

A Modified Hybrid Objective Model to Calculate the Weights of Cause and Effect Criteria in a System: DEMATEL and DEVELOPED SWARA (D-DS) Based Model

Seyed Hossain Ebrahimi¹

Abstract. Criteria weighting is a widely used and also an important feature of multi criteria decision making problems specially in engineering, computer science and management investigations. In particular in many studies related to complex systems there would be usually two main groups of cause and effect criteria. In this research it is intended to make an hybrid objective model comprising DEMATEL and SWARA techniques to assign classified weights to the subgroup of cause and effect criteria. As a main goal, the proposed hybrid model in this presented paper can afford to assign greater values for criteria who belong to cause group. In this regard we apply the objective information which derived from the parameters of (R, equal to sum of direct and indirect influence of a criteria), (R/C, named as net influence power of a criteria) and (R-C, named as net effect of a criteria) related to the final total influence matrix T in DEMATEL methodology. The main contribution in this work lies in utilizing the SWARA methodology and making us of its revision where the relatively Comparative Importance S_j , applied in SWARA technique is reconfigured by some aggregation operators including *max*, *Einstein* and *Hamacher* operators for obtaining more uniformed weights of cause and effect criteria relatively to SWARA basic methodology. Finally results shows that the (R/C) and (R-C) would transfer more clear and refined data and numeric information achieving better and highly reliable weights of criteria categorized into two groups of cause and effect group.

Keywords: DEMATEL method, SWARA method, cause and effect criteria ,criteria weight, mathematical model.

1.Introduction

¹Faculty of Economics and Administrative Sciences, University of Mazandaran ,Babolsar ,Iran. Email:shebrahimi1978@gmail.com

Determining the weights of criteria which generally known in a system is regarded as the most popular and elusive operation of multi-criteria decision making (MCDM) problems. Accordingly, criteria weighting that arises frequently in MCDM techniques would be specially the most challengeable part of a managerial decision making issues due to its direct impact of decision maker preferences and expert's opinions. Chiang [11] strictly expressed that "one of the most difficult tasks in multiple criteria decision analysis (MCDA) is determining the weights of individual criteria so that all alternatives can be compared based on the aggregate performance of all criteria". There are too many methods being commonly applied in complex economic and social systems which presented by several researchers to evaluate weights of criteria. Categorically, these weighting methods are often classified into three groups of subjective methods [also including the pairwise comparison methods], objective and integrated weighting approach methods [17]. In the subjective techniques of criteria weighting the direct expert's opinions based on the significance of each criteria are used to calculate the weights of criteria. In the opposite form, in the objective models of criteria weighting the indirect information which gathered in data derived from mathematical model are applied for final criteria weighting. Moreover, the integrated weighting models apply a combination of subjective and objective form of criteria weighting. Methods such as the SMARTER (Simple Multi Attribute Rating Technique Exploiting Ranks) [14], Swing method [61], Trade-off method [27], Analytical Hierarchy Processes (AHP) method [54], Step-Wise Weight Assessment Ratio Analysis (SWARA) method [29], Full Consistency Method (FUCOM) [43], Best Worst Method (BWM) [51], Level Based Weight Assessment (LBWA) [66], Simple Additive Weighing (SAW) method [36] and Resistance to Change Method [52] are some subjective form of criteria weighting methods. Contrary to subjective models of criteria weighting methods there are some objective forms like the Entropy method [55], FANMA (named by the first letters of the authors) method [35] and CRiteria Importance Through Intercriteria Correlation (CRITIC) method [12]. Closely looking into some MCDM methods, it would be perceived that there are some applying benefits and also some weaknesses and shortcomings associated to their procedures and outputs too. For example the simple additive weighting method (SAW) as a most widely used method assumes that the criteria are mutually independent. AHP method effectively watch the information between criteria and the information within criteria. No capturing the interaction between alternatives within a criterion and across criteria besides the complexity and the probable inconsistencies are the main weaknesses relevant to AHP methodology. A non-linear and more general type of AHP using Markov-chain-based aggregation is the main benefits of ANP methodology. The computational complexity related to AHP method would also be for ANP methodology too. Identifying the best and the worst criteria followed by conducting a fewer pairwise comparisons (than AHP) between each of the best and worst criteria and other ones are the benefits of BMW method. Additionally for some more comprehensible study besides a closer look at each method mentioned before and also other multi criteria decision making weighting techniques we refer to [63,41,38,7,37,13].

Generally and succinctly speaking, over the past decades assigning reasonable weights to criteria in multi criteria decision making problems has been a commonly used procedure to elicit the numerical value of each criteria for better taking decisive actions particularly in the area of operation research management analysis. On the other hand, multi criteria decision software especially those are dedicated to weighting determination plays a vital and an inevitable role in solving many real and experimental world problems in many various scientific fields of interest such as the "engineering" [47,21,50,10,42], "computer science" [34,4,48], "management science" [45,39] and also the "healthcare science" [3,22,33]. As it is clear, the usual MCDM weighting techniques definitely those of which briefly discussed or referred before have been suggested or proposed to reflect the criteria weightings just by using simple or more sophisticated mathematical modeling to derive the numerical values from the initial data given by expert's. But, it is relatively hard to find some effective methods using the overall data to evaluate the criteria weights for those which are inter-rationally cause and effect criteria. Clearly expressing we mean the mutual influences of criteria in a complicated system which are ignored in many practical MCDM methods when using for criteria weighting assignment problems. Although, there would be some rare studies found that the classical DEMATEL (Decision making trial and evaluation laboratory) method as a structural modeling technique was used to determine the weights of criteria [8,64,31,30,60]. In this study we are intended to make use of all in hand information taken from the total influence matrix in DEMATEL methodology all along with the SWARA method's procedure to present an hybrid mathematical model for cause and effect criteria weightings. On the other hand, it has been proposed to modify the SWARA methodology when it is computing the s_{ji} (Comparative Importance correspondent to each criteria j to criteria i in descending ranking order). As it is mathematically apparent in classic SWARA methodology [29], the s_{ji} has been exploited to determine the comparative importance of each criteria in relative to the next criteria (as a local form) in a fully ranked criteria order (from the most important/significant criteria to the least important/significant criteria). Having the s_{ji} calculating form from the classic SWARA technique, it is intended to define a novel procedural way to obtain the comparative importance of each criteria in relative to all criteria coming next in a fully ranked criteria order. In this way the overall comparative importance of each criteria in relative to other criteria (as a global form) would be calculated. Briefly speaking, this article presents an hybrid model to calculate the weights of criteria which are casually and effectively dependent to each other in a system by making use of DEMATEL and SWARA methodology. Besides, it is worth mentioning that the classic SWARA methodology is to be reformed in procedure to better obtain the comparative importance of each criteria in relative to other criteria.

The remain part of this study consists of 5 sections. Section 2 is devoted to introduction of the structural modeling, DEMATEL methodology. In section 3, it is designated to introduce the SWARA method as a technique of criteria weighting. Problem statement and presenting our proposed mathematical models (accompanied with numerical case studies)

are then pursued respectively in sections 4 and 5. Ultimately conclusion part would also be expressed in section 6.

2. Structural modeling and DEMATEL methodology

Structural modeling is nearly a view of a system that emphasizes the structure of the objects, including their classifiers, relationships, attributes and operations. A structural model is inherently purposed to depict a graphical diagram which consists of a set of nodes and connections between the nodes. It should be noticed that in this diagram the nodes are usually considered as the main factors influencing the total operation of a system and besides the connections are shown by numbers or some directed vectors which logically derived from the mathematical model that deployed to simulate a real complicated problem. Generally speaking, structural diagrams are being used to understand some aspects of a system complexity particularly the interrelationships between its components. In this sense, the casual inter-dependency and inter-relationship among a group of factors are the two vital and mandatory features which have been proposed by structural modeling diagrams. Briefly, we are keen to realize and visualize the critical cause and effect relationships between the factors/criteria influencing the whole system performance to better manipulating of decisions and evaluating some major factors/criteria. Therefore a great deal of attention has been set by researchers to design useful techniques for presenting comprehensive approaches to scientifically investigate about the cause and effect pattern recognition using graphs and matrixes.

Decision making trial and evaluation laboratory (DEMATEL) introduced by Fontela & Gabus [16] as a kind of structural modeling has been widely used for analyzing the cause and effect relationships among elements of a system. DEMATEL method is a methodology to deal with complex systems. Its core process is to visualize structurally the graphical interrelation among some critical factors known as the most important factors affecting on the performance or the decision making issues. The DEMATEL methodology has been also extended to delineate graphically the real-world systems especially those associated with uncertainty and imprecise data involved in problems. Nowadays DEMATEL method is recognized as an effective structural technique due to its identification of cause and effect relationship among a group of known factors in a complex system. The DEMATEL technique can convert the interrelations between factors into an intelligible structural model of the system and divide them into a cause group and an effect group [20]. Additionally, over the past decades DEMATEL method and its related applications have been particularly applied in a lot of scientific areas to better making decision. Finding the key barriers to the implementation of green supply chain management by Wang et al [62], identifying critical risks in Sponge City PPP projects using DEMATEL method by Zhang et al [65], evaluating the key factors affecting customer satisfaction in an internet banking system by Asad et al [6], applying fuzzy DEMATEL to explore the decisive factors of the auto lighting aftermarket industry in Taiwan by Li et al [23] and identifying the key performance evaluation criteria for achieving customer satisfaction through balanced scorecard (BSC) by

Pan and Ngnyen [46] are typical applications of DEMATEL method. Besides some hybrid mathematical models including DEMATEL methodology have been applied for industry applications and decision making problems. Suggesting a novel approach to group multi-criteria decision making based on interval rough numbers using a hybrid model of DEMATEL-ANP-MAIRCA by Pamučar et al [44], application of AHP and DEMATEL methods in choosing and analyzing the measures for the distribution of goods in szczecin region by Kijewska et al [32], supplier selection using fuzzy DEMATEL and fuzzy AHP by Ergun and Kuruoglu [15], a combination of DEMATEL and BWM-Based ANP (Analytical Network Process) methods for exploring the green building rating system in Taiwan by Liu et al [49], structural modeling ISM (Interpretive Structural Modeling) and decision-making trail and evaluation laboratory (DEMATEL) method approach for the analysis of barriers of waste recycling in India by Chauhan et al [9], a hybrid method of Fuzzy DEMATEL/AHP/VIKOR(VIKOR stands for "Vlekriterijumsko KOmpromisno Rangiranje", a Serbian term for "multi-criteria optimization and compromise solution") approach to rank and select the best hospital nurses by Taati and Esmaili-Dooki [40], Integrated Fuzzy-DEMATEL and Fuzzy-Topsis (Topsis stands for Technique for Order of Preference by Similarity to Ideal Solution) Approach for Supplier Selection by Agrawal and Kant [2] are some typical applications of hybrid models comprising DEMATEL method. Sheng-Li et.al [56] reviewed the DEMATEL methodologies, its advantages in addition to its applications comprehensively and technically. Effectively analysis of the mutual influences (both direct and indirect effects) among different factors and understanding the complicated cause and effect relationships in the decision making problem, visualizing the interrelationships between factors via an IRM (Influential Relation Map) and enabling the decision maker to clearly understand which factors have mutual influences on one another and also finding out critical evaluation criteria and measuring the weights of evaluation criteria can be considered as its pragmatic advantages. Furthermore, their study showed vastly and pervasively the DEMATEL usability for different situations of decision making and various industrial applications. Computer science, engineering, business and managements and decision sciences are the four major categories which bolded in this study exploiting from DEMATEL methodologies. So, it would be not much far from the truth to say that DEMATEL has found its relevant utilization routes besides its basic mathematical approaches is still being improved.

2.1.DEMATEL methodology

As stated before, it would be clearly perceived that DEMATEL technique has been pervasively adopted in many areas of scientific interests. Accordingly, in this section, it is intended to review the classical DEMATEL method. Here are the following steps of DEMATEL listed below:

Step1:Building the primary relationship evaluation matrix M between the n -factors in a system.

(which identified and averaged by some experts. The integer scale of “no influence (0),” “low influence (1),” “medium influence (2),” “high influence (3),” and “very high influence (4)” is used to determine the group direct influence matrix $M=[m_{ij}]_{n \times n}$.)

Step2: Normalizing the direct influence matrix.

(The normalized direct influence matrix N can be achieved as follows:

$$N = M/k, \quad k = \max \left(\max_{1 \leq i \leq n} \sum_{j=1}^n m_{ij}, \max_{1 \leq j \leq n} \sum_{i=1}^n m_{ij} \right) \quad (1)$$

Where, $\max_{1 \leq i \leq n} \sum_{j=1}^n m_{ij}$ represents the total direct effect of criterion i applied on other criteria and $\max_{1 \leq j \leq n} \sum_{i=1}^n m_{ij}$ represents the total direct effect which the criterion j receives from other criteria.

Note that the normalized initial-direct relation matrix must have all the column sum of each column less than one as a sufficient condition for DEMATEL feasibility [19]).

Step3: Calculate the total influence matrix $T=[t_{ij}]_{n \times n}$ by the following equation.

(The total influence matrix T is computed by summation of consecutive powers of normalized matrix N .

$$\begin{aligned} T &= \lim_{k \rightarrow \infty} (N + N^2 + \dots + N^k) \\ &= N(I - N)^{-1} \end{aligned} \quad (2)$$

Where I is the identity matrix with the same dimension of matrix N .)

Step 4: Set a threshold value and draw the graphical influential relation map (GIRM) showing the final influential relationship between the criteria.

(In this step we have the following values:

R = sum of the rows of total influence matrix T .

C = sum of the columns of total influence matrix T .

Thus the cause and effect groups can be separated from each other by the element of $(R_i - C_i)$. The criterion i would be the effect factor if $(R_i - C_i)$ is negative and vice-versa it would be the cause factor if $(R_i - C_i)$ is positive. (For $i \in \{1, 2, \dots, n\}$)

For filtering out the negligible effects in matrix T , a threshold value is determined to revise the matrix T .

Completing these steps is resulted in depicting a valuable map as a structural explanation of prominent factors that can be used helpfully for decision making.

3.SWARA (Step-wise Weight Assessment Ratio Analysis) method

Step-wise Weight Assessment Ratio Analysis (SWARA) methodology was first structured by Kersulienė et al. [29] for criteria weighting. Significance ratio of the criteria in a system is considered as the core feature of SWARA methodology so as all the criteria are fully ranked from the most significant criteria to the least significant criteria [5,28]. Operationally SWARA technique is usually known for its non-complicated procedure and timely cost effective aspect [59]. Lower number of pairwise comparisons comparing to the AHP method is the other main feature of SWARA technique which makes it much easier to apply for real criteria weighting problem [68]. The SWARA methodology has been widely used in many various fields of study and many real world pragmatic applications including decision making issues in management area and the selection in engineering problems. Some studies which applied SWARA technique can be referred as strategy evaluation [69], Integrated evaluation of external wall insulation in residential buildings [53], personnel selection in organizations [24,25,26], ERP system selection using SWARA accompanied with PROMETEE (Preference Ranking Organization Method for Enrichment Evaluation) methodology [58], machine tool selection [1], the selection of the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants [67] and a hybrid model consisting of SWARA and WASPAS (Weighted Aggregated Sum Product Assessment) approaches for selection of best site regarding wind energy [18]. No need to check the consistency of judgments expressed by a group of decision makers, being very close to human thinking and no need of any comparative scale [18] would be the vital advantages of SWARA technique while comparing to the AHP method.

The main steps of SWARA methodology to weighting assignment for n criteria are simply ordered [60] as follows:

Step1. The criteria are sorted in the descending order, based on their expected significances.

Step2. Starting from the second criterion, the respondent expresses the relative importance of the criterion j in relation to the previous $(j-1)$ criterion, and does so for each particular criterion. According to Kersulienė et al. (2010), this ratio is called the Comparative Importance of the Average Value, s_j .

Step3. Determine the coefficient k_j as follows:

$$k_j = \begin{cases} 1, & j = 1 \\ s_j + 1, & j > 1 \end{cases} \quad (3)$$

Step4. Determine the recalculated weight q_j as follows (58):

$$q_j = \begin{cases} 1, & j = 1 \\ \frac{q_{j-1}}{k_j}, & j > 1 \end{cases} \quad (4)$$

Step5. The relative weights of the evaluation criteria are determined as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^n q_k} \quad (5)$$

4. Problem statement and motivation of the work

For criteria weighting of MCDM problems there have been frequently investigated and modeled too many techniques and mathematical procedures to estimate the individual weight of each criteria. Normally in all MCDM scientific subjects and real world topics, criteria weighting are usually being done without taking into account the casual and effective relationship between the whole system of criteria. Although as it was mentioned before in introduction section, there are rare studies [8,64,31,30,60] which contribute the data derived from DEMATEL method to evaluate the cause and effect criteria weights. For example ceci [8] used solely the sum (R+C) named "Prominence" illustrates the strength of influences that are given and received of the factor [56] to calculate the degrees of importance for website design parameters. In this study two other main important data like the "relation" parameter of (R-C) as the net effect of one factor which contributes to other factors of system and the (R) which shows the direct and indirect influence of one factor dispatching to others are missing. In another study [64] the term of prominence (R+C) has been directly applied for obtaining global weighting of criteria by Yazdani et al. To be more exact in this study, it has been considered that likewise the before reviewed investigation there are two other important data derived from DEMATEL methodology namely (R) and (R-C) missing to integrate for final global criteria weighting. Khazai et al.[31] have also applied the individual values of the final influence matrix T derived in the ultimate step of DEMATEL method. They calculated the overall weight of each criteria multiplying the importance weight and dependence weight related to each criteria. In their proposed methodology the importance weight of each criteria is given separately by experts and the dependency weighs as the correction factors are derived from DEMATEL final matrix. Thus the data represented directly by (R-C) and (R) are missing for having an integrated method of criteria weighting. Furthermore in this study it is needed to have expert's opinions for obtaining the importance weight of each criteria separately. Khalili-Damghani [38] made use of (R+C) directly to get the weights of criteria to solve a Land-use

Suitability Analysis and Planning Problem. Of course they applied an hybrid use of AHP-DEMATEL methodology to gain the weights of criteria. As it is clear in this study there are also the (R-C) and (R) data derived from total matrix T neglected to gain an integrated weight of each criteria. In another research [39] normalized form of each column in matrix T which derived from DEMATEL has been deployed for obtaining a weighted normalized fuzzy decision matrix in the project of evaluating service quality expectation in hot spring hotel's ranking problem in Taiwan. This study combined DEMATEL methodology and TOPSIS framework to rank the seven hot spring hotels. Similar to other studies, this one is also missed the two important data derived from total influence matrix T extracted from DEMATEL namely (R) and (R-C) to have an integrated criteria weighting. Hence, in this research it is proposed to address these gaps. Thus an integrated multi criteria decision making methodology consisting of DEMATEL and SWARA technique has been suggested for obtaining weights of criteria in a cause and effect problems. Specially in this presented investigation it is intended to deploy the data of (R), (R-C) and (R/C) derived from the final total influence matrix T in DEMATEL combined with SWARA as a fundamental procedure achieving an ultimate mean weight of each criteria understudied in a complex system. More importantly, in this study we are keen to present an hybrid criteria weighting model which can afford to give us bigger weight's values for those criteria who are grouped as cause group in a system. Emphatically, this issue comes from the clear and easily perceived assumption that criteria who belong to cause class earn bigger than those who belong to effect class in a complex system.

4.1. Whymaking use of (R), (R-C) and (R/C)

Given the final calculated total influence matrix T by DEMATEL method, we can get access to information and decisive data which can take into account for other analysis of all criteria including classification and yielding prominence (R+C), net effect of each criteria (R-C) and direct and indirect influence of one factor dispatching to others (R). Inherently, parameters of (R-C) and (R) would bring us the cleaned and excluded value and overall net data of each criteria respectively. In the opposite (R+C), which comprise the information of the strength of influences that are given and received of the factor [54] fails to extract the refined and non-gross data relevant to each criteria. Emphatically in this research we are interested to apply data from DEMATEL final matrix which hints the pureness as much as possible. In particular terms of (R-C) and (R) are in this research considered data that showing net flow of numeric information from each criteria toward the others. Additionally, parameter of (R/C) representing another net information related to each criteria is intended to use in our proposed framework of methodology. It is because that this parameter would help us to calculate the "net influence power" of each criteria. Actually (R/C) inspires us that how much the direct and indirect effects that each factor is receiving from the other factors could be compensated by the direct and indirect influence which dispatches from one criteria to others.

4.2. Why making use of SWARA method

As stated in previous section, it is intentionally aimed to exploit parameters of (R) , $(R-C)$ and (R/C) in our proposed hybrid mathematical model by DEMATEL and SWARA techniques. Deploying SWARA is for its essence of relative comparisons due to the selection of the most significant criteria determined by experts and then ranking other criteria in descending order to the least significant criteria. Hence SWARA procedure would inspire us to rank the criteria due to the hidden data information derived from total influence matrix T (yielded in last step of DEMATEL method) presented by parameters of (R) , $(R-C)$ and (R/C) . Emphatically the data arisen by these parameters gives us the objective and non-direct information which will be used in our proposed model. So in our suggested hybrid mathematical, DEMATEL methodology would be first started by direct (subjective) data given by experts and SWARA technique would be then applied to deploy the non-direct (objective) data to evaluate the weightings of criteria which grouped in two cause and effect classification. Lastly, making use of SWARA methodology for criteria weighting here in this research would be hinted out that there is no need to compute the consistency ratio in relative to BWM or AHP when criteria weights obtained. Thus this would be a helpful and time consuming aspect of the proposed model.

5. The framework of the proposed hybrid and integrated mathematical model

In this step we are ready to propose our hybrid and integrated model for determining the criteria weights in a system that there are some criteria belonging to cause group and those remained which are belonging to effect group. It is again worth of mentioning that DEMATEL and SWARA methodologies play the central role in our suggested mathematical model. First of all, parameters of (R) , $(R-C)$ and (R/C) are to be calculated from the final total influence matrix T in DEMATEL technique. Second, SWARA technique is to be considered in three independent scenarios applying the data using (R) , $(R-C)$ and (R/C) to obtain weights of each criteria. Steps of the proposed algorithm model are as follows:

Step 1: Execute the DEMATEL methodology (for a predetermined set of criteria and an average initial intelligible relation matrix given by some experts).

Step 2: Calculate the parameters of (R) , (R/C) and $(\exp(R-C))$.

(R equals to direct and indirect influence of one factor dispatching to others, equivalent to summation of the elements in each row of total matrix T . C is the sum of direct and indirect effects that a criteria is receiving from the other criteria, equivalent to summation of the elements of each column of total matrix T .)

Step 3: Execute the SWARA technique in three scenarios regarding the (R), (R/C) and (exp(R-C)) parameters to obtain the corresponding weight for each criteria.

Step 4: Calculate an average value (preferably geometric mean) of weights for each criteria.

Now we are ready to use our proposed hybrid model to solve some numerical cases. Moreover, alongside going through the proposed method step by step, here it is aimed to closely manipulate our model to be effective capable of yielding weights accordingly to cause and effect classification in a system.

5.1.Numerical study for more illumination and clarity

5.1.Case 1: Assume that an average initial intelligible relation matrix given by some experts as below:

$$A = \begin{matrix} & \begin{matrix} C1 & C2 & C3 & C4 \end{matrix} \\ \begin{matrix} C1 \\ C2 \\ C3 \\ C4 \end{matrix} & \begin{bmatrix} 0 & 2 & 1.67 & 2.33 \\ 1.67 & 0 & 2.67 & 2.67 \\ 0.67 & 2.33 & 0 & 1 \\ 2.67 & 2.67 & 2.67 & 0 \end{bmatrix} \end{matrix}$$

Then the normalized initial direct-relation matrix , by finding the maximum of the row sums and column sums (8.01) would be calculated as follows:

$$N = \begin{bmatrix} 0 & 0.25 & 0.208 & 0.291 \\ 0.208 & 0 & 0.333 & 0.333 \\ 0.084 & 0.291 & 0 & 0.125 \\ 0.333 & 0.333 & 0.333 & 0 \end{bmatrix}$$

Finally, the total matrix T is computed according to DEMATEL procedure (step 3).

$$T = \begin{bmatrix} 0.585 & 0.976 & 0.956 & 0.906 \\ 0.813 & 0.861 & 1.121 & 0.997 \\ 0.489 & 0.774 & 0.558 & 0.595 \\ 0.962 & 1.203 & 1.21 & 0.832 \end{bmatrix}$$

Now we can obtain parameters of (R), (R/C) and exp(R-C) as follows in table (1):

Table 1. Calculated values of (R), (R/C) and exp(R-C).

Criteria	R	C	R/C	R-C	Exp(R-C)
C ₁	3.423	2.849	1.201	0.574	1.775
C ₂	3.792	3.814	0.994	-0.022	0.978
C ₃	2.416	3.845	0.628	-1.429	0.239
C ₄	4.207	3.330	1.263	0.877	2.403

In the next step, SWARA technique will be run in three scenarios considering to (R), (R/C) and (exp(R-C)) parameters.

5.1. Case 1. Scenario 1. Regarding parameter (R):

For running SWARA technique in this scenario we consider the following table (2) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (R). It should be mentioned that for obtaining criteria ranking here we take the criteria C₄ as the most significant criteria (having maximum direct and indirect influence relatively to other criteria) and also criteria C₃ as the least criteria (having minimum direct and indirect influence relatively to other criteria).

Table 2. Criteria ranking based on the most important criteria.

Criteria ranks	R
The most significant criteria: C ₄	R ₄ =4.207
C ₂	R ₂ =3.792
C ₁	R ₁ =3.423
The least significant criteria=C ₃	R ₃ =2.416

Consequently using the data from table (2) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (3). It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the ratio of $(\frac{R_{upper ranked}}{R_{lower ranked}})$ for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 3. SWARA procedure and final criteria weights.

C_j	s_j	k_j	q_j	w_j
The most significant criteria: C_4	0	1	1	0.558
C_2	1.109	2.109	0.474	0.265
C_1	1.108	2.108	0.225	0.126
The least significant criteria: C_3	1.417	2.417	0.093	0.052
			$\sum q_j = 1.792$	

5.1. Case 1. Scenario 1. More explanation and discussion:

As it can be understood from the column (R-C) in table (1), criteria C_4 and C_1 would be grouped into cause group by DEMATEL methodology. But given careful looking to criteria weights by SWARA methodology, we see the criteria C_4 and C_2 have gained the maximum values in weights (0.558 ,0.265) respectively. Thus until now, it seems that our proposed model cannot afford to assign reasonable and classified weights to cause and effect group separately just using information derived from (R) parameter in final total influence matrix T.

5.1. Case 1. Scenario 2. Regarding parameter (R/C):

For running SWARA technique in scenario 2, we consider the following table (4) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (R/C). It should be mentioned that for obtaining criteria ranking here we take the criteria C_4 as the most important criteria (having maximum net influence power relatively to other criteria) and also criteria C_3 as the least important criteria (having minimum net influence power relatively to other criteria).

Table 4. Criteria ranking based on the most important criteria.

Criteria ranks	R/C
The most significant criteria: C_4	$(R/C)_4 = 1.263$
C_1	$(R/C)_1 = 1.201$
C_2	$(R/C)_2 = 0.994$
The least significant criteria: C_3	$(R/C)_3 = 0.628$

Consequently using the data from table (4) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (5) . It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the

ratio of $\frac{(R/C)_{upper ranked}}{(R/C)_{lower ranked}}$ for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 5. SWARA procedure and final criteria weights.

C_j	s_j	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.557
C_1	1.052	2.052	0.487	0.271
C_2	1.208	2.208	0.221	0.123
The least significant criteria= C_3	1.583	2.583	0.086	0.048
			$\sum q_j=1.794$	

5.1.Case 1.Scenario 2. More explanation and discussion:

As it can be again understood from the column (R-C) in table (1), criteria C_4 and C_1 would be grouped into cause group by DEMATEL methodology. But given careful looking to criteria weights by SWARA methodology, we can observe the criteria C_4 and C_1 have also accordingly gained the maximum values in weights (0.557 ,0.271) respectively. Thus, it seems that our proposed model will have the ability to assign reasonable and classified weights to cause and effect group separately just using information derived from (R/C) parameter in final total influence matrix T.

5.1.Case 1.Scenario 3.Regarding parameter (exp(R-C)):

For running SWARA technique in scenario3, we consider the following table (6) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (exp(R-C)). It should be mentioned that for obtaining criteria ranking here we take the criteria C_4 as the most important criteria (having maximum net effect relatively to other criteria) and also criteria C_3 as the least important criteria (having minimum net effect relatively to other criteria).

Table 6. Criteria ranking based on the most important criteria.

Criteria ranks	exp(R-C)
The most significant criteria: C_4	$\exp(R-C)_4=2.403$
C_1	$\exp(R-C)_1=1.775$
C_2	$\exp(R-C)_2=0.978$
The least significant criteria= C_3	$\exp(R-C)_3=0.239$

Consequently using the data from table (6) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (7) . It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the ratio of $(\exp(R - C))_{upper ranked} / (\exp(R - C))_{lower ranked}$ for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 7. SWARA procedure and final criteria weights.

C_j	s_j	k_j	q_j	w_j
The most significant criteria: C_4	0	1	1	0.623
C_1	1.354	2.354	0.425	0.265
C_2	1.815	2.815	0.151	0.094
The least significant criteria= C_3	4.092	5.092	0.029	0.018
			$\sum q_j=1.605$	

5.1.Case 1.Scenario3.More explanation and discussion:

As it can be again understood from the column (R-C) in table (1), criteria C_4 and C_1 would be grouped into cause group by DEMATEL methodology. Furthermore, given careful looking to criteria weights by SWARA methodology, we can observe the criteria C_4 and C_1 have also accordingly gained the maximum values in weights (0.623 ,0.265) respectively. Thus, it seems that our proposed model will have the ability to assign reasonable and classified weights to cause and effect group separately just using information derived from (R-C) parameter in final total influence matrix T.

5.1.Case 2: Assume that we have another average initial intelligible relation matrix given by some experts as below:

$$A = \begin{matrix} & \begin{matrix} c_1 & c_2 & c_3 & c_4 & c_5 & c_6 \end{matrix} \\ \begin{matrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \\ c_6 \end{matrix} & \begin{bmatrix} 0 & 1.66 & 3.66 & 0.66 & 2.33 & 1.33 \\ 2.33 & 0 & 3.25 & 1.25 & 2 & 1.5 \\ 1.66 & 2.5 & 0 & 1.25 & 2.5 & 1.5 \\ 1.66 & 2.75 & 1.5 & 0 & 2 & 2 \\ 1.33 & 3 & 3.25 & 0.25 & 0 & 0.5 \\ 3 & 2.75 & 3 & 3.25 & 2.75 & 0 \end{bmatrix} \end{matrix}$$

Then the normalized initial direct-relation matrix N , by finding the maximum of the row sums and column sums (14.75) would be calculated as follows:

$$N = \begin{bmatrix} 0 & 0.112 & 0.248 & 0.045 & 0.158 & 0.09 \\ 0.158 & 0 & 0.22 & 0.085 & 0.135 & 0.102 \\ 0.112 & 0.169 & 0 & 0.085 & 0.169 & 0.102 \\ 0.112 & 0.186 & 0.102 & 0 & 0.135 & 0.135 \\ 0.09 & 0.203 & 0.22 & 0.017 & 0 & 0.034 \\ 0.203 & 0.186 & 0.203 & 0.22 & 0.186 & 0 \end{bmatrix}$$

Eventually, the total matrix T is computed according to DEMATEL procedure.

$$T = \begin{bmatrix} 0.237 & 0.402 & 0.558 & 0.199 & 0.417 & 0.25 \\ 0.392 & 0.321 & 0.561 & 0.245 & 0.419 & 0.275 \\ 0.337 & 0.443 & 0.349 & 0.232 & 0.421 & 0.259 \\ 0.356 & 0.475 & 0.463 & 0.169 & 0.412 & 0.229 \\ 0.289 & 0.430 & 0.492 & 0.153 & 0.242 & 0.183 \\ 0.525 & 0.602 & 0.685 & 0.419 & 0.569 & 0.254 \end{bmatrix}$$

Now we can obtain parameters of (R), (R/C) and (exp(R-C)) as follows in table (8):

Table 8.Calculated values of (R), (R/C) and exp(R-C).

Criteria	R	C	R/C	R-C	Exp(R-C)
C ₁	2.063	2.136	0.966	-0.073	0.929
C ₂	2.213	2.673	0.828	-0.46	0.631
C ₃	2.041	3.108	0.657	-1.067	0.344
C ₄	2.104	1.417	1.485	0.687	1.988
C ₅	1.789	2.480	0.721	-0.691	0.501
C ₆	3.054	1.450	2.106	1.604	4.972

In this step, SWARA technique will be run in three scenarios considering to (R), (R/C) and (exp(R-C)) parameters.

5.1.Case 2.Scenario 1.Regarding parameter (R):

For running SWARA technique in this scenario we consider the following tables (9) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (R). It should be mentioned that for obtaining criteria ranking here we take the criteria C₆ as the most important criteria (having maximum direct and indirect influence relatively to other criteria) and also criteria C₅ as the least important criteria (having minimum direct and indirect influence relatively to other criteria).

Table 9. Criteria ranking based on the most important criteria.

Criteria ranks	R
The most significant criteria:C ₆	R ₆ =3.054
C ₂	R ₂ =2.213
C ₄	R ₄ =2.104
C ₁	R ₁ =2.063
C ₃	R ₃ =2.041
The least significant criteria=C ₅	R ₅ =1.789

Consequently using the data from table (9) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (10) . It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the ratio of $(\frac{R_{upper ranked}}{R_{lower ranked}})$ for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 10. SWARA procedure and final criteria weights.

C _j	s _j	k _j	q _j	w _j
The most significant criteria:C ₆	0	1	1	0.555
C ₂	1.380	2.38	0.420	0.233
C ₄	1.052	2.052	0.205	0.114
C ₁	1.019	2.019	0.102	0.057
C ₃	1.011	2.011	0.051	0.028
The least significant criteria=C ₅	1.141	2.141	0.024	0.013
			$\sum q_j=1.802$	

5.1.Case 2.Scenario1.More explanation and discussion:

As it can be understood from the column (R-C) in table (8), criteria C₆ and C₄ would be grouped into cause group by DEMATEL methodology. But given careful looking to criteria weights by SWARA methodology, we see the criteria C₆ and C₂ have gained the maximum values in weights (0.555 ,0.233) respectively. Thus until now, it seems that our proposed model cannot afford to assign reasonable and classified weights to cause and effect group separately just using information derived from (R) parameter in final total influence matrix T.

5.1.Case 2.Scenario 2.Regarding parameter (R/C):

For running SWARA technique in scenario 2, we consider the following table (11) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (R/C). It should be mentioned that for obtaining criteria ranking here we take the criteria C₆ as the most important criteria (having maximum net influence power relatively to other criteria) and also criteria C₃ as the least important criteria (having minimum net influence power relatively to other criteria).

Table 11. Criteria ranking based on the most important criteria.

Criteria ranks	R/C
The most significant criteria:C ₆	(R/C) ₆ =2.106
C ₄	(R/C) ₄ =1.485
C ₁	(R/C) ₁ =0.966
C ₂	(R/C) ₂ =0.828
C ₅	(R/C) ₅ =0.721
The least significant criteria=C ₃	(R/C) ₃ =0.657

Consequently using the data from table (11) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (12) . It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the ratio of $(\frac{R}{C})_{upper ranked} / (\frac{R}{C})_{lower ranked}$) for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 12. SWARA procedure and final criteria weights.

C _j	s _j	k _j	q _j	w _j
The most significant criteria:C ₆	0	1	1	0.587
C ₄	1.418	2.418	0.414	0.243
C ₁	1.537	2.537	0.163	0.096
C ₂	1.167	2.167	0.075	0.044
C ₅	1.148	2.148	0.035	0.021
The least significant criteria=C ₃	1.097	2.097	0.017	0.010
			∑ q _j =1.704	

5.1.Case 2.Scenario2.More explanation and discussion:

As it can be again understood from the column (R-C) in table (8), criteria C_6 and C_4 would be grouped into cause group by DEMATEL methodology. Additionally, given careful looking to criteria weights by SWARA methodology, we can observe the criteria C_6 and C_4 have also accordingly gained the maximum values in weights (0.587 ,0.243) respectively. Thus, it seems that our proposed model will have the ability to assign reasonable and classified weights to cause and effect group separately using information derived from (R/C) parameter in final total influence matrix T.

5.1.Case 2.Scenario 3.Regarding parameter (exp(R-C)):

For running SWARA technique in scenario 3, we consider the following tables (13) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (exp(R-C)). It should be mentioned that for obtaining criteria ranking here we take the criteria C_6 as the most important criteria (having maximum net effect relatively to other criteria) and also criteria C_3 as the least important criteria (having minimum net effect relatively to other criteria).

Table 13. Criteria ranking based on the most important criteria.

Criteria ranks	exp(R-C)
The most significant criteria: C_6	$\exp(R-C)_6=4.972$
C_4	$\exp(R-C)_4=1.988$
C_1	$\exp(R-C)_1=0.929$
C_2	$\exp(R-C)_2=0.631$
C_5	$\exp(R-C)_5=0.501$
The least significant criteria= C_3	$\exp(R-C)_3=0.344$

Consequently using the data from table (13) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (14) . It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the ratio of $\frac{(\exp(R - C))_{upper ranked}}{(\exp(R - C))_{lower ranked}}$ for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 14. SWARA procedure and final criteria weights.

C_j	s_j	k_j	q_j	w_j
The most significant criteria: C_6	0	1	1	0.696
C_4	2.501	3.501	0.286	0.199
C_1	2.139	3.139	0.091	0.063
C_2	1.472	2.472	0.037	0.026
C_5	1.259	2.259	0.016	0.011
The least significant criteria= C_3	1.456	2.456	0.007	0.005
			$\sum q_j=1.437$	

5.1.Case 2.Scenario3.More explanation and discussion:

As it can be again understood from the column (R-C) in table (8), criteria C_6 and C_4 would be grouped into cause group by DEMATEL methodology. Furthermore, given careful looking to criteria weights by SWARA methodology, we can observe the criteria C_6 and C_4 have also accordingly gained the maximum values in weights (0.696 ,0.199) respectively. Thus, it seems that our proposed model will have the ability to assign reasonable and classified weights to cause and effect group separately just using information derived from (R-C) parameter in final total influence matrix T.

5.1.Case 3: In this point, it is aimed to use our proposed hybrid model for a real world initial average matrix A. This matrix has been used to evaluate the importance of the seven criteria determining the key success factors of hospital service quality in Taiwan [55,57].

$$A = \begin{bmatrix} 0 & 1.5789 & 2.0526 & 1.7895 & 2.2632 & 2 & 1.3158 \\ 1.5263 & 0 & 2.0526 & 2.3684 & 2.3684 & 2.0526 & 1.6316 \\ 1.9474 & 1.9474 & 0 & 2.0526 & 2.4211 & 2.5263 & 1.9474 \\ 1.3684 & 2.2632 & 2.1053 & 0 & 2.2105 & 2.2632 & 1.5789 \\ 1.8421 & 2 & 2.2105 & 1.7895 & 0 & 2.2105 & 1.4737 \\ 2.0526 & 1.8421 & 2.1579 & 1.8421 & 2.2105 & 0 & 1.6842 \\ 1.0526 & 1.7368 & 1.8421 & 1.6316 & 1.5236 & 1.7368 & 0 \end{bmatrix}$$

Then the normalized initial direct-relation matrix N is:

$$N = \begin{bmatrix} 0 & 0.1215 & 0.1579 & 0.1377 & 0.1741 & 0.1538 & 0.1012 \\ 0.1174 & 0 & 0.1579 & 0.1822 & 0.1822 & 0.1579 & 0.1255 \\ 0.1498 & 0.1498 & 0 & 0.1579 & 0.1862 & 0.1579 & 0.1498 \\ 0.1053 & 0.1741 & 0.1619 & 0 & 0.1700 & 0.1741 & 0.1215 \\ 0.1417 & 0.1538 & 0.1700 & 0.1377 & 0 & 0.1700 & 0.1134 \\ 0.1579 & 0.1417 & 0.1659 & 0.1417 & 0.1700 & 0 & 0.1296 \\ 0.0809 & 0.1336 & 0.1417 & 0.1255 & 0.1174 & 0.1336 & 0 \end{bmatrix}$$

And the total matrix T is obtained as:

$$T = \begin{bmatrix} 0.8298 & 1.0460 & 1.1475 & 1.0636 & 1.2031 & 1.1380 & 0.9013 \\ 0.9985 & 1.0119 & 1.2266 & 1.1717 & 1.2910 & 1.2199 & 0.9840 \\ 1.0425 & 1.1631 & 1.1137 & 1.1749 & 1.3181 & 1.2429 & 1.0213 \\ 0.9775 & 1.1462 & 1.2144 & 1.0035 & 1.2665 & 1.2168 & 0.9693 \\ 0.9882 & 1.1099 & 1.1988 & 1.1039 & 1.0989 & 1.1919 & 0.9453 \\ 1.0141 & 1.1165 & 1.2128 & 1.1224 & 1.2615 & 1.0634 & 0.9711 \\ 0.8035 & 0.9416 & 1.0115 & 0.9402 & 1.0306 & 0.9996 & 0.7115 \end{bmatrix}$$

Now we can obtain parameters of (R), (R/C) and (exp(R-C)) as follows in table (15):

Table 15. Calculated values of (R), (R/C) and exp(R-C).

Criteria	R	C	R/C	R-C	Exp(R-C)
C ₁	7.329	6.655	1.101	0.674	1.962
C ₂	7.904	7.535	1.049	0.369	1.446
C ₃	8.077	8.130	0.993	-0.053	0.948
C ₄	7.795	7.581	1.028	0.214	1.239
C ₅	7.636	8.471	0.901	-0.835	0.434
C ₆	7.762	8.071	0.962	-0.309	0.734
C ₇	6.443	6.503	0.991	-0.060	0.942

In this step, SWARA technique will be run in three scenarios considering to (R), (R/C) and (exp(R-C)) parameters.

5.1. Case 3. Scenario 1. Regarding parameter (R):

For running SWARA technique in this scenario we consider the following tables (16) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (R). It should be mentioned that for obtaining criteria ranking here we take the criteria C₃ as the most important criteria (having maximum direct and indirect influence relatively to other criteria) and also criteria C₇ as the least important criteria (having minimum direct and indirect influence relatively to other criteria).

Table 16. Criteria ranking based on the most important criteria.

Criteria ranks	R
The most significant criteria:C ₃	R ₃ =8.077
C ₂	R ₂ =7.204
C ₄	R ₄ =7.795
C ₆	R ₆ =7.762
C ₅	R ₅ =7.636
C ₁	R ₁ =7.329
The least significant criteria=C ₇	R ₇ =6.443

Consequently using the data from table (16) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (17) . It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the ratio of $(\frac{R_{upper ranked}}{R_{lower ranked}})$ for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 17. SWARA procedure and final criteria weights.

C _j	s _j	k _j	q _j	w _j
The most significant criteria:C ₃	0	1	1	0.508
C ₂	1.022	2.022	0.495	0.252
C ₄	1.014	2.014	0.246	0.125
C ₆	1.004	2.004	0.123	0.063
C ₅	1.017	2.017	0.061	0.031
C ₁	1.042	2.042	0.029	0.015
The least significant criteria=C ₇	1.138	2.138	0.014	0.007
			$\sum q_j=1.968$	

5.1.Case 3.Scenario 1 .More explanation and discussion:

As it can be understood from the column (R-C) in table (15), criteria C₄,C₁ and C₂ would be grouped into cause group by DEMATEL methodology. But given careful looking to criteria weights by SWARA methodology, we see the criteria C₃,C₂ and C₄ accompanied with C₆ have gained the maximum values in weights (0.538 ,0.252,0.125) respectively. Thus until now, it seems that our proposed model cannot afford to assign reasonable and classified weights to cause and effect group separately just using information derived from (R) parameter in final total influence matrix T.

5.1.Case 3. Scenario2.Regarding parameter (R/C):

For running SWARA technique in scenario 2, we consider the following tables (18) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (R/C). It should be mentioned that for obtaining criteria ranking here we take the criteria C_1 as the most important criteria (having maximum net influence power relatively to other criteria) and also criteria C_5 as the least important criteria (having minimum net influence power relatively to other criteria).

Table 18. Criteria ranking based on the most important criteria.

Criteria ranks	R/C
The most significant criteria: C_1	$(R/C)_1 = 1.101$
C_2	$(R/C)_2 = 1.049$
C_4	$(R/C)_4 = 1.028$
C_3	$(R/C)_3 = 0.993$
C_7	$(R/C)_7 = 0.991$
C_6	$(R/C)_6 = 0.962$
The least significant criteria= C_5	$(R/C)_5 = 0.901$

Consequently using the data from table (18) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (19) . It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the ratio of $\left(\frac{(R/C)_{upper ranked}}{(R/C)_{lower ranked}} \right)$ for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 19. SWARA procedure and final criteria weights.

C_j	s_j	k_j	q_j	w_j
The most significant criteria: C_1	0	1	1	0.513
C_2	1.049	2.049	0.488	0.250
C_4	1.020	2.020	0.242	0.124
C_3	1.035	2.035	0.119	0.061
C_7	1.002	2.002	0.059	0.030
C_6	1.030	2.030	0.029	0.015
The least significant criteria= C_5	1.068	2.068	0.014	0.007
			$\sum q_j = 1.951$	

5.1.Case 3.Scenario2.More explanation and discussion:

As it can be again understood from the column (R-C) in table (15), criteria C₄,C₁ and C₂ would be grouped into cause group by DEMATEL methodology. Additionally, given careful looking to criteria weights by SWARA methodology, we can observe the criteria C₁,C₂ and C₄ have also accordingly gained the maximum values in weights (0.513,0.250,0.124) respectively. Thus, it seems that our proposed model will have the ability to assign reasonable and classified weights to cause and effect group separately using information derived from (R/C) parameter in final total influence matrix T.

5.1.Case 3.Scenario 3.Regarding parameter (exp(R-C)):

For running SWARA technique in scenario 3, we consider the following tables (20) to make the ranking of all criteria according to the most significant criteria selection based on the values of parameter (exp(R-C)). It should be mentioned that for obtaining criteria ranking here we take the criteria C₁ as the most important criteria (having maximum net effect relatively to other criteria) and also criteria C₅ as the least important criteria (having minimum net effect relatively to other criteria).

Table 20. Criteria ranking based on the most important criteria.

Criteria ranks	exp(R-C)
The most significant criteria:C ₁	(exp(R-C)) ₁ =1.962
C ₂	(exp(R-C)) ₂ =1.442
C ₄	(exp(R-C)) ₄ =1.239
C ₃	(exp(R-C)) ₃ =0.948
C ₇	(exp(R-C)) ₇ =0.942
C ₆	(exp(R-C)) ₆ =0.734
The least significant criteria=C ₅	(exp(R-C)) ₅ =0.434

Consequently using the data from table (20) and SWARA procedure we'll have the final weights of criteria evaluated and gathered in the following table (21) . It should be stated that for obtaining the Comparative Importance s_j correspondent to each criteria, we applied the ratio of $\frac{(\exp(R - C))_{upper ranked}}{(\exp(R - C))_{lower ranked}}$ for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Table 21. SWARA procedure and final criteria weights.

C_j	s_j	k_j	q_j	w_j
The most significant criteria: C_1	0	1	1	0.564
C_2	1.361	2.361	0.424	0.239
C_4	1.164	2.164	0.196	0.111
C_3	1.307	2.307	0.085	0.048
C_7	1.006	2.006	0.042	0.024
C_6	1.283	2.283	0.018	0.010
The least significant criteria= C_5	1.691	2.691	0.007	0.004
			$\sum q_j=1.772$	

5.1.Case 3. Scenario3. More explanation and discussion:

As it can be again understood from the column (R-C) in table (15), criteria C_1, C_2 and C_4 would be grouped into cause group by DEMATEL methodology. Furthermore, given careful looking to criteria weights by SWARA methodology, we can observe the criteria C_1, C_2 and C_4 have also accordingly gained the maximum values in weights (0.564, 0.239, 0.111) respectively. Thus, it seems that our proposed model will have the ability to assign reasonable and classified weights to cause and effect group separately just using information derived from (R-C) parameter in final total influence matrix T.

5.2.Results and discussion

Now here in this point, we are intended to take a brief close look at case studies previously solved using the proposed mathematical model to accomplish our comprehensive investigation. By the model, it was firstly expected to obtain weights correspondent to each criteria while the cause and effect classification are still preserved. But, as indicated in case studies, criteria weight's values for which data taken from (R) information derived from total influence matrix T are not fully agree with cause and effect classification in a system. On the other hand, when applying (R) data for criteria weighting assignment, there may be bigger weight values gained for some criteria who don't belong to cause group. For having a better view and understanding, all the points are gathered in table(22).

Table 22.Criteria weights based on the cause and effect categorization.

			Criteria weighting using Derived data from total matrix T			Does the Cause group all have bigger weights?		
			R	R/C	R-C	R	R/C	R-C
Case 1	C ₁	Cause	W ₄ =0.558	W ₄ =0.557	W ₄ =0.623	no	yes	yes
	C ₂	group:C ₁ ,C ₄	W ₁ =0.126	W ₁ =0.271	W ₁ =0.265			
	C ₃	Effect	W ₂ =0.265	W ₂ =0.123	W ₂ =0.094			
	C ₄	group:C ₂ ,C ₃	W ₃ =0.052	W ₃ =0.048	W ₃ =0.018			
Case 2	C ₁	Cause	W ₆ =0.555	W ₆ =0.587	W ₆ =0.696	no	yes	yes
	C ₂	group:C ₆ ,C ₄	W ₄ =0.114	W ₄ =0.243	W ₄ =0.199			
	C ₃	Effect	W ₁ =0.057	W ₁ =0.096	W ₁ =0.063			
	C ₄	group:C ₁ ,C ₂ ,C ₃ ,C ₅	W ₂ =0.233	W ₂ =0.044	W ₂ =0.026			
	C ₅		W ₃ =0.028	W ₃ =0.010	W ₃ =0.005			
	C ₆		W ₅ =0.013	W ₅ =0.021	W ₅ =0.011			
Case 3	C ₁	Cause	W ₁ =0.015	W ₁ =0.513	W ₁ =0.564	no	yes	yes
	C ₂	group:C ₁ ,C ₂ ,C ₄	W ₂ =0.252	W ₂ =0.250	W ₂ =0.239			
	C ₃		W ₄ =0.125	W ₄ =0.124	W ₄ =0.111			
	C ₄	Effect	W ₃ =0.508	W ₃ =0.061	W ₃ =0.048			
	C ₅	group:C ₃ ,C ₅ ,C ₆ ,C ₇	W ₅ =0.031	W ₅ =0.007	W ₅ =0.004			
	C ₆		W ₆ =0.063	W ₆ =0.015	W ₆ =0.010			
	C ₇		W ₇ =0.007	W ₇ =0.030	W ₇ =0.024			

So by reviewing data in table(22), it absolutely inspires us to rethink about our proposed model. Criteria weighting using information derived from (R) may not help us to obtain bigger weighting values for criteria those belonging to cause group in a complex system, although information based on (R/C) and (R-C) can bring us to criteria weightings exactly in agreement to cause and effect grouping in addition to gaining bigger values for those criteria who are in cause group. This fundamental point may return to the data which based on the term of (R/C) and (R-C) which defined before as "net influence power" and "net effect" respectively. However this issue is experimentally proofed by some case studies .Consequently for making a revision of our proposed model we will present a modified version of the suggested model in the next section.

Lastly, after discussion being finished now we are ready to run the forth step of proposed model connected to each numerical case study. For reaching to an average value of each criteria by using data (criteria weighting derived from parameter (R/C) and (R-C)) in table(22), it is be intentionally interested to deploy the geometric mean. It is because that we are facing with the weights which are calculated by data aligned with different parameters (namely as (R/C) and (R-C) that can be considered as various units. So the output of step 4 of proposed model can be seen in table(23).

Table 23. Output of proposed model

Cases	Criteria	Criteria grouping	Geometric mean applying weights achieved by (R/C) and (R-C) data		
			R/C	R-C	Geometric mean
Case 1	C ₁	Cause group: C ₁ , C ₄	W ₄ =0.557	W ₄ =0.623	0.589
	C ₂		W ₁ =0.271	W ₁ =0.265	0.268
	C ₃	Effect group: C ₂ , C ₃	W ₂ =0.123	W ₂ =0.094	0.108
	C ₄		W ₃ =0.048	W ₃ =0.018	0.029
Case 2	C ₁	Cause group: C ₆ , C ₄	W ₆ =0.587	W ₆ =0.696	0.639
	C ₂		W ₄ =0.243	W ₄ =0.199	0.219
	C ₃	Effect group: C ₁ , C ₂ , C ₃ , C ₅	W ₁ =0.096	W ₁ =0.063	0.078
	C ₄		W ₂ =0.044	W ₂ =0.026	0.034
	C ₅		W ₃ =0.010	W ₃ =0.005	0.007
	C ₆		W ₅ =0.021	W ₅ =0.011	0.015
Case 3	C ₁	Cause group: C ₁ , C ₂ , C ₄	W ₁ =0.513	W ₁ =0.564	0.538
	C ₂		W ₂ =0.250	W ₂ =0.239	0.244
	C ₃		W ₄ =0.124	W ₄ =0.111	0.117
	C ₄	Effect group: C ₃ , C ₅ , C ₆ , C ₇	W ₃ =0.061	W ₃ =0.048	0.057
	C ₅		W ₅ =0.007	W ₅ =0.004	0.005
	C ₆		W ₆ =0.015	W ₆ =0.010	0.012
	C ₇		W ₇ =0.030	W ₇ =0.024	0.027

5.3. Basic and Modifications *A* and *B* of the proposed hybrid and integrated mathematical model

5.3.1. Basic model

According to numerical case studies and results discussed in previous part we are now to present an effectively modified and perfectly refined model. In this point, we are to revise our proposed model by little changes in steps 2 and 3 of the previous framework of the hybrid model. On the other hand having all steps in hand, there is no need to use the information derived from (R) in our proposed model. So, modification *A* of the proposed hybrid model would be described as below:

Step 1: Execute the DEMATEL methodology (for a predetermined set of criteria and an average initial intelligible relation matrix given by some experts).

Step 2: Calculate the parameters of (R/C) and (exp(R-C)).

(R equals to direct and indirect influence of one factor dispatching to others, equivalent to summation of the elements in each row of total matrix T. C is the sum of direct and indirect effects that a criteria is receiving from the other criteria, equivalent to summation of the elements of each column of total matrix T.)

Step 3: Execute the SWARA technique in two scenarios regarding the (R/C) and $(\exp(R-C))$ parameters to obtain the corresponding weight for each criteria. (Notice that for obtaining the Comparative Importance s_j correspondent to each criteria, it must be applied the ratio of $(\exp(R-C))_{\text{upper ranked}} / (\exp(R-C))_{\text{lower ranked}}$ and $(R/C)_{\text{upper ranked}} / (R/C)_{\text{lower ranked}}$) for each criteria c_j and we put $s_j = 0$ for the most significant criteria.

Step 4: Calculate an average value (preferably geometric mean) of weights for each criteria.

5.3.2. Modification A

In this part, it would be deliberately intended to consolidate our proposed hybrid model. Briefly and exactly speaking, it has been appropriately considered to unify the information derived by (R/C) and $(\exp(R-C))$ parameters in the step 3 of our proposed model where these information are to be combined into one mathematical formula. Consequently, the step 4 of our hybrid model would be omitted. As a result, the suggested hybrid model can be improved same as re-described below.

Step 1: Execute the DEMATEL methodology (for a predetermined set of criteria and an average initial intelligible relation matrix given by some experts).

Step 2: Calculate the parameters of (R/C) and $(\exp(R-C))$.
(R equals to direct and indirect influence of one factor dispatching to others, equivalent to summation of the elements in each row of total matrix T . C is the sum of direct and indirect effects that a criteria is receiving from the other criteria, equivalent to summation of the elements of each column of total matrix T .)

Step 3: Execute the SWARA technique regarding and making use information of the (R/C) and $(\exp(R-C))$ parameters into one of the desired formulas listed below (formulas 6, 7, 8, 9, 10) to calculate the s_{ji} (Comparative Importance correspondent to each criteria j to criteria i in descending ranking order) to ultimately obtain the corresponding weight for each criteria.

$$s_{ji} = 1 - \frac{\max \left\{ \left(\frac{R_j}{C_j} \right), (\exp(R_j - C_j)) \right\}}{\max \left\{ \left(\frac{R_j}{C_j} \right), (\exp(R_j - C_j)) \right\} + \max \left\{ \left(\frac{R_i}{C_i} \right), (\exp(R_i - C_i)) \right\}} \quad (6)$$

$$s_{ji} = 1 - \frac{\left\{ \left(\frac{R_j}{C_j} \right) \otimes_E (\exp(R_j - C_j)) \right\}}{\left\{ \left(\frac{R_j}{C_j} \right) \otimes_E (\exp(R_j - C_j)) \right\} + \left\{ \left(\frac{R_i}{C_i} \right) \otimes_E (\exp(R_i - C_i)) \right\}},$$

where $\otimes_E$ is the Einstein multiplicative operator, $a \otimes_E b$

$$= \frac{a.b}{1 + (1-a).(1-b)} \quad a, b \in [0,1]^2 \quad (7)$$

$$s_{ji} = 1 - \frac{\left\{ \left(\frac{R_j}{C_j} \right) \oplus_E (\exp(R_j - C_j)) \right\}}{\left\{ \left(\frac{R_j}{C_j} \right) \oplus_E (\exp(R_j - C_j)) \right\} + \left\{ \left(\frac{R_i}{C_i} \right) \oplus_E (\exp(R_i - C_i)) \right\}},$$

where $\oplus_E$ is the Einstein additive operator, $a \oplus_E b$

$$= \frac{a + b}{1 + a.b} \quad a, b \in [0,1]^2 \quad (8)$$

$$s_{ji} = 1 - \frac{T_\gamma(\frac{R_j}{C_j}, \exp(R_j - C_j))}{T_\gamma(\frac{R_j}{C_j}, \exp(R_j - C_j)) + T_\gamma(\frac{R_i}{C_i}, \exp(R_i - C_i))},$$

where T_γ is the Hamacher t – norm operator, $T_\gamma(a, b)$

$$= \frac{a.b}{\gamma + (1-\gamma)(a+b-a.b)}, \quad \gamma \geq 0 \quad (9)$$

$$s_{ji} = 1 - \frac{S_\gamma(\frac{R_j}{C_j}, \exp(R_j - C_j))}{S_\gamma(\frac{R_j}{C_j}, \exp(R_j - C_j)) + S_\gamma(\frac{R_i}{C_i}, \exp(R_i - C_i))},$$

where S_γ is the Hamacher t – conorm operator, $S_\gamma(a, b) = \frac{a + b - (2-\gamma)a.b}{1 - (1-\gamma)(a.b)}$ $\gamma \geq 0$ (10)

And now it is aimed to apply the modification A of the proposed hybrid model for solving some numerical case studies. The data which is decided to make use for testing our model would be the data correspondent to our previous case studies (cases 1,2,3) in this research.

5.3.2.1.Numerical study:

5.3.2.1.Case 1: As it has been calculated before (*case 1*), it would be first gathered again the necessary data needed to be deployed to evaluate our model as shown in table (24).

Table 24.Criteria ranking and needed data.

Criteria ranks	R/C	exp(R-C)
The most significant criteria:C ₄	(R/C) ₄ =1.263	exp(R-C) ₄ =2.403
C ₁	(R/C) ₁ =1.201	exp(R-C) ₁ =1.775
C ₂	(R/C) ₂ =0.994	exp(R-C) ₂ =0.978
The least significant criteria=C ₃	(R/C) ₃ =0.628	exp(R-C) ₃ =0.239

Consequently using the data from table (24) and SWARA procedure (while making use of formula 6 desirably) we'll have the final weights of criteria evaluated and gathered in the following table (25) .

Table 25. SWARA procedure and final criteria weights.

C _j	s _{ji}	k _j	q _j	w _j
The most important criteria:C ₄	0	1	1	0.386
C ₁	0.425	1.425	0.702	0.271
C ₂	0.359	1.359	0.517	0.199
The least significant criteria=C ₃	0.387	1.387	0.373	0.144
			$\sum q_j=2.592$	

5.3.2.1.Case 2: As it has been previously obtained (*case 2*), it would be first gathered again the necessary data needed to be deployed to evaluate our model as shown in table (26).

Table 26. Criteria ranking and needed data.

Criteria ranks	R/C	exp(R-C)
The most significant criteria:C ₆	(R/C) ₆ =2.106	exp(R-C) ₆ =4.972
C ₄	(R/C) ₄ =1.485	exp(R-C) ₄ =1.988
C ₁	(R/C) ₁ =0.966	exp(R-C) ₁ =0.929
C ₂	(R/C) ₂ =0.828	exp(R-C) ₂ =0.631
C ₅	(R/C) ₅ =0.721	exp(R-C) ₅ =0.501

The least significant criteria= C_3	$(R/C)_3=0.657$	$\exp(R-C)_3=0.344$
---------------------------------------	-----------------	---------------------

Consequently using the data from table (26) and SWARA procedure (while making use of formula 6 desirably) we'll have the final weights of criteria evaluated and gathered in the following table (27).

Table 27. SWARA procedure and final criteria weights.

C_j	s_{ji}	k_j	q_j	w_j
The most significant criteria: C_6	0	1	1	0.310
C_4	0.286	1.286	0.777	0.241
C_1	0.327	1.327	0.586	0.182
C_2	0.463	1.463	0.400	0.124
C_5	0.465	1.465	0.273	0.085
The least significant criteria= C_3	0.467	1.467	0.186	0.058
			$\sum q_j=3.222$	

5.3.2.1. Case 3: As it has been previously obtained (*case 3*), it would be first gathered again the necessary data needed to be deployed to evaluate our model as shown in table (28).

Table 28. Criteria ranking and needed data.

Criteria ranks	R/C	$\exp(R-C)$
The most significant criteria: C_1	$(R/C)_1=1.101$	$(\exp(R-C))_1=1.962$
C_2	$(R/C)_2=1.049$	$(\exp(R-C))_2=1.442$
C_4	$(R/C)_4=1.028$	$(\exp(R-C))_4=1.239$
C_3	$(R/C)_3=0.993$	$(\exp(R-C))_3=0.948$
C_7	$(R/C)_7=0.991$	$(\exp(R-C))_7=0.942$
C_6	$(R/C)_6=0.962$	$(\exp(R-C))_6=0.734$
The least significant criteria= C_5	$(R/C)_5=0.901$	$(\exp(R-C))_5=0.434$

Consequently using the data from table (28) and SWARA procedure (while making use of formula 6 desirably) we'll have the final weights of criteria evaluated and gathered in the following table (29).

Table 29. SWARA procedure and final criteria weights.

C_j	s_{ji}	k_j	q_j	w_j
-------	----------	-------	-------	-------

The most significant criteria:C ₁	0	1	1	0.335
C ₂	0.424	1.424	0.702	0.235
C ₄	0.461	1.461	0.480	0.161
C ₃	0.445	1.445	0.332	0.111
C ₇	0.499	1.499	0.221	0.074
C ₆	0.493	1.493	0.148	0.049
The least significant criteria=C ₅	0.484	1.484	0.099	0.033
			$\sum q_j=2.982$	

At this point, we want to try other formulas related to calculating of s_{ji} ,namely formulas 7,8,9 and 10. Hence it has been tried to apply formulas 7,8,9 and 10 to obtain criteria weights only for the numerical study *case 1*.

5.3.2.1.Case 1 (Using formula 7 and 8):Here at first, numbers associated to R/C and exp(R-C) in table (24) must be normalized to be capable applying into formula 8.For this reason the linear normalization method of $r_j/\max r_j$ would be used and thus the normalized numbers besides the *Einstein* multiplicative and additive operations ($\otimes_E$ and $\oplus_E$) of parameters R/C and exp(R-C) are totally gathered in table (30).

Table 30. *Einstein* multiplicative and additive operations of parameters R/C and exp(R-C).

Criteria ranks	R/C normalized	exp(R-C) normalized	$(R/C)_n \otimes_E$ $(\exp(R-C))_n$	$(R/C)_n \oplus_E$ $(\exp(R-C))_n$
The most significant criteria:C ₄	(R/C) ₄ =1	exp(R-C) ₄ =1	1	1
C ₁	(R/C) ₁ =0.951	exp(R-C) ₁ =0.739	0.694	0.992
C ₂	(R/C) ₂ =0.787	exp(R-C) ₂ =0.407	0.284	0.904
The least significant criteria=C ₃	(R/C) ₃ =0.497	exp(R-C) ₃ =0.099	0.034	0.568

Consequently using the data from table (30) and SWARA procedure (while making use of formula 7 and 8 respectively) we'll have the final weights of criteria evaluated and gathered in the following tables (31,32) .

Table 31. SWARA procedure and final criteria weights using formula 7.

C_j	s_{ji} correspondent to $\otimes_E$	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.415
C_1	0.759	1.759	0.569	0.236
C_2	0.290	1.290	0.441	0.183
The least significant criteria= C_3	0.107	1.107	0.398	0.165
			$\sum q_j=2.408$	

Table 32. SWARA procedure and final criteria weights using formula 8.

C_j	s_{ji} correspondent to $\oplus_E$	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.409
C_1	0.498	1.498	0.668	0.273
C_2	0.477	1.477	0.452	0.185
The least significant criteria= C_3	0.386	1.386	0.326	0.133
			$\sum q_j=2.446$	

5.3.2.1.Case 1 (Using formula 9 and 10): At this stage of our numerical case study ,it is intended to apply formulas 9 and 10 to obtain criteria weights just only for the *case 1* numerical study. So we use the *Hamacher* operators in three typical scenarios related to $\gamma \geq 0$ to obtain the s_{ji} and final criteria weights.

5.3.2.1.Case 1 (Using formula 9 and 10), Scenario 1:In this scenario we set $\gamma = 0$.Therefore using the data from table(24), making use of *Hamacher* operators and formulas 9 and 10 we have the s_{ji} as shown in tables (33,34).

Table 33.Calculating of s_{ji} using Hamacher operator of T_0 .

Criteria ranks	R/C	$\exp(R-C)$	$T_0(\frac{R_j}{C_j}, \exp(R_j - C_j))$	s_{ji}
The most significant criteria: C_4	$(R/C)_4=1.263$	$\exp(R-C)_4=2.403$	4.809	0
C_1	$(R/C)_1=1.201$	$\exp(R-C)_1=1.775$	2.525	0.344
C_2	$(R/C)_2=0.994$	$\exp(R-C)_2=0.978$	0.972	0.278
The least significant criteria= C_3	$(R/C)_3=0.628$	$\exp(R-C)_3=0.239$	0.209	0.177

Table 34. Calculating of s_{ji} using Hamacher operator of S_0 .

Criteria ranks	R/C	$\exp(R-C)$	$S_0(R_j/C_j, \exp(R_j - C_j))$	s_{ji}
The most significant criteria: C_4	$(R/C)_4=1.263$	$\exp(R-C)_4=2.403$	1.181	0
C_1	$(R/C)_1=1.201$	$\exp(R-C)_1=1.775$	1.138	0.491
C_2	$(R/C)_2=0.994$	$\exp(R-C)_2=0.978$	0.995	0.466
The least significant criteria= C_3	$(R/C)_3=0.628$	$\exp(R-C)_3=0.239$	0.667	0.401

Consequently using the data from table (33,34) and SWARA procedure (while making use of formula 9 and 10 respectively) we'll have the final weights of criteria evaluated and gathered in the following tables (35,36) .

Table 35. SWARA procedure and final criteria weights using formula 9.

C_j	s_{ji} correspondent to T_0	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.355
C_1	0.344	1.344	0.744	0.264
C_2	0.278	1.278	0.582	0.206
The least significant criteria= C_3	0.177	1.177	0.494	0.175
			$\sum q_j=2.820$	

Table 36. SWARA procedure and final criteria weights using formula 10.

C_j	s_{ji} correspondent to S_0	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.407
C_1	0.491	1.491	0.671	0.273
C_2	0.466	1.466	0.458	0.186
The least significant criteria= C_3	0.401	1.401	0.327	0.133
			$\sum q_j=2.456$	

5.3.2.1.Case 1 (Using formula 9 and 10), Scenario 2:In this scenario we set $\gamma = 1$. Therefore using the data from table(24), making use of *Hamacher* operators and formulas 9 and 10 we have the s_{ji} as shown in tables (37,38).

Table 37. Calculating of s_{ji} using Hamacher operator of T_1 .

Criteria ranks	R/C	exp(R-C)	$T_1(R_j/C_j, \exp(R_j - C_j))$	s_{ji}
The most significant criteria: C_4	$(R/C)_4=1.263$	$\exp(R-C)_4=2.403$	3.035	0
C_1	$(R/C)_1=1.201$	$\exp(R-C)_1=1.775$	2.132	0.413
C_2	$(R/C)_2=0.994$	$\exp(R-C)_2=0.978$	0.972	0.313
The least significant criteria: C_3	$(R/C)_3=0.628$	$\exp(R-C)_3=0.239$	0.150	0.134

Table 38. Calculating of s_{ji} using Hamacher operator of S_1 .

Criteria ranks	R/C	exp(R-C)	$S_1(R_j/C_j, \exp(R_j - C_j))$	s_{ji}
The most significant criteria: C_4	$(R/C)_4=1.263$	$\exp(R-C)_4=2.403$	0.631	0
C_1	$(R/C)_1=1.201$	$\exp(R-C)_1=1.775$	0.844	0.572
C_2	$(R/C)_2=0.994$	$\exp(R-C)_2=0.978$	0.999	0.542
The least significant criteria: C_3	$(R/C)_3=0.628$	$\exp(R-C)_3=0.239$	0.717	0.418

Consequently using the data from table (37,38) and SWARA procedure (while making use of formula 9 and 10 respectively) we'll have the final weights of criteria evaluated and gathered in the following tables (39,40) .

Table 39. SWARA procedure and final criteria weights using formula 9.

C_j	s_{ji} correspondent to T_1	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.367
C_1	0.413	1.413	0.708	0.260
C_2	0.313	1.313	0.539	0.198
The least significant criteria= C_3	0.134	1.134	0.475	0.175
			$\sum q_j=2.722$	

Table 40. SWARA procedure and final criteria weights using formula 10.

C_j	s_{ji} correspondent to S_1	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.428
C_1	0.572	1.572	0.636	0.272
C_2	0.542	1.542	0.412	0.176
The least significant criteria= C_3	0.418	1.418	0.294	0.124
			$\sum q_j=2.339$	

5.3.2.1. Case 1 (Using formula 9 and 10), Scenario 3:In this scenario we set $\gamma = 2$. Therefore using the data from table(24), making use of *Hamacher* operators and formulas 9 and 10 we have the s_{ji} as shown in tables (41,42).

Table 41. Calculating of s_{ji} using Hamacher operator of T_2 .

Criteria ranks	R/C	$\exp(R-C)$	$T_2(\frac{R_j}{C_j}, \exp(R_j - C_j))$	s_{ji}
The most significant criteria: C_4	$(R/C)_4=1.263$	$\exp(R-C)_4=2.403$	2.217	0
C_1	$(R/C)_1=1.201$	$\exp(R-C)_1=1.775$	1.844	0.454
C_2	$(R/C)_2=0.994$	$\exp(R-C)_2=0.978$	0.972	0.345
The least significant criteria= C_3	$(R/C)_3=0.628$	$\exp(R-C)_3=0.239$	0.117	0.107

Table 42. Calculating of s_{ji} using Hamacher operator of S_2 .

Criteria ranks	R/C	$\exp(R-C)$	$S_2(\frac{R_j}{C_j}, \exp(R_j - C_j))$	s_{ji}
The most significant criteria: C_4	$(R/C)_4=1.263$	$\exp(R-C)_4=2.403$	0.909	0
C_1	$(R/C)_1=1.201$	$\exp(R-C)_1=1.775$	0.950	0.511
C_2	$(R/C)_2=0.994$	$\exp(R-C)_2=0.978$	0.999	0.513
The least significant criteria: C_3	$(R/C)_3=0.628$	$\exp(R-C)_3=0.239$	0.754	0.430

Consequently using the data from table (41,42) and SWARA procedure (while making use of formula 9 and 10 respectively) we'll have the final weights of criteria evaluated and gathered in the following tables (43,44) .

Table 43. SWARA procedure and final criteria weights using formula 9.

C_j	s_{ji} correspondent to T_2	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.376
C_1	0.454	1.454	0.688	0.258
C_2	0.345	1.345	0.512	0.192
The least significant criteria: C_3	0.107	1.107	0.463	0.174
			$\sum q_j=2.663$	

Table 44. SWARA procedure and final criteria weights using formula 10.

C_j	s_{ji} correspondent to S_2	k_j	q_j	w_j
The most important criteria: C_4	0	1	1	0.416
C_1	0.511	1.511	0.662	0.275
C_2	0.513	1.513	0.438	0.182
The least significant criteria: C_3	0.430	1.430	0.306	0.127
			$\sum q_j=2.406$	

5.3.3. Modification B

In this section, it is once more proposed to make some modifications for our hybrid mathematical model. It is worth of mentioning that the modifications suggested here would be about reshaping the calculating form of s_{ji} (Comparative Importance correspondent to each criteria j to criteria i in descending ranking order) in step 3 of our proposed hybrid model. As it is mathematically apparent in classic SWARA methodology, the s_{ji} has been exploited to determine the Comparative Importance of each criteria in relation to the next

criteria in a fully ranked criteria order (from the most important/significant criteria to the least important/significant criteria). By assumption, we name this kind of s_{ji} calculation form as *local* or *nearby* value assigned to s_{ji} . This matter is depicted schematically in figure (1) for an assumed ranked order criteria.

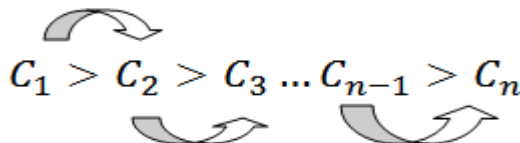


Figure 1. Local assumed criteria ranking order.

Having the s_{ji} calculating form from the classic SWARA technique, it is intended to define a procedural way to obtain the Comparative Importance of each criteria in relative to all criteria coming next in a fully ranked criteria order. This concept has been depicted in figure (2). We call this kind of the s_{ji} calculating form as *global* value assigned to $((s_{ji})_{glb})$.

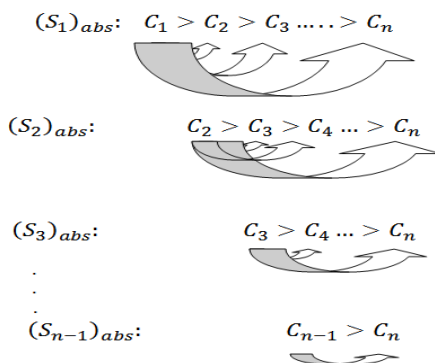


Figure 2. Global assumed criteria ranking order.

Hence the global form of s_{ji} is then computed by formula (11).

$$(s_{ji})_{glb} = \left(\sum_{i=j+1}^n \|s_{ji}\|^p \right)^{1/p} \quad (11)$$

$$\text{Where } s_{ji} = 1 - \frac{\max \left\{ \left(\frac{R_j}{C_j} \right), (\exp (R_j - C_j)) \right\}}{\max \left\{ \left(\frac{R_j}{C_j} \right), (\exp (R_j - C_j)) \right\} + \max \left\{ \left(\frac{R_i}{C_i} \right), (\exp (R_i - C_i)) \right\}} \text{ and } p \in \{2, \dots, n\}.$$

Until now there have been two formulas for calculating the s_j named as *local* and *global* values. So, it must be considered an approach to combine them to get one determined value for s_j to apply in SWARA methodology. For this reason, we prefer to use the *harmonic* mean to obtain the final value assigned to s_j . Harmonic mean of two values of x_1 and x_2 would be calculated by formula (12).

$$\begin{aligned} & \text{Harmonic mean } (x_1, x_2) \\ &= \frac{2x_1x_2}{x_1 + x_2} \end{aligned} \quad (12)$$

Ultimately, the steps of our proposed hybrid model in this section could be again expressed same as below.

Step 1: Execute the DEMATEL methodology (for a predetermined set of criteria and an average initial intelligible relation matrix given by some experts).

Step 2: Calculate the parameters of (R/C) and $(\exp(R-C))$.

(R equals to direct and indirect influence of one factor dispatching to others, equivalent to summation of the elements in each row of total matrix T . C is the sum of direct and indirect effects that a criteria is receiving from the other criteria, equivalent to summation of the elements of each column of total matrix T .)

Step 3: Execute the SWARA technique regarding and making use information of the (R/C) and $(\exp(R-C))$ parameters into formula 6 to calculate the s_{ji} (Comparative Importance correspondent to each criteria j to criteria i in descending ranking order), the $(s_j)_{\text{glb}}$ (formula 11) and the harmonic mean of s_{ji} and $(s_j)_{\text{glb}}$ to ultimately obtain the corresponding weight for each criteria. (For simplicity, let $p=2$ as Euclidean norm for calculating the $(s_j)_{\text{glb}}$)

5.3.3.1. Numerical study

5.3.3.1. Case 1: As it has been calculated in previous sections, we use data as shown before in table (24) which is needed to be deployed to evaluate our model. For more clarification at this point, it is deliberately decided to show some simple arithmetic calculations to obtain the $(s_j)_{\text{glb}}$. Thus we have:

$$S_{4_1} = 1 - \frac{\max\{1.263, 2.403\}}{\max\{1.263, 2.403\} + \max\{1.201, 1.775\}} = 0.425$$

$$S_{4_2} = 1 - \frac{\max\{1.263, 2.403\}}{\max\{1.263, 2.403\} + \max\{0.994, 0.978\}} = 0.293$$

$$S_{4_3} = 1 - \frac{\max\{1.263, 2.403\}}{\max\{1.263, 2.403\} + \max\{0.628, 0.239\}} = 0.207$$

Consequently, $(s_4)_{\text{glb}}$ can be determined as $(s_4)_{\text{glb}} = (S_{4_1}^2 + S_{4_2}^2 + S_{4_3}^2)^{1/2} = 0.556$. Additionally, to get the $(s_1)_{\text{glb}}$ we will have the following calculations.

$$S_{1_2} = 1 - \frac{\max\{1.201, 1.775\}}{\max\{1.201, 1.775\} + \max\{0.994, 0.978\}} = 0.359$$

$$S_{1_3} = 1 - \frac{\max\{1.201, 1.775\}}{\max\{1.201, 1.775\} + \max\{0.628, 0.239\}} = 0.261$$

Consequently, $(s_1)_{\text{glb}}$ can be determined as $(s_1)_{\text{glb}} = (S_{1_2}^2 + S_{1_3}^2)^{1/2} = 0.444$. Lastly, to get the $(s_2)_{\text{glb}}$ we will have the following calculation.

$$S_{2_3} = 1 - \frac{\max\{0.994, 0.978\}}{\max\{0.994, 0.978\} + \max\{0.628, 0.239\}} = 0.387 = (s_2)_{\text{glb}}$$

Finally, making use of data from table (24), $(s_4)_{\text{glb}}$, $(s_1)_{\text{glb}}$ and $(s_2)_{\text{glb}}$ while running SWARA procedure we'll obtain the final weights of each criteria evaluated and gathered in the following table (45).

Table 45. SWARA reconfigured procedure and final criteria weights.

C_j	s_{ji}	$(s_j)_{\text{glb}}$	s_j (Harm. mean)	k_j	q_j	w_j
The most important criteria: C_4	0	0	0	1	1	0.399
C_1	0.425	0.556	0.482	1.482	0.675	0.269
C_2	0.359	0.444	0.397	1.397	0.483	0.193
The least significant criteria: C_3	0.387	0.387	0.387	1.387	0.348	0.139
					$\sum q_j = 2.506$	

5.3.3.1. Case 2: Using data from table (26) and applying step 3 of our hybrid model we'll find the criteria weights gathered in table (46).

Table 46. SWARA reconfigured procedure and final criteria weights.

C_j	s_{ji}	$(s_j)_{glb}$	s_j (Harm. mean)	k_j	q_j	w_j
The most significant criteria: C_6	0	0	0	1	1	0.335
C_4	0.286	0.398	0.333	1.333	0.750	0.251
C_1	0.327	0.571	0.416	1.416	0.529	0.177
C_2	0.463	0.749	0.572	1.572	0.337	0.113
C_5	0.465	0.642	0.539	1.539	0.219	0.073
The least significant criteria= C_3	0.467	0.467	0.467	1.467	0.149	0.049
					$\sum q_j=2.984$	

5.3.3.1. Case 3: Using data from table (28) and applying step 3 of our hybrid model we'll find the criteria weights gathered in table (47).

Table 47. SWARA reconfigured procedure and final criteria weights.

C_j	s_{ji}	$(s_j)_{glb}$	s_j (Harm. mean)	k_j	q_j	w_j
The most significant criteria: C_1	0	0	0	1	1	0.385
C_2	0.424	0.873	0.571	1.571	0.637	0.245
C_4	0.461	0.922	0.615	1.615	0.394	0.152
C_3	0.445	0.834	0.580	1.580	0.249	0.096
C_7	0.499	0.836	0.625	1.625	0.153	0.059
C_6	0.493	0.685	0.573	1.573	0.097	0.037
The least significant criteria= C_5	0.484	0.484	0.484	1.484	0.065	0.025
					$\sum q_j=2.595$	

5.3.4. Overall results and discussion

For better comparison and taking a brief look at what finally happened by our basic hybrid model and its modification versions (A, B) we primarily gather all cause and effect criteria weights yielded by each of the proposed model in table (48).

Table 48.Criteria weights applying three hybrid models for case studies.

Cases	Criteria	Criteria grouping	w _j achieved by									
			Basic model	Modification <i>A</i> model using formula 6	Modification <i>A</i> model using formula 7	Modification <i>A</i> model using formula 8	Modification <i>A</i> model using formula 9 $\gamma = 0$	Modification <i>A</i> model using formula 9 $\gamma = 1$	Modification <i>A</i> model using formula 9 $\gamma = 2$	Modification <i>A</i> model using formula 10 $\gamma = 0$	Modification <i>A</i> model using formula 10 $\gamma = 1$	Modification <i>A</i> model using formula 10 $\gamma = 2$
Case 1	C ₁	Cause group: C ₁ , C ₄	W ₄ =0.58 9	W ₄ =0.38 6	W ₄ =0.41 5	W ₄ =0.40 9	W ₄ =0.35 5	W ₄ =0.36 7	W ₄ =0.37 6	W ₄ =0.40 7	W ₄ =0.42 8	W ₄ =0.41 5
	C ₂		W ₁ =0.26 8	W ₁ =0.27 1	W ₁ =0.23 6	W ₁ =0.27 3	W ₁ =0.26 4	W ₁ =0.26 0	W ₁ =0.25 8	W ₁ =0.27 3	W ₁ =0.27 2	W ₁ =0.27 5
	C ₃	Effect group: C ₂ , C ₃	W ₂ =0.10 8	W ₂ =0.19 9	W ₂ =0.18 3	W ₂ =0.18 5	W ₂ =0.20 6	W ₂ =0.19 8	W ₂ =0.19 2	W ₂ =0.18 6	W ₂ =0.17 6	W ₂ =0.18 2
	C ₄		W ₃ =0.02 9	W ₃ =0.14 4	W ₃ =0.16 5	W ₃ =0.13 3	W ₃ =0.17 5	W ₃ =0.17 5	W ₃ =0.17 4	W ₃ =0.13 3	W ₃ =0.12 4	W ₃ =0.12 7
Case 2	C ₁	Cause group: C ₆ , C ₄	W ₆ =0.63 9	W ₆ =0.31 0								W ₆ =0.33 5
	C ₂		W ₄ =0.21 9	W ₄ =0.24 1								W ₄ =0.25 1
	C ₃	Effect group: C ₁ , C ₂ , C ₃ , C ₅	W ₁ =0.07 8	W ₁ =0.18 2								W ₁ =0.17 7
	C ₄		W ₂ =0.03 4	W ₂ =0.12 4								W ₂ =0.11 3
	C ₅		W ₃ =0.01 5	W ₃ =0.08 5								W ₃ =0.07 5
	C ₆		W ₇ =0.00 7	W ₇ =0.05 8								W ₇ =0.04 9
Case 3	C ₁	Cause group: C ₁ , C ₂ , C ₄	W ₁ =0.53 8	W ₁ =0.33 5								W ₁ =0.38 5
	C ₂		W ₂ =0.24 4	W ₂ =0.23 5								W ₂ =0.24 5
	C ₃		W ₄ =0.11 7	W ₄ =0.16 1								W ₄ =0.15 2
	C ₄	Effect group: C ₃ , C ₅ , C ₆ , C ₇	W ₃ =0.05 7	W ₃ =0.11 1								W ₃ =0.09 6
	C ₅		W ₇ =0.02 7	W ₇ =0.07 4								W ₇ =0.05 9
	C ₆		W ₆ =0.01 2	W ₆ =0.04 9								W ₆ =0.03 7
	C ₇		W ₅ =0.00 5	W ₅ =0.03 5								W ₅ =0.02 5

Taking a glance on data in the above table, first of all it can be easily perceived that the three suggested hybrid model could afford to classify criteria handling in a system into two main categories of cause and effect group and also it thus follows the greater number values would be assigned to criteria belongs to cause group. Moreover criteria weights would have the descending order due to criteria ranking from the most significant to the least significant criteria. Being more exact on the most significant criteria weights assigned in each cases, it is attentively observed that the most significant criteria would have relatively more larger values to other criteria which assigned by our basic model. On the other hand, our basic model would assign solely more than 50% of weights to the most significant criteria. It may be returned to exploitation of the way of information derived from (R/C) and (R-C) in our basic hybrid model. It is because that in the basic model it has been proposed to use the information of (R/C) and (R-C) separately. But, this issue has improved when applying and running model steps in our modified version models (*A,B*). Emphatically, the modification models have deployed the aggregate information derived from (R/C) and (R-C) using formulas (6,7,8,9,10) to determine the s_j (Comparative Importance correspondent to each criteria j). Roughly speaking, criteria weights assigned by our modified models are more uniformly distributed relatively to criteria weighting in the basic model and besides our

modification models (A, B) together provide a series of criteria weightings which can be ultimately picked up by decision maker . This important feature can be quickly perceived by depicted graphs (3,4,5) shown below.

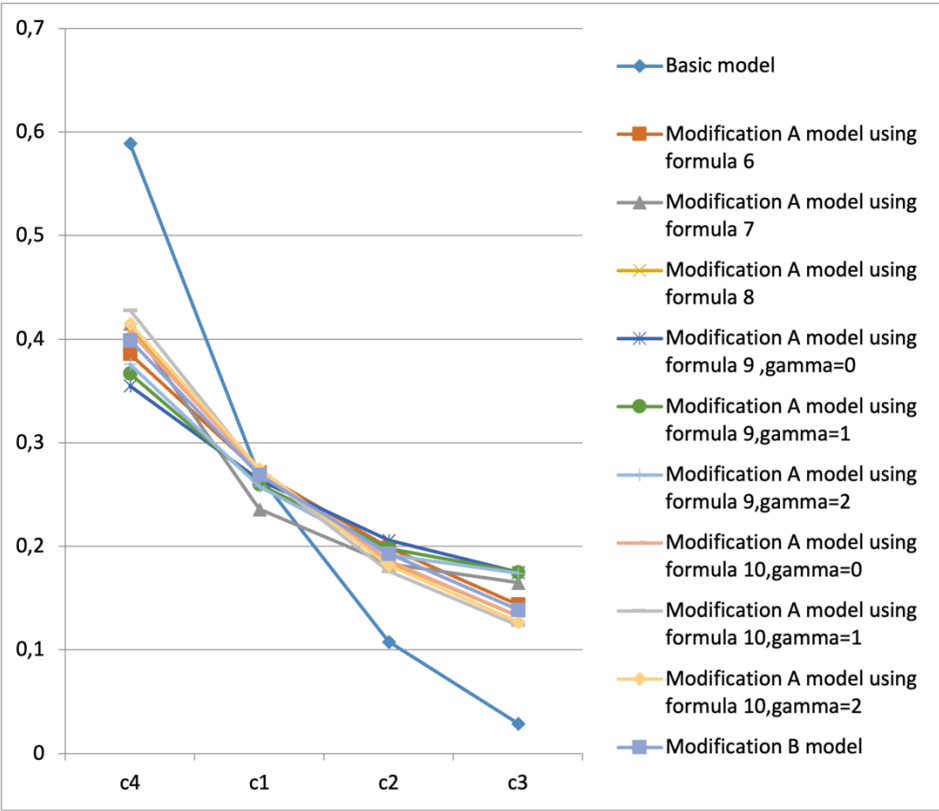


Figure 3. Criteria weighting distribution for case 1.

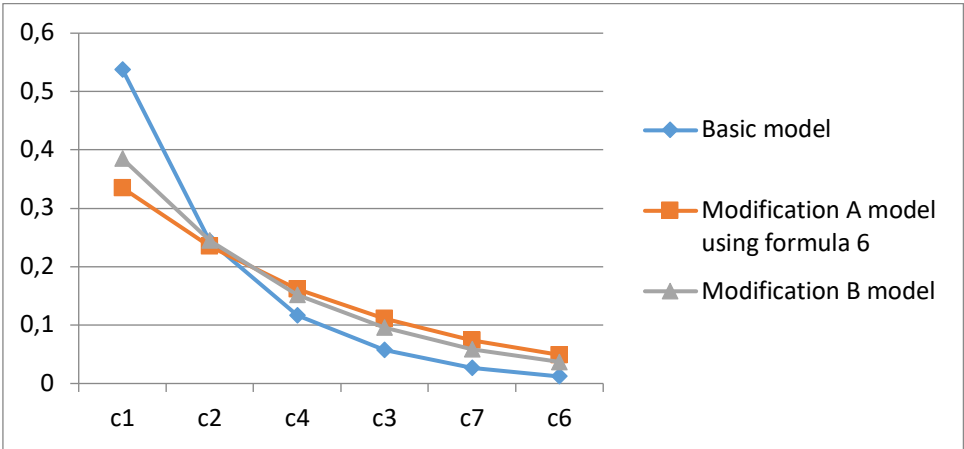


Figure 4.Criteria weighting distribution for case 2.

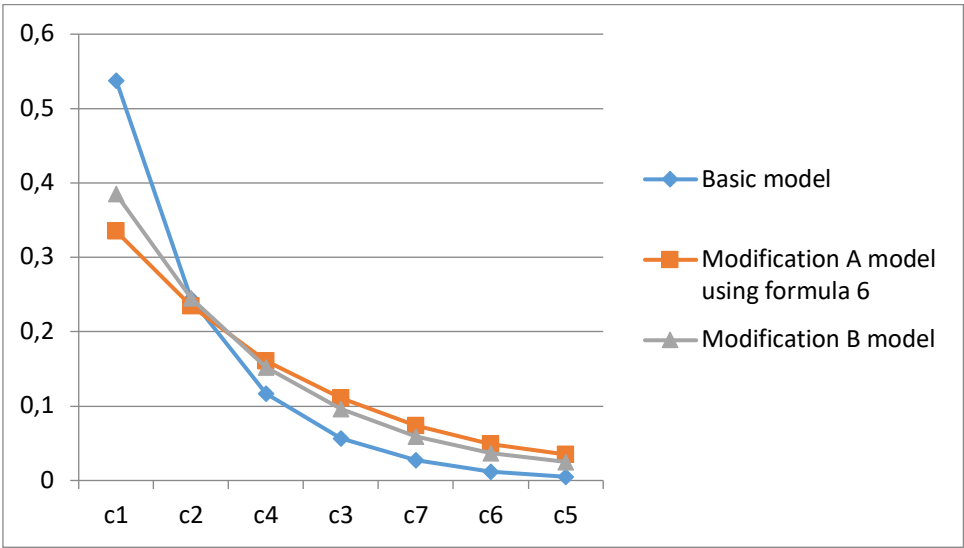


Figure 5.Criteria weighting distribution for case3.

It is besides worth of mentioning that the proposed modification *B* model (making use of local and global comparative importance of criteria j) for criteria weighting behaves between the basic hybrid model and the modification *A* hybrid model. It can be concluded that revising the formula of computing the s_j (Comparative Importance correspondent to

each criteria j) in SWARA methodology in modified hybrid model B has been operating as an adjuster to control the distribution of criteria weighting.

6. Conclusion and future research

In this research, it has been focused to present a mathematical multi criteria decision making model (D-DS model) to assign weights for criteria which have fundamentally casual effect on each other. So DEMATEL methodology as the basic structure of the proposed model is selected to analyze and categorize criteria into two cause and effect groups. In this regard, considering the DEMATEL technique's final step (total influence matrix T), gives us data such as the (R) , (R/C) and $(R-C)$ which they are inherently known as objective information are additionally used to calculate the weights of those sub-grouped criteria. Furthermore in this study it has been intentionally aimed to configure a weighting multi criteria model which can first apply the information derived from those parameters who would transfer better and more significant data specially resulting in greater values for cause criteria group. For this reason, parameters (R) , (R/C) and $(R-C)$ named as "direct and indirect influence", "net influence power" and "net effect" are respectively selected to apply in this hybrid model. Data determined by these three parameters are then deployed in the second part of our model which uses SWARA technique. Moreover devoting SWARA technique using the objective data derived from the total influence matrix T will result in that the information derived from (R) cannot afford to classify criteria into two cause and effect groups. But the information derived from (R/C) and $(R-C)$ could dominantly classify all criteria into two groups of cause and effect group while assigning larger values to criteria belonging to cause group. More importantly in the present investigation it has been tried to find a mathematical formula to effectively combine the aggregate information derived from (R/C) and $(R-C)$. Hence in this present study we apply three mathematical model including *max*, *Einstein* and *Hamacher* aggregation operators to calculate the Comparative Importance correspondent to each criteria j . Thus making use of these mentioned operators would cause the weights of cause and effect criteria in a system to be more uniformed. So as a salient feature of our proposed hybrid models would be their integrities of making use of combinatorial information of (R/C) and $(R-C)$ and its capabilities to benefit from the classic SWARA methodology and furthermore from the revised form of SWARA technique especially where the s_j (Comparative Importance correspondent to each criteria j) has been reconfigured *locally* and *globally* in the modified model B . Lastly there would be an another important aspect of the suggested hybrid model in this research and that is its ability to exploit the objective information extracted by DEMATEL methodology. As a major insight of this investigation, it can be expressed that making use of hidden objective data in DEMATEL methodology's final matrix $((R/C)$ and $(R-C))$ combing with modified SWARA method (explained in section 5.3.2 and 5.3.3) all along applying the *max*, *Einstein* and *Hamacher* aggregation operators yield much uniformed criteria weighting in a system. Moreover, assigning greater values to criteria which play casual role to those play effect role in a system would be main contribution of this research.

For future study and research, it would be recommended to integrate another structural modeling techniques like ISM (Interpretive Structural Modeling), TISM (Total Interpretive Structural Modeling) and FCM (Fuzzy Cognitive Map) with SWARA to calculate the weights of a system's criteria which can be grouped into cause and effect class. The results can be compared to the proposed model in this research. Additionally, it is also advised to combine the Fuzzy DEMATEL (F-DEMATEL) technique with the other criteria weighting method (like FUCOM, LBWA and SIMOS) to obtain the weights of cause and effect criteria. It is worth of mentioning that in all the suggested criteria weighting method of FUCOM, LBWA and SIMOS, the concept of best or most desirable criteria is put which reasonably can afford to make use of some parameters such as the (R) and (R/C) derived from F-DEMATEL.

Funding: There is no fund to support this work.

Conflict of Interest: There is no conflict of interests.

Availability of data and material : All those used data from other sources are referenced.

Code availability :Not applicable

References:

- [1] Aghdaie M.H., Zolfani S.H., Zavadskas E.K., Decision making in machine tool selection: an integrated approach with SWARA and COPRAS-G methods, *InzinerineEkonomika-Eng. Econ* ,24, 2013, 5–17.
- [2] Agrawal N., KantS., Integrated Fuzzy-Dematel, Fuzzy-Topsis Approach for Supplier Selection: A Case Study. *Advanced Research in Electrical and Electronic Engineering*. Volume 5, Issue 2, April-June, 2018,pp. 129-133.
- [3] Ahmadi H., Nilashi M., O Ibrahim., Organizational decision to adopt hospital information system: an empirical investigation in the case of Malaysian public hospitals, *Int. J. Med. Inform*, 84 ,2015, 166–188.
- [4] Ahmadi H., Rad M.S., Nilashi M., Ibrahim O., A Almaee., Ranking the Microlevel critical factors of electronic medical records adoption using TOPSIS method, *Health Inf*, 4 ,2013.
- [5] Alimardani M., Hashemkhani Zolfani S., Aghdaie M.H., Tamo'saitien'e J., A novel hybrid SWARA and VIKOR methodology for supplier selection in an agile environment, *Technol. Econ. Dev. Econ*, 19 ,2013, 533–548.

-
- [6] Asad M.M., Mohajerani N., Nourseresh M., Prioritizing factors affecting customer satisfaction in the internet banking system based on cause and effect relationships, *Proc Econ Finance*, 36, 2016, 210–219.
- [7] Aydin F., Gümüş B., Comparative analysis of multi-criteria decision making methods for the assessment of optimal SVC location, *BULLETIN OF THE POLISH ACADEMY OF SCIENCES TECHNICAL SCIENCES*, Vol. 70(2), 2022.
- [8] Cebi S., Determining importance degrees of website design parameters based on interactions and types of websites, *Decision Support Systems*, vol. 54, no. 2, 2013, pp. 1030–1043.
- [9] Chauhan A., Singh A., Jharkharia S., An interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL) method approach for the analysis of barriers of waste recycling in India. *J. Air Waste Manag. Assoc.* 2018, 68, 100–110.
- [10] Chaurasiya R., Jain D., Hybrid MCDM method on pythagorean fuzzy set and its application, *Decision Making: Applications in Management and Engineering*, 4(2), 2022, 76–105.
- [11] Chiang K., Weight Determination for Consistently Ranking Alternatives in Multiple Criteria Decision Analysis, *Applied Mathematical Modeling*, 34(7), 2009, 1779–1787.
- [12] Diakoulaki D., Mavrotas G., Papayannakis L., Determining objective weights in multiple criteria problems: the CRITIC method, *Computers and Operations Research*, 22, 1995, 763–770.
- [13] Dhurkari R.K., MCDM METHODS: PRACTICAL DIFFICULTIES AND FUTURE DIRECTIONS FOR IMPROVEMENT, *RAIRO-Oper. Res.* 56 2022, <https://doi.org/10.1051/ro/2022060>.
- [14] Edwards W., Barron H., SMARTS and SMARTER: Improved Simple Methods for Multi attribute Utility Measurement. *Organizational Behavior and Human Decision Processes*, 60(3), 1994, 306–325.
- [15] Ergun A.T., Kuruoglu E., Visual program application for supplier selection using fuzzy DEMATEL and fuzzy AHP. In Proceedings of the International Conference on Computer Science and Engineering (UBMK 2017), Antalya, Turkey, 5–8 October, 2017; pp. 1055–1060.
- [16] Fontela E., Gabus A., The DEMATEL observer, DEMATEL 1976 report. Switzerland Geneva: Battelle Geneva Research Center, 1976.
- [17] Ginevicius R., Podvezko V., Objective and subjective approaches to determining the criterion weight in multi criteria models. *Proceedings of International Conference RelStat, Transport and Telecommunication*, 6(1), 2005, 133–137.

- [18] Heidarzade F., Varzandeh M.H.M., Rahbari O., Zavadskas E.K., Vafaeipour M, Placement of wind farms based on a hybrid multi criteria decision making for Iran, In Proceedings of the 4th World Sustainability Forum,4, 2014, 1–20.
- [19] Hsuan-Shih Lee., Gwo-Hshiung Tzeng., Weichung Yeih., Yu-Jie Wang., Shing-Chih Yang., Revised DEMATEL: Resolving the Infeasibility of DEMATEL. *Applied Mathematical Modeling*, Volume 37,2013,pp 6746–6757.
- [20] Huang C.Y., Shyu J.Z., Tzeng G.H., Reconfiguring the innovation policy portfolios for Taiwan's SIP mall industry, *Technovation*, vol. 27, no. 12, 2007,pp. 744–765.
- [21] Hung Y.H., Huang T.L., Hsieh J.C., Tsuei H.J., Cheng C.C., Tzeng G.H., Online reputation management for improving marketing by using a hybrid MCDM model, *Knowl. Based Syst*, 35, 2012, 87–93.
- [22] Jamshidi A., Rahimi S.A., Ait-kadi D., Ruiz A., A comprehensive fuzzy risk-based maintenance framework for prioritization of medical devices, *Appl. Soft Comput*, 32,2015, 322–334.
- [23] Jing Li., Chi-Hui Wu L., Chien-Wen Chen., Yi-Fen Huang., Ching-Torng Lin., Apply Fuzzy DEMATEL to Explore the Decisive Factors of the Auto Lighting Aftermarket Industry in Taiwan. *Mathematics*, 8, 1187,2020, doi:10.3390/math8071187.
- [24] Karabasevic D., Stanujkic D., Urosevic S., The MCDM model for personnel selection based on SWARA and ARAS methods. *Management*, 77,2015, 43-52. DOI: 10.7595/management.fon.2015.0029.
- [25] Karabasevic D., StanujkicD., UrosevicS., Maksimovic M., Selection of candidates in the mining industry based on the application of the SWARA and the MULTIMOORA methods. *Acta Montanistica Slovaca*, 20(2), 2015, 116-124.
- [26] Karabasevic D., Stanujkic D., Urosevic S., Maksimovic M., An approach to personnel selection based on Swara and Waspas methods. *Bizinfo (Blace)*, 7(1), 2016, 1-11. DOI: 10.5937/bizinfo1601001K.
- [27] Keeney R. L., Raiffa H., Decisions with Multiple Objectives. Wiley, New York,1976.
- [28] Keršulienė V., Turskis Z., Integrated fuzzy multiple criteria decision making model for architect selection, *Technol. Econ. Dev. Econ*, 17 ,2011, 645–666.
- [29] Keršulienė V., Zavadskas E.K., Turskis Z., Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA), *J. Bus. Econ. Manage*,11, 2010, 243–258.
- [30] Khalili-Damghani K., Aminzadeh-Goharizi B., Rastegar S., Aminzadeh-Goharizi B., Solving land-use suitability analysis and planning problem by a hybrid meta-heuristic algorithm, *International Journal of Geographical Information Science*, vol. 28, no. 12, 2014, pp. 2390–2416.

-
- [31] Khazai B., Merz M., Schulz C., Borst D., An integrated indicator framework for spatial assessment of industrial and social vulnerability to indirect disaster losses, *Natural Hazards*, vol. 67, no. 2, 2013, pp. 145–167.
- [32] Kijewska K., Torbacki W., Iwan S., Application of AHP and DEMATEL Methods in Choosing and Analysing the Measures for the Distribution of Goods in Szczecin Region. *Sustainability*, 2018, 10, 2365, doi:10.3390/su10072365.
- [33] Kulak O., Goren H.G., Supciller A.A., A new multi criteria decision making approach for medical imaging systems considering risk factors, *Appl. Soft Comput.*, 35 ,2015, 931–941.
- [34] Li M., Jin L., Wang J., A new MCDM method combining QFD with TOPSIS for knowledge management system selection from the user's perspective in intuitionistic fuzzy environment, *Appl. Soft Comput.*, 21 ,2014, 28–37.
- [35] Ma J., Fan Z.P., Huang L.H., A subjective and objective integrated approach to determine attribute weights. *European Journal of Operations Research*, 112,397-404, 1999.
- [36] MacCrimmon K.R., Decision making Among Multiple-attribute Alternatives: a Survey and Consolidated Approach, In, DTIC Document, 1968.
- [37] Madanchian M., Taherdoost H., Multi-Criteria Decision Making (MCDM) Methods and Concepts, *Encyclopedia*, 2023, 3, 77–87. <https://doi.org/10.3390/encyclopedia3010006>.
- [38] Mardani A., Nilashi M., Zakuan N., Loganathan N., Soheilrad S., Saman M.Z.M., Ibrahim O., A systematic review and meta-Analysis of SWARA and WASPAS methods: Theory and applications with recent fuzzy developments, *Applied Soft Computing*, 57,265–292. <http://dx.doi.org/10.1016/j.asoc.2017.03.045>.
- [39] Mardani A., Jusoh A., Zavadskas E.K., Zakuan N., Valipour A., Kazemilari M., Proposing a new hierarchical framework for the evaluation of quality management practices: a new combined fuzzy hybrid MCDM approach, *J. Bus. Econ. Manage.* 17 (2016) 1–16.
- [40] Narges Taati S., Esmaili-Dooki A., A hybrid method of Fuzzy DEMATEL/AHP/VIKOR approach to rank and select the best hospital nurses of a Years: A case study. *J. Appl. Res. Ind. Eng.* 4(2),2017,116-132.
- [41] ODUG.O., Weighting Methods for Multi-Criteria Decision Making Technique, *J. Appl. Sci. Environ. Manage.* Vol. 23 (8),2019, 1449-1457. <https://dx.doi.org/10.4314/jasem.v23i8.7>.
- [42] Osintsev N., Rakhmangulov A., Baginova V., EVALUATION OF LOGISTIC FLOWS IN GREEN SUPPLY CHAINS BASED ON THE COMBINED DEMATEL-

- ANP METHOD, *Mechanical Engineering* Vol.19, No3, Special Issue, 2021, pp. 473 - 498. <https://doi.org/10.22190/FUME210505061O>
- [43] Pamučar D., Stević Ž., Sremac S., A New Model for Determining Weight Coefficients of Criteria in MCDM Models: Full Consistency Method (FUCOM), *Symmetry*, 10(9), 2018, 393. <https://doi.org/10.3390/sym10090393>
- [44] Pamučar D., Mihajlović M., Obradović R., Atanasković P., Novel approach to group multi-criteria decision making based on interval rough numbers: Hybrid DEMATEL-ANP-MAIRCA model, *Expert Systems with Applications*, 88, 2017, 58-80.
- [45] Patil S.K., Kant R., A hybrid approach based on fuzzy DEMATEL and FMCDM to predict success of knowledge management adoption in supply chain, *Appl. Soft Comput*, 18, 2014, 126–135.
- [46] Pan J. N., Ngnyen H. T. N., Achieving customer satisfaction through product–service systems. *Eur J Oper Res*, 247, 2015, 179–190.
- [47] Peng Y., Wang G., Wang H., User preferences based software defect detection algorithms selection using MCDM, *Inf. Sci.* 191 ,2012, 3–13.
- [48] Peng Y., Kou G., Wang G., Shi Y., FAMCDM. A fusion approach of MCDM methods to rank multiclass classification algorithms, *Omega*, 39 ,2011, 677–689.
- [49] Perry C., Liu Y., Huai-Wei Lo., James J.H. Liou., A Combination of DEMATEL and BWM-Based ANP Methods for Exploring the Green Building Rating System in Taiwan. *Sustainability*, 2020, 12, 3216, doi:10.3390/su12083216.
- [50] Quang N.H., Yu V.F., Lin A.C., Dat L.Q., Chou S.Y., Parting curve selection and evaluation using an extension of fuzzy MCDM approach, *Appl. Soft Comput*, 13, 2013, 1952–1959.
- [51] Rezaei J., Best-worst Multi-criteria Decision-making Method, *Omega*, 53, 2015, 49-57.
- [52] Roberts R., Goodwin P., Weight approximations in multi-attribute decision models, *Journal of Multi criteria Decision Analysis*, 2002, 11, 291-303, <https://doi.org/10.1002/mcda.320>.
- [53] Ruzgys A., Volvačiovas R., Ignatavičius Č., Turskis Z., Integrated evaluation of external wall insulation in residential buildings using SWARA-TODIM MCDM method. *Journal of Civil Engineering and Management*, 20(1), 2014, 103-110, DOI: 10.3846/13923730.2013.843585.
- [54] Saaty T.L., Analytic hierarchy process. McGraw-Hill, New York, 1980.
- [55] Shannon C.E., Weaver W., The mathematical theory of communication. Urbana: The University of Illinois Press, 1947.

-
- [56] Sheng-Li Si., Xiao-Yue You., Hu-Chen Liu., Ping Zhang., DEMATEL Technique: A Systematic Review of the State-of-the-Art Literature on Methodologies and Applications. *Mathematical Problems in Engineering*, Volume 2018, Article ID 3696457, 33 pages <https://doi.org/10.1155/2018/3696457>.
- [57] Shieh J.I., Wu H.H., Huang K.K., A DEMATEL method in identifying key success factors of hospital service, *Knowl.-Based Syst*, 23 ,3, 2010, 277–282.
- [58] Shukla S., Mishra P.K., Jain R., Yadav H.C., An integrated decision making approach for ERP system selection using SWARA and PROMETHEE method. *International Journal of Intelligent Enterprise*, 3(2), 2016, 120-147. DOI: 10.1504/IJIE.2016.076041.
- [59] Stanujkic D., Karabasevic D., Zavadskas E. K., A framework for the Selection of a packaging design based on the SWARA method. *Inzinerine Ekonomika -Engineering Economics*, 26(2), 2015,181-187. DOI: 10.5755/j01.ee.26.2.8820.
- [60] Tzeng M.L., Using hybrid MCDM to evaluate the service quality expectation in linguistic preference, *Applied Soft Computing*, vol. 11, no. 8, 2011, pp. 4551–4562.
- [61] Von Winterfeldt D., Edwards W., Decision analysis and behavioral research, Cambridge University Press,1986.
- [62] Wang Z., Mathiyazhagan K., Xu L., Diabat A., A decision making trial and evaluation laboratory approach to analyze the barriers to Green Supply Chain Management adoption in a food packaging company, *J Clean Prod*,117,2016,19–28.
- [63] Watróbski J. et al., Generalised framework for multi-criteria method selection, *Omega*,2018, <https://doi.org/10.1016/j.omega.2018.07.004>.
- [64] Yazdani-Chamzini A., Shariati S., Yakhchali S.H., Zavadskas E.K., Proposing a new methodology for prioritising the investment strategies in the private sector of Iran, *Economic Research-Ekonomska Istrazivanja*, vol. 27, no. 1, 2014, pp. 320–345.
- [65] Zhang L., Sun X., Xue H., Identifying critical risks in Sponge City PPP projects using DEMATEL method: A case study of China, *J. Clean. Prod.* 226,2019, 949–958.
- [66] Žižović M., Pamucar D., New model for determining criteria weights: Level Based Weight Assessment (LBWA) model. Decision Making, *Applications in Management and Engineering*, 2(2), 2019,126-137.
- [67] Zolfani S.H., Esfahani M.H., Bitarafan M., Zavadskas E.K., Arefi S.L., Developing a new hybrid MCDM method for selection of the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants during automobile accidents, *Transport*,28, 2013, 89–96.
- [68] Zolfani S.H., Saparauskas J., New application of SWARA method in prioritizing sustainability assessment indicators of energy system, *Eng.Econ*, 24, 2013, 408–414.

- [69] Zolfani S.H., Zavadskas E. K., Turskis Z., Design of products with both International and Local perspectives based on Yin-Yang balance theory and SWARA method. *Ekonomskaitraživanja- Economic Research*, 26(2), 2013,153-166. DOI: 10.1080/1331677X.2013.11517613.

Received 24.02.2022, Accepted 20.12.2022