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Identification of Factors Affecting Quality of Teaching Engineering Drawing using a Hybrid MCDM Model

H. Haghshenas Gorgani* and A. Jahantigh Pak

Engineering Graphics Center, Sharif University of Technology, Tehran, Iran.

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**Corresponding author: h_haghshenas@sharif.edu (H. Haghshenas).*

Abstract
Identification of the factors affecting the teaching quality of engineering drawing and interaction between them is necessary until it is determined which manipulation will improve the quality of teaching this course. Since the above issue is a multi-criteria decision making problem, and, on the other hand, we are faced with human factors, the fuzzy DEMATEL method is suggested for solving it. In addition, since the DEMATEL analysis does not lead to a weighting of the criteria, it is combined with ANP, and a hybrid fuzzy DEMATEL-ANP (FDANP) methodology is used. The results of investigating 7 dimensions and 21 criteria show that the quality of teaching this course increases, if the updated teaching methods and contents are used, the evaluation policy is tailored to the course, the professor and his/her assistants are available to correct the students' mistakes, and there is also an interactive system based on the student comments.

Keywords: *Teaching, Engineering Drawing, DEMATEL, ANP, Fuzzy Logic.*

1. Introduction

Engineering drawing is an important course for engineering students; it is included as a compulsory course in the curriculum of most universities that present this discipline [1] because industrial drawings are in fact a common language between the engineers to transfer the concepts [2]. The main objectives of the engineering drawing course include enhancing the spatial ability, understanding the basic concepts of drawing, familiarity with the standards, and 2D and 3D drawing methods of the mechanical components [3]. Like any other process, the extent that these goals are achieved is known as the efficiency of this course [4].

On the other hand, since significant changes have been made in educational practices in the recent decades, each training course must be designed in such a way that its output is determined in accordance with the objectives of the curriculum [5]. For this purpose, it is important to identify the parameters affecting the achievement of goals, and measure the importance of each, the extent of their impact, and influencing them by other parameters using a reliable method appropriate to human characteristics so that the ideality degree of the system is increased [6].

The DEMATEL method is a commonly used and effective tool that can illustrate the complex causal relationship structure using matrices and charts, and can help decision-making or optimization in different fields by isolating the range of system involvement and turning it into causal groups. This method was first proposed by the Geneva Research Center between 1973 and 1976 [7-10].

Although many multi-criteria problems can be solved using the DEMATEL method, it is difficult to express human judgments in exact numbers [11]. Human linguistics has a fuzzy nature [12], so the fuzzy theory can be useful when there is incomplete or unknown information [13-15]. Therefore, a combination of DEMATEL and fuzzy logic seems appropriate to solve our problems. Before this, in particular, in the recent years and in various branches, fuzzy DEMATEL has been used to solve similar problems. Tsai et al. have used the above-mentioned approach for the determination of environmental performance [16], and Akyuz and Celik have used the evaluation of critical operational hazards during the gas freeing process

[17]. Tyagi, Kumar, and Kumar have used the above-mentioned method for the assessment of critical enablers for a flexible supply chain performance [18]. Then Muhammad and Cavus have used it for identifying the LMS evaluation criteria [19], and Seker and Zavadskas analyzed the occupational risk on the construction sites [20]. Moreover, the study conducted by Ranjan, Chatterjee, and Chakraborty can be mentioned as an example of employing this method in solving the educational problems. They introduced a multi-criteria decision-making framework to evaluate the performance and ranking of engineering colleges at an Indian university [21]. On the other hand, the DEMATEL method provides only one influential network relation map (INRM) but no weights are achieved for the factors [22], while in selection methods, such as Electre, Vikor, and Topsis, the weight of the factors is required to evaluate the alternatives and compare them. Initial multi-criteria decision-making methods such as AHP could be managed on the basis of decomposing a decision problem into smaller problems. The structure of this method is linear hierarchy, and the interaction between the factors is ignored. This technique was introduced by Saaty [23] but ignoring the interaction between the factors was a disadvantage for it and sometimes would distort the result of the problem because the real issues do not behave like this [7].

After it, Saaty and Turner proposed the ANP method in order to overcome this problem, and considered the interrelationships between the factors [24]. Another major difference between ANP and AHP was the non-linear ANP structure against the ANP linear structure [25]. In the ANP method, a structure is initially designed as different levels, and then a pairwise comparison takes place between the two criteria, and ultimately, the weight and, in fact, the degree of importance of each factor is determined with a series of math operations based on the Markov chain [24]. The serious weakness of the ANP method was to assume that the weight of the clusters was the same, which would not happen in the real world [22].

The DANP method is a combination of the DEMATEL and ANP methods [26]. This method solves the problem by looking at the factors impact map using DEMATEL and obtaining the final weights of the priority weights using the ANP method. In this way, there will be a suitable method including the interdependence and interaction between the dimensions and the criteria in accordance with the real-world processes. The DANP method, like the fuzzy DEMETEL, is widely used in many sciences and engineering branches. For example, it has been used by Hsu et al. for supplier selection [26], and then by Tsai et al. for the same order [16], the risk assessment by Yang, Shieh, and Tzeng [27], in business improvement by Chiu et al. [22], and by Chen and Lin for promoting the emerging technology through intermediaries [28].

As mentioned earlier in this section, considering the nature of the problem and utilization of the capacity of the existing algorithms as well as the human mental nature in order to fit the mental inferences, a hybrid method is selected based on fuzzy logic, DEMATEL, and ANP for solving the basic problem of this research worked, and is now referred to as FDANP.

Here, the basic questions of this study arise as follow:

- What are the effective inefficiency factors of teaching engineering drawing?
- What are the direct and indirect effects of the above factors on each other?
- Control and manipulation of which factors can improve the quality of teaching this course?

In this paper, we first address the method used and the algorithm designed to answer the above questions, and then the effective factors will be identified and described. Afterwards, the proposed method is applied to the factors, the questionnaires are developed, and the results of the experts' opinions will be collected and analyzed. Finally, the results will be summarized.

2. Methodology and solution-making

Since the main problem is considered as a multi-criteria decision-making (MCDM) and because the effective factors may have an interactive effect, the DEMATL technique can form the structure of the effects of the criteria on each other. On the other hand, a combination of the DEMATEL and ANP methods can find the weight of each criterion and determine the most important criteria, so that we can focus on them. Since, the traditional method that combines DEMATEL and ANP is normalized from total relations matrices and works using a "threshold" value [16, 29], it can have this disadvantage that eliminates some effects in an unwanted manner or does not accurately indicate the severity of some of the effects. Therefore, the DANP method is used, which does not have such a problem [22, 30-32].

Moreover, the information on the impact matrices is collected by a fuzzy method due to the fuzzy nature of the human behaviors, and then converted

to crisp data, and the DANP method is applied on it [13-15, 33, 34].
Meanwhile, the consistency of data is measured because more than one expert is used, and then the method of their combination is expressed. In the following, the details of this method are addressed.

2.1. Step 1: Determination of dimensions and criteria

Due to the nature of the problem, and by reviewing the studies conducted in this field, also through interviews with a number of experts in this field, problem dimensions or $D_{i's}$ and problem criterions or $C_{j's}$ are determined. Thus each D_i contains one or more C_j (refer to Figure 1).

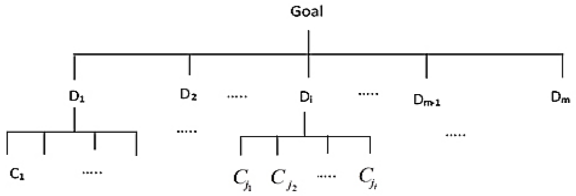


Figure 1. Relationship between criterions and dimensions.

2.2. Step 2: Preparation of interaction question naire and completing it by experts

If we assume that the number of $D_{i's}$ is m and the number of $C_{j's}$ is n, then we form the interaction matrix for $C_{j's}$ (regardless of the presence of $D_{i's}$), which is an n × n matrix, as shown in (1) (Matrix x). This matrix can be converted into a table, and it can be given to each expert to complete (to determine the entries of matrix x). The fuzzy linguistic variables are used due to the nature of the human mental inference [35-37]. Each entry x_{ij} of matrix x is a fuzzy number, indicating the effect of the element i on the element j (the effect of C_i on C_j), which, after completed by the experts, each one of its linguistic variables is expressed in the form of a triangular fuzzy number according to figure 2 and table 1 [38].

Table 1. Proposed table for the fuzzy linguistic scale.

Linguistic terms	Influence score	Triangular fuzzy Numbers
Very High influence (VH)	5	(0.7, 0.9, 1.0)
High influence (H)	4	(0.5, 0.7, 0.9)
Medium influence (M)	3	(0.3, 0.5, 0.7)
Low influence (L)	2	(0.1, 0.3, 0.5)
Very Low influence (VL)	1	(0.0, 0.1, 0.3)
No influence (N)	0	(0.0, 0.0, 0.0)

$$x = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_j \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 \ldots & C_j \ldots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} \ldots & x_{ij} \ldots & x_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{j_1} & x_{j_2} \ldots & x_{jj} \ldots & x_{jn} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n_1} & x_{n_2} \ldots & x_{nj} \ldots & x_{nn} \end{bmatrix} \end{array} \quad (1)$$

Therefore, at the end of this step, we will have a matrix x as fuzzy triangular numbers from each expert:

$$\tilde{x}^k = \left[\tilde{x}^k_{ij}\right] = \left[\left(l^k_{ij}, m^k_{ij}, u^k_{ij}\right)\right] \quad (2)$$

where k indicates the expert No. k, and L^k_{ij}, M^k_{ij} and U^k_{ij} indicate the lower, middle and upper limits of the fuzzy triangular number corresponding to $\tilde{x}^k_{ij}$, respectively.

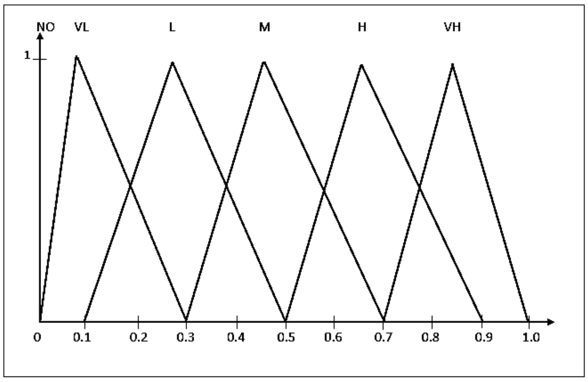


Figure 1. Triangular fuzzy numbers for linguistic variables.

2.3. Step 3: Integration of experts' views

To do this, we convert the resulting matrix $\tilde{x}^k$ into three matrices x_l, x_m, x_u, as follows:

$$x^k_l = \left[l^k_{ij}\right] \;;\; x^k_m = \left[m^k_{ij}\right] \;;\; x^k_u = \left[u^k_{ij}\right] \quad (3)$$

In order to integrate the views of all experts, assuming that P experts have participated in this survey, the average of the following (3, 4, and 5) is obtained:

$$x_l^{avg} = \left[\frac{\sum_{k=1}^{p} l_{ij}^k}{P} \right] = \left[l_{ij}^{avg} \right] \quad (4)$$

$$x_m^{avg} = \left[\frac{\sum_{k=1}^{p} m_{ij}^k}{P} \right] = \left[m_{ij}^{avg} \right] \quad (5)$$

$$x_u^{avg} = \left[\frac{\sum_{k=1}^{p} u_{ij}^k}{P} \right] = \left[u_{ij}^{avg} \right] \quad (6)$$

2.4. Step 4: Converting integrated fuzzy data to crisp data

Now, the fuzzy interaction matrix is converted to the crisp interaction matrix, as follows, which is a n-by-n matrix in the form of A:

$$A = \left[a_{ij} \right] \ , \ a_{ij} = \frac{l_{ij}^{avg} + 2m_{ij}^{avg} + u_{ij}^{avg}}{4} \quad (7)$$

In this way, the fuzzy and linguistic views of P experts would be converted into a DEMATEL table in the form of a crisp and could be used as input in the analysis process.

Table 2. Dimensions and criteria affecting the efficiency of teaching engineering mapping.

Lecturing	D1	C1	Lecture Duration
		C2	Example Load
		C3	Up-to-Date Curriculum
		C4	Interactive Lecturing
Class Works	D2	C5	Exercise Load
		C6	Presence of TA's in Class
Home Works	D3	C7	Home Works Load
		C8	Home Works Follow up Rate
		C9	Projects Load
Assessment	D4	C10	Frequency of Assessment
		C11	Final Assessment Policy
		C12	Clarity of Evaluation Policy
Job-Related Activities	D5	C13	Describing Application of Topics
		C14	Field Trip
		C15	Defining Industry-Oriented Project for Students
Facilities and Equipment	D6	C16	Well Equipped Classrooms
		C17	Good Internet System
		C18	Availability of Good Text Books and Journals
		C19	Existence of Student Satisfaction Measurement System
Teacher Extra-Works	D7	C20	Having Industrial Experience
		C21	Availability for student bug fixes

2.5. Step 5: Measurement of reliability of the data

It is mandatory to ensure that none of the data obtained from the views of a particular expert has a serious difference with the average of other experts. Therefore, the following variables are defined:

$$l_{ij}^{(f)} = \frac{\sum_{K=1, K\neq f}^{P} l_{ij}^{k}}{P-1} \quad (8)$$

$$m_{ij}^{(f)} = \frac{\sum_{K=1, K\neq f}^{P} m_{ij}^{k}}{P-1} \quad (9)$$

$$u_{ij}^{(f)} = \frac{\sum_{K=1, K\neq f}^{P} u_{ij}^{k}}{P-1} \quad (10)$$

This way, $l_{ij}^{(f)}$, $m_{ij}^{(f)}$ and $u_{ij}^{(f)}$ are the mean of the relevant data, except for the data related to expert No. f. Now, we define the variable $q_{ij}^{(f)}$ as follows:

$$q_{ij}^{(f)} = \frac{l_{ij}^{(f)} + 2m_{ij}^{(f)} + u_{ij}^{(f)}}{4} \quad (11)$$

where $q_{ij}^{(f)}$ is the crisp equivalent of the average of the data with the exception of the f[th] data. Now, Q_f, which shows the reliability of the data of the expert No. f, is defined as follows:

$$Q_f = \frac{1}{n(n-1)} \sum_{j=1}^{n} \sum_{i=1}^{n} \frac{\left| a_{ij} - q_{ij}^{(f)} \right|}{a_{ij}} \quad (12)$$

This value should be applied from numbers 1 to P, and the minimum $(Q_f^{(\min)})$, maximum $(Q_f^{(\max)})$, and average $(Q_f^{(avg)})$ values are determined. The allowable value for each one of the above values is determined by the experts, and if the data does not exceed the allowable limit, it will not be stable, and the survey process should be repeated or the data that has caused instability is eliminated.

2.6. Step 6: Normalization of interaction matrix

Now, we calculate the value of a_M as follows:

$$a_M = \max\left\{ \max_{1\le j\le n}\left(\sum_{i=1}^{n} a_{ij}\right), \max_{1\le i\le n}\left(\sum_{j=1}^{n} a_{ij}\right) \right\} \quad (13)$$

Then the normalized matrix of the direct effects (matrix B) is obtained as follows:

$$B = \frac{1}{a_M}\{A\} = \left[\frac{a_{ij}}{a_M}\right] = \left[b_{ij}\right] \quad (14)$$

Thus, we will have for matrix B:

$$0 \le b_{ij} \le 1 \Rightarrow \lim_{h\to\infty} B^h = [0]_{n\times n} \quad (15)$$

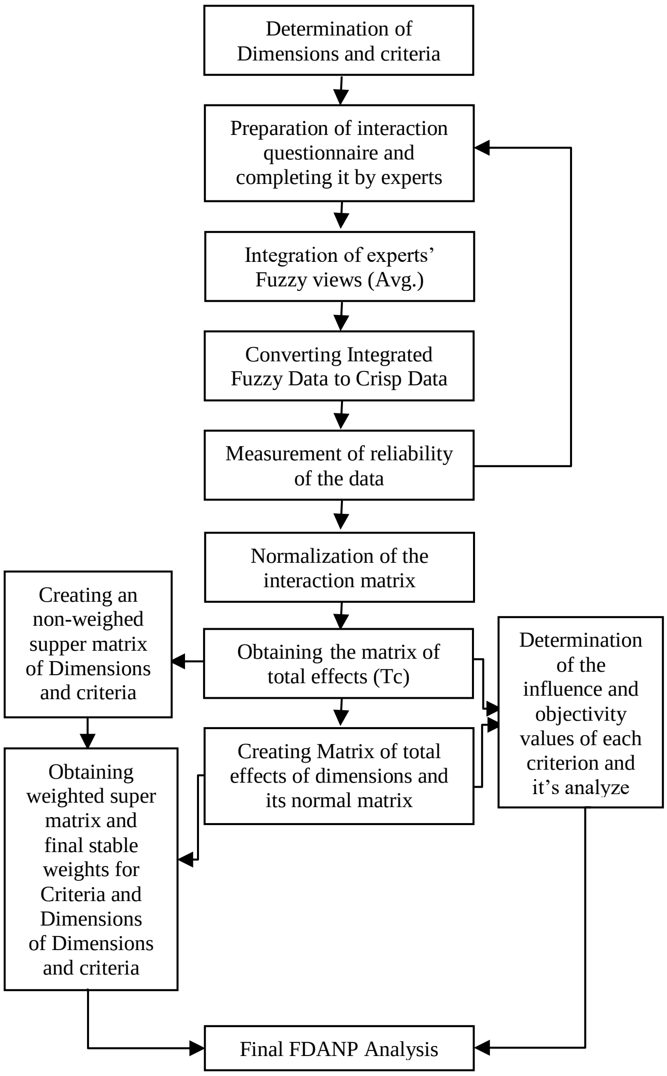


Figure 2. Flowchart of the proposed method.

2.7. Step 7: Obtaining matrix of total effects

The matrix of the indirect effects is obtained by applying exponentiation on the matrix of direct effects, and B^2, B^3 … and B^h indicate the indirect effects, respectively. Therefore, it is required that the sum of all these matrices is obtained to achieve the matrix of the total effects. If the matrix of the total effects is called T_c, we will have:

$$\begin{cases} T_C = B + B^2 + \ldots + B^h \\ h \to \infty \end{cases} \quad (16)$$

where:

$$T_C = B(I + B + B^2 + \ldots + B^{h-1})(I-B)(I-B)^{-1} \quad (17)$$

$$T_C = B(I - B^h)(I - B^{-1}) \underset{h\to\infty}{\Rightarrow} T_C = B(I-B)^{-1} \quad (18)$$

Table 3. Questionnaire (matrix) of direct influences given to each expert.

DEMATEL			Lecturing			Class Works			Home Works			Assessment			Job-related Activities			Facilities and Equipment			Teacher Extra-Works		
			D1			D2			D3			D4			D5			D6			D7		
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
Lecturing	D1	C1																					
		C2																					
		C3																					
		C4																					
Class Works	D2	C5																					
		C6																					
Home Works	D3	C7																					
		C8																					
		C9																					
Assessment	D4	C10																					
		C11																					
		C12																					
Job-Related Activities	D5	C13																					
		C14																					
		C15																					
Facilities and Equipment	D6	C16																					
		C17																					
		C18																					
		C19																					
Teacher Extra-Works	D7	C20																					
		C21																					

2.8. Step 8: Determination of influence and objectivity values of each criterion

If we consider the matrix T_c (matrix of the total effect) as follows:

$$T_c = \left[t_{ij}\right], \qquad i, j = 1, \ldots, n \tag{19}$$

define the influence as follows:

$$r = \left[r_i\right]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{20}$$

and so define the objectivity as follows:

$$s = \left[s_j\right]_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} \tag{21}$$

where r_i is the sum of the rows and s_i is the sum of the columns of the matrix of total effect (T_c).
In other words, r_i indicates the sum of the direct and indirect effects of criterion No. i on the other criteria, and s_i indicates the sum of direct and

indirect effects of the other criteria on criterion No. i.

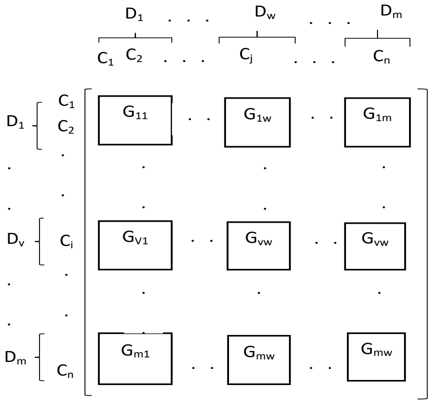
The value of "$r_i + s_j$" indicates the sum of the influence and objectivity of the criterion No. i and expresses its role in the whole problem [39]. Correspondingly, "r_i-s_i" expresses the net effect of the i^{th} criterion, and, if positive, indicates that the i^{th} criterion has been more effective than is affected [7].

2.9. Step 9: Creating a matrix of total effects of dimensions and its normal matrix

If the matrix of the total effects (obtained from DEMATEL) for the criteria is called "T_c" and the same matrix for dimensions is called "T_D", each T_D element is defined as follows:

$$T_D = [d_{VW}]_{m\times n} \tag{22}$$

When d_{vw} is the mean of $t_{ij's}$ related to criteria of the subset of the domain Di. In other words, if we divide the matrix T_c as follows, we will have:



Therefore:

$$T_D = \begin{bmatrix} d_{11} & .... & d_{1w} & .... & d_{i1m} \\ . & & . & & . \\ . & & . & & . \\ . & & . & & . \\ .d_{v1} & ..... & d_{vw} & ..... & d_{vm} \\ . & & . & & . \\ . & & . & & . \\ . & & . & & . \\ d_{n1} & .... & d_{mw} & .... & d_{mm} \end{bmatrix} \tag{23}$$

where d_{vw} is the average of G_{VW}.

Thus the influence and objectivity of each dimension can be calculated according to (20) and (21), and the values of r-s, r + s, s, r, can be obtained and, the INRM chart can also be plotted in which the direction of the arrow means as the influence based on considering the average value of the T_D matrix as the threshold [40].

Furthermore, the normal value of the T_D matrix can be defined as T_{DN}:

$$T_{DN} = \begin{bmatrix} h_{11} & .... & h_{1w} & .... & h_{i1m} \\ . & & . & & . \\ . & & . & & . \\ . & & . & & . \\ .h_{v1} & ..... & h_{vw} & ..... & h_{vm} \\ . & & . & & . \\ . & & . & & . \\ . & & . & & . \\ h_{m1} & .... & h_{mw} & .... & h_{mm} \end{bmatrix} \tag{24}$$

where for h_{vw} , we will have:

$$h_{vw} = \frac{d_{vw}}{\sum_{w=1}^{m} d_{vw}} \tag{25}$$

2.10. Step 10: Creating a non-weighted supper matrix

The matrix T'_{DN} is as follows:

$$T'_{DN} = Transpose(T_{DN}) = [h'_{vw}] \tag{26}$$

where, $h'_{DW} = h_{wv}$.

Now, if any t_{ij} element of the matrix T_c is replaced within relevant G_{vw}, assuming that:

$$size(G_{vw}) = m_{vw} \times n_{vw} \tag{27}$$

So, we will have:

$$G_{vw} = \left[\left(g_{vw} \right)_{yz} \right] \tag{28}$$

(when we know that $t_{ij} = (g_{vw})_{yz}$).

Now, the matrix T_{CN} is defined as follows:

$$T_{CN} = \left[G_{VW}^N \right] \tag{29}$$

where we have:

$$G_{VW}^N = \left[\left(g_{VW}^N \right)_{yz} \right] \tag{30}$$

and then we have:

$$\left(g_{VW}^N \right)_{yz} = \frac{(g_{VW})_{yz}}{\sum_{z=1}^{n_{vw}} (g_{VW})_{yz}} \tag{31}$$

In each G_{vw}, we divide each element into the sum of the rows in which it is located, and thus T_{CN} is called a non-weighted supermatrix.

2.11. Step 11: Obtaining weighted supermatrix and final weights

We define the non-weighted super-matrix, T_F, as follows:

Table 4. An example of a direct influence matrix completed by experts using linguistic fuzzy phrases.

DEMATEL			Lecturing			Class Works			Home Works			Assessment			Job-Related Activities			Facilities and Equipment			Teacher Extra-Works		
			D1			D2			D3			D4			D5			D6			D7		
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
Lecturing	D1	C1	N	M	M	M	H	L	VL	L	L	H	VL	N	VH	VL	N	L	VL	L	VL	N	L
		C2	VH	N	L	L	VL	N	N	M	M	N	N	N	L	L	M	L	VL	N	VL	N	N
		C3	M	VL	N	M	N	N	L	N	VL	L	H	VL	M	L	L	H	H	H	L	VL	L
		C4	VH	L	M	N	VL	L	L	VL	L	VL	H	M	H	L	L	H	VL	M	M	M	H
Class Works	D2	C5	M	VL	N	VL	N	VL	L	VL	M	VL	L	N	N	N	N	VL	L	L	VL	N	H
		C6	L	L	M	L	H	N	L	N	VL	L	VL	VL	VL	L	VL	L	N	L	L	M	L
Home Works	D3	C7	L	L	N	VL	M	L	N	H	H	N	L	N	L	L	M	N	L	L	VL	VL	L
		C8	L	N	N	H	L	M	L	N	L	VL	H	N	L	L	L	VL	VL	L	VL	N	L
		C9	VL	VL	M	VL	M	VL	M	VL	N	N	H	N	L	L	H	L	VL	N	M	N	M
Assessment	D4	C10	L	VL	M	M	M	N	M	VL	VL	N	M	M	N	L	M	L	L	L	VL	VL	H
		C11	VL	N	H	L	L	L	M	L	M	VH	N	VH	L	L	L	L	L	VL	M	L	H
		C12	N	N	N	L	N	VL	L	VL	L	M	H	N	L	L	L	VL	VL	VL	N	L	VL
Job-Related Activities	D5	C13	H	L	H	L	VL	VL	VL	N	H	M	VL	M	N	L	H	VL	VL	VL	N	VL	L
		C14	L	H	VL	M	L	L	N	VL	M	M	N	VL	VH	N	M	L	N	VL	L	M	L
		C15	N	N	VL	L	VL	M	VL	N	VL	L	M	VL	M	L	N	VL	L	VL	N	VL	N
Facilities and Equipment	D6	C16	H	H	VH	H	M	M	VL	H	M	M	M	L	M	L	L	N	VH	M	VH	VL	M
		C17	VH	L	M	VH	VL	VL	VL	M	L	VL	VL	L	VH	N	H	L	N	VH	M	M	M
		C18	M	M	VH	H	L	VL	M	VL	VL	VL	L	L	L	L	N	L	N	N	L	VL	VH
		C19	H	H	VH	H	VL	L	L	M	VL	L	H	VH	M	H	L	M	L	M	N	VL	N
Teacher Extra-Works	D7	C20	VL	N	L	L	N	N	VL	N	H	N	VH	VL	M	H	H	L	VL	L	L	N	N
		C21	L	M	N	L	L	H	VL	N	L	M	N	VL	L	L	L	VL	VL	VL	N	L	N

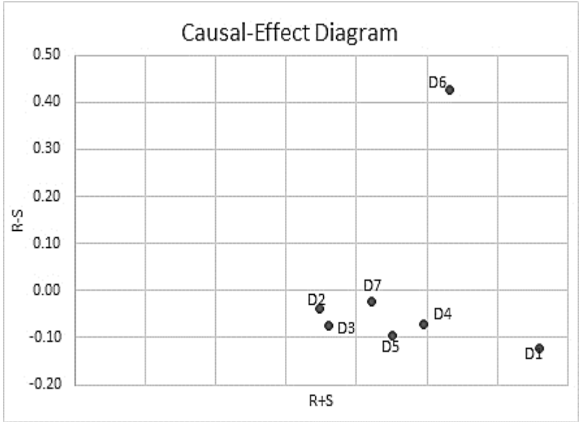


Figure 3. Causal-Effect diagram.

$$T_F = \left[\left(t_f \right)_{ij} \right] \quad (32)$$

Thus, we have:

$$G'^N_{VW} = \left[\left(g'^N_{VW} \right)_{zy} \right] = \left[\left(g_{VW} \right)_{yz} \right] \quad (33)$$

and also:

$$T'_{CN} = Transpose(T_{CN}) = Transpose\left[G^N_{VW} \right] \quad (34)$$

$$T'_{CN} = \left[G'^N_{VW} \right] \quad (35)$$

and the weighted supercontinent matrix is obtained as follows:

$$T_F = \left[h'_{WV} \times G'^N_{VW} \right] \quad (36)$$

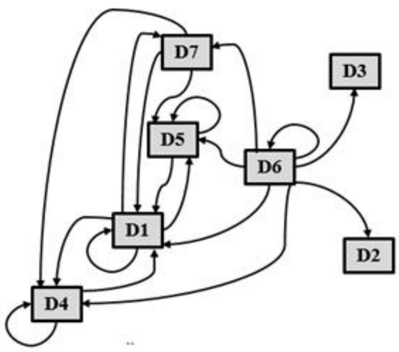


Figure 4. INRM diagram for dimensions.

Now, in order to converge weights, exponentiation should be applied on the weighted matrix as far as the weight of each criterion in the whole of that row converges to a single number (the difference between the numbers in a row is less than the target that is less than the predetermined value).

Thus, the weight of each criterion (C_i) is determined. In addition, the weight of each dimension is defined as the sum of the weights of the criteria of its subset, and a suitable context is provided to select different alternatives. A flowchart of the proposed algorithm is shown in the diagram in figure 3.

3. Factors affecting efficiency of teaching engineering drawing

In order to obtain the factors affecting the efficiency of teaching engineering drawing, the views of professional experts who were experienced teachers in the teaching and the students who had passed this course were calibrated and the studies conducted in this field were reviewed, and the results were presented as what follow.

Barrie and Ginns introduced five ones as the most effective factors on student satisfaction and teaching quality: appropriate assessment, clear goals, and good teaching skills in helping students develop their ability to plan their work and appropriate workload [41]. Jones, and Jones, and Lea by a study concluded that teaching a person was different from another person, and therefore required a proper interaction between the teacher and the student [42]. Furthermore, many studies have focused on the importance of the evaluation process in the level of learning and student self-esteem and motivation [43-45]. On the other hand, Olds, Moskal, and Miller concluded that assessment was not enough, and it was essential to follow up on the exercises and exams [46]. It has already been stated in 1998 that the provision of challenging assignments and extensive feedback lead to a greater student engagement and a higher achievement [47].

Renu, Garland, Grigg, Minor, and Yasmin (2016) investigated the importance of evaluating exercises and believed that it was very important, then described the advantages of using technology to evaluate the exercises by proposing an interactive assessment method in engineering drawing [48].

The use of technology and its role in student learning was investigated in another comparison by Parkin, Hepplestone, Holden, Irwin, and Thorpe [49].

Table 5. Matrix of the direct influence of the collected opinions of the experts in a crisp format.

DEMATEL			Lecturing			Class Works			Home Works			Assessment			Job-Related Activities			Facilities and Equipment			Teacher Extra-Works		
			D1			D2			D3			D4			D5			D6			D7		
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
Lecturing	D1	C1	0.00	0.73	0.48	0.69	0.67	0.08	0.08	0.07	0.16	0.53	0.40	0.06	0.48	0.48	0.16	0.06	0.08	0.09	0.08	0.08	0.29
		C2	0.72	0.00	0.45	0.53	0.23	0.06	0.05	0.14	0.07	0.28	0.05	0.05	0.29	0.29	0.31	0.08	0.08	0.06	0.08	0.15	0.09
		C3	0.74	0.45	0.00	0.74	0.14	0.13	0.35	0.26	0.48	0.36	0.78	0.08	0.77	0.48	0.33	0.55	0.53	0.78	0.58	0.21	0.48
		C4	0.77	0.67	0.77	0.00	0.09	0.40	0.20	0.16	0.15	0.35	0.45	0.81	0.50	0.38	0.14	0.31	0.14	0.16	0.74	0.24	0.62
Class Works	D2	C5	0.26	0.16	0.12	0.23	0.00	0.17	0.12	0.22	0.13	0.19	0.14	0.14	0.06	0.03	0.03	0.03	0.03	0.06	0.03	0.03	0.36
		C6	0.03	0.11	0.20	0.53	0.58	0.00	0.41	0.31	0.33	0.31	0.18	0.33	0.18	0.06	0.20	0.08	0.09	0.31	0.26	0.12	0.53
Home Works	D3	C7	0.05	0.08	0.05	0.16	0.50	0.08	0.00	0.43	0.55	0.11	0.53	0.15	0.05	0.18	0.40	0.06	0.13	0.08	0.17	0.08	0.29
		C8	0.18	0.15	0.06	0.28	0.05	0.50	0.18	0.00	0.11	0.12	0.33	0.14	0.07	0.09	0.22	0.06	0.03	0.05	0.13	0.06	0.26
		C9	0.08	0.05	0.33	0.16	0.31	0.07	0.50	0.26	0.00	0.08	0.55	0.18	0.06	0.14	0.48	0.06	0.12	0.19	0.11	0.07	0.28
Assessment	D4	C10	0.55	0.36	0.64	0.28	0.40	0.29	0.20	0.26	0.20	0.00	0.43	0.58	0.40	0.15	0.08	0.08	0.06	0.20	0.14	0.06	0.53
		C11	0.21	0.36	0.71	0.55	0.12	0.14	0.48	0.60	0.50	0.79	0.00	0.65	0.31	0.16	0.45	0.08	0.05	0.02	0.12	0.14	0.45
		C12	0.18	0.06	0.28	0.22	0.06	0.10	0.09	0.09	0.11	0.38	0.31	0.00	0.08	0.23	0.24	0.06	0.05	0.53	0.06	0.05	0.15
Job-Related Activities	D5	C13	0.72	0.48	0.74	0.14	0.05	0.08	0.18	0.05	0.35	0.33	0.26	0.14	0.00	0.31	0.40	0.10	0.18	0.22	0.09	0.14	0.06
		C14	0.09	0.38	0.53	0.26	0.06	0.14	0.06	0.06	0.19	0.14	0.18	0.13	0.53	0.00	0.48	0.18	0.09	0.17	0.05	0.48	0.09
		C15	0.18	0.14	0.38	0.36	0.09	0.18	0.20	0.11	0.28	0.29	0.50	0.11	0.36	0.28	0.00	0.06	0.05	0.06	0.06	0.33	0.27
Facilities and Equipment	D6	C16	0.81	0.64	0.72	0.59	0.38	0.33	0.12	0.64	0.26	0.33	0.28	0.38	0.69	0.14	0.40	0.00	0.69	0.26	0.78	0.08	0.55
		C17	0.76	0.53	0.74	0.79	0.12	0.26	0.03	0.55	0.13	0.35	0.05	0.28	0.74	0.16	0.29	0.33	0.00	0.85	0.65	0.45	0.48
		C18	0.83	0.85	0.67	0.76	0.29	0.14	0.50	0.28	0.03	0.40	0.06	0.11	0.26	0.09	0.14	0.06	0.09	0.00	0.14	0.09	0.79
		C19	0.72	0.45	0.72	0.83	0.08	0.22	0.55	0.33	0.28	0.35	0.67	0.67	0.31	0.48	0.15	0.72	0.71	0.55	0.00	0.33	0.28
Teacher Extra-Works	D7	C20	0.16	0.11	0.50	0.69	0.05	0.06	0.06	0.08	0.38	0.08	0.79	0.20	0.81	0.72	0.65	0.12	0.06	0.02	0.09	0.00	0.18
		C21	0.67	0.77	0.13	0.05	0.06	0.74	0.08	0.09	0.05	0.18	0.16	0.18	0.06	0.09	0.06	0.06	0.03	0.09	0.02	0.17	0.00

Moreover, Kukk and Heikkinen emphasized on the importance of continuous evaluation of exercises and believed that external motivators and some things that were attractive for students, such as Field-Trip had a significant effect on the efficiency of the course [2]. He emphasized that the intensity of the exercises should be designed according to the student's progress in the course. For example, at the beginning of the semester and in the basic issues, exercises should not be in such a way that it has a negative effect on the student's confidence, but after a more student familiarity with the course's content, more difficult exercises can be considered.

Table 6. Reliability of the input data for each one of the 8 experts.

Expert	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Q_f	0.064	0.124	0.084	0.052	0.077	0.108	0.105	0.103

Mälkki and Paatero, having conducted a study, concluded that a basic factor in the output of a training system was the existence of an up-to-date and proper curriculum, and they provided a strategic drawing method to achieve it [50].

Rodgers et al., in another comparison, investigated the importance of Teacher Assists in a better learning of students and creating a virtual feedback system [51]. Mustafa et al. examined the importance of the existence of a system for assessing the satisfaction of the engineering students in scientific progress and the motivation for progress in their discipline [52]. Shi points out that although we pay more attention to the teaching methods, the availability of textbooks for effective teaching is of utmost importance for both the students and the professors [53].

Bektaş and Tayauova, in a study, concluded that the collaboration between the universities and the industry would create new capacities and more effectiveness of the courses offered in the university. On this basis, it seems that the description of the applications of each topic and definition of industry-related projects for students of engineering disciplines is indispensable.

However, in this regard, the teacher should have sufficient industrial experiences and to be up to date through activities in the industry sector with academic activities [54]. Laguador and Dotong, believe that it is needful to followup on the training and assigning time to solve the problems of students. Therefore, the teacher should be available 5 hours a week to solve student problems [55]. Summarizing the above, in this section, we select Dimensions and Criteria in accordance with table 2.

Table 7. Maximum, minimum and mean values for Q_f

Q_f (Max)	Q_f (Min)	Q_f (Avg)
0.124	0.052	0.090

4. Findings and results

Based on Section 2.1, the dimensions and criteria are determined in Section 3 (D1 to D7 and C1 to C21, as presented in Table 2), then according to Section 2.2, a direct influencing questionnaire (x matrix) is established, which is shown in table 3.

In the next step, each expert expresses each x_{ij} as the effect of criterion No. i on the criterion No. j in the form of a linguistic expression (Table 1). An example of these completed tables is shown in table 4.

Similar tables were completed by eight experts including 5 experienced professors in engineering drawing at the Sharif University of Technology (Tehran-Iran) and 3 Mechanical Engineering students in the Sharif University of Technology with grades 12 to 20 in the course.

The tables obtained from each expert are converted to equivalent fuzzy triangular numbers using table 1, and the matrices x_u^k, x_m^k, x_l^k are formed for k = 1 to 8.

Afterwards, the values $x_u^{avg}, x_m^{avg}, x_l^{avg}$ are calculated according to (4), (5), and (6). Then the matrix of direct influence was obtained from the combination (average) of the collected opinions of the experts in the crisp format according to (7) (see Table 5). This matrix is the input of the DEMATEL process (Matrix A).

In the next step, calculation of the reliability of the input data for each one of the 8 experts is made according to (8), (9), (10), (11), and (12), and its Q_f is obtained, the results of which are given in table 6. In addition, the maximum, minimum, and mean values for Q_f are presented in table 7. According to the results obtained, the Q_f values obtained are less than the allowable value for the maximum Q_f by the experts ($Q_f^{\max} = 0.15$), and thus the reliability of the data obtained is acceptable.

Table 8. Normalized matrix A (matrix B).

DEMATEL			Lecturing			Class Works			Home Works			Assessment			Job-Related Activities			Facilities and Equipment			Teacher Extra-Works		
			D1			D2			D3			D4			D5			D6			D7		
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
Lecturing	D1	C1	0.00	0.08	0.05	0.07	0.07	0.01	0.01	0.01	0.02	0.06	0.04	0.01	0.05	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.03
		C2	0.08	0.00	0.05	0.06	0.02	0.01	0.00	0.02	0.01	0.03	0.00	0.00	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.01
		C3	0.08	0.05	0.00	0.08	0.02	0.01	0.04	0.03	0.05	0.04	0.08	0.01	0.08	0.05	0.04	0.06	0.06	0.08	0.06	0.02	0.05
		C4	0.08	0.07	0.08	0.00	0.01	0.04	0.02	0.02	0.02	0.04	0.05	0.09	0.05	0.04	0.02	0.03	0.02	0.02	0.08	0.03	0.07
Class Works	D2	C5	0.03	0.02	0.01	0.02	0.00	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.04
		C6	0.00	0.01	0.02	0.06	0.06	0.00	0.04	0.03	0.04	0.03	0.02	0.04	0.02	0.01	0.02	0.01	0.01	0.03	0.03	0.01	0.06
Home Works	D3	C7	0.00	0.01	0.00	0.02	0.05	0.01	0.00	0.05	0.06	0.01	0.06	0.02	0.00	0.02	0.04	0.01	0.01	0.01	0.02	0.01	0.03
		C8	0.02	0.02	0.01	0.03	0.00	0.05	0.02	0.00	0.01	0.01	0.03	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.01	0.01	0.03
		C9	0.01	0.00	0.04	0.02	0.03	0.01	0.05	0.03	0.00	0.01	0.06	0.02	0.01	0.02	0.05	0.01	0.01	0.02	0.01	0.01	0.03
Assessment	D4	C10	0.06	0.04	0.07	0.03	0.04	0.03	0.02	0.03	0.02	0.00	0.05	0.06	0.04	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.06
		C11	0.02	0.04	0.08	0.06	0.01	0.02	0.05	0.06	0.05	0.08	0.00	0.07	0.03	0.02	0.05	0.01	0.00	0.00	0.01	0.02	0.05
		C12	0.02	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.03	0.00	0.01	0.02	0.03	0.01	0.00	0.06	0.01	0.00	0.02
Job-Related Activities	D5	C13	0.08	0.05	0.08	0.02	0.00	0.01	0.02	0.00	0.04	0.04	0.03	0.01	0.00	0.03	0.04	0.01	0.02	0.02	0.01	0.01	0.01
		C14	0.01	0.04	0.06	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.06	0.00	0.05	0.02	0.01	0.02	0.00	0.05	0.01
		C15	0.02	0.02	0.04	0.04	0.01	0.02	0.02	0.01	0.03	0.03	0.05	0.01	0.04	0.03	0.00	0.01	0.00	0.01	0.01	0.03	0.03
Facilities and Equipment	D6	C16	0.09	0.07	0.08	0.06	0.04	0.04	0.01	0.07	0.03	0.04	0.03	0.04	0.07	0.01	0.04	0.00	0.07	0.03	0.08	0.01	0.06
		C17	0.08	0.06	0.08	0.08	0.01	0.03	0.00	0.06	0.01	0.04	0.00	0.03	0.08	0.02	0.03	0.04	0.00	0.09	0.07	0.05	0.05
		C18	0.09	0.09	0.07	0.08	0.03	0.01	0.05	0.03	0.00	0.04	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.08
		C19	0.08	0.05	0.08	0.09	0.01	0.02	0.06	0.04	0.03	0.04	0.07	0.07	0.03	0.05	0.02	0.08	0.08	0.06	0.00	0.04	0.03
Teacher Extra-Works	D7	C20	0.02	0.01	0.05	0.07	0.00	0.01	0.01	0.01	0.04	0.01	0.08	0.02	0.09	0.08	0.07	0.01	0.01	0.00	0.01	0.00	0.02
		C21	0.07	0.08	0.01	0.00	0.01	0.08	0.01	0.01	0.00	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.02	0.00

Table 9. Total influence matrix (T_C).

DEMATEL			Lecturing			Class Works			Home Works			Assessment			Job-related Activities			Facilities and Equipment			Teacher Extra-Works		
			D1			D2			D3			D4			D5			D6			D7		
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
Lecturing	D1	C1	0.07	0.14	0.12	0.13	0.10	0.04	0.04	0.04	0.05	0.10	0.10	0.05	0.10	0.09	0.06	0.03	0.03	0.04	0.04	0.03	0.08
		C2	0.13	0.05	0.10	0.10	0.05	0.03	0.03	0.04	0.03	0.07	0.05	0.04	0.07	0.06	0.06	0.03	0.03	0.03	0.04	0.04	0.05
		C3	0.20	0.16	0.13	0.19	0.07	0.07	0.10	0.09	0.11	0.12	0.17	0.08	0.17	0.12	0.11	0.10	0.10	0.14	0.12	0.07	0.14
		C4	0.18	0.16	0.18	0.10	0.06	0.09	0.07	0.07	0.07	0.11	0.13	0.14	0.13	0.10	0.08	0.07	0.06	0.07	0.12	0.06	0.14
Class Works	D2	C5	0.06	0.04	0.04	0.05	0.02	0.03	0.03	0.04	0.03	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.06
		C6	0.06	0.06	0.08	0.11	0.09	0.03	0.07	0.06	0.07	0.07	0.07	0.07	0.06	0.04	0.06	0.03	0.03	0.06	0.06	0.03	0.10
Home Works	D3	C7	0.05	0.04	0.05	0.06	0.07	0.03	0.02	0.07	0.08	0.04	0.09	0.04	0.04	0.04	0.07	0.02	0.03	0.03	0.04	0.03	0.07
		C8	0.05	0.05	0.04	0.06	0.02	0.07	0.04	0.02	0.03	0.04	0.06	0.04	0.03	0.03	0.04	0.02	0.02	0.02	0.03	0.02	0.06
		C9	0.05	0.05	0.08	0.06	0.05	0.03	0.08	0.05	0.03	0.04	0.10	0.05	0.04	0.04	0.08	0.02	0.03	0.04	0.03	0.03	0.07
Assessment	D4	C10	0.13	0.10	0.13	0.10	0.08	0.06	0.06	0.06	0.06	0.05	0.10	0.10	0.09	0.06	0.05	0.03	0.03	0.06	0.05	0.03	0.11
		C11	0.10	0.10	0.15	0.13	0.05	0.06	0.09	0.10	0.10	0.14	0.07	0.12	0.09	0.06	0.10	0.04	0.03	0.05	0.05	0.04	0.11
		C12	0.06	0.05	0.07	0.06	0.03	0.03	0.03	0.03	0.03	0.07	0.07	0.03	0.04	0.05	0.05	0.02	0.02	0.08	0.03	0.02	0.05
Job-Related Activities	D5	C13	0.14	0.11	0.14	0.08	0.04	0.04	0.05	0.04	0.07	0.08	0.08	0.05	0.05	0.07	0.08	0.03	0.04	0.06	0.04	0.04	0.06
		C14	0.07	0.09	0.11	0.08	0.03	0.04	0.03	0.03	0.05	0.05	0.06	0.04	0.10	0.03	0.09	0.04	0.03	0.05	0.03	0.07	0.05
		C15	0.07	0.06	0.09	0.09	0.03	0.04	0.05	0.04	0.06	0.07	0.10	0.04	0.08	0.06	0.03	0.03	0.02	0.03	0.03	0.05	0.07
Facilities and Equipment	D6	C16	0.21	0.17	0.19	0.18	0.09	0.09	0.07	0.13	0.09	0.12	0.12	0.11	0.16	0.08	0.11	0.05	0.12	0.09	0.14	0.05	0.15
		C17	0.20	0.16	0.19	0.19	0.07	0.08	0.06	0.11	0.07	0.12	0.09	0.10	0.17	0.09	0.09	0.08	0.04	0.15	0.12	0.09	0.14
		C18	0.17	0.16	0.15	0.15	0.07	0.05	0.09	0.07	0.04	0.10	0.07	0.06	0.09	0.06	0.06	0.04	0.04	0.04	0.06	0.04	0.14
		C19	0.20	0.16	0.20	0.21	0.07	0.08	0.12	0.10	0.09	0.12	0.17	0.14	0.13	0.12	0.09	0.12	0.12	0.12	0.07	0.08	0.13
Teacher Extra-Works	D7	C20	0.09	0.08	0.13	0.14	0.04	0.04	0.04	0.05	0.08	0.06	0.14	0.07	0.14	0.12	0.12	0.04	0.03	0.04	0.05	0.03	0.07
		C21	0.11	0.12	0.06	0.05	0.03	0.09	0.03	0.03	0.03	0.05	0.05	0.04	0.04	0.04	0.03	0.02	0.02	0.03	0.02	0.03	0.03

Table 10. Values for influence, and objectivity, sum of influence and objectivity, and net influence for each criterion and its relevant rank.

DEMATEL	Dimension	Criterion	r_i	Rank	s_j	Rank	r_i+s_j	Rank	r_i-s_j	Rank
Lecturing	D1	C1	1.51	10	2.40	2	3.91	3	-0.88	19
Lecturing	D1	C2	1.13	15	2.10	4	3.23	9	-0.97	21
Lecturing	D1	C3	2.56	2	2.46	1	5.03	1	0.10	7
Lecturing	D1	C4	2.20	5	2.33	3	4.53	2	-0.12	8
Class Works	D2	C5	0.66	21	1.17	17	1.83	21	-0.52	17
Class Works	D2	C6	1.31	12	1.13	18	2.44	16	0.18	6
Home Works	D3	C7	1.01	17	1.19	15	2.20	19	-0.18	11
Home Works	D3	C8	0.81	20	1.28	13	2.09	20	-0.47	15
Home Works	D3	C9	1.06	16	1.28	12	2.34	18	-0.22	13
Assessment	D4	C10	1.53	9	1.67	8	3.20	10	-0.13	9
Assessment	D4	C11	1.77	6	1.92	5	3.69	5	-0.15	10
Assessment	D4	C12	0.92	19	1.45	10	2.37	17	-0.52	18
Job-Related Activities	D5	C13	1.39	11	1.88	6	3.27	8	-0.49	16
Job-Related Activities	D5	C14	1.19	13	1.38	11	2.57	14	-0.20	12
Job-Related Activities	D5	C15	1.16	14	1.47	9	2.63	13	-0.31	14
Facilities and Equipment	D6	C16	2.51	3	0.88	21	3.38	6	1.63	1
Facilities and Equipment	D6	C17	2.40	4	0.88	20	3.28	7	1.52	2
Facilities and Equipment	D6	C18	1.75	7	1.26	14	3.01	11	0.49	5
Facilities and Equipment	D6	C19	2.65	1	1.18	16	3.83	4	1.46	3
Teacher Extra-Works	D7	C20	1.58	8	0.90	19	2.49	15	0.68	4
Teacher Extra-Works	D7	C21	0.95	18	1.86	7	2.81	12	-0.91	20

Table 11. Matrix T_D (total influences of dimensions).

Dimensions	D1	D2	D3	D4	D5	D6	D7	r_i	Rank	s_j	Rank	r_i+s_j	Rank	r_i-s_j	Rank
D1	0.13	0.06	0.06	0.10	0.10	0.07	0.08	0.60	2	0.72	1	1.32	1	-0.12	7
D2	0.06	0.04	0.05	0.05	0.04	0.03	0.05	0.33	6	0.37	6	0.70	7	-0.04	3
D3	0.05	0.05	0.05	0.06	0.05	0.03	0.04	0.32	7	0.40	5	0.72	6	-0.07	5
D4	0.10	0.05	0.06	0.08	0.07	0.04	0.06	0.46	3	0.53	2	0.99	3	-0.07	4
D5	0.09	0.04	0.05	0.06	0.07	0.04	0.06	0.40	5	0.50	3	0.90	4	-0.10	6
D6	0.18	0.08	0.09	0.11	0.10	0.09	0.10	0.75	1	0.32	7	1.06	2	0.43	1
D7	0.10	0.05	0.04	0.07	0.08	0.03	0.04	0.41	4	0.43	4	0.84	5	-0.02	2

Now, in accordance with Section 2.6, normalization of the matrix of crisp direct influence (Table 5) is investigated. The value of a_m according to the (13) is as follows:

$$a_m = \text{Max}\ \{9.203, 9.413\} = 9.413$$

Thus, by dividing each one of the entries of matrix A to a_m, the normalized matrix A (the matrix B) is obtained, as presented in table 8.
Then according to Section 2.7 and based on (18), (20), and (21), the matrix T_C and the values for r_i, s_j, $r_i + s_i$ and r_i-s_i are obtained in the form of tables 9 and 10.
In this step, the matrix T_D, according to the (22) and (23), is obtained from the T_C matrix. For this matrix, according to Section 2.9, the values for r_i, s_j, $r_i + s_i$, and r_i-s_i are obtained in the form of table 11 and the relevant causal-effect diagram is shown in figure 4. Then, if we consider the mean of the values of the matrix T_D (that is 0.07) as the threshold value, the influential relation matrix will be in the form of table 12. Now, the process of DEMATEL is completed, and the resulting INRM (influential network relationship map) will be in the form of figure 5. The result of this step is the non-weighted supermatrix using the T_{DN} and T_{CN} matrices after transposing them. Then according to Section 2.11, the weighted supermatrix (T_f) is obtained in the form of table 13. In order to achieve the weight of each criterion and domain, exponentiation can be applied to the weighted supermatrix to attain convergence between the data.
It can be observed that, in the power of 3 of the weighted supper-matrix, this matrix has a good convergence whose result is as table 14, and ultimately, the final weights and ranks of criteria and dimensions are obtained as of table 15.

5. Discussion

When the data is analyzed, it should be considered that the output weights of the FDANP process indicate the weight of each criterion in determination of the final quality of the course, and indeed, if an external observer wants to measure the quality of this course, he can put each criterion against the weights of the output of the FDNAP process. On the other hand, the output of the DEMATEL process, as r_i, s_j, $r_i + s_i$, and r_i-s_i, in general, explains which factors have more interaction with other factors, and this interaction is either influence or objectivity. Finally, an investigation of the weight of C_i's shows that the criteria of C21 (availability for student bug fixing), C11 (presence of TA in the class), and C3 (up to date curriculum and teaching style) will have a maximum weight in assessing this course.
Besides, investigating influence and objectivity graphs (Figure 3) shows that if we want to achieve the desired results and increase the quality of the presentation of this course, factors of C3 (up to date curriculum and teaching style), C4 (Interactive lecturing), C19 (existence of student satisfaction measurement system), C16 (Well Equipped classroom) and C17 (Good internet system) should be considered.
In addition, about Di's, the weights of FDANP indicate that the domains of D1 (lecturing), D4 (Assessment), and D5 (job-related activities) will have more effect on the assessment of the quality of this lesson. According to the results of investigating the influence and objectivity table (Table 15) and causal diagrams (Figure 5), in order to achieve optimal quality, manipulating domains of D6 (Facilities and Equipment), D1 (lecturing) and D4 (Evaluation) will lead to achieving a favorable result. The above information can be used as a tool for improving the quality and efficiency of presenting the engineering drawing course.

Table 12. Influential relation matrix based on the threshold value of matrix T_D

Dimensions	D1	D2	D3	D4	D5	D6	D7
D1	1	0	0	1	1	0	1
D2	0	0	0	0	0	0	0
D3	0	0	0	0	0	0	0
D4	1	0	0	1	0	0	0
D5	1	0	0	0	1	0	0
D6	1	1	1	1	1	1	1
D7	1	0	0	1	1	0	0

6. Conclusion

Considering the importance of the course of engineering drawing and its effect on the professional future of engineering students, this course is offered as a compulsory course in most universities for the engineering discipline. Therefore, it is deemed necessary to teach this course in an appropriate quality, and a proper identification of the factors affecting its teaching quality, their interaction mechanism, and also control of the most important affecting factors is very important.
This problem is considered as a multi-criteria decision-making one, and one of its solutions is algorithms based on the use of the expert opinions.

Table 13. Weighted supper-matrix

DEMATEL			Lecturing			Class Works			Home Works			Assessment			Job-Related Activities			Facilities and Equipment			Teacher Extra-Works		
			D1			D2			D3			D4			D5			D6			D7		
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
Lecturing	D1	C1	0.04	0.08	0.07	0.07	0.06	0.04	0.04	0.04	0.04	0.06	0.04	0.05	0.07	0.04	0.05	0.07	0.06	0.07	0.06	0.05	0.08
		C2	0.07	0.03	0.05	0.06	0.04	0.04	0.04	0.04	0.03	0.05	0.05	0.04	0.05	0.06	0.05	0.06	0.05	0.06	0.05	0.04	0.08
		C3	0.06	0.06	0.04	0.07	0.04	0.05	0.04	0.03	0.06	0.06	0.07	0.06	0.07	0.08	0.07	0.06	0.06	0.06	0.06	0.07	0.04
		C4	0.06	0.06	0.06	0.04	0.05	0.07	0.05	0.05	0.04	0.05	0.06	0.06	0.04	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.03
Class Works	D2	C5	0.08	0.07	0.06	0.04	0.04	0.09	0.10	0.04	0.09	0.06	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.06	0.05	0.06	0.03
		C6	0.03	0.04	0.05	0.06	0.09	0.03	0.05	0.11	0.05	0.05	0.06	0.06	0.04	0.05	0.05	0.05	0.06	0.04	0.05	0.06	0.09
Home Works	D3	C7	0.03	0.03	0.03	0.04	0.04	0.05	0.02	0.06	0.07	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.05	0.04	0.03	0.03
		C8	0.03	0.04	0.03	0.03	0.06	0.05	0.06	0.03	0.05	0.05	0.05	0.04	0.03	0.03	0.03	0.05	0.05	0.04	0.04	0.03	0.04
		C9	0.04	0.04	0.04	0.03	0.05	0.05	0.07	0.05	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.03	0.03	0.04	0.05	0.03
Assessment	D4	C10	0.07	0.07	0.05	0.05	0.06	0.06	0.04	0.05	0.04	0.04	0.07	0.08	0.06	0.05	0.05	0.05	0.06	0.06	0.04	0.04	0.06
		C11	0.06	0.05	0.07	0.05	0.06	0.05	0.09	0.08	0.09	0.07	0.04	0.07	0.06	0.06	0.07	0.05	0.05	0.05	0.06	0.09	0.06
		C12	0.03	0.04	0.04	0.06	0.05	0.06	0.04	0.05	0.04	0.07	0.06	0.03	0.04	0.04	0.03	0.05	0.05	0.04	0.05	0.04	0.05
Job-Related Activities	D5	C13	0.07	0.06	0.07	0.07	0.05	0.04	0.04	0.05	0.04	0.07	0.05	0.04	0.04	0.08	0.08	0.06	0.07	0.06	0.05	0.07	0.07
		C14	0.06	0.05	0.05	0.05	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.06	0.03	0.06	0.03	0.03	0.04	0.05	0.06	0.06
		C15	0.04	0.05	0.04	0.04	0.03	0.04	0.07	0.06	0.07	0.04	0.05	0.05	0.07	0.06	0.03	0.04	0.04	0.04	0.04	0.06	0.06
Facilities and Equipment	D6	C16	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.02	0.02
		C17	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.03	0.01	0.03	0.03	0.02	0.01
		C18	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.02	0.05	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.02	0.03
		C19	0.03	0.03	0.03	0.04	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.02	0.02	0.02
Teacher Extra-Works	D7	C20	0.04	0.05	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.06	0.08	0.06	0.04	0.05	0.03	0.05	0.03	0.05
		C21	0.09	0.07	0.09	0.09	0.13	0.12	0.10	0.10	0.10	0.10	0.09	0.09	0.08	0.06	0.08	0.10	0.08	0.11	0.08	0.07	0.05

Table 14. Stable limiting weighted super-matrix while raising power.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
C1	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C2	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C3	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C4	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C5	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C6	0.0558	0.0500	0.0571	0.0536	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C7	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C8	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0199	0.0192
C9	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C10	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C11	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C12	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C13	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C14	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C15	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C16	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C17	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C18	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C19	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C20	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192
C21	0.0558	0.0500	0.0571	0.0537	0.0567	0.0576	0.0396	0.0405	0.0428	0.0556	0.0633	0.0462	0.0588	0.0461	0.0493	0.0200	0.0192

C18	C19	C20	C21
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887
0.0290	0.0265	0.0437	0.0887

Therefore, there is a need for a method like DEMATEL: on the other hand, it is required to use a logic that is appropriate to human views and characteristics, such as fuzzy logic. In addition, since the DEMATEL process does not attain the weight of the criteria, and in many of the next decision-making algorithms, the weight of the criteria is required, that ANP is combined with DEMATEL and fuzzy logic, and a hybrid method called fuzzy- DANP (FDANP) is used to solve this problem. During this algorithm, the reliability of the data was also investigated to prevent the undesirable effects of an outlier.

According to the results of this study, "updated content and lecturing methods", “evaluation policy in a manner appropriate to the content of the course and its clarity", "expressing applications of courses", and "the availability of professors and their assistants to solve the student problems" will have a significant effect on improving the quality of the engineering drawing course.

Table 15. Final weights for criteria and dimensions.

Dimension			Criterion	Criterion Weight	Total Rank	Dimension Weight	Total Rank
Lecturing	**D1**	**C1**	Lecture Duration	0.0558	7	0.217	1
		C2	Example Load	0.0500	10		
		C3	Up-to-Date Curriculum	0.0571	5		
		C4	Interactive Lecturing	0.0537	9		
Class Works	**D2**	**C5**	Exercise Load	0.0567	6	0.114	6
		C6	Presence of TA's in Class	0.0576	4		
Home Works	**D3**	**C7**	Home Works Load	0.0396	17	0.123	5
		C8	Home Works Follow up Rate	0.0405	16		
		C9	Projects Load	0.0428	15		
Assessment	**D4**	**C10**	Frequency of Assessment	0.0556	8	0.165	2
		C11	Final Assessment Policy	0.0633	2		
		C12	Clarity of Evaluation Policy	0.0462	12		
Job-Related Activities	**D5**	**C13**	Describing Application of Topics	0.0588	3	0.154	3
		C14	Field Trip	0.0461	13		
		C15	Defining Industry-Oriented Project for Students	0.0493	11		
Facilities and Equipment	**D6**	**C16**	Well Equipped Classrooms	0.0200	20	0.095	7
		C17	Good Internet System	0.0192	21		
		C18	Availability of Good Text Books and Journals	0.0290	18		
		C19	Existence of Student Satisfaction Measurement System	0.0265	19		
Teacher Extra-Works	**D7**	**C20**	Having Industrial Experience	0.0437	14	0.132	4
		C21	Availability for student bug fixes	0.0887	1		

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نشریه هوش مصنوعی و داده کاوی

شناسایی عوامل مؤثر بر کیفیت تدریس نقشه کشی مهندسی با استفاده از یک مدل MCDM ترکیبی

حمید حق شناس گرگانی* و علیرضا جهانتیغ پاک

مرکز گرافیک مهندسی، دانشگاه صنعتی شریف، تهران، ایران.

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چکیده:

شناسایی عوامل مؤثر بر کیفیت آموزش نقشه کشی مهندسی و برهمکنش میان آنها ضروری است تا مشخص شود کدام دستکاری باعث افزایش کیفیت تدریس این دوره می‌شود. از آنجا که موضوع فوق یک مسئله تصمیم گیری چند معیاره (MCDM) است و از طرف دیگر با عوامل انسانی روبرو هستیم ، برای حل آن روش Fuzzy DEMATEL پیشنهاد شده است. علاوه بر این، از آنجا که تجزیه و تحلیل DEMATEL منجر به وزن دهی معیارها نمی شود، با ANP تلفیق و از یک روش فازی ترکیبی (DEMATEL ANP (FDANP استفاده می‌شود. نتایج بررسی ۷ بعد و ۲۱ معیار نشان می‌دهد که، در صورت استفاده از روش‌ها و مطالب تدریس به روز شده، خط مشی ارزشیابی متناسب با دوره، در دسترس بودن استاد درس و دستیاران وی به منظور رفع اشکالات دانشجویان و همچنین وجود یک سیستم تعاملی مبتنی بر نظرات دانشجویان، کیفیت تدریس این دوره افزایش می‌یابد.

کلمات کلیدی: تدریس، نقشه کشی مهندسی، DEMATEL، ANP، منطق فازی.