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DEMATEL-CRITIC DECISION MODEL ON FEATURES OF INDUSTRY 4.0

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Abstract

The genesis of Industry 4.0 originates from the integration of technology with production systems. The integrated manufacturing system embedded with several features is presently gaining momentum. The production sectors are upgrading their production mechanisms with various added features of industry 4.0 to enhance their performance. Every manufacturing firm is making new initiatives to integrate the features of industry 4.0 to transform themselves into smart production firms to exhibit the best production performance without compromising quality. In connection with it, a question on incorporating the significant features of industry 4.0 certainly interludes the minds of the production decision-makers. The decision on integrating the features of technology to the existing production systems should be purely decided by the managerial persons, which is quite a challenging task. Decision-making is an inevitable and indispensable process in all phases of production. The optimal decisions are obtained by the right choice of multi-criteria decision-making methods. Selection of criteria and computation of each criterion weights are requisite in raking the alternatives. In line with it, this project work is undertaken to determine the efficiency of two integrated decision-making methods. One is the method of DEMATEL (Decision-making trial and evaluation laboratory) and the other is the method of CRITIC (CRiteria Importance Through Intercriteria Correlation). The former method is applied to analyze the interrelation and inter impacts between the criteria of decision-making and the latter is used to find the criterion weights. The proposed integrated DEMATEL-CRITIC will first determine the causal relationship between criteria and then compute the weights of

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only the criteria. The efficacy of the proposed novel method is tested by applying it to decision-making on the features of industry 4.0.

1. Introduction

Decision-making process takes place at regular intervals of time in all significant phases of industrial development. The decision-makers of a manufacturing company are always placed in a tough situation of making the right choices of alternatives. Every firm needs to upgrade itself with new trends of technology and now it is the era of industry 4.0. Every manufacturing sector incorporates different techniques that are embedded with the features of industry 4.0, but they face a decision-making challenge in choosing the right technology. To handle this, the decision-makers adopt different multi-criteria decision-making methods which are both used to find the criterion weights and to rank the alternatives.

The Decision-making trial and evaluation laboratory (DEMATEL) was first initiated by the Geneva Research Centre of the Battelle Memorial Institute [1]. This method is primarily used to find the cause and effect of the criteria which enables the decision-makers to acquire a profound understanding of the causal effect between the criteria. The method of DEMATEL is applied in various decision-making in the fields of medicine, environmental sciences, economics, econometrics, business, management, social sciences and decision sciences. Sheng et al. [2] has presented a review of DEMATEL in combination with other MCDM methods such TOPSIS, AHP, VIKOR but to the best of our knowledge, the method of DEMATL is not combined with CRITIC so far [3, 4, 5, 6].

The method of CRITIC was developed by Diakoulaki et al. [7] and it was applied to determine the criterion weights. Esra [8, 9] has described the combination of CRITIC with the methods of AHP, TOPSIS, VIKOR and other MCDM methods. In addition to the above combinations, this paper proposes a new combination of DEMATEL and CRITIC which are used to find the causal relationship and the criterion weights respectively. The paper is organized as follows, Section 2 presents the methodology; section 3 applies the newly combined method to make optimal decisions on the attributes of industry 4.0; section 4 concludes the paper.

2. Methodology

This section presents the steps involved in the multi-criteria decision-making methods of DEMATEL and CRITIC.

DEMATEL Procedure

Step 1. Formulation of direct relation decision-making matrix X based on expert's opinion

$$X = \begin{bmatrix} 0 & \cdots & x_{n1} \\ \vdots & \ddots & \vdots \\ x_{1n} & \cdots & 0 \end{bmatrix}$$

Step 2. Normalization of the direct relation matrix using the below expression

$$k = \max\left\{\max \sum_{j=1}^{n} x_{ij}, \sum_{i=1}^{n} x_{ij}\right\} \; N = \frac{1}{k} * X$$

Step 3. Determination of the Total Relation Matrix T

$$T = N \times (I - N)^{-1}.$$

Step 4. Final output and create a causal diagram

$$D = \sum_{j=1}^{n} T_{ij}$$

$$R = \sum_{i=1}^{n} T_{ij}$$

Where D is the sum of rows and R is the sum of columns

The values of $D + R$ and $D - R$ can be calculated by D and R, where $D + R$ represent the degree of importance of factor i in the entire system and $D - R$ represent net effects that factor i contributes to the system.

CRITIC Procedure

Step 1. Formulation of decision-making problem with alternatives and

criteria together with initial decision-making matrix.

Step 2. Normalization of the matrix

$$u_j(x_{ij}) = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \, i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n.$$

Step 3. Determine the standard deviation of each criteria and correlation between the criteria to find the weights W_j of the criteria.

$$W_j = \frac{c_j}{\sum_{j=1}^{n} c_j}, \; C_j = \sigma * \sum_{j=1}^{n} (1 - r_{ij})$$

Where C_j is the quantity of information and r_{ij} is the correlation between the criteria.

3. Application of DEMATRL-CRITIC in Decision Making on Features of Industry 4.0

In this section, the combined decision-making method is applied to determine the causal relationship between predominate features of industry 4.0 and their weightage. In general, every industry is getting embellished into the context of industry 4.0 in one or another way by incorporating many technologies. The technology associated with industry 4.0 is expected to possess certain mandate attributes stated in Table 3.1. It is very essential for the industrial decision-makers to have widespread knowledge of the causal-effect between the attributes of industry 4.0 so as to make optimal decisions in choosing the most suitable technology embedded with such attributes. To determine the weightage of each attribute, the method of CRITIC is used and the alternatives are ranked by weighted sum method

Attributes	Meaning
Modularity	Design manufacturing and assembly to reduce complexity
Interoperability	Sharing of Technical communications within the

	systems
Decentralisation	Cyber physical systems to make decisions
Information conceptualization	Maintenance of information
Instant responsiveness	Immediate response to the stimulus

By using the method of DEMATEL the causal and effect attributes are determined as follows

Direct relation matrix

	Modularity	Interoperability	Decentralisation	Information conceptualization	Instant responsiveness
Modularity	0	2	3	2	2
Interoperability	3	0	3	3	3
Decentralisation	2	3	0	2	3
Information conceptualization	3	3	3	0	2
Instant responsiveness	3	4	2	3	0

The normalized direct-relation matrix

	Modularity	Interoperability	Decentralisation	Information conceptualization	Instant responsiveness
Modularity	0	0.167	0.25	0.167	0.167
Interoperability	0.25	0	0.25	0.25	0.25
Decentralisation	0.167	0.25	0	0.167	0.25
Information conceptualization	0.25	0.25	0.25	0	0.167
Instant responsiveness	0.25	0.333	0.167	0.25	0

The total relation matrix

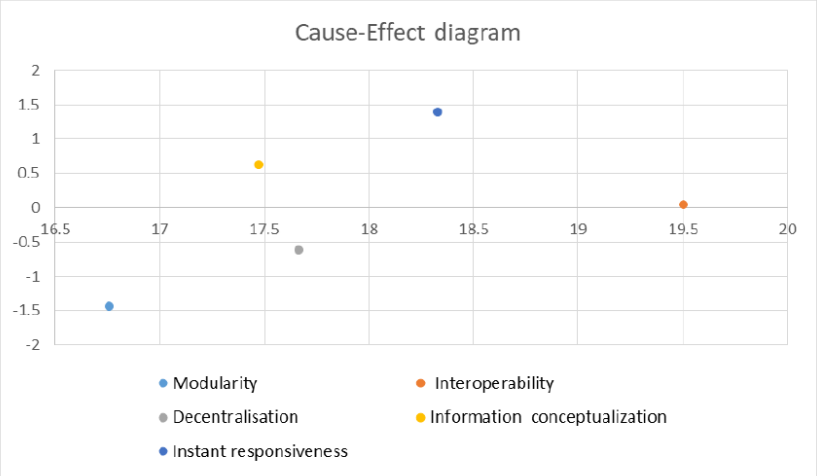
	Modularity	Interoperability	Decentralisation	Information conceptualization	Instant responsiveness
Modularity	1.423	1.669	1.634	1.462	1.473
Interoperability	2.019	1.946	2.028	1.885	1.894
Decentralisation	1.732	1.902	1.593	1.617	1.682
Information conceptualization	1.884	1.999	1.896	1.558	1.714
Instant responsiveness	2.039	2.216	1.991	1.903	1.709

The total-relationships matrix by considering the threshold value of 1.795

	Modularity	Interoperability	Decentralisation	Information conceptualization	Instant responsiveness
Modularity	0	0	0	0	0
Interoperability	2.019	1.946	2.028	1.885	1.894
Decentralisation	0	1.902	0	0	0
Information conceptualization	1.884	1.999	1.896	0	0
Instant responsiveness	2.039	2.216	1.991	1.903	0

The final output

	R	D	D+R	D-R
Modularity	9.097	7.661	16.759	-1.436
Interoperability	9.732	9.773	19.505	0.042
Decentralisation	9.142	8.526	17.668	-0.616
Information conceptualization	8.424	9.05	17.474	0.626
Instant responsiveness	8.472	9.857	18.329	1.385



CRITIC Method to determine the weight of the attributes. Let us consider the following decision-making matrix with five alternative industry 4.0 technologies. The decision-maker has to determine the technology that shall be incorporated into his manufacturing systems. The data in the matrix comprises of the percentage of the presence of each criterion in the technology.

	Modularity	Interoperability	Decentralisation	Information conceptualization	Instant responsiveness
Technology I	85	75	45	85	55
Technology II	35	85	95	75	65
Technology III	45	75	85	55	45
Technology IV	95	85	75	45	35
Technology V	85	65	45	25	35

The normalized matrix

0.833333	0.5	0	1	0.666667
0	1	1	0.833333	1
0.166667	0.5	0.8	0.5	0.333333

1	1	0.6	0.333333	0
0.833333	0	0	0	0

The standard Deviation

0.450308536 0.418330013 0.460434577 0.397911213 0.434613494

The criterion weights are

Modularity	Interoperability	Decentralisation	Information conceptualization	Instant responsiveness
0.376596	0.142311	0.187821	0.169262	0.12401

By using the simple method of ranking the alternatives with the above criterion weight and normalized matrix, the alternatives are ranked as follows

Technology I	1
Technology II	2
Technology III	4
Technology IV	3
Technology V	5

Conclusion

This paper proposes a newly combined method of DEMATEL and CRITIC with a weighted sum method to rank the alternate technologies of industry 4.0. This combined method is used to find the criterion weights and to find the causal relationship between the criteria. This method is a novel attempt that shall be extended in combination with other methods.

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