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Diagnosing the Organizational Climate of Junior High Schools in Taiwan:
A Fuzzy DEMATEL-Based ANP Investigation

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ABSTRACT

The study aims to prioritize critical climate components for school improvement. A psychometrically validated instrument named the Chinese "Organizational Climate Diagnostic Instrument for Junior High Schools" (OCDI-JH) was used to diagnose climate factors through expert judgments and fuzzy DEMATEL-based ANP. Results of the study identified the six factors clustered under the two dimensions of 'Safety' (D1) or 'Academic emphasis' (D2) should be given particular attention for school effectiveness. The established climate diagnosis appraisal computed by fuzzy DEMATEL-based ANP can be extended to other school regions for systematically developing school climate based on contextually specific needs and concerns. Future research studies are expected to provide incremental and value-added contributions to the competitive advantages of Taiwan's junior high school education.

KEYWORDS

Diagnostic Instrument, Fuzzy DEMATEL-Based ANP, Multiple Criteria Decision-Making (MCDM), Organizational Health, School Climate

INTRODUCTION

Organizational climate of schools has been a central concern for researchers worldwide, over the past five decades, including Taiwan (Thapa et al., 2013; Hung et al., 2016; Cohen et al., 2009). Ample research efforts have devoted to a primarily linear or unidirectional understanding of school climate's influences on a myriad of demographic and outcome variables, including student characteristics, maladaptive behaviors, academic success, emotional health of students and school faculty, to name a few (Collie et al., 2011; Hoy et al., 2002; Wang & Degal, 2016; Werang, 2018; Yang et al., 2018; Marchante et al., 2022). As in the case of Taiwan, research studies on international large-scale assessments (e.g. PISA, TIMSS) revealed that school climate was identified as an indirect latent variable that positively associated with students' reading and math achievements (Sit et al., 2021;

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Chen et al., 2012). Despite the fact that a positive school climate is pivotal to varying aspects of school accountability and outcomes, a glaring gap exists between research findings on inherent interrelatedness of various school climate components, diagnosis mechanisms to detect mutual influence of components based on contextually specific educational practices and outcomes are grossly inadequate (Raudenbush et al., 1991; Thapa et al., 2013; Wong & Siu, 2016). Assessing and improving school climate is an enduring criterion for sustaining the reform efforts (Chen,2020). Hence, the aim of the study is to estimate priority climate factors for enhancing healthy organizational climate of junior high schools in Taoyuan City of Taiwan.

Regarding the methodological aspect of the research design, fuzzy logic, in particular, is applied to tackle the ambiguities and vagueness involved in the process of quantifying linguistic information across various parameters (Janáček, 2015; Mardani et al., 2015; Ishizaka et al., 2020; Gadekar et al., 2022). DEMATEL technique is adopted subsequently to form a structural model depicting intertwined factors or causal relationship among factors. The ANP technique, thus, is able to deal with possible mutual relationships of interdependent factors and determine priority factors that are of more fundamental importance to the whole fuzzy DEMATEL-based ANP modeling process in an attempt to diagnose casual impacts among school climate dimensions, their associate criteria and identifying key influential factors for sustainable school development (e.g. Kuan & Chen, 2014; Tavana et al., 2015; Hu, & Tzeng, 2019; Mavi & Standing, 2018). The school climate diagnostic appraisal evaluated by fuzzy DEMATEL ANP proposed by the present study is one of the pioneer attempts in the educational literature to construct contextually specific strategies for school improvements by MCDM techniques.

LITERATURE REVIEW

The literature review is organized as follows: First, the development and psychometric validation of "Organizational Climate Diagnostic Instrument for Junior High Schools" (OCDI-JH) in Chinese language used in Taiwan (Tang & Lee, 2021), DEMATEL-based ANP, namely a hybrid Multiple Criteria Decision Making (MCDM) approach to detect independent/dependent, reciprocal, interdependent or inner-dependent correlations among factors of the system under investigation.

Organizational Climate Diagnostic Instrument for Junior High Schools (OCDI-JH)

To mirror the complexity of school climate, a sizable models together with a wide array of climate attributes have been established over the past 50 years to address specific research-driven or practical needs for measuring the perceived goodness and well-being of school climate (Schneider et al., 2013; Schneider et al., 2017). Building upon an evolving body of generic reviews of research literature on components of school climate, the Chinese version of "Organizational Climate Diagnostic Instrument for Junior High Schools" (OCDI-JH) in the study were initially based on a confluence of 30 climate factors clustered in a five-dimensional model generated from three current reviews of school climate construct, as displayed in the left column of Table 1 (Thapa et al., 2013; Wang & Degol 2016; Zullig et al., 2010). After a standardized translation procedure into the Chinese language, expert panel reviews, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA) were performed on two separate samples in a prior study to validate the removal of 8 items from the a priori 30 factorial framework (Tang & Lee, 2021). The psychometrically validated OCDI-JH construct was formulated into five dimensions, including a total of 22 factors (criteria). The five school climate dimensions are *Safety* (D^1) with 3 items (criteria); *Academic* (D^2) with 3 items (criteria); *Relationships* (D^3) with 7 items (criteria); *Institutional environment* (D^4) with 5 items (criteria), and *Leadership* (D^5) with 4 items (criteria), as displayed on the right column of Table 1.

Table 1. The initial and validated school climate diagnostic frameworks

Dimensions	Factors (initial)	Factors (psychometrically validated)
Safety **(D[1])**	*C^1 = Physical safety* *C^2 =Social/emotional safety* *C^3 =Rules & Norms*	*C^1 = Physical safety* *C^2 =Social/emotional safety* *C^3 =Rules & Norms*
Academic **(D[2])**	*C^4 = Quality of instruction* *C^5 = Social, emotional and ethical learning* *C^6 = Professional development* *C^7=Academic emphasis* *C^8 =Orientation to change*	*C^4 = Quality of instruction* *C^5 = Social, emotional and ethical learning* *C^6 = Professional development*
Relationships **(D[3])**	*C^9= Respect for diversity* *C^{10}= Partnership* *C^{11}= Morale and connectedness* *C^{12}=Teacher-student relationships* *C^{13}= Overall relationship* *C^{14} =Openness in communication* *C^{15}=Role clarity* *C^{16}= Overall relationship*	*C^7= Orientation to change* *C^8 = Respect for diversity* *C^9 =Openness in communication/ decision-making* *C^{10}= Morale and connectedness* *C^{11}=Teacher-student relationships* *C^{12}= Overall relationship* *C^{13}= Shared responsibilities*
Institutional environment **(D[4])**	*C^{17}= Environmental* *C^{18}= Structural organization* *C^{19}= Resource support* *C^{20}=Financial incentives* *C^{21}=Appraisal and recognition* *C^{22}=Institutional integrity*	*C^{14}= Environmental* *C^{15}= Structural organization* *C^{16}= Resource support* *C^{17}=Financial incentives* *C^{18}= Shared vision*
Leadership **(D[5])**	*C^{23}= Shared vision* *C^{24} = Participative decision-making* *C^{25} = Principal influence* *C^{26} = Intellectual stimulation* *C^{27}= Consideration* *C^{28} = Modeling behavior* *C^{29}=Morale* *C^{30}=Instructional leadership*	*C^{19} = Principal influence* *C^{20} = Intellectual stimulation* *C^{21}= Consideration* *C^{22} = Modeling behavior*

The Application of Fuzzy DEMATEL-Based ANP to Educational and Organizational Research

Decision-Making Trial and Evaluation Laboratory (DEMATEL), legitimately considered as an effective MCDM technique, allowing for visualizing impact-relation map (IRM) among factors within a target system in network formats, detecting casual or maybe non-casual relationships, and approximating compound effects and relative importance across factors for quality decision making (Kabak, 2013; Si et al., 2018). The ostensible advantage of DEMATEL technique lies in its arithmetic capability through graph theory and matrix tool for confirming the stability of a network structure and the influence degrees among factors of a target system involved with complex components. Nevertheless, there are a number of inherent drawbacks in DEMATEL applications. First, inconsistencies of factor prioritization are based on diverse parameters, including influence degrees, affected degrees, centrality degrees and cause degrees. Second, the impact-relation map is in a certain sense restrained by the mechanism of approximating interdependence degrees and directions of influences among dimensions and criteria. The synthesized effects and comparative importance across dimensions/criteria, however, cannot be resolved by DEMATEL solely (Kuan & Chen, 2014). As improvement efforts in MCDM techniques, a wide array of meta-heuristics have been incorporated into DEMATEL, including AHP, ANP, fuzzy set theory, Maximum Mean De-Entropy Algorithm (MMDE), VIKOR, grey relational analysis, TOPSIS, interpretative structural modeling method (ISM) and system dynamics (SD), aiming at quantifying weights of interactions among alternatives, dimensions and criteria, so as to depict intertwined correlations and interdependences among factors in MCDM studies (Chen et al., 2012; Mardani et al., 2015; Li et al., 2015; Ng & Zhang, 2016; Mostamand et al., 2017; Chen et al., 2013). In summary, DEMATEL and ANP, when combined, offer a unique advantage in handling complex decision problems by identifying interdependencies and impact-relations among criteria and then leveraging this information for decision-making. Other methods like AHP, TOPSIS, ISM, MMDE and VIKOR focus on different aspects of decision analysis and may not explicitly address interdependencies among criteria as comprehensively as DEMATEL-ANP. The choice of DEMATEL and ANP in the present study emphasizes identifying impact relationships among criteria and then leveraging ANP for considering both internal and external dependencies among criteria by structuring the decision problem as a visualized network (Chakraborty et al., 2023; Zayat et al., 2023).

With regard to "payoffs of triangular fuzzy numbers", it refers to a concept widely used in game theory and decision-making under uncertainty (Li & Liu, 2014; Li, 2013). In cases where the exact mathematic values yielded from DEMATEL survey based on the OCDI-JH framework is with inherent vagueness and uncertainties, the payoffs of triangular fuzzy numbers is therefore integrated into the decision-making modelling, where the range of potential survey outcomes are transformed into three points: the minimum possible value, the most likely value, and the maximum possible value in order to make more informed decisions under conditions of uncertainty by considering all possible values and their likelihoods for more nuanced and realistic representation (Li, 2012). The adoption of fuzzy DEMATEL-based ANP in the present study aims to at first tackle the vagueness and uncertainties of human thoughts (Zadeh 1983), followed by DEMATEL to convert the influence degrees of each component over others within its dimension and the whole system, to gauge independences, interdependences or inner dependences among components, and to quantify components into an impact-relation map in a network format. ANP thereafter is used to compensate for fuzzy DEMATEL's incapability in resembling weights of distinct components into the given hierarchical framework. The impact-relation map is then finalized into a steady-state supermatrix for overall prioritizations of components in a given decision-making context (Çelikbilek and Adıgüzel, 2019; Tüylü Shen & Liu, 2012). As noted earlier, hybrid meta-heuristic to permit scenario-based strategic plans has received widespread attention in various fields of MCDM investigations, including selecting applicants for a specific job position (Kabak et al., 2014), fostering the use of internal cloud services in a university (Wu et al., 2013), evaluating alternative improvement plans for e-learning system (Çelikbilek & Adıgüzel Tüylü, 2019), diagnosing leadership competences (Mirhosseini et al., 2020), identifying key performance evaluation criteria for enhancing customer satisfaction (Pan & Nguyen, 2015), to name a few.

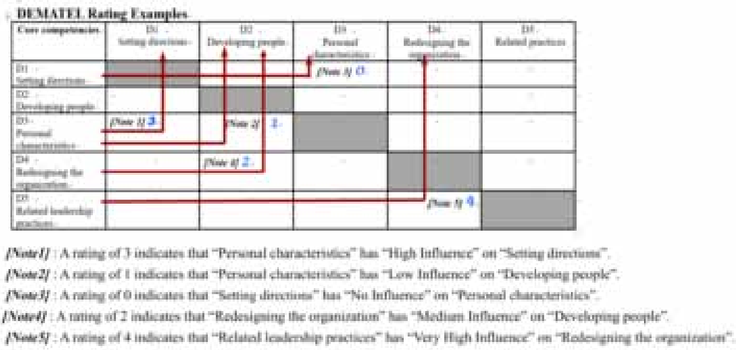
METHODOLOGY

Fuzzy DEMATEL-based modeling procedure consists of 3 general phases: (1) expert panelists and sample selections; (2) fuzzy DEMATEL instrumentation; (3) fuzzy DEMATEL-based ANP analysis.

Expert Panelists Selections

Participants, considered as expert panelists, were certified as seed trainees by the National 12-year Basic Education Seed Program co-organized by Taiwan's K- Education Administration, National Taiwan Normal University and Ming Chuan University, including 8 junior school principals, 5 scholars in the field of educational leadership/management, 8 experienced junior high school administrators and teachers, as well as 2 MCDM experts. Other criteria for inclusion were: (1) aged 30 or above, (2) a minimum of 5-year administrative and teaching experience in Taoyuan City, Taiwan, (3) the

Figure 1. DEMATEL pairwise comparisons at the dimensional level and scale measure



5 scholars in educational leadership/management and 2 MCDM experts are university professors from Northern Taiwan and with reputations and expertise in their areas of studies (Green, 2013; Novakowski & Wellar, 2009). A total of 23 panelists were selected representing each stakeholder group to participate in the OCDI-JH survey in DEMATEL format, allowing for harmonized responses offered by multiple stakeholder groups with possible characteristic heterogeneity by mathematical aggregation in consensus decision making.

DEMATEL Instrumentation

A DEMATEL survey based on the OCDI-JH framework was issued to determine the most important climate factors and measure the relationship among them via fuzzy DEMATEL modeling. A 5-point scale scheme ranging from 0 to 4 are applied for iteration of pair-wise judgments: 0—No influence; 1—Low influence; 2—Medium influence; 3—High influence; 4—Very high influence (Fontela & Gabus 1974; Si et al., 2018). An illustrative example on the dimensional level of the DEMATEL survey was given in Figure 1.

Fuzzy DEMATEL-Based ANP Analysis: A Modeling Study on Taiwan Junior High Schools

Fuzzy DEMATEL-based ANP elicitation process consists of three phases: The first phase is DEMATEL instrumentation, the remaining 2 phases were presented below alongside the results of the DEMATEL-based ANP computations.

Phase 1: Building the Impact-Relation Network by Fuzzy DEMATEL

The fuzzy D EMATEL modeling and computation consists of four steps summarized below (Çelikbilek & Adıgüzel Tüylü, 2019; Shen & Liu, 2012).

Step 1: Formulating the direct-influence matrix based on the fuzzy DENATEL:

In order to take the imprecision and vagueness of human expressive assessments into consideration, the triangular fuzzy numbers are defined with the membership function of triangular fuzzy numbers on linguistic variables as shown in Figure 2 and Table 2. Each participant was asked to make pair-wise comparisons between sets of factors demonstrated by $F = \left\{ F_i \middle| i = 1, 2, \ldots, n \right\}$. An initial direct relation/influence matrix $\tilde{Z}^k$ representing participant k's response was produced, as illustrated in equation (1) below:

Figure 2. The membership function of triangular fuzzy numbers on linguistic variables

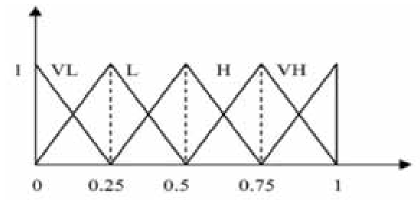


Table 2. Triangular fuzzy linguistic scales

Linguistic variables	Corresponding triangular fuzzy numbers
no influence (0)	(0, 0, 0.25)
very low influence (1)	(0, 0.25, 0.5)
low influence (2)	(0.25, 0.5, 0.75)
high influence (3)	(0.5, 0.75, 1)
extremely high influence (4)	(0.75, 1, 1)

$$\tilde{Z}^k = \begin{bmatrix} 0 & \tilde{Z}_{12}^{(k)} & \cdots & \tilde{Z}_{1n}^{(k)} \\ \tilde{Z}_{21}^{(k)} & 0 & \cdots & \tilde{Z}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{Z}_{n1}^{(k)} & \tilde{Z}_{n2}^{(k)} & \cdots & 0 \end{bmatrix}; k = 1, 2, \ldots, p \quad (1)$$

$$\tilde{Z}_{ij}^k = \left(l_{ij}^k, m_{ij}^k, r_{ij}^k \right)$$

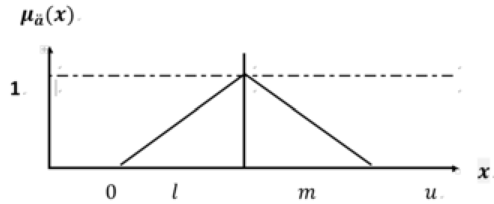
Since each expert was given a 5x5 and a 22x22 direct influence matrix ***T*** for pairwise comparisons within a linguistic/fuzzy scale measurement mechanism, the 1st expert's fuzzy direct influence matrix $\tilde{Z}^{D1}$ at the dimensional level is shown as an illustrative matrix in Table 3.

Zadeh (1983) proposed that in accordance with the characteristics of triangular fuzzy numbers and the extension principle, the operational laws of triangular fuzzy numbers, $\tilde{A} = (l_1, m_1, r_1)$ and $\tilde{B} = (l_2, m_2, r_2)$ are presented as follow:

Table 3. Fuzzy direct influence matrix at the dimensional level $\tilde{Z}^{D1}$ exemplified by the 1st expert

	D1	***D2***	***D3***	***D4***	***D5***
D1	0	(0.75, 1, 1)	(0.25, 0.5, 0.75)	(0.75, 1, 1)	(0.25, 0.5, 0.75)
D2	(0, 0.25, 0.5)	0	(0, 0, 0.25)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)
D3	(0.75, 1, 1)	(0.25, 0.5, 0.75)	0	(0, 0, 0.25)	(0.5, 0.75, 1)
D4	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	0	(0.75, 1, 1)
D5	(0.5, 0.75, 1)	(0, 0.25, 0.5)	(0, 0.25, 0.5)	(0, 0.25, 0.5)	0

Figure 3. Membership functions of triangular fuzzy numbers



(1) Addition of two fuzzy numbers:

$$(l_1, m_1, r_1) \oplus (l_2, m_2, r_2) = (l_1 + l_2, m_1 + m_2, r_1 + r_2)$$

(2) Subtraction of two fuzzy numbers:

$$(l_1, m_1, r_1) \Theta (l_2, m_2, r_2) = (l_1 - r_2, m_1 - m_2, r_1 - l_2)$$

(3) Multiplication of two fuzzy numbers:

$$(l_1, m_1, r_1) \otimes (l_2, m_2, r_2) \cong (l_1 l_2, m_1 m_2, r_1 r_2)$$

(4) Division of two fuzzy numbers:

$$(l_1, m_1, r_1) \varnothing (l_2, m_2, r_2) \cong (l_1 / r_2, m_1 / m_2, r_1 / l_2)$$

Fuzzy numbers denote a gradation of membership within a fuzzy subset, spanning from 0 to 1. And a on R represents a triangular fuzzy number whereas its membership function $\mu_{\tilde{\alpha}}$: R →[0,1] can also be processed in figure 3.

Wherein, l and μ, respectively, represent the lower and upper bounds of the fuzzy number $\tilde{a}$, and m as the modal value, as shown in Figure 4.

To convert the fuzzy value into the crisp value, the normalization and crisping for factor D1 to D2 were computed as an illustrative example. A fuzzy linguistic scale of (0, 0.25, 0.50) is currently assigned for this comparison by expert 1. Initially, it indicates that expert1 believes factor D1 has a Very low influence on factor D2. Table 4 presented the defuzzified crisp values of matrix *A*.

$$xr_{12}^{1} = \frac{0.5 - 0}{1} = 0.5$$

$$xm_{12}^{1} = \frac{0.25 - 0}{1} = 0.25$$

$$xl_{12}^{1} = \frac{0 - 0}{1} = 0$$

Table 4. Defuzzified crisp values of direct influence matrix A for dimensions

	D1	D2	D3	D4	D5
D1	0.00	0.35	0.41	0.12	0.33
D2	0.27	0.00	0.37	0.21	0.21
D3	0.25	0.32	0.00	0.29	0.37
D4	0.43	0.41	0.33	0.00	0.25
D5	0.35	0.33	0.27	0.33	0.00

$$xrs_{12}^{1} = \frac{0.5}{[1+0.5-0.25]} = 0.4$$

$$xls_{12}^{1} = \frac{0.25}{[1+0.25-0]} = 0.2$$

$$x_{12}^{1} = \frac{\left[0.2\left(1-0.2\right)+\left(0.4\times 0.4\right)\right]}{\left[1-0.2+0.4\right]} = 0.26$$

Based on the direct-influence matrix, denoted as A, the normalized direct-relation matrix can be acquired through equation (2) as follows:

$$\text{X} = {}^{A}\!/_{s} \tag{2}$$

$$s = \max\left\{ {}_{1\le i\le n}^{max} \sum\nolimits_{j=0}^{n} a_{ij}, {}_{1\le j\le n}^{max} \sum\nolimits_{i=0}^{n} a_{ij} \right\}$$

The direct-influence, normalized direct-influence matrices on the dimension level were presented in Tables 5 for illustration purpose.

Step 2: Obtaining the total-influence matrix.

Table 5. The direct-influence, normalized direct-influence matrix and total-influence matrices for dimensions

	Direct-Influence Matrix						Normalized Direct-Influence Matrix						Total-Influence Matrix				
	D_1	D_2	D_3	D_4	D_5		D_1	D_2	D_3	D_4	D_5		D_1	D_2	D_3	D_4	D_5
D_1	0.00	0.35	0.41	0.12	0.33	D_1	0.00	0.25	0.29	0.09	0.23	D_1	0.10	0.10	0.10	0.08	0.09
D_2	0.27	0.00	0.37	0.21	0.21	D_2	0.19	0.00	0.26	0.14	0.14	D_2	0.09	0.09	0.09	0.07	0.08
D_3	0.25	0.32	0.00	0.29	0.37	D_3	0.17	0.22	0.00	0.20	0.26	D_3	0.10	0.11	0.11	0.08	0.09
D_4	0.43	0.41	0.33	0.00	0.25	D_4	0.30	0.29	0.23	0.00	0.17	D_4	0.11	0.12	0.12	0.09	0.10
D_5	0.35	0.33	0.27	0.33	0.00	D_5	0.25	0.23	0.19	0.23	0.00	D_5	0.10	0.11	0.11	0.08	0.10

Based on the normalized direct-influence fuzzy matrix $\tilde{D}$, the full direct/indirect influence matrix $\tilde{T}$ can be derived from equation (3), where I refers to the identity matrix.

$$\tilde{T} = \tilde{D} + \tilde{D}^2 + \tilde{D}^3 + \cdots\cdots + \tilde{D}^{\varnothing}$$
$$= \tilde{D}\left(I + \tilde{D} + \tilde{D}^2 + \cdots\cdots + \tilde{D}^{\varnothing-1}\right)\left[\left(I - D\right)\left(I - D\right)^{-1}\right]$$
$$= \tilde{D}\left(I - \tilde{D}^{\varnothing}\right)\left(I - \tilde{D}\right)^{-1}$$

followed by:

$$\tilde{T} = \tilde{D}\left(I - \tilde{D}\right)^{-1}, \text{when } \varnothing \to \infty,\ \tilde{D}^{\varnothing} = \left[0\right]_{n\times n}$$

$$\tilde{D} = \left[\tilde{d}_{ij}\right]_{n\times n} = d_{ij}^{l}, d_{ij}^{m},\ d_{ijn\times n}^{h}, 0 \le \tilde{d}_{ij} < 1, 0 < \sum_{j=1}^{n} d_{ij}^{h} \le 1, 0 < \sum_{i=1}^{n} d_{ij}^{h} \le 1 \tag{3}$$

The sum value of 1 in at least one row or column of the total-influence fuzzy matrix is prerequisite to ensure the convergence of $\lim_{\phi\to\infty} D^{\phi} = \left[0\right]_{n\times n}$ for structuring the total influence fuzzy matrix $\tilde{T} = \left[\tilde{t}_{ij}\right]$.

Step 3: Plotting the impact-relations map (IRM).

The sums of rows $\sum_{i=1}^{n} \tilde{t}_{ij} = \tilde{t}_{i}$ and columns $\sum_{i=1}^{n} \tilde{t}_{ij} = \tilde{t}_{j}$ are presented in separate fuzzy vectors $\tilde{r} = \left(\tilde{r}_{1},\ldots,\tilde{r}_{i},\ldots\tilde{r}_{n}\right)$ and $\tilde{c} = \left(\tilde{c}_{1},\ldots,\tilde{c}_{i},\ldots\tilde{c}_{n}\right)$ computed by equations (4), (5) and (6), as displayed follow:

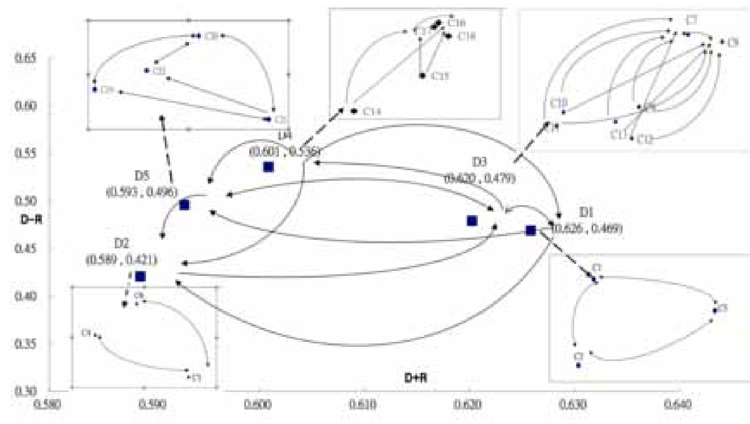
$$\tilde{T} = \left[\tilde{t}\right]_{n\times n}, i, j = 1, 2, \ldots, n \tag{4}$$

$$\tilde{r} = \left[\sum\nolimits_{j=1}^{n} \tilde{t}\right]_{n\times 1}^{'} = \left[\tilde{t}\right]_{n\times 1} = \left(\tilde{r}_{1},\ldots,\tilde{r}_{i},\ldots\tilde{r}_{n}\right)^{'} \tag{5}$$

$$\tilde{c} = \left[\sum\nolimits_{j=1}^{n} \tilde{t}\right]_{n\times 1}^{'} = \left[\tilde{t}\right]_{n\times 1} = \left(\tilde{c}_{1},\ldots,\tilde{c}_{i},\ldots\tilde{c}_{n}\right)^{'} \tag{6}$$

The next step is to determine a threshold value which allows for filtering out some negligible effects in matrix $\tilde{T}$ depicting the full direct/indirect influences of factors on the decision scenario under investigation. More explicitly stated, factors whose influence degree in matrix $\tilde{T}$ exceeds the threshold value should be chosen and converted into a casual diagram, referring to as "the impact-relations map" (IRM). Factors, on the other hand, whose influence degree in matrix T

Figure 4. The impact-relation map (IRM) in the net format



is lower than the threshold value are removed as unwanted factors to be graphed in the IRM (Li & Tzeng, 2009). Several methods have been proposed to identify a threshold value in DEMATEL applications, such as a specific value assigned by expert panelists, computed by the arithmetic mean, and the maximum mean de-entropy algorithm (Chiu et al., 2013). To simplify the computation and avoid subjectivity in the decision making, the study computed a threshold value p by arithmetic mean of matrix factors. Prior to plotting the final IRM, the threshold value is identified to reduce the complexity of the final IRM.

Let $j = i$, the sum ($\tilde{r}_j + \tilde{c}_j$), referring to as the "centrality degree", represents the variation in the total relations being affected by or affecting others, or the strength of connection or the degree of influence that factor i has with the other factors (total sum of effects dispatched and received). On the other hand, the ($\tilde{r}_j - \tilde{c}_j$), denoting the "cause degree", is computed by subtracting r_i from c_j, categorizing factors into a cause group and an effect group. When the value of ($\tilde{r}_j - \tilde{c}_j$) is positive, factor i is categorized into the cause group, also termed as "a net dispatcher"; whereas the value of ($\tilde{r}_j - \tilde{c}_j$), is negative, factor i is placed into the effect group, known as "a net receiver" (Chang et al., 2011; Chen et al., 2012; Kuan & Chen 2014). The extent to which a factor affects or is affected by others is mapped into the IRM. To convert the complex factor-level total-relation map into a simplified visualized structure, geometric means of the influence degrees and affected degrees are computed to plot the factors into four quadrants of "high centrality degree and high cause degree", "high centrality degree and low cause degree", "low centrality degree and high cause degree" and "low centrality degree and low cause degree". Factors grouped into the quadrants of "high centrality degree and high cause degree" should be focused for maximizing the decision-making quality (Kuan & Chen, 2014; Wu et al., 2013). The IRM in its net format was plotted in Figure 4.

Step 4: Determining a threshold value and creating the total impact-relations map (IRM).

By synthesizing the 23 panelists' judgments, a threshold value $p = 0.096$ at the dimension level and $p = 0.234$ at the factor level was acquired by arithmetic mean of T matrix numbers. If the effects of dimensions and factors in matrix T exceed the threshold value, they should be plotted with arrows in a casual diagram to form 'the impact-relations map'. If the effect of dimensions and factors in matrix T is lower than the threshold value, they dispatch minor influence on other dimensions/factors, as shown in Figure 4 (Li & Tzeng, 2009; Wu et al., 2013).

The utilization of ANP, as a follow-up procedure of DEMATEL, aimed to merge the dimension-level influence into their corresponding factors in the form of a supermatrix for a holistic prioritization of climate factors within the given decision-making system (Yan et al., 2015).

Phase 2: Estimating the Priority Weights by ANP

Step 1: The unweighted supermatrix is then built by normalizing each level with total degree of effect yielded by the total relation matrix $\tilde{T}$ provided by fuzzy DEMATEL, as can be seen in equation (7):

$$\tilde{T}_c = \begin{array}{c} D_1 \\ \vdots \\ \vdots \\ D_2 \\ \vdots \\ \vdots \\ D_3 \end{array} \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_j} \\ \vdots \\ c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_j} \\ \vdots \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \overset{\begin{array}{ccccc} D_1 & \cdots & D_1 & \cdots & D_1 \\ c_{11}\cdots c_{1m_j} & \cdots & c_{j1}\cdots c_{jm_j} & \cdots & c_{n1}\cdots c_{nm_n} \end{array}}{\begin{bmatrix} \tilde{T}_c^{11} & \cdots & \tilde{T}_c^{1j} & \cdots & \tilde{T}_c^{1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{T}_c^{i1} & \cdots & \tilde{T}_c^{ij} & \cdots & \tilde{T}_c^{in} \\ \vdots & & \vdots & & \vdots \\ \tilde{T}_c^{n1} & \cdots & \tilde{T}_c^{nj} & \cdots & \tilde{T}_c^{nm} \end{bmatrix}} = \left(T_c^1, T_c^m, T_c^h\right) \qquad (7)$$

A newly formed matrix, tagged $\tilde{T}_c^a$ below in equation (8), is created by normalizing the supermatrix $\tilde{T}_c$ for the ANP first-level factor weights on the total relation matrix $\tilde{T}$.

$$\tilde{T}_c^a = \begin{array}{c} D_1 \\ \vdots \\ \vdots \\ D_2 \\ \vdots \\ \vdots \\ D_3 \end{array} \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_j} \\ \vdots \\ c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_j} \\ \vdots \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \overset{\begin{array}{ccccc} D_1 & \cdots & D_1 & \cdots & D_1 \\ c_{11}\cdots c_{1m_j} & \cdots & c_{j1}\cdots c_{jm_j} & \cdots & c_{n1}\cdots c_{nm_n} \end{array}}{\begin{bmatrix} \tilde{T}_c^{a11} & \cdots & \tilde{T}_c^{a1j} & \cdots & \tilde{T}_c^{a1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{T}_c^{ai1} & \cdots & \tilde{T}_c^{aij} & \cdots & \tilde{T}_c^{ain} \\ \vdots & & \vdots & & \vdots \\ \tilde{T}_c^{an1} & \cdots & \tilde{T}_c^{anj} & \cdots & \widetilde{Ta}_c^{nn} \end{bmatrix}} = \left(T_c^{a1}, T_c^{am}, T_c^{ah}\right) \qquad (8)$$

By transposing the normalized total relation matrix $\tilde{T}_c^a$ into the first-level factors, an unweighted supermatrix is formed as shown in equation (9):

$$W^{\alpha l} = T_D^{\alpha l} W^l = \begin{bmatrix} t_D^{\alpha 11} \times W^{11l} & \cdots & t_D^{\alpha i11} \times W^{i1l} & \cdots & t_D^{\alpha n11} \times W^{n1l} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1j1} \times W^{1jl} & \cdots & t_D^{\alpha ij1} \times W^{ij1} & \cdots & t_D^{\alpha nj1} \times W^{njl} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1n1} \times W^{1nl} & \cdots & t_D^{\alpha in1} \times W^{inl} & \cdots & t_D^{\alpha nn1} \times W^{nnl} \end{bmatrix} \tag{9}$$

An unweighted supermatrix $W = (T_D^a)$ is then formulated by transposing the normalized total relation matrix T_c^α by dimensions through equation (10), as shown in Table 6.

$$W = \begin{matrix} & & \begin{matrix} D_1 & D_2 & & D_n \\ c_{11} \cdots c_{1m_1} & c_{21} \cdots c_{2m_2} & & c_{n1} \cdots c_{nm_n} \end{matrix} \\ \begin{matrix} D_1 \\ \\ D_2 \\ \vdots \\ D_n \end{matrix} & \begin{matrix} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \\ c_{21} \\ c_{22} \\ \vdots \\ c_{2m_2} \\ \vdots \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{matrix} & \begin{bmatrix} W^{11} & W^{12} & \cdots & W^{1n} \\ W^{21} & W^{22} & \cdots & W^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ W^{n1} & W^{n2} & \cdots & W^{nn} \end{bmatrix} \end{matrix} \tag{10}$$

Step 2: The weighted supermatrix of each dimension referring to as $\tilde{T}_D$ is obtained by equation (11).

Normalization of each dimension of matrix $\tilde{T}_D$ with total degree of influence to structure a new normalized matrix $\tilde{T}_D^{al}$ can be obtained by equation (12) as follows and presented in Table 7:

$$\tilde{T}_D = \begin{bmatrix} \tilde{t}_D^{11} & \cdots & \tilde{t}_D^{1j} & \cdots & \tilde{t}_D^{1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{t}_D^{i1} & \cdots & \tilde{t}_D^{ij} & \cdots & \tilde{t}_D^{in} \\ \vdots & & \vdots & & \vdots \\ \tilde{t}_D^{n1} & \cdots & \tilde{t}_D^{nj} & \cdots & \tilde{t}_D^{nn} \end{bmatrix} = \left(T_D^l,\ T_D^m,\ T_D^h\right) \tag{11}$$

Table 6. The total-influence matrix for criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	0.222	0.260	0.297	0.248	0.307	0.266	0.251	0.290	0.270	0.230	0.248	0.277	0.259	0.239	0.235	0.243	0.239	0.244	0.249	0.240	0.240	0.241
C2	0.247	0.216	0.293	0.225	0.272	0.257	0.245	0.258	0.236	0.198	0.203	0.254	0.252	0.228	0.258	0.228	0.222	0.239	0.236	0.230	0.242	0.221
C3	0.274	0.298	0.274	0.264	0.320	0.295	0.276	0.312	0.299	0.249	0.246	0.313	0.278	0.262	0.288	0.257	0.254	0.282	0.258	0.256	0.282	0.270
C4	0.245	0.231	0.270	0.172	0.248	0.192	0.204	0.241	0.234	0.212	0.177	0.238	0.248	0.187	0.219	0.197	0.197	0.218	0.212	0.199	0.227	0.202
C5	0.274	0.275	0.305	0.248	0.260	0.259	0.267	0.281	0.283	0.248	0.231	0.300	0.275	0.254	0.279	0.255	0.248	0.267	0.254	0.251	0.272	0.249
C6	0.258	0.267	0.282	0.196	0.298	0.209	0.220	0.270	0.256	0.226	0.229	0.280	0.243	0.240	0.235	0.215	0.224	0.244	0.237	0.222	0.254	0.231
C7	0.264	0.284	0.304	0.214	0.304	0.237	0.214	0.273	0.262	0.237	0.234	0.277	0.258	0.257	0.271	0.217	0.235	0.261	0.242	0.231	0.267	0.246
C8	0.287	0.291	0.321	0.269	0.312	0.274	0.252	0.244	0.275	0.241	0.238	0.294	0.278	0.257	0.269	0.241	0.249	0.254	0.244	0.255	0.276	0.258
C9	0.220	0.226	0.259	0.203	0.250	0.223	0.192	0.199	0.172	0.158	0.166	0.206	0.195	0.174	0.186	0.174	0.180	0.188	0.173	0.172	0.189	0.177
C10	0.171	0.164	0.191	0.151	0.179	0.160	0.151	0.173	0.154	0.116	0.133	0.168	0.165	0.149	0.163	0.138	0.138	0.147	0.139	0.139	0.158	0.149
C11	0.154	0.155	0.164	0.116	0.157	0.150	0.150	0.154	0.148	0.120	0.111	0.152	0.156	0.141	0.157	0.144	0.136	0.142	0.137	0.135	0.142	0.149
C12	0.186	0.190	0.201	0.167	0.206	0.174	0.183	0.193	0.177	0.157	0.149	0.162	0.184	0.172	0.182	0.168	0.165	0.171	0.170	0.164	0.176	0.165
C13	0.177	0.191	0.198	0.165	0.205	0.183	0.181	0.190	0.189	0.149	0.170	0.195	0.151	0.168	0.184	0.166	0.161	0.172	0.166	0.160	0.178	0.165
C14	0.164	0.169	0.183	0.142	0.193	0.176	0.169	0.177	0.170	0.155	0.163	0.183	0.163	0.131	0.168	0.152	0.148	0.161	0.157	0.153	0.172	0.157
C15	0.221	0.232	0.253	0.201	0.259	0.218	0.226	0.244	0.208	0.218	0.218	0.257	0.253	0.220	0.200	0.207	0.221	0.246	0.240	0.223	0.242	0.229
C16	0.278	0.301	0.326	0.247	0.322	0.276	0.276	0.293	0.298	0.254	0.254	0.298	0.273	0.259	0.277	0.212	0.252	0.266	0.261	0.256	0.280	0.261
C17	0.281	0.292	0.295	0.251	0.306	0.264	0.276	0.292	0.282	0.235	0.248	0.299	0.260	0.251	0.289	0.251	0.208	0.262	0.265	0.257	0.280	0.256
C18	0.286	0.290	0.307	0.267	0.315	0.271	0.271	0.291	0.279	0.230	0.253	0.299	0.278	0.258	0.294	0.256	0.249	0.225	0.256	0.251	0.279	0.256
C19	0.283	0.293	0.310	0.248	0.305	0.275	0.264	0.289	0.269	0.217	0.253	0.282	0.253	0.250	0.276	0.249	0.241	0.247	0.211	0.245	0.264	0.249
C20	0.285	0.306	0.330	0.249	0.344	0.277	0.286	0.308	0.308	0.257	0.247	0.304	0.278	0.257	0.283	0.252	0.260	0.277	0.266	0.218	0.281	0.259
C21	0.268	0.272	0.324	0.258	0.311	0.284	0.282	0.288	0.291	0.229	0.229	0.274	0.264	0.252	0.277	0.248	0.246	0.260	0.259	0.246	0.228	0.248
C22	0.264	0.287	0.322	0.248	0.301	0.282	0.276	0.296	0.282	0.235	0.244	0.292	0.279	0.261	0.282	0.248	0.247	0.274	0.245	0.258	0.281	0.214

Table 7. The normalized dimension matrix T_D^{α} and unweighted supermatrix for dimensions $W=(T_D^{a})$

Normalized Dimension Matrix						Unweighted Supermatrix For Dimensions					
T_D^{α}	***D1***	***D2***	***D3***	***D4***	***D5***	$W=(T_D^{a})'$	***D1***	***D2***	***D3***	***D4***	***D5***
D1	0.1863	0.1864	0.1917	0.2259	0.2097	***D1***	0.1863	0.2062	0.2062	0.2114	0.2080
D2	0.2062	0.1656	0.1947	0.2219	0.2116	***D2***	0.1864	0.1656	0.1848	0.1847	0.1841
D3	0.2062	0.1848	0.1738	0.2238	0.2115	***D3***	0.1917	0.1947	0.1738	0.1942	0.1961
D4	0.2114	0.1847	0.1942	0.2005	0.2093	***D4***	0.2259	0.2219	0.2238	0.2005	0.2231
D5	0.2080	0.1841	0.1961	0.2231	0.1887	***D5***	0.2097	0.2116	0.2115	0.2093	0.1887

$$T_D^{al}=\begin{bmatrix} \tilde{t}_D^{11l}/d_1^l & \cdots & \tilde{t}_D^{1jl}/d_1^l & \cdots & \tilde{t}_D^{1nl}/d_1^l \\ \vdots & & \vdots & & \vdots \\ \tilde{t}_D^{i1l}/d_1^l & \cdots & \tilde{t}_D^{ijl}/d_1^l & \cdots & \tilde{t}_D^{inl}/d_1^l \\ \vdots & & \vdots & & \vdots \\ \tilde{t}_D^{n1l}/d_1^l & \cdots & \tilde{t}_D^{njl}/d_1^l & \cdots & \tilde{t}_D^{nnl}/d_1^l \end{bmatrix}=\begin{bmatrix} \tilde{t}_D^{\alpha 11l} & \cdots & \tilde{t}_D^{\alpha 1jl} & \cdots & \tilde{t}_D^{\alpha 1nl} \\ \vdots & & \vdots & & \vdots \\ \tilde{t}_D^{\alpha n1l} & \cdots & \tilde{t}_D^{\alpha njl} & \cdots & \tilde{t}_D^{\alpha nnl} \\ \vdots & & \vdots & & \vdots \\ \tilde{t}_D^{\alpha 11} & \cdots & \tilde{t}_D^{\alpha 11} & \cdots & \tilde{t}_D^{\alpha 11} \end{bmatrix} \tag{12}$$

Likewise, matrixes $T_D^{\alpha m}$ and $T_D^{\alpha h}$ can be formulated. The new normalized matrix $\tilde{T}_D^{\alpha}$ is then blended into the unweight supermatrix W to attain the weight supermatrix exemplified by is given by equation (13) and presented in Table 8:

$$W^{\alpha l}=T_D^{\alpha l}W^{l}=\begin{bmatrix} t_D^{\alpha 111}\times W^{11l} & \cdots & t_D^{\alpha i11}\times W^{i1l} & \cdots & t_D^{\alpha n11}\times W^{n1l} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1j1}\times W^{1jl} & \cdots & t_D^{\alpha ij1}\times W^{ijl} & \cdots & t_D^{\alpha nj1}\times W^{njl} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1n1}\times W^{1nl} & \cdots & t_D^{\alpha in1}\times W^{inl} & \cdots & t_D^{\alpha nn1}\times W^{nnl} \end{bmatrix} \tag{13}$$

Step 3: Limiting the weighted supermatrix, or soliciting the weight of each criterion.

The weighted supermatrix was limited by multiplying itself continuously until it had reach the largest tensile strength and transposed into a durable stable supermatrix $\lim_{z\to\infty}\left(W^{\alpha}\right)^{z}$, wherein z denotes an arbitrary number that arrives at the sufficient level of tensile strength, framing a stable matrix format. By summing up the global weights of factors/criteria, local weights of dimensions were obtained; local weights of factors/criteria, thereafter, were computed by dividing the global weights of factors/criteria by their corresponding local weights and global weights at the dimension level. Table 9 incorporates the centrality and cause degrees produced by fuzzy DEMATEL analysis. Results of local and global weight computations indicted that the aggregated local weights of the three top dimensions were: 'Academic emphasis' (D2; weight = 0.2212), 'Relationship' (D3; weight = 0.2210), and 'Safety' (D1; weight = 0.205); the dimension considered to be the least influential is 'Institutional environment' (D4; weight = 0.161). The dimensions estimated to be relatively with "high centrality

Table 8. The weighted supermatrix W^{α} for climate factors/criteria

W^{α}	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	0.0288	0.0350	0.0357	0.0350	0.0356	0.0339	0.0337	0.0349	0.0349	0.0353	0.0369	0.0341	0.0341	0.0247	0.0226	0.0251	0.0251	0.0285	0.0301	0.0296	0.0281	0.0294
C2	0.0319	0.0291	0.0352	0.0317	0.0315	0.0327	0.0329	0.0312	0.0304	0.0304	0.0302	0.0312	0.0332	0.0235	0.0248	0.0236	0.0233	0.0279	0.0284	0.0283	0.0284	0.0271
C3	0.0355	0.0401	0.0330	0.0373	0.0370	0.0375	0.0371	0.0377	0.0385	0.0381	0.0367	0.0385	0.0366	0.0270	0.0277	0.0265	0.0267	0.0331	0.0311	0.0316	0.0330	0.0330
C4	0.0273	0.0258	0.0272	0.0259	0.0285	0.0270	0.0276	0.0284	0.0282	0.0288	0.0259	0.0271	0.0302	0.0187	0.0204	0.0201	0.0200	0.0240	0.0242	0.0237	0.0241	0.0237
C5	0.0305	0.0308	0.0308	0.0373	0.0299	0.0364	0.0360	0.0331	0.0342	0.0338	0.0339	0.0342	0.0335	0.0254	0.0259	0.0260	0.0253	0.0293	0.0289	0.0299	0.0290	0.0293
C6	0.0287	0.0299	0.0284	0.0295	0.0343	0.0293	0.0297	0.0318	0.0310	0.0308	0.0335	0.0320	0.0297	0.0240	0.0219	0.0220	0.0228	0.0268	0.0270	0.0265	0.0270	0.0271
C7	0.0177	0.0184	0.0181	0.0177	0.0200	0.0179	0.0171	0.0203	0.0202	0.0213	0.0206	0.0202	0.0197	0.0150	0.0148	0.0134	0.0143	0.0181	0.0176	0.0170	0.0178	0.0174
C8	0.0192	0.0189	0.0191	0.0222	0.0205	0.0207	0.0202	0.0181	0.0212	0.0217	0.0210	0.0214	0.0213	0.0150	0.0146	0.0148	0.0151	0.0176	0.0178	0.0188	0.0184	0.0182
C9	0.0147	0.0147	0.0154	0.0167	0.0164	0.0169	0.0154	0.0148	0.0132	0.0142	0.0146	0.0150	0.0149	0.0102	0.0101	0.0107	0.0109	0.0130	0.0126	0.0127	0.0126	0.0125
C10	0.0114	0.0107	0.0114	0.0124	0.0118	0.0121	0.0121	0.0129	0.0119	0.0105	0.0118	0.0122	0.0126	0.0087	0.0089	0.0085	0.0084	0.0102	0.0101	0.0103	0.0105	0.0105
C11	0.0103	0.0101	0.0098	0.0096	0.0103	0.0113	0.0121	0.0115	0.0114	0.0108	0.0098	0.0111	0.0119	0.0082	0.0085	0.0089	0.0083	0.0099	0.0100	0.0099	0.0095	0.0105
C12	0.0124	0.0124	0.0120	0.0138	0.0136	0.0132	0.0147	0.0144	0.0136	0.0141	0.0131	0.0118	0.0141	0.0101	0.0099	0.0103	0.0100	0.0118	0.0124	0.0121	0.0117	0.0117
C13	0.0119	0.0124	0.0118	0.0136	0.0135	0.0139	0.0145	0.0141	0.0146	0.0134	0.0150	0.0142	0.0116	0.0098	0.0100	0.0102	0.0098	0.0119	0.0121	0.0118	0.0119	0.0117
C14	0.0134	0.0140	0.0132	0.0152	0.0151	0.0155	0.0032	0.0033	0.0033	0.0034	0.0031	0.0032	0.0036	0.0111	0.0113	0.0115	0.0111	0.0132	0.0134	0.0131	0.0132	0.0129
C15	0.0191	0.0187	0.0190	0.0200	0.0212	0.0224	0.0042	0.0039	0.0040	0.0040	0.0040	0.0040	0.0039	0.0132	0.0156	0.0161	0.0155	0.0177	0.0175	0.0177	0.0199	0.0165
C16	0.0257	0.0257	0.0263	0.0283	0.0284	0.0276	0.0035	0.0037	0.0036	0.0036	0.0039	0.0038	0.0035	0.0222	0.0186	0.0219	0.0232	0.0270	0.0267	0.0258	0.0280	0.0242
C17	0.0323	0.0332	0.0339	0.0348	0.0353	0.0350	0.0020	0.0024	0.0024	0.0025	0.0024	0.0024	0.0023	0.0261	0.0258	0.0224	0.0264	0.0292	0.0290	0.0296	0.0324	0.0275
C18	0.0302	0.0297	0.0283	0.0327	0.0310	0.0310	0.0319	0.0318	0.0323	0.0299	0.0308	0.0315	0.0300	0.0235	0.0249	0.0246	0.0202	0.0267	0.0273	0.0275	0.0300	0.0250
C19	0.0209	0.0203	0.0195	0.0230	0.0219	0.0214	0.0215	0.0216	0.0214	0.0216	0.0226	0.0225	0.0225	0.0163	0.0167	0.0164	0.0161	0.0167	0.0197	0.0196	0.0199	0.0199
C20	0.0206	0.0205	0.0197	0.0214	0.0212	0.0217	0.0210	0.0215	0.0206	0.0204	0.0226	0.0213	0.0205	0.0158	0.0157	0.0160	0.0156	0.0183	0.0162	0.0191	0.0188	0.0193
C21	0.0208	0.0214	0.0209	0.0214	0.0239	0.0218	0.0227	0.0229	0.0236	0.0241	0.0221	0.0230	0.0225	0.0162	0.0161	0.0162	0.0168	0.0205	0.0205	0.0170	0.0201	0.0201
C22	0.0195	0.0190	0.0206	0.0222	0.0216	0.0224	0.0224	0.0214	0.0223	0.0215	0.0204	0.0207	0.0214	0.0159	0.0158	0.0159	0.0160	0.0193	0.0199	0.0192	0.0163	0.0192

Table 9. Centrality degrees, cause degrees, local, global priority weights and ranking of criteria/dimensions

	Centrality Degree	Cause Degree	Local Weight	Global Weight
D1	**0.626(1)**	**0.469 (+)**	**0.205(3)**	
C1	10.9008(2)	0.286	0.299(3)	0.061(6)
C2	10.7473(3)	-0.233	0.332(2)	0.068(4)
C3	12.1143(1)	0.096	0.369(1)	0.076(1)
D2	**0.589(5)**	**0.421 (+)**	**0.221 (1)**	
C4	9.517(3)	0.019	0.315(3)	0.067(5)
C5	11.809(1)	-0.142	0.353(1)	0.074(2)
C6	10.539(2)	0.136	0.332(2)	0.070(3)
D3	**0.620(2)**	**0.479 (+)**	**0.221 (2)**	
C7	10.698(2)	0.475	0.181(2)	0.0380(12)
C8	11.437(1)	0.321	0.197(1)	0.041(8)
C9	9.618(3)	-1.060	0.151(3)	0.032(17)
C10	7.967(6)	-1.175	0.117(6)	0.025(21)
C11	7.817(7)	-1.474	0.105(7)	0.022(22)
C12	9.463(4)	-1.739	0.127(4)	0.027(19)
C13	9.106(5)	-1.376	0.123(5)	0.026(20)
D4	**0.601(3)**	**0.536 (+)**	**0.161 (5)**	
C14	8.473(5)	-1.260	0.174(5)	0.028(18)
C15	10.304(4)	-0.234	0.234(3)	0.038(14)
C16	10.735(2)	1.305(2)	0.294(2)	0.047(7)
C17	10.621(3)	1.179(3)	0.298(1)	0.038(13)
C18	11.004(1)	0.915(5)	0.206(4)	0.033(16)
D5	**0.593(4)**	**0.496 (+)**	**0.192 (4)**	
C19	10.648(4)	0.896	0.204(2)	0.039(11)
C20	10.888(2)	1.372(1)	0.206(1)	0.040(10)
C21	11.048(1)	0.629	0.193(3)	0.037(14)
C22	10.768(3)	1.063(4)	0.191(4)	0.037(15)

degree and high cause degree" are: 'Institutional environment' (D4; centrality degree = 0.601; cause degree = 0.536), and 'Relationship' with high centrality degree and low cause degree (D3; centrality degree = 0.620; cause degree = 0.479). The dimension with "low centrality degree and low cause degree" is 'Leadership' (D5; centrality degree = 0.593; cause degree = 0.496) and 'Social, emotional and ethical learning' (C2; centrality degree = 0.589; cause degree = 0.421).

The holistic ranking of climate criteria was computed by the global weights presented in Table 10. '*Rules & Norms*' (C_3), '*Social, emotional and ethical learning*' (C_5), '*Professional development*' (C_6), '*Social/emotional safety*' (C_2), and '*Quality of instruction*' (C_4), with comparatively high global weights of 0.076, 0.074, 0.070, 0.068 and 0.067 in ranking order, were the five prioritized factors when making school climate improvement plans in the present undertaking.

CONCLUSION AND FUTURE DIRECTIONS

Literature often shows a heterogeneous corpus of school effectiveness resulting from positive organizational climate. Much ink has been spilt to find how the quality of school climate can be assessed for improving educational accountability. The purpose of present study was to measure and offer strategic approach to dragonize and sustain positive school climate by the "Organizational Climate Diagnostic Instrument for Junior High Schools" (OCDI-JH). Fuzzy DEMATEL-based ANP was adopted to illustratively model climate measurement procedures for junior high schools in Taoyuan City, Taiwan. Results yielded by fuzzy DEMATEL-based ANP revealed almost reversed rankings by 'centrality degrees' and global weights, with an exception of D_5 and D_3 ranked in consistent order. One significant dimension is '*Academic emphasis*' (D_2), whose centrality is the lowest while the local weight is the highest among the five dimensions. This can be explained by the fact that '*Academic emphasis*' (C_2) casted low strength of connections to other dimensions and factors; nevertheless, once the connections were there, it dispatched high strength of influences to factors within its dimension and other dimensions. Worth noting is that all five dimensions were identified as net dispatchers with positive 'cause degrees'. They were likely to exert great impacts on overall school climate performance.

Regarding the factor-level analysis by fuzzy DEMATEL-based ANP, seven factors exceeded the average global weight value of 0.043 in ranking order: C_3=*Rules & Norms*, $C_{5=}$ *Social, emotional and ethical learning,* C_6=*Professional development,* $C_{2=}$ *Social/emotional safety,* C_4=*Quality of instruction,* C_1 =*Physical safety,* and C_{16}=*Resource support.* Among the top ranking factors exceeding the average value of 0.043, six of them are endorsed either in the dimensions of *'Safety' (D_1)* or '*Academic emphasis*' (D_2). School principals and decision makers, therefore, should give particular attentions to highly prioritized climate dimensions and factors to maximize school effectiveness while addressing the values, and cultural norms of junior high schools in Taoyuan City of Taiwan.

Implications for Practices

The present study bears significance for it is among one of the pioneer educational studies applying a hybrid fuzzy DEMATEL and ANP to identify critical climate factors that are detrimental to improving and sustaining positive school climate. The school climate diagnostic mechanism, named the Chinese OCDI-JH, was used to decompose factors in intertwined format. Based on the peripheral multi-criteria reasoning featured by MCDM methods, the school climate prioritization resulted from weighting techniques can be used as a rubric for diagnose school climate in other regions of Taiwan. The synthesized climate diagnostic mechanism can also be used to comparatively investigate climate of schools across different regions in Taiwan for identifying critical climate features of schools in need of enhancement. Armed with such scientific inquiry into individual school's climate, school principals, teachers and faculty are in a position to engage in developing systematical strategies in order to achieve educational accountability and success.

Limitations and Recommendations for Further Research

One of the major limitations comes from the inclusion of only 23 experts in Taoyuan City, Taiwan to perform priority ranking of climate dimensions/factors by fuzzy DANP. It should be highlighted that results yielded by the proposed MCDM approach was contextually specific and would only be applicable to the target region where the study sets to investigate. Generalization of the priority results to other regions in Taiwan or elsewhere is not be appropriate. Further studies may expand the current study by adopting OCDI-JH validated for use in Taiwan through regional experts' judgments and perspectives (Tang & Lee, 2021). The present study also provide opportunity for further experimental studies to find out whether the changing landscape of school climate, as direct or indirect latent variables, could foster a wide range of academic, behavioral, and socio-emotional outcomes, such as safety, healthy relationships, engaged learning and teaching, life-satisfaction of students and teachers, bullying/violence preventions, and so on (Cohen et al., 2009; Collie et al., 2013; Espelage, 2014; Wong & Siu, 2017).

As a conclusion remark, the study set to accumulate the body of knowledge on the importance of scenario-based diagnosis of critical climate factors for improving school effectiveness; the hybrid MCDM method could lead to future research on how school climate can be diagnosed and how comprehensive school climate improvement plans can be strategically developed to achieve maximum impact on school climate enhancement. Contextually specific analyses of priority factors based on the proposed method will provide incremental and value-added contributions to leverage the competitive advantages of Taiwan's junior high school education. Diagnosing school climate is certainly far from evaluating the holistic performance of schools; the full spectrum of learning contexts and life within schools requires further research across multiple domains of school operations for improving educational outcomes.

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