrm{A}) = \mathrm{OB}_{\mathrm{X} \in [\mathrm{x}]_\mathrm{A}} \ \mathrm{R_A} \downarrow \mathrm{X}$$

where card – the set cardinality and $POS_B(A)$ – a positive zone of categorization $[x]_A$ (or shortly a positive zone of A) for B. The set $POS_B(A)$ includes the objects of OB that perhaps be categorized as pertaining to one equivalence class of R_A, utilizing attributes from B. The parameter $\gamma_B(A)$ determines ratio of the objects that can be correctly categorized. It can be said that A relies on B to degree $\gamma_B(A)$. The value of $\gamma_B(A)$ ranges from 0 to 1.

Importance of Attributes

The parameter γ is utilized to identify a vital conception for investigations about importance of an attribute as revealed in (6).

(6) $$\sigma_\mathrm{a}^\mathrm{B} = \gamma_\mathrm{B}(\mathrm{A}) - \gamma_{\mathrm{B}-\{\mathrm{a}\}}(\mathrm{A})$$

where σ_a^B – the importance of an attribute a, $a \in B$, $B \subseteq ATT$, which indicates how significant the attribute a is in B, concerning categorization $[x]_A$. Removal of attribute a is tested and its importance is determined by the resultant change in categorization $[x]_A$.

The described importance relies on both set A and B so it is relative value. Thus, an attribute perhaps owns different importance for different categorizations and in different sets (set B in (6)). To identify an absolute importance of an attribute in (7), the entire set of attributes ATT is taken as the sets A and B in the description A = B = ATT.

(7) $$\sigma_\mathrm{a}^\mathrm{ATT}(\mathrm{ATT}) = \gamma_\mathrm{ATT}(\mathrm{ATT}) - \gamma_{\mathrm{ATT}-\{\mathrm{a}\}}(\mathrm{ATT})$$

And taking in consideration that $\boldsymbol{\gamma}_\mathbf{ATT}(\mathbf{ATT}) = \mathbf{1}$, then:

(8) $$\boldsymbol{\sigma}_\mathbf{a}^\mathbf{ATT}(\mathbf{ATT}) = \mathbf{1} - \boldsymbol{\gamma}_{\mathbf{ATT}-\{\mathbf{a}\}}(\mathbf{ATT})$$

Attributes Reduct and Core Attributes

Suppose an attribute a, $a \in B$, $B \subseteq ATT$, if $POS_B([x]_A) = POS_{B-\{a\}}([x]_A)$, then a is redundant to B, concerning $[x]_A$, otherwise a is indispensable.

If $R_B = R_{ATT}$ and $POS_B([x]_A) \neq POS_{B-\{a\}}([x]_A)$, then B is named a reduct subset for information system and symbolized as RED(ATT); the intersection of these reduct subsets is called core and symbolized as CORE = $\cap$RED(ATT).

Weights of Attributes

When each attribute importance is normalized, each attribute weight (wt_i) can be obtained as stated in (9).

(9) $$\mathbf{wt_i} = \frac{\boldsymbol{\sigma}_{\mathbf{a_i}}^\mathbf{ATT}(\mathbf{ATT})}{\sum_{\mathbf{j}=1}^{\mathbf{n}} \boldsymbol{\sigma}_{\mathbf{a_j}}^\mathbf{ATT}(\mathbf{ATT})}$$

CODAS

CODAS is a modern method utilized efficiently in MCDM. In this technique, the desirability of all obtainable alternates is measured based on two criteria, first of them, the Euclidean spacing (l^2-norm) measurement between every alternate and the worst solution. The second criterion is the corresponding measurement of Taxicab spacing (l-norm) [32]. It's obvious that the alternate that owns larger spacing from the worst solution is more desired. In this technique, if two alternates are incomparable in accordance with the Euclidean spacing, the Taxicab spacing will be utilized as secondary measurement [33]. Assume that there are m alternates and k criteria. The steps of CODAS for MCDM are as following:

1st Step

The decision-making matrix (X), is constructed as below:

(10) $$\mathrm{X} = [\mathrm{x_{ij}}]_{\mathrm{m}\times\mathrm{k}} = \begin{bmatrix} \mathrm{x_{11}} & \mathrm{x_{12}} & \cdots & \mathrm{x_{1k}} \\ \mathrm{x_{21}} & \mathrm{x_{22}} & \cdots & \mathrm{x_{2k}} \\ \vdots & \vdots & \vdots & \vdots \\ \mathrm{x_{m1}} & \mathrm{x_{m2}} & \cdots & \mathrm{x_{mk}} \end{bmatrix}$$

where x_{ij} ($x_{ij} > 0$) – the value of performance of alternate i on criterion j ($i \in \{1, 2\ldots, m\}$ and $j \in \{1, 2\ldots, k\}$).

2nd Step

The matrix of normalized values (n_{ij}) of performance, is computed using linear normalization as following:

(11) $$\mathrm{n_{ij}} = \begin{cases} \dfrac{\min_\mathrm{i} \mathrm{x_{ij}}}{\mathrm{x_{ij}}} & \text{if} \quad \mathrm{j} \in \mathrm{N_c} \\ \dfrac{\mathrm{x_{ij}}}{\max_\mathrm{i} \mathrm{x_{ij}}} & \text{if} \quad \mathrm{j} \in \mathrm{N_b} \end{cases}$$

where N_c,N_b – the groups of cost and benefit criteria, consecutively

3rd Step

The matrix of the weighted normalized values (r_{ij}) of performance, is computed as follows:

$$\mathrm{r_{ij}} = \mathrm{wt_j} \mathrm{n_{ij}}$$

where wt_j – the weight of criterion j, which is computed using (9) and subjected to the two following conditions:

(12) $$0 < \mathrm{wt_j} < 1$$

(13) $$\sum_{\mathrm{j}=1}^{\mathrm{k}} \mathrm{wt_j} = 1$$

4th Step

The worst solution (ws) is the minimum value of the weighted normalized values of performance as calculated below:

(14) $$\mathrm{ws} = [\mathrm{ws_j}]_{1\times\mathrm{k}}$$

(15) $$\mathrm{ws_j} = \min_\mathrm{i} \mathrm{r_{ij}}$$

5th Step

The Euclidean spacing (E_i) and Taxicab spacing (T_i) between alternates and the worst solution, are computed as below:

$$E_i = \sqrt{\sum_{j=1}^{k}\left(r_{ij} - ws_j\right)^2} \quad (16)$$

$$T_i = \sum_{j=1}^{k}\left|r_{ij} - ws_j\right| \quad (17)$$

6th Step

The relative assessment matrix (RE) is constructed, as following.

$$RE = [h_{ik}]_{m\times m} \quad (18)$$

$$h_{in} = (E_i - E_n) + \left(\delta(E_i - E_n) \times (T_i - T_n)\right) \quad (19)$$

where n ∈ {1, 2…, m} and δ – a threshold function for determining whether two alternates own equal Euclidean distances or not, and is stated as below:

$$\delta(E_i - E_n) = \begin{cases} 1 & \text{if} \quad |E_i - E_n| \geq \beta \\ 0 & \text{if} \quad |E_i - E_n| < \beta \end{cases} \quad (20)$$

where β – the threshold parameter which the decision-makers had defined. The value of β is between 0.01 and 0.05.

Two alternates will be compared using the Taxicab distance as an additional value if the variance between their Euclidean distances is less than β. In this paper, β = 0.02 is utilized for the computations.

7th Step

The assessment score for every alternate, is calculated as following:

$$H_i = \sum_{n=1}^{m} h_{in} \quad (21)$$

8th Step

The alternates are ranked in descending order in accordance with the assessment scores values.

The flowchart in Fig. 1 displays the steps of the suggested approach including RST and CODAS for siting HPP.

Results, Validations, and Discussions

In this section, a case study located in northern Iran is tested to legalize the performance and the effectiveness of the suggested approach in MCDM for sitig HPP.

Knowledge System of Siting HPP

Table 1 includes the required information system for RST about available locations of HPP. Twenty-two available locations (Loc1, Loc2…, Loc22) and twelve conditional attributes (ca1, ca2…, ca12) with their values are displayed in Table 1. Decision attribute (DA) indicates the level of suitability (0 for low appropriateness, 1 for medium appropriateness, 2 for high appropriateness). Interpretations of conditional attributes (ca1, ca2…, ca12) and their values (1, 2, 3) are revealed in Table 2.

Categorization and attributes dependency, which are computed using (1) to (5), are not mentioned to avoid boring lengthy article to the readers but their values are utilized to calculate the reduct and importance of attributes.

Attributes Reduct by RST

The consistency of appropriateness level with twelve conditional attributes is tested during this stage. For extracting reduct using RST, redundant attributes need to be defined and a decision table is required to be created free of inconsistencies. To find the redundant attributes of assessments, removal of attributes one by one is tested, and the categorization is checked each time to insure no inconsistency has arisen. The results reveal that a2, a6, a7, a9, a10, a11, a12 are redundant attributes and a1, a3, a4, a5, a8 are indispensable attributes. That is to say, accessibility to electrical grid, water flow rate, watery head, economical respects, and topography are the core for appropriateness level for siting HPP and the other indices can be omitted because they are unnecessary information for siting HPP. Consequently, Table 3 is gotten by removing the redundant attributes from Table 1.

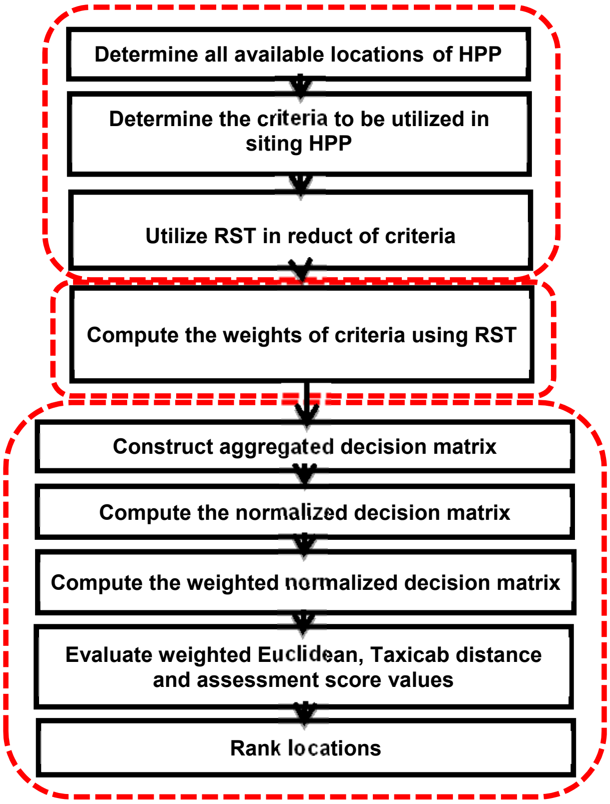

Fig. 1. Flowchart of siting HPP by RST and CODAS

Determination of Importance and Weights of Attributes by RST

The importance of the core attributes ca1, ca3, ca4, ca5, ca8 is calculated using (8) and the results are 0.091, 0.227, 0.227, 0.136, 0.091 respectively. The attributes weight of ca1, ca3, ca4, ca5, ca8 is calculated by normalization of attribute importance using (9) as revealed in (23) to (27).

$$wt(ca1) = \frac{0.091}{0.091+0.227+0.227+0.136+0.091} = 0.118 \quad (23)$$

$$wt(ca3) = \frac{0.227}{0.091+0.227+0.227+0.136+0.091} = 0.294 \quad (24)$$

$$wt(ca4) = \frac{0.227}{0.091+0.227+0.227+0.136+0.091} = 0.294 \quad (25)$$

$$wt(ca5) = \frac{0.136}{0.091+0.227+0.227+0.136+0.091} = 0.176 \quad (26)$$

$$wt(ca8) = \frac{0.091}{0.091+0.227+0.227+0.136+0.091} = 0.118 \quad (27)$$

Table 1. Information system of siting HPP

Locations	Conditional attributes												Decision attribute
	ca1	ca2	ca3	ca4	ca5	ca6	ca7	ca8	ca9	ca10	ca11	ca12	DA
Loc1	1	1	3	1	2	1	2	2	3	3	1	1	0
Loc2	1	1	1	3	1	2	2	2	2	2	2	2	1
Loc3	1	1	3	2	3	1	1	1	2	3	1	2	0
Loc4	2	1	2	1	1	1	1	1	3	1	1	1	2
Loc5	1	1	3	1	3	2	2	1	3	3	2	2	0
Loc6	2	2	2	1	2	1	1	2	2	2	1	1	1
Loc7	2	2	2	1	2	1	1	1	2	2	1	1	1
Loc8	1	2	1	1	2	1	1	1	2	2	1	1	2
Loc9	1	3	3	1	3	1	2	2	2	3	1	2	0
Loc10	1	1	1	1	1	1	1	1	2	2	1	1	2
Loc11	2	3	3	2	3	1	3	2	3	3	1	2	0
Loc12	1	1	1	1	1	1	2	1	2	2	1	1	2
Loc13	1	2	2	2	3	2	3	2	2	3	3	3	0
Loc14	1	1	1	2	1	1	1	1	2	1	1	1	2
Loc15	1	1	2	2	2	1	1	2	2	3	1	1	0
Loc16	2	2	1	3	2	1	3	1	3	2	1	2	1
Loc17	2	1	2	2	1	2	1	1	1	2	2	1	1
Loc18	1	3	3	1	2	2	2	1	3	3	2	2	0
Loc19	2	2	1	1	2	1	1	1	1	1	1	1	2
Loc20	2	1	2	1	1	1	1	1	1	1	1	1	2
Loc21	1	2	2	1	2	1	1	1	2	1	1	1	2
Loc22	2	2	2	2	1	2	2	3	2	1	2	3	0

Table 2. Conditional attributes and their values

Conditional attributes		Values
ca1	accessibility to electrical grid	1- near 2- moderate distance 3- far
ca2	roads to the project	1- exist 2- minor roads 3- absent
ca3	water flow rate	1- large 2- medium 3- small
ca4	watery head	1- large 2- medium 3- small
ca5	economical respects	1- highly economic 2- moderately economic 3- not economic
ca6	environment influences	1- no influences 2- solvable influences 3- severe influences
ca7	future expansions considerations	1- no problem 2- some roads need to be destroyed 3- farmland houses need to be destroyed
ca8	topography	1- flat ground 2- hills 3- mountains
ca9	tectonics and geology	1- compacted fine-grained soil 2- sedimentary strata 3- possibility of landslide or layers motion
ca10	ground floods	1- there is no structure 2- there are roads 3- there are farmland houses
ca11	flood riskiness	1- no riskiness 2- low riskiness 3- high riskiness
ca12	bearing capability of soil	1- large 2- medium 3- small

Table 3. Core attributes

Locations	Attributes					DA
	ca1	ca3	ca4	ca5	ca8	
Loc1	1	3	1	2	2	0
Loc2	1	1	3	1	2	1
Loc3	1	3	2	3	1	0
Loc4	2	2	1	1	1	2
Loc5	1	3	1	3	1	0
Loc6	2	2	1	2	2	1
Loc7	2	2	1	2	1	1
Loc8	1	1	1	2	1	2
Loc9	1	3	1	3	2	0
Loc10	1	1	1	1	1	2
Loc11	2	3	2	3	2	0
Loc12	1	1	1	1	1	2
Loc13	1	2	2	3	2	0
Loc14	1	1	2	1	1	2
Loc15	1	2	2	2	2	0
Loc16	2	1	3	2	1	1
Loc17	2	2	2	1	1	1
Loc18	1	3	1	2	1	0
Loc19	2	1	1	2	1	2
Loc20	2	2	1	1	1	2
Loc21	1	2	1	2	1	2
Loc22	2	2	2	1	3	0

Ranking the Available Locations of HPP by CODAS

After determination of the criteria weights by RST, the rank of HPP sites is obtained using CODAS. In CODAS, firstly decision-making matrix is constructed in Table 4.

In siting HPP problem, ca1, ca3, ca4, ca5, ca8 criteria are cost criteria because they are desired to be minimized. The matrix of normalized values of performance is computed in Table 5 using (11).

The weighted normalized performance values and the worst solution are computed in Table 6 using (12) and (16), consecutively.

The Euclidean and Taxicab distances between alternatives and the worst solution are computed in Table 7 using (17) and (18), consecutively. The relative assessment matrix is computed using (20). The assessment scores (H) of alternatives are computed using (22) and the locations are ranked in descending order in accordance with H values as revealed in Table 7.

Table 4. Decision-making matrix

Weights	0.118	0.294	0.294	0.176	0.118
Locations	ca1	ca3	ca4	ca5	ca8
Loc1	1	3	1	2	2
Loc2	1	1	3	1	2
Loc3	1	3	2	3	1
Loc4	2	2	1	1	1
Loc5	1	3	1	3	1
Loc6	2	2	1	2	2
Loc7	2	2	1	2	1
Loc8	1	1	1	2	1
Loc9	1	3	1	3	2
Loc10	1	1	1	1	1
Loc11	2	3	2	3	2
Loc12	1	1	1	1	1
Loc13	1	2	2	3	2
Loc14	1	1	2	1	1
Loc15	1	2	2	2	2
Loc16	2	1	3	2	1
Loc17	2	2	2	1	1
Loc18	1	3	1	2	1
Loc19	2	1	1	2	1
Loc20	2	2	1	1	1
Loc21	1	2	1	2	1
Loc22	2	2	2	1	3

Table 5. The matrix of normalized values of performance

Locations	ca1	ca3	ca4	ca5	ca8
Loc1	1	0.3333	1	0.5	0.5
Loc2	1	1	0.3333	1	0.5
Loc3	1	0.3333	0.5	0.3333	1
Loc4	0.5	0.5	1	1	1
Loc5	1	0.3333	1	0.3333	1
Loc6	0.5	0.5	1	0.5	0.5
Loc7	0.5	0.5	1	0.5	1
Loc8	1	1	1	0.5	1
Loc9	1	0.3333	1	0.3333	0.5
Loc10	1	1	1	1	1
Loc11	0.5	0.3333	0.5	0.3333	0.5
Loc12	1	1	1	1	1
Loc13	1	0.5	0.5	0.3333	0.5
Loc14	1	1	0.5	1	1
Loc15	1	0.5	0.5	0.5	0.5
Loc16	0.5	1	0.3333	0.5	1
Loc17	0.5	0.5	0.5	1	1
Loc18	1	0.3333	1	0.5	1
Loc19	0.5	1	1	0.5	1
Loc20	0.5	0.5	1	1	1
Loc21	1	0.5	1	0.5	1
Loc22	0.5	0.5	0.5	1	0.3333

Results without Attributes Reduct

In the previous subsection, the alternatives order for siting HPP is gotten by CODAS after using RST with attributes reduct. In this section, the same case study is tested without attributes reduct to prove usefulness and effectiveness of the proposed method in MCDM for siting HPP. All the criteria in Table 1 are going to be utilized to make a decision. Table 8 displays the criteria weights when utilizing all criteria. Therefore, the rank of all locations is revealed in Table 9.

Obviously, the same rank is obtained and the most desirable choice in two different situations is identical. Consequently, the proposed approach is proved to be useful and effective tool in siting HPP. Furthermore, the proposed approach saves much time and energy due to attributes reduct by RST and avoids human perceptions and judgments using information entropy weight which is dependent on the real data.

Table 6. The matrix of the weighted normalized values of performance and the worst solution

Locations	ca1	ca3	ca4	ca5	ca8
Loc1	0.118	0.098	0.294	0.088	0.059
Loc2	0.118	0.294	0.098	0.176	0.059
Loc3	0.118	0.098	0.147	0.0587	0.118
Loc4	0.059	0.147	0.294	0.176	0.118
Loc5	0.118	0.098	0.294	0.0587	0.118
Loc6	0.059	0.147	0.294	0.088	0.059
Loc7	0.059	0.147	0.294	0.088	0.118
Loc8	0.118	0.294	0.294	0.088	0.118
Loc9	0.118	0.098	0.294	0.0587	0.059
Loc10	0.118	0.294	0.294	0.176	0.118
Loc11	0.059	0.098	0.147	0.0587	0.059
Loc12	0.118	0.294	0.294	0.176	0.118
Loc13	0.118	0.147	0.147	0.0587	0.059
Loc14	0.118	0.294	0.147	0.176	0.118
Loc15	0.118	0.147	0.147	0.088	0.059
Loc16	0.059	0.294	0.098	0.088	0.118
Loc17	0.059	0.147	0.147	0.176	0.118
Loc18	0.118	0.098	0.294	0.088	0.118
Loc19	0.059	0.294	0.294	0.088	0.118
Loc20	0.059	0.147	0.294	0.176	0.118
Loc21	0.118	0.147	0.294	0.088	0.118
Loc22	0.059	0.147	0.147	0.176	0.0393
Worst solution	0.059	0.098	0.098	0.0587	0.0393

Table 7. Rank of alternatives

Locations	E_i	T_i	H	Rank
Loc1	0.20771	0.304	0.21882	14
Loc2	0.23675	0.392	0.8777	8
Loc3	0.10987	0.18667	−1.5579	19
Loc4	0.24652	0.441	1.1449	6
Loc5	0.21928	0.33367	0.46716	11
Loc6	0.2051	0.294	0.16624	16
Loc7	0.21878	0.353	0.4609	12
Loc8	0.29557	0.559	2.5413	3
Loc9	0.20563	0.27467	0.17714	15
Loc10	0.31665	0.647	3.3091	1
Loc11	0.052799	0.068667	−2.1945	22
Loc12	0.31665	0.647	3.3091	2
Loc13	0.093112	0.17667	−1.8379	21
Loc14	0.25348	0.5	1.3689	5
Loc15	0.097623	0.206	−1.8274	20
Loc16	0.21322	0.304	0.33449	13
Loc17	0.15735	0.294	−0.8127	17
Loc18	0.22124	0.363	0.51682	10
Loc19	0.28962	0.5	2.2778	4
Loc20	0.24652	0.441	1.1449	7
Loc21	0.2266	0.412	0.6545	9
Loc22	0.13627	0.21533	−1.1226	18

Table 8. The attributes weights without attributes reduct

Attribute	ca1	ca2	ca3	ca4	ca5	ca6
Weight	0.0025	0.107	0.214	0.071	0.173	0.0014
Attribute	ca7	ca8	ca9	ca10	ca11	ca12
Weight	0.0021	0.0354	0.001	0.2862	0.0354	0.071

Table 9. Rank of alternatives without attributes reduct

Locations	Loc1	Loc2	Loc3	Loc4	Loc5	Loc6
Rank	14	8	19	6	11	16
Locations	Loc7	Loc8	Loc9	Loc10	Loc11	Loc12
Rank	12	3	15	1	22	2
Locations	Loc13	Loc14	Loc15	Loc16	Loc17	Loc18
Rank	21	5	20	13	17	10
Locations	Loc19	Loc20	Loc21	Loc22		
Rank	4	7	9	18		

Conclusions

Rank of the available locations for installing HPP can be considered as MCDM problem. Hybrid approach of RST and CODAS has been presented for this purpose. RST is utilized for attributes reduct and attributes weights calculation. CODAS is utilized for locations rank determination. The obtainable sites for installing HPP are ranked by the proposed approach for a case study placed in northern Iran. The same case study is tested without attributes reduct. Sameness of the gotten results in two states verifies that the proposed approach is characterized by good performance, efficacy and saving in the required time and energy. Hence, the proposed approach can be recommended as MCDM tool for siting PPs other than HPP.

***Authors**: Ahmed Mahmoud Agwa, Electrical Engineering Department, Faculty of Engineering, Northern Border University, Arar 1321, Saudi Arabia & Electrical Engineering Department, Faculty of Engineering, Al-Azhar University, Cairo 11651, Egypt, E-mail: ah1582009@yahoo.com; Shaaban Mohamed Shaaban, Electrical Engineering Department, Faculty of Engineering, Northern Border University, Arar 1321, Saudi Arabia & Department of Engineering Basic Science, Faculty of Engineerin, Menoufia University, Shebin El-Kom 32511, Egypt, E-mail: shabaan27@gmail.com*

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