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SIMULTANEOUS INTERPRETIVE STRUCTURAL MODELLING AND WEIGHTING (SISMW)

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Multi-criteria decision-making (MCDM) methods have been implemented in many fields. In the meantime, several methods have been proposed to obtain the weight of the criteria determined by various methods in different ways. In this paper, a new approach, called simultaneous interpretive structural modelling and weighting (SISMW), is proposed to solve a multi-criterion decision-making (MCDM) problem. Using SISMW, the weight of the criteria and the relationship between them could be determined simultaneously. In this approach, like the ISM method, pair comparison between criteria was made by the decision-maker to determine the relationships among the different criteria. With the help of this data, the weight of the criteria, as well as the causal (cause and effect) relationships between them, were determined in 12 steps. The main advantage of this method is that only one stage of data collection is required for obtaining weights and modelling, and so the research process may be faster. This may increase the reliability of the collected data because, in a one-step survey, the impact of time is minimized. This process can be useful for conceptualizing and developing theories to help decision-makers understand the problem better.

Keywords. *SISMW, MCDM, criteria, modelling, weighting*

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1. Introduction

In multiple-criteria decision-making (MCDM), there are various methods to study and model casual terms among variables [10, 11]. Among all, interpretive structural modelling (ISM) and total interpretive structural modelling (TISM) methods are highly applicable. ISM was presented by Warfield [27], and it is an interactive process in which a general model consists of a group of variables that affects a system or case directly or indirectly [12]. ISM was designed as a group-learning process, but also can be used by individuals [19]. ISM is a relative mathematical process that recognizes and defines unclear and indistinct relations among variables and defective mental models of systems as a form of the connected structural collection well [26]. ISM model interprets system barriers based on descriptions of system elements. However, the term interpretation in ISM is almost weak [20].

Over the past decades, various methods were posed to determine the weight of decision criteria or to determine the relative importance of elements in a system that each has different attributes. Some of the most important methods of weighing are the analytical hierarchy process (AHP) [16], analytic network process (ANP) [17], Shannon entropy [5], and criteria importance through inter-criteria correlation (CRITIC) [3]. The main feature of all these methods is that they determine the relative importance of criteria individually and as an independent method. At the same time, the inability of ISM to identify the importance of criteria is one of its main weaknesses. Due to such defects, researchers are obliged to spend time and excess cost to gather data (expert opinions) in a field research process to determine the significance of each criterion. Hence, despite ISM showing the relation among elements (variables), the importance of these elements should be determined. So the main research question is presented as follows:

What is the best way to determine the weight of factors simultaneously with determining the model of relationships between them?

Therefore, this paper is an effort to determine the weight of criteria in a system with its interpretive structural modelling simultaneously. Thereby, in addition to recognizing cause and effect relation between elements, decision-makers can determine the relative importance of each simultaneously and therefore presents the enhanced framework for simultaneous interpretive structural modelling and weighting. The proposed framework has been validated with a numerical example in the field of evaluation criteria of resilient IT project suppliers. The remainder of this paper is as follows. Section 2 presents the framework of simultaneous interpretive structural modelling and weighting (SISMW). One of the strengths of the proposed method is to combine soft and hard operations research and to propose a combined quantitative and qualitative method. In Section 3, a numerical example has been presented, and finally, in conclusion, various applications of the model in different issues and several suggestions for further studies were raised.

2. Literature review

Vishnu et al. [23] used the integrated DEMATEL–ISM–PROMETHEE method to analyze the impact potential and dependence behaviour of the risk factors. The analysis asserts the absence of critical risk factors that have a direct impact on patient safety in the present healthcare system under investigation. However, the results illustrate the remarkable impact potential attributed to the risk factor, namely, staff shortage in inducing other risk factors such as employee attitudinal issues, employee health issues and absenteeism altogether resulting in community mistrust/misbeliefs. Mousavizade and Shakibazad [8] studied the critical success factors (CSF) of knowledge management (KM) in Iranian urban water and sewage companies (IUWSC) using the interpretive structural modelling (ISM)-decision-making trial and evaluation laboratory (DEMATEL) method. The analysis of the results showed that among the studied factors, strategies and goals would have the greatest impact on the success of KM implementation and senior management support, and teamwork and organizational culture are other CSFs of KM in IUWSC. The author’s model for implementation of KM was presented based on the results for the status quo of the studied community.

Soni et al. [18] prioritized Indian energy sector projects, namely, coal, gas, hydro and solar using fuzzy PROMETHHE (F-PROMETHEE) and Visual PROMETHEE applications and multicriteria decision-making analyses. On applying F-PROMETHEE on four energy projects, coal and solar projects outrank high and results show that coal--based project is preferable and should be considered. Girubha et al. [4] reported a study on the application of interpretative structural modelling (ISM) integrated with multicriteria decision-making techniques for enabling sustainability supplier selection. In this study, two modules ISM–ANP–ELECTRE and ISM–ANP–VIKOR were compared for the problem of sustainable supplier selection. ELECTRE results with a single solution showed that supplier 2 can be selected as the best supplier; VIKOR result shows that supplier 1 and supplier 2 can be selected as the best suppliers. Priya et al. [14] evaluated the interplay of various measures used by different governments around the world in combatting COVID-19. This research uses interpretative structural modelling (ISM) for assessing the powerful measures amongst the recognized ones, whereas to establish the cause-and-effect relations amongst the variables, the decision-making trial and evaluation laboratory (DEMATEL) method is used. Both approaches utilized in the study aid in the comprehension of the relationship among the assessed measures.

Jain and Ajmera [6] used interpretive structural modelling to model the factors affecting Indian medical tourism sector. The results of the survey and the model show that cost of medical procedures, facilitation, and care, the infrastructure of Indian hospitals, clinical excellence and the competence of doctors and staff are the top-level factors. Jain and Soni [7] identified the flexible manufacturing system performance variables and analyze the interactions among these variables. Interpretive structural modelling (ISM) has been reported for this but no study has been done regarding the interaction of its variables. Therefore, fuzzy TISM (total ISM) has been applied to deduce the relationship and interactions between the variables and the driving and dependence power of these variables are examined by fuzzy MICMAC. Pandey et al. [13] used ISM methodology to examine the interrelationship between the identified variables and the DEMATEL approach to find cause-effect relationships. An integrated approach helps managers with better total quality management (TQM) implementation. This study was further extended using total interpretative structural modelling (TISM). Aghaee et al. [1] evaluated maintenance strategies based on fuzzy decision-making trial evaluation and laboratory and fuzzy analytic network process (ANP) in the petrochemical industry. The results identify strategic management complexity as the top criterion. Predictive maintenance (PdM) with the highest priority is the best strategy. It is followed by reliability-centred (RCM), condition-based (CBM), total productive (TPM), predictive (PM) and corrective maintenance (CM). Nasrollahi et al. [9] identified resilient supplier selection criteria in the desalination supply chain and analyze the interactions between them. Two different multi-criteria decision-making techniques, i.e., interpretive structural modelling (ISM) and fuzzy decision-making testing and evaluation laboratory (fuzzy-DEMATEL), were used to identify driving criteria. Furthermore, standard criteria from each technique, their hierarchies and inter-relationships have been established. The criteria modelling using ISM and Fuzzy-DEMATEL shows that the most influential/driving criteria are management, financial status, and culture.

3. Simultaneous interpretive structural modelling and weighting

In this section, a new model is presented to handle the issue of determining the importance of criteria when determining the causal relationship between them. This method aims to determine the significance of criteria simultaneously by drawing relationships between them.

The most important difference between the proposed method and ISM is that ISM only determines the relationships between factors and cannot determine the degree of importance or weight of factors. While the SISMW method simultaneously determines the weight and relationships and does not need to collect data in several steps. Although ISM is one of the soft methods of operational research, the SISMW method with fundamental resemblance to ISM is a combination of soft and hard operational research methods and helps the decision-maker to better understand the factors under consideration through a data collection step from the experts. Especially when, in addition to identifying the influential factors, we also want to determine the importance of the factors. In addition, the proposed method can be easily used in other similar methods Such as DEMATEL and FGM, FTISM to model factors.

For this purpose, the interpretive structural modelling process has been changed, and the necessary steps have been added to that. ISM mathematical basics exist in many references [24, 25]. ISM has been used in many contexts. Talib et al. [22] used the ISM approach in modelling comprehensive quality management components in service sectors. Chen and Chen [2] used ISM to identify the relationship between present barriers in the organizational innovation process. In another research, the relation between Six Sigma success factors was analyzed using ISM [21]. Zhou et al. [28] in a study employed interpretive structural modelling (ISM) approach to identify the drivers of the Chinese ELV recycling business from the government, recycling organizations and consumers' perspectives. ISM is an interactive learning process that uses letters and shapes to create structural models and represents the pattern of complex relationships existing in a system. ISM is a tool by which decision-makers can develop a map of complex connections between elements of a system. Although ISM is a group learning process, it can also be used by individual decision-makers.

The steps to simultaneous modelling and weighting are as follows:

Identifying criteria. Suppose that we have a problem with structural modelling with n factors (criteria) where the weight of each criterion w_j, $j \in \{1, 2, ..., n\}$ is unknown. These weights can be identified by different methods such as literature reviews and expert opinion surveys.

Structural self-interaction matrix (SSIM). The SSIM is a matrix of the contextual relationship among each pair of enablers. The contextual relationship of "leads to" or "influences" has been chosen. This means one enabler leads to or influences another. While developing the SSIM, the following notations have been used:

V – enabler i affects enabler j,
A – enabler j influences enabler i,
X – enablers i and j influence each other,
O – enabler i and j are not related.

Initial reachability matrix. The reachability matrix is derived from the SSIM. It contains the relationship between the factors in a binary form. The SSIM is transformed into the reachability matrix using the following rules;

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix is assigned 1, and the (j, i) entry is assigned 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix is assigned 0, and the (j, i) entry is assigned 1.
- If the (i, j) entry in the SSIM is X, then both (i, j) and (j, i) entry in the reachability matrix are assigned 1.
- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix is assigned 0, and the (j, i) entry is assigned 0.

Final reachability matrix. From the initial reachability matrix, the final reachability matrix is constructed taking into account the transitivity rule, which states that if a variable *A* is related to *B* and *B* is related to *C*, then *A* is necessarily related to *C*.

Aggregated preference indices. Criterion $\pi(a,j)$ states to what degree factor *a* has priority over all factors, and $\pi(j, a)$ states how much all factors have a preference to factor *a*.

- If $\pi(a,j) = 0$, this means that *a* has no priority over other factors.
- If $\pi(j, a) = n$, this means that *a* has a complete priority over other factors.

The following condition applies to all factors:

$$\begin{cases} 0 \le \pi(a,j) \le n \\ 0 \le \pi \sum_{t=1}^{T} (j,a) \le n \end{cases}$$

$\pi(a,j)$ is obtained from the sum of row values *a* in the reachability matrix representing the power of influence of factor *a*. Similarly, $\pi(j, a)$ represents the power of influence of factor *a* from other factors and is obtained from the sum of the column value in the final reachability matrix.

Outranking flows. Each factor *a* face with factor $n-1$.

Let us define the two following outranking flows:

- the positive outranking flow:

$$\phi_a^+ = \frac{\pi(a, j)}{n}$$

- the negative outranking flow:

$$\phi_a^- = \frac{\pi(j, a)}{n}$$

Net outranking flow. To calculate the net outranking flow, the positive outranking flow should be subtracted from the negative outranking flow.

$$\phi_a^n = \phi_a^+ - \phi_a^-$$

To calculate the total outranking flow, the positive outranking flow should be added to the negative flow

$$\phi_a^t = \phi_a^+ + \phi_a^-$$

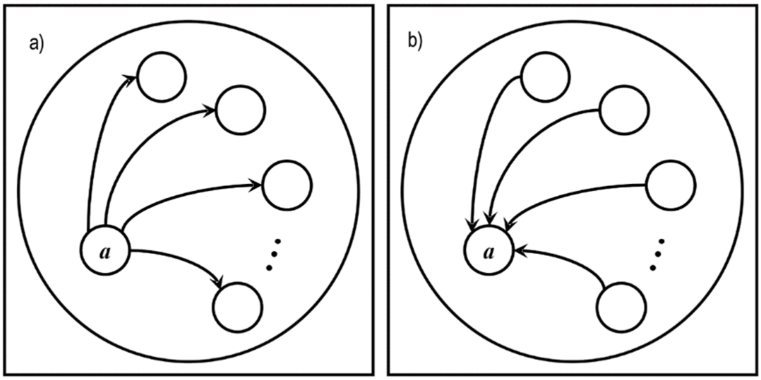

Fig. 1. Outranking flows: a) $\phi^{+}(a)$, b) $\phi^{-}(a)$

Determination of net flow effect. Firstly, the net current rating of each factor (from the biggest to the smallest) is identified (the biggest flow gets the rank one and the smallest flow the rank *n*). If the value of two or more flows is the same, we should consider the average rating for ranking. Therefore, to calculate the effect of factor *a*, we must add one to the highest score among the factors and subtract from the factor rank *a* and divide the result into total ratings

$$I_a^n = \frac{\max(\operatorname{rank}\phi_a^n) + 1 - (\operatorname{rank}\phi_a^n)}{\sum_{a=1}^{n} \operatorname{rank}\phi_a^n}$$

Determination of total flow effect. In this step, the total flow of each factor is divided into the sum of the outranking flow of the total factors

$$I_a^t = \frac{\phi_a^t}{\sum_{a=1}^{n} \phi_a^t}$$

Final weight determination. The final weight of each factor is obtained from average of net flow and total flow. The gained weight needs to be normalized to sum it up to one. Therefore, the final weight of each factor is divided into the total weight of the factors

$$w_a^n = \frac{I_a^n + I_a^t}{2}, \quad w_a = \frac{w_a^n}{\sum_{a=1}^{n} w_a^n}$$

Partitioning the final reachability matrix at different levels. The final reachability matrix is partitioned into different levels through successive iterations. For this, the reachability set and antecedent set of each criterion is found considering the following assumptions.

- The reachability set of a criterion consists of itself and all the other criteria which are influenced by it.
- The antecedent set of a criterion consists of itself and all the criteria which influence it. The intersection of these sets is obtained for all the criteria.
- The criteria for which the reachability set and intersection set are the same are assigned the topmost level in the hierarchy.
- Once the hierarchy of an individual or a group of enablers is set, they are not considered for analysis in subsequent iterations.

Using the mentioned procedure, the hierarchy of each enabler has been set.

Developing the ISM model. The ISM model is constructed using the final reachability matrix and the hierarchical level of the criteria, which are described in the previous step.

4. Numerical example

In the section presenting SISMW, the problem of identification and ranking of effective criteria in evaluating resilient IT projects contractors is used [15].

Identification of evaluation criteria for resilient IT project supplier selection. Nineteen criteria for the evaluation of resilient IT project suppliers have been identified through literature review and discussions with domain experts. These are quality (1), cost-efficiency (2), reputability (3), work experience (4), risk awareness (5), minimum vulnerability against disruptions (6), dispersion of key resources, production, and market capacity (7), agility (8), commitment to contract (9), research and development (10), technical capability to adapt to the latest innovations (11), compliance with standards (domestic and international) (12), development of new and alternative technologies (13), prioritizing environmental concerns (14), backup energy resources (15), management stability and specialized staff, personnel (16), information and cyber-security (17), network scale (18), and brand value (19).

Structural self-interaction matrix (SSIM). Once the criteria are identified, it is necessary to determine the contextual relationships between the criteria to develop the

SSIM. This means one criterion influences another. In total, ten experts were chosen to provide their expert views. While developing the SSIM (Table 1), the following notations are used: criterion *i* influences criterion *j* (V), criterion *j* influences criterion *i* (A), criteria *i* and *j* influence each other (X), and criteria *i* and *j* are not related (O).

Table 1. SSIM for evaluation criteria for resilient IT projects supplier selection

Crit. No.	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	V	O	O	O	O	O	A	A	O	A	A	O	O	V	A	O	A	X
2	O	O	O	A	A	O	A	O	V	A	A	X	A	X	A	A	O	
3	X	O	A	A	O	A	O	A	O	A	X	A	O	O	O	A		
4	V	O	O	O	O	O	O	V	O	A	O	O	O	O	V			
5	O	O	V	A	V	V	A	O	A	A	O	X	O	V				
6	V	A	X	A	A	O	A	A	A	A	A	V	V					
7	O	A	A	V	X	O	A	O	O	O	O	V						
8	V	O	A	A	A	A	A	X	A	X	V							
9	V	A	O	A	O	O	O	O	A	A								
10	O	V	V	O	V	V	V	O	V									
11	V	O	V	A	V	X	X	O										
12	V	O	A	A	O	O	A											
13	O	X	V	O	V	O												
14	V	O	O	O	V													
15	O	O	O	O														
16	O	O	V															
17	V	O																
18	O																	

Initial and final reachability matrices from the SSIM. The reachability matrix is derived from the SSIM. It contains the relationships between the factors in binary form. The SSIM is transformed into the reachability matrix using the following rules.

- If the (*i*, *j*) entry in the SSIM is V, then the (*i*, *j*) entry in the reachability matrix is assigned 1, and the (*j*, *i*) entry is assigned 0. If the (*i*, *j*) entry in the SSIM is A, then the (*i*, *j*) entry in the reachability matrix is assigned 0, and the (*j*, *i*) entry is assigned 1.
- If the (*i*, *j*) entry in the SSIM is X, then both (*i*, *j*) and (*j*, *i*) entry in the reachability matrix are assigned 1.
- If the (*i*, *j*) entry in the SSIM is O, then both (i, j) and (*j*, *i*) entry in the reachability matrix are assigned. Applying the above rules to the SSIM, an initial reachability matrix is obtained.

From this matrix, a final reachability matrix (Table 2) is constructed, taking into account the transitivity rule, which states that if a variable *A* is related to *B* and *B* is related to *C*, then *A* is necessarily related to *C*.

Table 2. Final reachability matrix (including transitivity)

Crit. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	1^*	0	0	1	1^*	1^*	0	0	1^*	0	0	0	0	0	0	0	1
2	1	1	0	0	1^*	1	1^*	1^*	1^*	0	1	0	1^*	1^*	1^*	0	1^*	0	1^*
3	1	1^*	1	0	0	1^*	0	0	1	0	0	0	0	0	0	0	0	0	1
4	1^*	1	1	1	1	1^*	0	1^*	1^*	0	1^*	1	1^*	1^*	1^*	0	1^*	0	1
5	1	1	1^*	0	1	1	1^*	1	1^*	1^*	1^*	1^*	0	1	1	0	1	0	1^*
6	1^*	1	1^*	0	1^*	1	1	1	1^*	1^*	1^*	1^*	0	0	1^*	1^*	1	0	1
7	1^*	1	1^*	0	1^*	1^*	1	1	1^*	1^*	1^*	1^*	0	0	1	1	0	0	1^*
8	1^*	1	1	1^*	1	1^*	0	1	1	1	1^*	1	1^*	1^*	1^*	0	1^*	1^*	1
9	1	1	1	0	0	1	1^*	1^*	1	0	0	0	0	0	0	0	1^*	0	1
10	1	1	1	1	1	1	1^*	1	1	1	1	1^*	1	1	1	0	1	1	1^*
11	1^*	1^*	1^*	0	1	1	1^*	1	1	1^*	1	1^*	1	1	1	0	1	1^*	1
12	1	1^*	1	0	1^*	1	1^*	1	1^*	1^*	0	1	0	0	0	0	0	0	1
13	1	1	1^*	0	1	1	1	1	1^*	1^*	1	1	1	1^*	1	1^*	1	1	1^*
14	1^*	1^*	1	0	1^*	1^*	1^*	1	1^*	1^*	1	1^*	1^*	1	1	0	1^*	0	1
15	1^*	1	1^*	0	1^*	1	1	1	1^*	0	1^*	1^*	0	0	1	0	1^*	0	1^*
16	1^*	1	1	0	1	1	1^*	1	1	1^*	1	1	1^*	1^*	1^*	1	1	0	1^*
17	1^*	1^*	1	0	1^*	1	1	1	1^*	1^*	0	1	0	0	1^*	1^*	1	1^*	1
18	1^*	1^*	1^*	0	0	1	1	1^*	1	1^*	1^*	0	1	0	1^*	1^*	1^*	1	1^*
19	1^*	0	1	0	0	0	0	0	1^*	0	0	0	0	0	0	0	0	0	1

Values marked with an asterisk (*)are changed due to transitivity.

Aggregated preference indices. $\pi(a, j)$ is obtained from the sum of row values a in the final reachability matrix and similarly $\pi(j, a)$ from the sum of column values a in the final reachability matrix.

Crit. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
$\pi(a, j)$	8	13	6	15	15	15	14	17	9	17	17	11	18	16	13	17	15	15	4	255
$\pi(j, a)$	19	18	18	3	14	18	15	17	18	12	14	12	9	9	14	6	14	6	19	255

Outranking flows

Crit. No.	1	2	3	4	5	6	7	8	9	10
ϕ_a^+	0.421	0.684	0.316	0.789	0.789	0.789	0.737	0.895	0.474	0.895
ϕ_a^-	1.000	0.947	0.947	0.158	0.737	0.947	0.789	0.895	0.947	0.632
Crit. No.	11	12	13	14	15	16	17	18	19	
ϕ_a^+	0.895	0.579	0.947	0.842	0.684	0.895	0.789	0.789	0.211	
ϕ_a^-	0.737	0.632	0.474	0.474	0.737	0.316	0.737	0.316	1.000	

For example, for the first criterion, positive and negative flow is counted as

$$\phi_1^+ = \frac{8}{19} = 0.421, \quad \phi_1^- = \frac{19}{19} = 1$$

Calculation of net and total outranking flows

Crit. No.	1	2	3	4	5	6	7	8	9	10
ϕ_a^n	–0.579	–0.263	–0.632	0.632	0.053	–0.158	–0.053	0.000	–0.474	0.263
ϕ_a^t	1.421	1.632	1.263	0.947	1.526	1.737	1.526	1.789	1.421	1.526
Crit. No.	11	12	13	14	15	16	17	18	19	
ϕ_a^n	0.158	–0.053	0.474	0.368	–0.053	0.579	0.053	0.474	–0.789	
ϕ_a^t	1.632	1.211	1.421	1.316	1.421	1.211	1.526	1.105	1.211	

For example, for the second criterion, net and total flows are counted as

$$\phi_2^n = 0.684 - 0.947 = -0.263, \quad \phi_2^t = 0.684 + 0.947 = 1.632$$

Determination of net current effect

Crit. No.	1	2	3	4	5	6	7	8	9	10
ϕ_a^n	0.474	–0.895	–0.158	–0.474	0.000	0.053	0.053	0.053	0.000	0.526
Rank	3	19	14	18	12.5	10	8	10	12.5	2
I_a^n	0.089	0.005	0.032	0.011	0.039	0.053	0.063	0.053	0.039	0.095
Crit. No.	11	12	13	14	15	16	17	18	19	Total
ϕ_a^n	0.105	0.316	0.158	0.684	0.158	–0.368	–0.316	–0.421	0.053	
Rank	7	4	6	1	5	16	15	17	10	190
I_a^n	0.068	0.084	0.074	0.100	0.079	0.021	0.026	0.016	0.053	1

Considering the amount of net current value for some criteria (such as 5 and 9) are equal, their rank will be derived from the average rank. For example, the weight of overall flow for the third criterion is counted as

$$I_3^n = \frac{19 + 1 - 14}{190} = 0.032$$

Determination of total flow effect

Crit. No.	1	2	3	4	5	6	7	8	9	10
ϕ_a^t	1.421	1.632	1.263	0.947	1.526	1.737	1.526	1.789	1.421	1.526
I_a^t	0.053	0.061	0.047	0.035	0.057	0.065	0.057	0.067	0.053	0.057

Crit. No.	11	12	13	14	15	16	17	18	19	Total
ϕ_a^t	1.632	1.211	1.421	1.316	1.421	1.211	1.526	1.105	1.211	26.842
I_a^t	0.061	0.045	0.053	0.049	0.053	0.045	0.057	0.041	0.045	1

For example, the effect of total flow for the fourth criterion is counted as

$$I_4^t = \frac{\phi_4^t}{\sum_{a=1}^{19} \phi_a^t} = \frac{0.974}{26.841} = 0.035$$

Final weight determination

Crit. No.	1	2	3	4	5	6	7	8	9	10
w_a^n	0.098	0.063	0.063	0.041	0.077	0.091	0.088	0.093	0.073	0.104
w_a	0.065	0.042	0.042	0.027	0.051	0.061	0.059	0.062	0.048	0.069
Crit. No.	11	12	13	14	15	16	17	18	19	Total
w_a^n	0.095	0.087	0.090	0.099	0.092	0.056	0.070	0.049	0.071	1.500
w_a	0.063	0.058	0.060	0.066	0.062	0.037	0.047	0.033	0.048	1.000

For example, final weight for the fifth criterion is counted as:

$$w_5^n = \frac{I_5^n + I_5^t}{2} = \frac{1.526 + 0.057}{2} = 0.077, \quad w_5 = \frac{w_5^n}{\sum_{a=1}^{19} w_a^n} = \frac{0.077}{1.500} = 0.051$$

Partitioning the reachability matrix at different levels. The reachability matrix is partitioned into different levels through successive iterations. For this, the reachability set and the antecedent set of each enabler were found. The reachability set of an enabler consists of itself and all the other enablers which are influenced by it, whereas the antecedent set of an enabler consists of itself and all the enablers which influence it. The intersection of these sets is derived from all the enablers. The enablers for which the reachability set and intersection set are the same, are assigned the topmost level in the hierarchy. In iteration 1 quality (1) and brand value (19) have the same reachability and intersection sets. Hence they will occupy the topmost level in the ISM hierarchy. Once the hierarchy of an individual or a group of criteria is set, they are not considered for analysis in subsequent iterations. Using this procedure, the hierarchy of each criterion has been set. The iterations (1–8) are presented in Table 3.

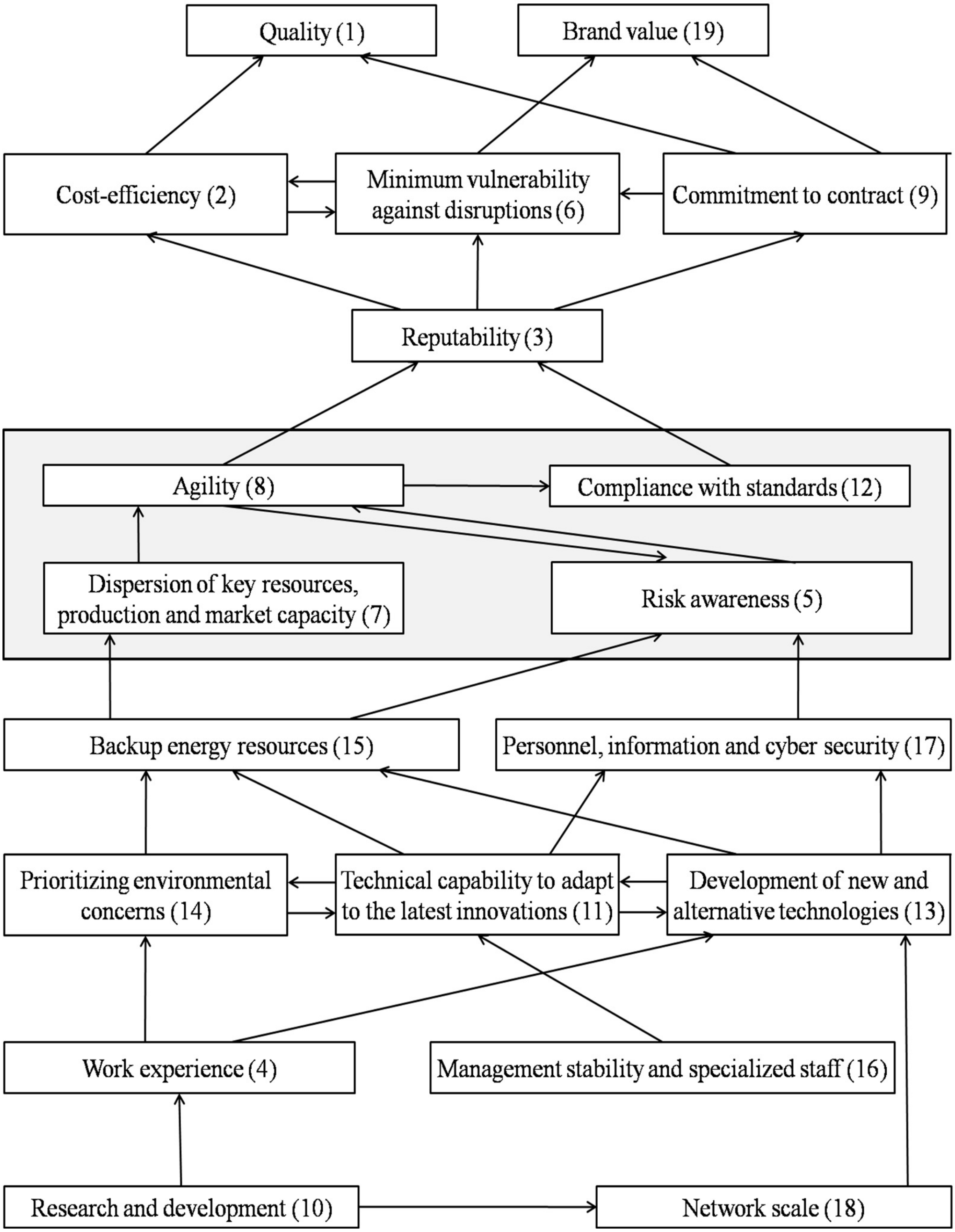

Fig. 2. ISM model of evaluation criteria for resilient IT project supplier selection

Table 3. Iterations 1–8

Crit. No.	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 6, 7, 8, 11, 19	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19	1, 2, 3, 6, 7, 8, 11, 19	I
2	2, 5, 6, 7, 8, 9, 11, 13, 14, 15, 17	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	2, 5, 6, 7, 8, 9, 11, 13, 14, 15, 17	II
3	3	3, 4, 5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18	3	III
4	4	4	4	VII
5	5, 7, 8, 10, 11, 12, 14, 15, 17	4, 5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17	5, 7, 8, 10, 11, 12, 14, 15, 17	IV
6	2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, 17	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, 17	II
7	5, 7, 8, 10, 11, 12, 15, 16	5, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18	5, 7, 10, 11, 12, 15, 16	IV
8	4, 5, 8, 10, 11, 12, 13, 14, 15, 17, 18	4, 5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18	4, 5, 8, 10, 11, 12, 13, 14, 15, 17, 18	IV
9	2, 3, 6, 7, 8, 9, 17	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	2, 3, 6, 7, 8, 9, 17	II
10	10, 18	10, 18	10, 18	VIII
11	10, 11, 13, 14, 18	4, 10, 11, 13, 14, 16, 18	10, 11, 13, 14, 18	VI
12	5, 7, 8, 10, 12	4, 5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17	5, 7, 8, 10, 12	IV
13	10, 11, 13, 14, 16, 18	4, 10, 11, 13, 14, 16, 18	10, 11, 13, 14, 16, 18	VI
14	10, 11, 13, 14	4, 10, 11, 13, 14, 16	10, 11, 13, 14	VI
15	11, 15, 17	4, 10, 11, 13, 14, 15, 16, 17, 18	11, 15, 17	V
16	16	16, 18	16	VII
17	10, 15, 16, 17, 18	4, 10, 11, 13, 14, 15, 16, 17, 18	10, 15, 16, 17, 18	V
18	18	18	18	VIII
19	1, 3, 9, 19	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19	1, 3, 9, 19	I

Developing the ISM model. The ISM model presented in Fig. 2 is constructed by utilizing the final reachability matrix (Table 2) and the hierarchical level of the criteria shown in Table 3. The model demonstrates that for the selection of resilient IT project suppliers, research and development (10) and network scale (18) are undoubtedly the most driving enabler.

5. Conclusion

In recent decades, various methods have been proposed to determine the criteria weight as well as relationships between criteria. Each of these methods alone performs either modelling or obtains criterion weight. Thus, they need a vast amount of data and time to get results that may lead to a contradiction in experts' opinions or different approaches over time. In this paper, an improved method of interpretive structural modelling called SISMW has been proposed for simultaneous modelling and weighting criteria in an MCDM problem. This improved method eliminates the shortcomings of the ISM. The purpose of this method is to maximize decision-making efficiency by providing decision-makers with appropriate information on criteria allowing them to make effective and timely decisions. In this method, in 12 steps, using experts' opinions, effective criteria are extracted, and criteria weights are obtained by examining the effectiveness of the elements on each other. At the same time, the relationship between the factors is modelled following the ISM modelling technique. To validate the proposed model, a numerical example with 19 criteria was used. In the proposed method, unlike other common methods such as AHP and BWM, there is no need to make pairwise comparisons between criteria that confuse experts. Because obtaining criteria for weight and modelling is done with one step of data collection, it can reduce the time required for decision making. This study carries some limitations. Firstly, even though the absolute advantage of the ISM-based approach, the disadvantages of the ISM method limit this study.

Future research may also consider the aspect of simultaneous modelling and weighing in methods such as classical and fuzzy DEMATEL and FTISM. The result obtained by this study through the proposed approach could be compared and analysed with other methods.

The present research has several significant implications for academics and practitioners. The proposed SISMW represents a tool that is capable of being successfully integrated with other MCDM techniques. This method will also help decision-makers to identify the causal relationships between factors as well as their weights simultaneously within a simple process. Thus, The SISMW model developed in this study may provide a more practical tool for the problems faced by decision-makers, academicians, and top managers in different industries.

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