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A Hybrid Model of DANP and INRM for Logistics Companies' Performance Evaluation and Improvement

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Abstract: New challenges about how to measure the performance of organizations have arisen since big data can be found everywhere. In order to make proper decisions, management needs to have strong insight into what is important to the firm and how to improve it. This study looks into logistics companies that rely heavily upon labor as the examples. While transportation and distribution are very important processes for logistics companies to meet customers' requirements, the process of creating appropriate measures is difficult due to the complexity of these activities. The aim of this research is to evaluate the relationship among these key performance indicators and find out the possible direction and coverage of improvement for such companies using hybrid DANP[1] cause-effect and Influential Network Relation Map models. We collected data through expert questionnaires with questions based on discussions with experts (including managers and scholars). The research results help support managers' decision making for improvements in their firm and also can be applied in employee reward systems.

Keywords: hybrid model, performance evaluation and improvement, DANP, Influential Network Relation Map, logistics companies, transportation and distribution.

INTRODUCTION

As different types of performance measures have been used to characterize systems, particularly production, distribution, and inventory systems, we take logistics companies that heavily rely upon labor as our examples. When analyzing the performance of logistics companies, qualitative evaluations such as "good", "adequate", satisfaction and "not bad" are vague and difficult when estimating a numerical result that is known to all. With the application of Internet of Things (IoT) that covers technology and big data analysis, difficult problems that could not be measured in the past are now easily solvable, because IoT reintroduces the issue of how to improve something quickly after obtaining specific information. Therefore, the increasing use of information technology in small- and medium-sized companies facilitates data collection on a broader scale and could lead to more extensive performance measurements [1]. However, numerical performance measurements may inadequately describe the quality of a total solution system and may be vague and hard to use as qualitative evaluations. The goal most industries target is the Key Performance Index, which includes many logistics activities in the supply chain such as on-time delivery, overall customer satisfaction, accurate product, accurate quantity, etc. This study focuses on performance parameters and objectives that play a role in the operating process of organizations.

Logistics companies strive for perfect delivery fulfillment to enhance customer satisfaction, whether the customer is an end-user or another company. Thus, this paper selects the transportation and distribution processes that affect a customer's impression directly as the analysis targets. We look to provide greater insight into the relationships among the indicators so as to catch the point of penetration and improve the operational processes for managers of companies. This study mainly builds a measure model of the relationships among operation performance indicators and proposes suggestions to improve the operation processes for organizations such as logistics companies.

[1] Decision Making Trial and Evaluation Laboratory based Analytic Network Process is abbreviated as DANP.

LITERATURE REVIEW

Evaluation Method of Operation Performance

Many analysis methods of logistics performance adopt financial ratio, productive efficiency, and utilization measurements, such as the SCOR model [2], which defines five performance attributes: reliability, responsiveness, agility, costs and assets. Mohsen, Claudine, Behnam, & Joseph [3] proposed a framework that adopts a multidimensional approach to assessing and designing sustainable supply chains, as it not only incorporates economic and environmental dimensions, but also provides a practical approach to quantifying and embedding the social dimension into decision-making. Kaplan & Norton [4] combined several dimensions of performance measurement in a linear cause-effect model, claiming that it serves both measurement and management objectives.

Hanaoka & Kunadhamraks [5] methodologically examined multiple evaluation criteria and fuzzy-based logistics performance for intermodal transport. Gulgun and Gulcin [6] used the analytical network process (ANP) to determine the most effective performance attributes and applied the framework in two logistics companies in southeast Europe. To meet logistics companies' real world situation, we integrate some meaningful non-financial performance indices attributed from several dimensions to construct the performance evaluation matrix of Perfect Delivery Fulfillment and to find the causal relationships among the performance indices and the inter-influence among dimensions by DEMATEL method. In addition to linking Key Performance Indicator (KPI) to strategic planning, it can be integrated with managerial decision making, which depends on KPI identification in complex supply chain situations [7, 8].

Transportation and Distribution Performance Indicators

Wang & Liu [9] pointed out that the performance evaluation of a logistics company is conducted through customer satisfaction, including cost-effectiveness of logistics services, reliability, cargo intact rate, degree of rapid response, customer complaint resolution, on-time arrival rate, error rate, etc. Moreover, Liu & Andrew [10] indicated that on-time and accurate delivery is the most important item.

Measuring the quality performance of logistics processes and products is one way to improve them and at the same time insure customers' satisfaction level. Timeliness is related to the response time of the supply chain to satisfy customer requirements; Logistics Cost is related to logistics financial performance; and Productivity & Capacity are related to the efficiency of the resource usage [11]. Karia & Wong [12] also proposed how logistical resources influence the performance of logistics providers. Liu & Andrew [10] offered several key items of operational performance related to logistics activities that are divided into five performance attributes: delivery, quality, flexibility, cost, and innovation.

In this paper we adopt the following five attributes: timeliness, quality, utility, cost and safety. Each attribute's dimensions and supporting measurement are generally causally oriented and thus selected due to their importance to a company's real operations.

Decision Making Trial and Evaluation Laboratory (DEMATEL)

Since it is difficult to find the cause-effect relation among performance indicators by traditional measurement methods, this paper adopts DEMATEL methodology to solve the problem. DEMATEL, which originated from the Geneva Research Centre of the Battelle Memorial Institute [13, 14], is used to investigate and solve complicated problem groups. The methodology, according to the characteristics of objective affairs, can verify interdependence among variables/attributes/criteria and confirm the relation that reflects the characteristics with an essential system and evolutionary trend [15, 16]. The method is a practical and useful tool, especially for visualizing the structure of complex causal relationships with matrices or digraphs.

Decision Making Trial and Evaluation Laboratory based Analytic Network Process (DANP)

Saaty [17] published ANP, which removes the limitation from Analytic Hierarchy Process (AHP) and is applied to solve non-linear and complex network relations. The purpose of ANP is to decipher the relaying and feedback problems of the criteria. DEMATEL is useful for confirming the interacting relationship among each factor, and ANP helps obtain the most accurate weights. DEMATEL is combined with the ANP method into a new DANP approach that calculates the weights of quality factors. Ou Yang, Shieh, Leu, & Tzeng [18] proposed these methods to solve the dependence and feedback problems found in the real world.

METHODOLOGY

DEMATEL

The DEMATEL method can be summarized in the following steps. Step 1: Find the average matrix. Step 2: Calculate the normalized initial direct-relation matrix. Step 3: Compute the total relation matrix. Step 4: Set a threshold value and obtain the impact-relations map. We note the detailed steps as follows.

Step 1: Find the average matrix. Suppose we have H experts in this study and n factors to consider. Each stakeholder is asked to indicate the degree to which he or she believes a factor i affects factor j. These pairwise comparisons between any two factors are denoted by aij and are given an integer score ranging from 0, 1, 2, 3, and 4, representing ‘No influence (0),’ ‘Low influence (1),’ ‘Medium influence (2),’ ‘High influence (3),’ and ‘Very high influence (4),’ respectively. The scores by each expert provide an n x n non-negative answer matrix $\mathbf{X}^k = [x_{ij}^k]$, with $1 \le k \le H$. Thus, $X^1, X^2, \ldots, X^H$ are the answer matrices for each H expert, and each element of X^k is an integer denoted by x_{ij}^k. The diagonal elements of each answer matrix X^k are all set to zero. We now compute the n x n average matrix **A** for all expert opinions by averaging the H experts’ scores as:

$$a_{ij} = \frac{1}{H} \sum_{k=1}^{H} x_{ij}^k \tag{1}$$

The average matrix **A**=[a_{ij}] is also called the initial direct relation matrix, where A presents the initial direct effects that a factor exerts on and receives from other factors.

Step 2: Calculate the normalized initial direct-relation matrix. We obtain the normalized initial direct-relation matrix **D** by normalizing the average matrix **A** in the following way:

$$\text{Let } s = \max\left(\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}, \max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij} \right) \tag{2}$$

$$\text{Then } D = \frac{A}{s} \tag{3}$$

Since the sum of each row *j* of matrix **A** represents the total direct effects that factor *i* gives to the other factors, $\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}$ represents the total direct effects of the factor with the most direct effects on others. Likewise, since the sum of each column *i* of matrix **A** represents the total direct effects received by factor *i*, $\max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij}$ represents the total direct effects received by the factor that receives the most direct effects from others. The positive scalar s takes the lesser of the two as the upper bound, and we obtain **matrix D** by dividing each element of A by the scalar s. Note that each element d_{ij} of matrix **D** is between zero and less than 1.

Step 3: Compute the total relation matrix. A continuous decrease of the indirect effects of problems along the powers of matrix D, e.g. $\mathbf{D}^2, \mathbf{D}^3, \ldots, \mathbf{D}^\infty$, guarantees convergent solutions to the matrix inversion similar to an absorbing Markov chain matrix. Note that $\lim_{m \to \infty} \mathbf{D}^m = [\mathbf{0}]_{n \times n}$ and $\lim_{m \to \infty} (\mathbf{I} + \mathbf{D} + \mathbf{D}^2 + \mathbf{D}^3 + \ldots + \mathbf{D}^m) = (\mathbf{I} - \mathbf{D})^{-1}$, where 0 is the $n \times n$ null matrix and I is the $n \times n$ identity matrix. The total relation matrix **T** is an $n \times n$ matrix and is defined as:

$$\mathbf{T} = [t_{ij}] \quad i, j = 1, 2, \ldots, n$$

$$\text{Where } T = \mathbf{D} + \mathbf{D}^2 + \ldots + \mathbf{D}^m = \mathbf{D}(\mathbf{I} + \mathbf{D} + \mathbf{D}^2 + \ldots + \mathbf{D}^{m-1})$$

$$= \mathbf{D}[(\mathbf{I} + \mathbf{D} + \mathbf{D}^2 + \ldots + \mathbf{D}^{m-1})(1 - \mathbf{D})](1 - \mathbf{D})^{-1}$$

$$= \mathbf{D}(\mathbf{I} - \mathbf{D})\text{-1}, \text{ as } m \to \infty \tag{4}$$

We also define *r* and *c* as $n \times 1$ vectors representing the sum of rows and sum of columns of the total relation matrix **T** as follows:

$$r = [r_i]_{n \times 1} = \left(\sum_{j=1}^{n} t_{ij} \right)_{n \times 1} \tag{5}$$

$$c = [c_j]'_{1 \times n} = \left(\sum_{i=1}^{n} t_{ij} \right)'_{1 \times n} \tag{6}$$

Here, superscript $'$ denotes transpose.

Let r_i be the sum of the i^{th} row in matrix **T**; then r_i shows the total effects, both direct and indirect, given by factor *i* to the other factors. Let c_j denote the sum of the j^{th} column in matrix **T**; then c_j shows the total effects, direct and indirect, received by factor *j* from the other factors. Thus, when *j* = *i*, the sum $(r_i + c_i)$ gives an index representing the total effects both given and received by factor *i*. In other words, $(r_i + c_i)$ shows the degree of importance (total sum of effects given and received) that factor *i* plays in the system. In addition, the difference $(r_i - c_i)$ shows the net effect that factor *i* contributes to the system. When $(r_i - c_i)$ is positive, factor *i* is a net causer, and when $(r_i - c_i)$ is negative, factor *i* is a net receiver. This means that if $(r_i - c_i)$ is positive, then factor *i* influences the other factor, and if $(r_i - c_i)$ is negative, then factor *i* is influenced by the other factor.

Step 4: Set a threshold value and obtain the impact-relations map. In order to explain the structural relation among the factors while keeping the complexity of the system to a manageable level, it is necessary to set a threshold value p to filter out some negligible effects in matrix **T**. While each factor of matrix **T** provides information on how one factor affects another, the decision-maker must set a threshold value in order to reduce the complexity of the structural relation model implicit in matrix **T**. Only some factors, which's effect in matrix **T** is greater than the threshold value, should be chosen and shown in an influential network relation map (INRM).

DANP

DANP is divided into the following steps [19]. The first step develops the structure of the question. The questions are clearly described and then broken down to a level structure. The second step develops the Unweighted Supermatrix and normalizes each level with a total degree of effect that is obtained from the total effect matrix **T** of DEMATEL as shown in (7).

$$\boldsymbol{T}_C = \begin{array}{c} \\ D_1 \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \end{array} \\ D_2 \begin{array}{c} c_{21} \\ c_{22} \\ \vdots \\ c_{2m_2} \end{array} \\ \vdots \\ D_3 \begin{array}{c} c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \end{array} \overset{\begin{array}{cccc} D_1 & D_2 & \cdots & D_n \\ c_{11}\cdots c_{1m_1} & c_{21}\cdots c_{2m_2} & \cdots & c_{n1}\cdots c_{nm_n} \end{array}}{\begin{bmatrix} \boldsymbol{T}_C^{11} & \boldsymbol{T}_C^{12} & \cdots & \boldsymbol{T}_C^{1n} \\ \boldsymbol{T}_C^{21} & \boldsymbol{T}_C^{22} & \cdots & \boldsymbol{T}_C^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{T}_C^{n1} & \boldsymbol{T}_C^{n2} & \cdots & \boldsymbol{T}_C^{nn} \end{bmatrix}} \quad (7)$$

Normalize $\boldsymbol{T}_c$ with a total degree of effect to obtain $\boldsymbol{T}_c^{\alpha}$, as shown below in (8).

$$\boldsymbol{T}_c^{\alpha} = \begin{array}{c} \\ D_1 \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \end{array} \\ D_2 \begin{array}{c} c_{21} \\ c_{22} \\ \vdots \\ c_{2m_2} \end{array} \\ \vdots \\ D_3 \begin{array}{c} c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \end{array} \overset{\begin{array}{cccc} D_1 & D_2 & \cdots & D_n \\ c_{11}\cdots c_{1m_1} & c_{21}\cdots c_{2m_2} & \cdots & c_{n1}\cdots c_{nm_n} \end{array}}{\begin{bmatrix} \boldsymbol{T}_c^{\alpha 11} & \boldsymbol{T}_c^{\alpha 12} & \cdots & \boldsymbol{T}_c^{\alpha 1n} \\ \boldsymbol{T}_c^{\alpha 21} & \boldsymbol{T}_c^{\alpha 22} & \cdots & \boldsymbol{T}_c^{\alpha 2n} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{T}_c^{\alpha n1} & \boldsymbol{T}_c^{\alpha n2} & \cdots & \boldsymbol{T}_c^{\alpha nn} \end{bmatrix}} \quad (8)$$

Normalize $\boldsymbol{T}_c^{\alpha 11}$ as obtained by formulae (9) and (10), and $\boldsymbol{T}_c^{\alpha nn}$ is also as obtained according to the same function.

$$d_i^{11} = \sum_{j=1}^{m_1} t_{c\,ij}^{11}, \quad i = 1, 2, \ldots, m_1 \quad (9)$$

$$T_c^{\alpha 11} = \begin{bmatrix} t_{c11}^{11}/d_1^{11} & \cdots & t_{c1j}^{11}/d_1^{11} & \cdots & t_{c1m_1}^{11}/d_1^{11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{11}/d_i^{11} & \cdots & t_{cij}^{11}/d_i^{11} & \cdots & t_{cim_1}^{11}/d_i^{11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{11}/d_{m_1}^{11} & \cdots & t_{cm_1j}^{11}/d_{m_1}^{11} & \cdots & t_{cm_1m_1}^{11}/d_{m_1}^{11} \end{bmatrix} = \begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{c1j}^{\alpha 11} & \cdots & t_{c1m_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{\alpha 11} & \cdots & t_{cm_11}^{\alpha 11} & \cdots & t_{cm_1m_1}^{\alpha 11} \end{bmatrix} \quad (10)$$

Finally, the total effect matrix is normalized into the Supermatrix according to the group by relying upon the relationship to obtain the Unweighted Supermatrix as shown in (11).

$$W = \begin{array}{c} \\ D_1 \; \begin{matrix} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \end{matrix} \\ D_2 \; \begin{matrix} c_{21} \\ c_{22} \\ \vdots \\ c_{2m_2} \end{matrix} \\ \vdots \\ D_n \; \begin{matrix} c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{matrix} \end{array} \overset{\begin{matrix} D_1 & D_2 & \cdots & D_n \\ c_{11}\cdots c_{1m_1} & c_{21}\cdots c_{2m_2} & & c_{n1}\cdots c_{nm_n} \end{matrix}}{\begin{bmatrix} W^{11} & W^{12} & \cdots & W^{1n} \\ W^{21} & W^{22} & \cdots & W^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ W^{n1} & W^{n2} & \cdots & W^{nn} \end{bmatrix}} \quad (11)$$

In addition, we obtain matrix W^{11} and W^{12} by formula (12). A blank or 0 shown in the matrix means the group or criterion is independent, then we obtain W^{nn} according to the same function.

$$W^{11} = (T^{11})' = \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \end{array} \overset{\begin{matrix} c_{11} & c_{12} & \cdots & c_{1m_1} \end{matrix}}{\begin{bmatrix} t_{c11}^{\alpha 11} & t_{c21}^{\alpha 11} & \cdots & t_{cm_11}^{\alpha 11} \\ t_{c12}^{\alpha 11} & t_{c22}^{\alpha 11} & \cdots & t_{cm_12}^{\alpha 11} \\ \vdots & \vdots & \ddots & \vdots \\ t_{c1m_1}^{\alpha 11} & t_{c2m_1}^{\alpha 11} & \cdots & t_{cm_1m_1}^{\alpha 11} \end{bmatrix}}$$

$$W^{12} = (T^{21})' = \begin{array}{c} c_{12} \\ c_{22} \\ \vdots \\ c_{m_12} \end{array} \overset{\begin{matrix} c_{21} & c_{22} & \cdots & c_{2m_2} \end{matrix}}{\begin{bmatrix} t_{c11}^{\alpha 21} & t_{c21}^{\alpha 21} & \cdots & t_{cm_21}^{\alpha 21} \\ t_{c12}^{\alpha 21} & t_{c22}^{\alpha 21} & \cdots & t_{cm_22}^{\alpha 21} \\ \vdots & \vdots & \ddots & \vdots \\ t_{c1m_1}^{\alpha 21} & t_{c2m_1}^{\alpha 21} & \cdots & t_{cm_2m_1}^{\alpha 21} \end{bmatrix}} \quad (12)$$

The third step obtains the Weighted Supermatrix and makes the dimensions of the total effect relationship matrix T_D as (13). Let each dimension of matrix T_D be normalized with a total degree of effect to obtain T_D^{α}, as shown in (14).

$$d_i = \sum_{j=1}^{n} t_D^{ij}, \; i = 1, 2, \ldots, n$$

$$T_D = \begin{bmatrix} t_D^{11} & \cdots & t_D^{1j} & \cdots & t_D^{1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{i1} & \cdots & t_D^{ij} & \cdots & t_D^{in} \\ \vdots & & \vdots & & \vdots \\ t_D^{n1} & \cdots & t_D^{nj} & \cdots & t_D^{nn} \end{bmatrix} \quad (13)$$

$$T_D^{\alpha} = \begin{bmatrix} t_D^{11}/d_1 & \cdots & t_D^{1j}/d_1 & \cdots & t_D^{1n}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_D^{i1}/d_2 & \cdots & t_D^{ij}/d_2 & \cdots & t_D^{in}/d_2 \\ \vdots & & \vdots & & \vdots \\ t_D^{n1}/d_n & \cdots & t_D^{nj}/d_n & \cdots & t_D^{nn}/d_n \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \cdots & t_D^{\alpha 1j} & \cdots & t_D^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha i1} & \cdots & t_D^{\alpha ij} & \cdots & t_D^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha n1} & \cdots & t_D^{\alpha nj} & \cdots & t_D^{\alpha nn} \end{bmatrix} \quad (14)$$

Next, we drive the normalized T_D^{α} into the Unweighted Supermatrix W to obtain Weighted Supermatrix W^{α}, with the result shown in (15).

$$W^{\alpha} = T_D^{\alpha} \times W = \begin{bmatrix} t_D^{\alpha 11} \times W^{11} & t_D^{\alpha 21} \times W^{12} & \cdots & \cdots & t_D^{\alpha n1} \times W^{1n} \\ t_D^{\alpha 12} \times W^{21} & t_D^{\alpha 22} \times W^{22} & \vdots & & \vdots \\ \vdots & \cdots & t_D^{\alpha ji} \times W^{ij} & \cdots & t_D^{\alpha ni} \times W^{ni} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1n} \times W^{n1} & t_D^{\alpha 2n} \times W^{n2} & \cdots & \cdots & t_D^{\alpha nn} \times W^{nn} \end{bmatrix} \quad (15)$$

The fourth step obtains the Limited Supermatrix. The Weighted Spuermatrix W^{α} is multiplied by itself many times to obtain the Limited Supermatrix. The ANP weights of each criterion can then be obtained by $\lim_{z \to \infty} (W^{\alpha})^z$, where z represents any number for power. This process is called DANP; i.e., a DEMATEL-based ANP.

Influential Network Relation Map, INRM

Depending on the results of DEMATEL, we map out the cause-effect between each pair of factors in a system by drawing an influence map. Each letter represents a factor in the system. An arrow from a to b shows the effect that a has on b, and the strength of its effect is the number on the path. DEMATEL can convert the structural relations among the factors of a system into an intelligible map. It is called the influential network relation map, INRM.

Empirical Analysis

We present the analytical steps as follows. The first step collects the operational performance indicators through managers' interviews and literature review. The second step selects the operational performance indicators attributed to categories. The next step constructs the performance evaluation matrix. The transportation and distribution performance measure model is developed by referring to previous research and by conducting personal interviews with managers. We then collect data by expert questionnaires, with questions based on the literature review and discussions with a number of experts (including managers, professors, and researchers). Therefore, the questionnaire could be accepted as possessing content validity.

We express the performance measurement of Perfect Delivery Fulfillment, which is the ultimate goal of transportation and distribution operations, by timeliness, quality, utility, cost, and safety. Table 1 lists the evaluation matrix of Perfect Delivery Fulfillment.

Table-1: Indicators of evaluation

Dimensions	Indicators
D_1 Timeliness	C_1 Outbound Delay Rate
	C_2 Delivery Delay Rate
	C_3 Order Delay Rate (Average lateness of orders)
D_2 Quality	C_4 Delivery Error Rate (Due to inaccurate shipment)
	C_5 Short Delivery (Due to losses from finished goods in transit)
	C_6 Damage Rate of Delivery Cargo (Due to damages from finished goods in transit)
D_3 Utility	C_7 Own Vehicle Utility Rate
	C_8 Other Company (non-own) Vehicle Utility Rate
	C_9 Dead Heading
	C_{10} Weight Utilization
	C_{11} Load Factor
	C_{12} Loading Capacity (Ton-Kilometer)
D_4 Cost	C_{13} Transportation Income/Total Earnings
	C_{14} Transportation Cost/Logistics Cost
	C_{15} Transportation Cost/Delivery Income
D_5 Safety	C_{16} Vehicle Accident
	C_{17} Delivery (Traffic) Accident

We design the expert questionnaire by a scale of 0-4 when comparing the two dimensions/indicators. Here, a score of 0 represents indifference between the two dimensions/indicators, and 4 show an overwhelming dominance of the dimension/indicator under consideration over the comparison dimension/indicator. There are five dimensions with a total of seventeen indicators in the expert questionnaire. We disseminated it to managers who have more than five years of practical management experience and to scholars who have more than ten years of research and coaching experience in logistics companies.

EMPIRICAL RESULTS

This paper confirms the DEMATEL decision-making structure and analyzes the five dimensions with seventeen quality indicators of Perfect Delivery Fulfillment. According to the expert questionnaires, we obtain the total effect matrix T of dimensions and indicators, such as shown in Table 2 to Table 4. We find the cognition and opinion from experts in the five dimensions, and the relationship between the extents of the impact can also be found, which is then compared to other dimensions as shown in Table 2.

Table-2: The total effect matrix of T and sum of effects on the dimensions

Dimensions		D_1	D_2	D_3	D_4	D_5	r_i	c_i	r_i+c_i	r_i-c_i
D_1	Timeliness	0.559	0.754	0.751	0.808	0.562	3.434	3.547	6.980	-0.113
D_2	Quality	0.736	0.606	0.742	0.899	0.584	3.567	3.676	7.242	-0.109
D_3	Utility	0.759	0.746	0.600	0.886	0.570	3.560	3.657	7.217	-0.097
D_4	Cost	0.911	0.959	0.943	0.838	0.745	4.397	4.164	8.560	0.233
D_5	Safety	0.582	0.611	0.621	0.733	0.384	2.931	2.844	5.775	0.086

According to the total influential prominence (r_i+c_i), "Cost" (D_4) is the most important influencing dimension. "Safety" (D_5) has the lowest degree of strength of relation among all dimensions. According to the influential relation ($rc_{ii}-$), we can also find that “Cost” (D_4) has the highest degree of impact relationship that affects other dimensions directly; otherwise, “Timeliness” (D_1) is the most vulnerable to an impact versus the other dimensions.

The DEMATEL technique can be used to determine the interactions among the indicators. According to Table 3, we obtain the impact relations for all indicators. Table 4 presents the relationships of the impact that can find directly or indirectly effect to compare with other indicators. “Transportation Income/Total Earnings” (C_{13}) plays a critical role among all indicators in having the most important consideration of all indicators; in addition, “Outbound Delay Rate” (C_1) has the least interaction with other indicators. Furthermore, Table 4 shows “Vehicle Accident” (C_{16}) has the highest degree of impact relationship among all the indicators; otherwise, “Loading Capacity (Ton-Kilometer)” (C_{12}) is the most vulnerable to being impact by indicators when compared to those other indicators.

Table-3: The total effect matrix of T for the indicators

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
C_1	0.097	0.185	0.191	0.141	0.154	0.155	0.192	0.151	0.182	0.174	0.187	0.193	0.203	0.199	0.197	0.120	0.158
C_2	0.166	0.114	0.214	0.154	0.163	0.163	0.214	0.167	0.200	0.187	0.204	0.216	0.217	0.214	0.216	0.133	0.172
C_3	0.171	0.177	0.137	0.162	0.171	0.169	0.225	0.172	0.224	0.220	0.232	0.237	0.230	0.226	0.229	0.140	0.178
C_4	0.139	0.163	0.180	0.127	0.184	0.163	0.222	0.182	0.227	0.218	0.221	0.244	0.272	0.267	0.271	0.144	0.159
C_5	0.139	0.154	0.179	0.174	0.136	0.172	0.218	0.178	0.231	0.227	0.221	0.244	0.267	0.267	0.271	0.144	0.159
C_6	0.128	0.141	0.156	0.147	0.173	0.112	0.193	0.166	0.193	0.189	0.192	0.204	0.244	0.240	0.248	0.128	0.168
C_7	0.159	0.184	0.204	0.183	0.190	0.174	0.220	0.240	0.284	0.279	0.278	0.296	0.320	0.310	0.314	0.176	0.188
C_8	0.141	0.157	0.170	0.161	0.180	0.161	0.266	0.167	0.261	0.252	0.250	0.266	0.294	0.289	0.293	0.159	0.168
C_9	0.151	0.162	0.191	0.186	0.205	0.172	0.277	0.232	0.215	0.267	0.274	0.305	0.313	0.312	0.316	0.164	0.184
C_{10}	0.157	0.170	0.203	0.191	0.206	0.169	0.283	0.229	0.274	0.212	0.272	0.302	0.314	0.304	0.312	0.179	0.191
C_{11}	0.161	0.173	0.207	0.200	0.211	0.177	0.289	0.238	0.279	0.279	0.221	0.308	0.320	0.310	0.319	0.183	0.199
C_{12}	0.151	0.167	0.196	0.190	0.191	0.167	0.277	0.228	0.276	0.272	0.275	0.230	0.316	0.311	0.315	0.174	0.189
C_{13}	0.173	0.182	0.209	0.206	0.227	0.206	0.316	0.263	0.316	0.306	0.309	0.333	0.282	0.363	0.368	0.204	0.225
C_{14}	0.166	0.183	0.200	0.202	0.214	0.202	0.302	0.258	0.306	0.297	0.304	0.328	0.368	0.271	0.366	0.205	0.217
C_{15}	0.166	0.179	0.205	0.203	0.219	0.203	0.303	0.263	0.307	0.297	0.300	0.328	0.369	0.358	0.276	0.205	0.222
C_{16}	0.163	0.174	0.191	0.150	0.159	0.148	0.233	0.206	0.237	0.237	0.241	0.255	0.258	0.253	0.256	0.125	0.215
C_{17}	0.156	0.161	0.183	0.151	0.161	0.167	0.224	0.198	0.227	0.233	0.236	0.250	0.253	0.244	0.247	0.192	0.137

Note: The average sample gap = $\frac{1}{n(n-1)}\sum_{i=1}^{n}\sum_{j=1}^{n}(|a_{ij}^{s} - a_{ij}^{s-1}| / a_{ij}^{s})$ x 100% = 4.38%<5%, where n is the number of indicators, s is the sample of experts, and the significant confidence level is 95.62% (more than 95%).

Table-4: The sum of effects and the weight and ranking of each indicator

Indicator	r_i	c_i	$r_i + c_i$	$r_i - c_i$	Degree of importance (Global weight)	Ranking
D_1					**0.198**	**4**
C_1	2.880	2.584	5.464	0.295	0.0596	3
C_2	3.114	2.827	5.941	0.287	0.0650	2
C_3	3.300	3.217	6.517	0.083	0.0735	1
D_2					**0.205**	**2**
C_4	3.382	2.928	6.310	0.454	0.0667	3
C_5	3.380	3.143	6.522	0.237	0.0716	1
C_6	3.021	2.879	5.900	0.142	0.0668	2
D_3					**0.204**	**3**
C_7	3.998	4.253	8.251	-0.254	0.0348	2
C_8	3.633	3.537	7.170	0.096	0.0289	6
C_9	3.926	4.239	8.165	-0.314	0.0347	3
C_{10}	3.968	4.145	8.114	-0.177	0.0339	5
C_{11}	4.075	4.215	8.290	-0.141	0.0347	3
C_{12}	3.926	4.540	8.467	-0.614	0.0372	1
D_4					**0.233**	**1**
C_{13}	4.490	4.840	9.329	-0.350	0.0785	1
C_{14}	4.390	4.739	9.129	-0.349	0.0769	3
C_{15}	4.404	4.815	9.219	-0.410	0.0780	2
D_5					**0.159**	**5**
C_{16}	3.500	2.775	6.276	0.725	0.0744	2
C_{17}	3.419	3.129	6.548	0.291	0.0847	1

This paper not only uses DEMATEL to confirm the interrelationships among the indicators, but also expects to obtain the most accurate weights. Therefore, it structures the quality assessment model using the DANP model to obtain the weight of each indicator as shown in Table 4. This paper constructs an improvement model (see INRM in Fig. 1) of Perfect Delivery Fulfillment for transportation and distribution managers of logistics firms to initiate improvement strategies and gain insight into such approaches.

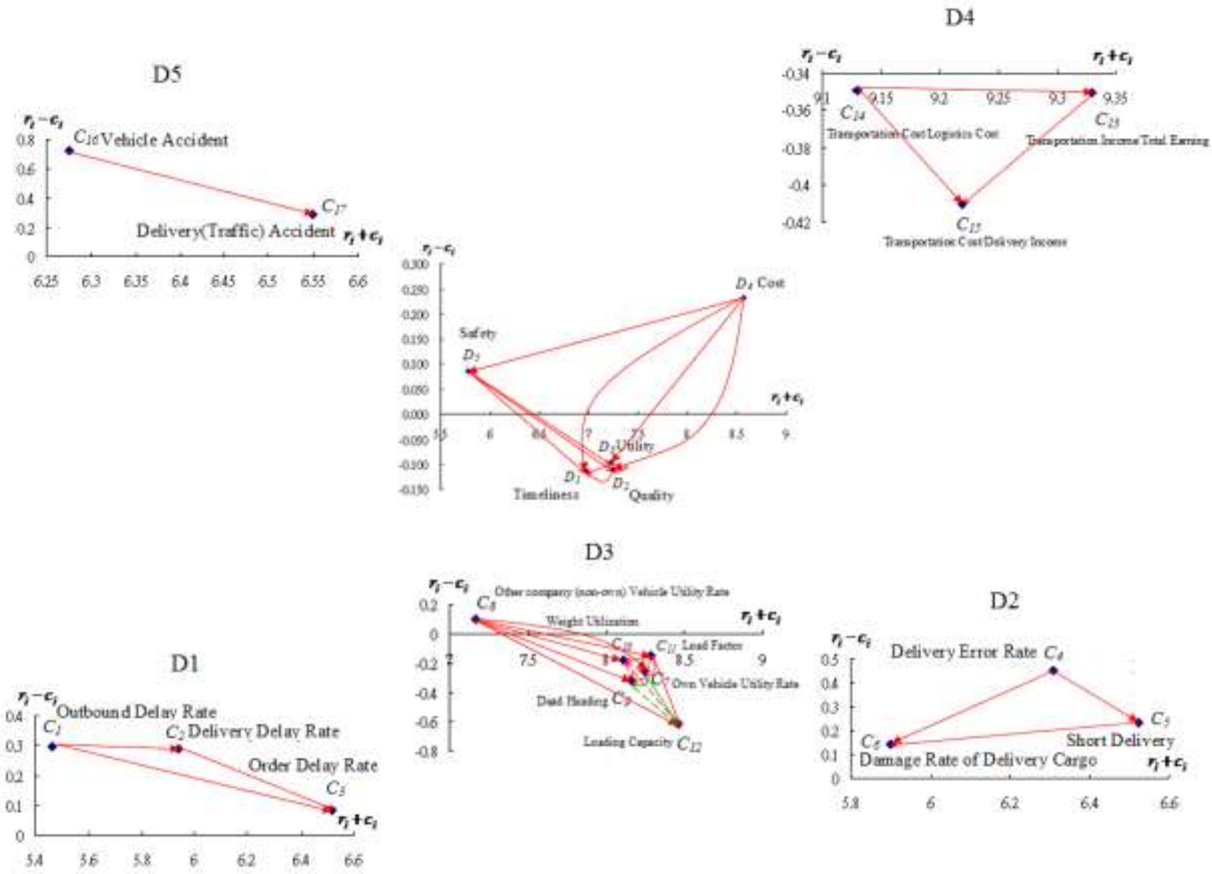

Fig-1: The influential network relation map of each dimension and indicator of the evaluation matrix of perfect delivery fulfilment

DISCUSSIONS AND CONCLUSIONS

The empirical results using DANP method show that Cost (D_4) is the most important influencing dimensions and has the highest degree of impact relationship that affects other dimensions directly. In the real world, users (especially companies) of logistics services usually resort to bargain prices without extra value-added services offered by the logistics company. Thus, the logistics company must haggle over every penny, so to speak.

We interestingly find that the least influencing dimension is Safety (D_5), while Timeliness (D_1) has a minimum impact. It means that Safety (D_5) usually is not valued so much, but does affect the performance of other dimensions in the event of a serious problem.

We order the influential priority as "Cost (D_4) → Safety (D_5) → Utility (D_3) → Quality (D_2) → Timeliness (D_1)". When considering operational improvement, the first priority should be to make sure the vehicle is in good condition or to pay attention to routine maintenance besides the transportation cost.

INRM presents the degree of significance and the cause-effect relationship of each indicator among all indicators in each dimension. For "Cost (D_4)", Transportation Cost/Logistics Cost (C_{14}) affects Transportation Income/Total Earnings (C_{13}) and Transportation Cost/Delivery Income (C_{15}). For "Safety (D_5)", Vehicle Accident (C_{16}) affects Delivery (Traffic) Accident (C_{17}) very much. Finally, in the case of "Timeliness (D_1)", Outbound Delay Rate (C_1) influences Delivery Delay Rate (C_2) and may increase Order Delay Rate (C_3).

In some cases, an indicator of poor performance is not of its own making, but rather is influenced by other factors, such as Delivery (Traffic) Accident (C_{17}) causing Delivery Delay Rate (C_2). According to the above results, managers can inspect which factors affect the poor performance indicator quickly at a glance and to solve the root cause of the problem.

In terms of implications for real world practices, the proposed framework and performance assessment methodology can assist internal management and decision-making at various levels. The strategic and long-term objective of any company's business would be to optimize the best possible configuration of operation models for all value-added activities. Our framework enables a multidimensional assessment of Perfect Delivery Fulfilment based on the simultaneous consideration of Timeliness, Quality, Utility, Cost, and Safety goals.

The findings herein offer insight into how decisions can be made in terms of priority: 1) the degree of importance and influential relation from each indicator among all indicators in each dimension to another indicator; 2) the strategic selection of a firm's improvement direction for operation managers to enhance competitiveness and to achieve their objectives quickly and effectively; and 3) ranking many departments of transportation and finding each benchmark. We believe that these results can assist companies at improving their activities' performances with less effort and provide explanations for observable differences in said performances.

Future research may look at the relationships among indicators on different operations, or on the comprehensive operations within a company, or on different managerial levels.

Declarations of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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REFERENCES

1. Melnyk, S. A., Stewart, D. M., & Swink, M. (2004). Metrics and performance measurement in operations management: dealing with the metrics maze. *Journal of Operations Management*, 22, 209-217.
2. Council, S. C. (2008). Supply-chain operations reference-model. *Overview of SCOR version*, *5*(0).
3. Varsei, M., Soosay, C., Fahimnia, B., & Sarkis, J. (2014). Framing sustainability performance of supply chains with multidimensional indicators. *Supply Chain Management: An International Journal*, *19*(3), 242-257.
4. Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard: measures that drive performance. *The Harvard Business Review*, January/February, 71-79.
5. Hanaoka, S., & Kunadhamraks, P. (2009). Multiple criteria and fuzzy based evaluation of logistics performance for intermodal transportation. *Journal of Advanced Transportation*, *43*(2), 123-153.
6. Kayakutlu, G., & Buyukozkan, G. (2011). Assessing performance factors for a 3PL in a value chain. *International Journal of Production Economics*, *131*(2), 441-452.
7. Cabral, I., Grilo, A., & Cruz-Machado, V. (2012). A decision-making model for lean, agile, resilient and green supply chain management. *International Journal of Production Research*, *50*(17), 4830-4845.
8. Grimm, J. H., Hofstetter, J. S., & Sarkis, J. (2014). Critical factors for sub-supplier management: A sustainable food supply chains perspective. *International Journal of Production Economics*, *152*, 159-173.
9. Liu, Y. (2014, May). Study on Performance Evaluation System of Third Party Logistics Enterprise. In *International Conference on Logistics Engineering, Management and Computer Science (LEMCS 2014)*. Atlantis Press.
10. Liu, C. L., & Lyons, A. C. (2011). An analysis of third-party logistics performance and service provision. *Transportation Research Part E: Logistics and Transportation Review*, *47*(4), 547-570.
11. Garcia, F. A., Marchetta, M. G., Camargo, M., Morel, L., & Forradellas, R. Q. (2012). A framework for measuring logistics performance in the wine industry. *International Journal of Production Economics*, *135*(1), 284-298.
12. Karia, N., & Wong, C. Y. (2013). The impact of logistics resources on the performance of Malaysian logistics service providers. *Production Planning & Control*, *24*(7), 589-606.
13. Fontela, E., & Gabus, A. (1976). The DEMATEL Observer, DEMATEL 1976 Report, Switzerland: Battlle Geneva Research Center.
14. Gabus, A., & Fontela, E. (1973). Perceptions of the world problematique: Communication procedure, communicating with those bearing collective responsibility. *Battelle Geneva Research Centre, Geneva, Switzerland*.

15. Huang, C. Y., Shyu, J. Z., & Tzeng, G. H. (2007). Reconfiguring the innovation policy portfolios for Taiwan's SIP Mall industry. *Technovation*, *27*(12), 744-765.
16. Chiu, Y. J., Chen, H. C., Tzeng, G. H., & Shyu, J. Z. (2006). Marketing strategy based on customer behaviour for the LCD-TV. *International journal of management and decision making*, *7*(2-3), 143-165.
17. Saaty, T. L. (1996). Decision making with dependence and feedback: The analytic network process. Pittsburgh. *PA: RWS Publications. International Journal of Production Research*, *50*(12), 32113221.
18. Ou-Yang, Y. P., Shieh, H. M., Leu, J. D., & Tzeng, G. H. (2008). A novel hybrid MCDM model combined with DEMATEL and ANP with applications. *International journal of operations research*, *5*(3), 160-168.
19. Lee, W. S., Tzeng, G. H., & Cheng, C. M. (2009). Using novel MCDM Methods Based on Fama-French three-factor model for probing the stock selection. *APIEASM*, Dec (14-16), 1460-1474.