# A Model of Trust Function to Study Will of Information Sharing between Partners

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**Abstract:** Trusts within organization and partner relationship are complicated issues in the information sharing of the supply chain. This paper aims at establishing a model of trust function to make partners reach the value of trust threshold and more willing in information sharing. This paper proposes a model which is established on the integrated trust dimension with Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP), with fuzzy theory to judge the willingness of information sharing. Verification is made with the idea of risk. On the established model of trust function, we make partners supervise one another to reach the value of trust threshold and increase the willingness of information sharing. Therefore, it is an alternative method in enhancing an overall supply chain performance.

**Keywords:** Supply Chain Management, Information Sharing, Trust

## I. Introduction

Trust has been frequently involved in building up partner relationship and applied to measure members about their will of information sharing. The research was just carried out objecting information sharing to study the impacts of trust between partners on the will of information sharing, and provided appropriate basis for corporations in supply chain management. A trust function was hereby constructed to explore the will of information sharing, meaning the partners expected to share information while the value was equal to the threshold. Yet, if the value was lower than the threshold, the research suggested to the partners that they should take the most effective way to improve their quality, service, delivery speed, costs, and etc through the most beneficial dimension indexes of the function to finally realize information sharing.

## II. Literature Review

### Information Sharing

So far, scholars have expressed their similar understanding of information sharing in many literatures, most of which defined it as the corporations intended to achieve more scale benefits by exchanging and transmitting information completely, transparently and in due course, as well as jointly conduct marketing and manufacturing. In 1995, Carter and Ferrin once pointed out that the information sharing was to extend internal function to the other corporations of the supply chain to form cooperative and integrated network, by which providing shared information and detailed plan to improve the benefit of the place. Also, Gentry [3] proposed that information sharing was to exchange and communicate information between corporations of the supply chain in an open way. Later in 2001, Robert et al. suggested that the extent to what the information was shared in the supply chain affected the supplier in providing information for the buyer.
To sum it up, information sharing emphasized actual degree to what the information was exchanged.

### Trust

For transaction parties, trust referred to the following two aspects: one was the nature of trust including honest, reliable, open and fairly cooperation, and compliance of the agreed contract or agreement; the other was the process to build the trust between the partners, which means the parties' behaviors were important.
Presently, partner relationships between the corporations of supply chain were barely satisfied, primarily because the partners distrusted each other. From this point of view, to shape mutual trust between the partners was regarded as an important issue to upgrade supply chain management across Taiwan.Properties of trust were compiled as Table I, which were then summarized as competence, integrity, care and predictable.

## III. Research Structure

The research was firstly structured on the basis of literature concerning trusts, followed by development of literature analysis and methods applied in the research. Then, the research described requested hypotheses and explained about designing of questionnaire, which were finally collected back for analysis. The research structure is illustrated in Figure 1.

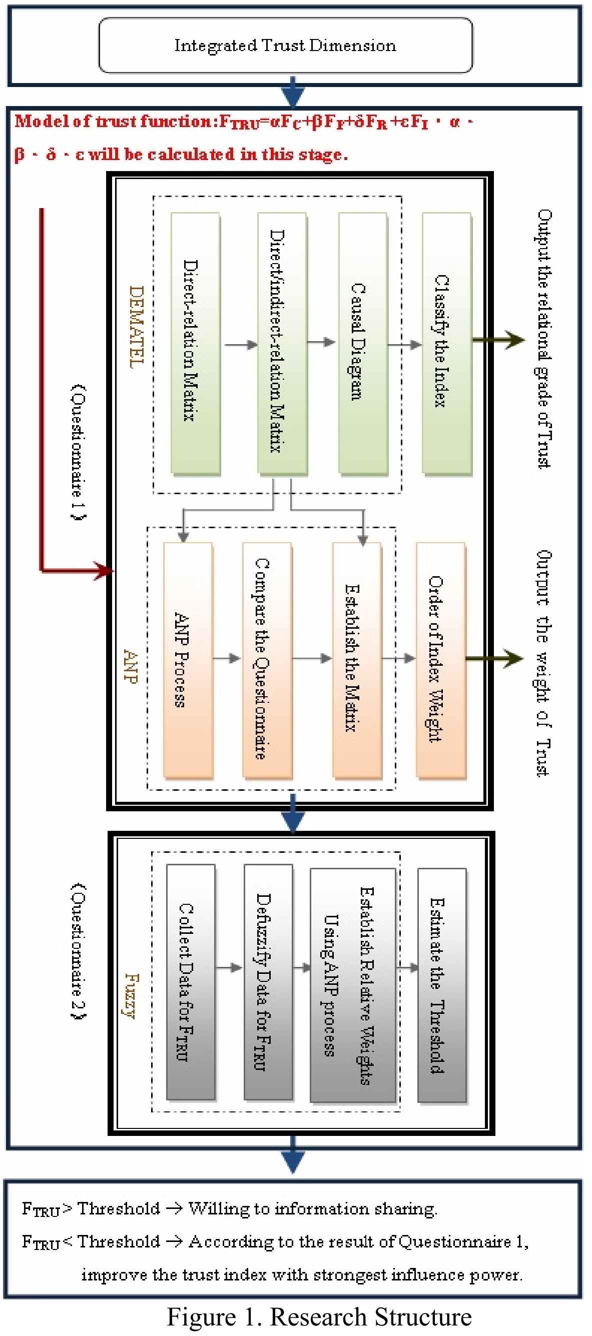



Figure 1. Research Structure

**Methods to Construct Trust Dimension Indexes**

Through reviewing the literature, the research found trust dimension indexes were used as basis to compile preliminary indexes. Then, it conducted interviews and invited professional experts to review and validate the indexes to achieve complete consequences.

**Using DEMATEL to Determine Relational Grade of Trust Dimensions**

After selecting the trust dimension indexes, the research applied DEMATEL to determine the relational grade of the dimensions.

1. Designed and filled up questionnaire. 2. Integrate experts' opinions and set up direct-relation matrix of indexes. 3. Calculated matrix to generate direct/indirect-relation matrix.

**Using ANP to Determine Weight of Trust Dimension Indexes**

1. DEMATEL-based questionnaire was used to generate direct/indirect-relation matrix of trust dimension indexes between supply partners. Then, the method recommended by Ricardo et al. [11] was taken to construct network architecture of the indexes.
2. ANP questionnaire was designed based upon the network architecture generated from the last step. It firstly defined every trust dimension indexes to help the respondents understanding the research purpose. The respondents were requested to compare every two clusters by means of pairwise comparison.
3. Built up pairwise comparison matrix. ANP questionnaire was transformed into matrix and presented in pairwise comparison matrix as follows:

$$A=\lfloor a_{ij}\rfloor_{n*n}=\begin{bmatrix}1 & a_{12} & \cdots & a_{1n}\\ a_{21} & 1 & \cdots & a_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ a_{n1} & a_{n2} & \cdots & 1\end{bmatrix}=\begin{bmatrix}\frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n}\\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n}\\ \vdots & \vdots & \ddots & \vdots\\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n}\end{bmatrix} \quad (1)$$

Of which the $a_{ij}=\frac{1}{a_{ij}}i,j=1,2,3,...,n$, $a_{ij}=\frac{W_i}{W_j}$, meaning relative weight of the two elements; and $a_{ii}=1$, $i=1,2,3,...,n$, $a_{ii}=\frac{W_i}{W_i}$ meaning the weight of the element itself, each of which was 1; and $w_i$ $i=1,2,3,...,n$, $w_i$ representing weight of every element.
4. Integrated experts' preference. The mean was calculated geometrically rather than calculated arithmetically recommended by Saaty [12]. So, the research used geometric mean to integrate multiple pairwise comparison matrixes for every expert into a pairwise comparison matrix.
5. After generating pairwise comparison matrix, weight of each hierarchy criterion can be calculated. Eigenvector was just the geometric mean (GM) and normalized geometric mean of every row of matrix A.
6. Consistence Assured:
(a) Use approximation to generate λmax, a maximum-eigenvalue.
If pairwise comparison matrix of n elements (A1,A2,…Ai,…,An) was $A=\lfloor a_{ij}\rfloor$ $i,j=1,2,3,...,n$, weight of element Ai was:

$$W_i=\frac{\sum_{j=1}^{n}\left(\frac{a_{ij}}{\sum_{i=1}^{n}a_{ij}}\right)}{n}, \text{ i,j=1,2,3,…,n} \quad (2)$$

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \text{， i=1,2,3,…,n} \quad (3)$$

(b) Calculated consistency indexes (C.I.)

$$C.I. = \frac{\lambda_{max} - n}{n-1} \quad (4)$$

Of which the "n" was number of hierarchy factor and λmax was the maximum-eigenvalue of comparison matrix set up by the evaluators. If the C.I. was equal to 0, then judgment made by decision maker were consisted. The higher the C.I. was, the higher the inconsistency was. Saaty recommended that bias was probably accepted if C.I. ≤0.1.

(c) Random Indexes (R.I.)

R.I. was determined according to the rank of pairwise comparison matrix, or in other words, the number (n) of evaluation criteria defined as the following table 1.

Table 1. The Contrast Form of Random Indexes (R.I.)

| n | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| R.I. | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 |
| n | 6 | 7 | 8 | 9 | 10 |
| R.I. | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Source: Saaty [13]

(d) Calculated consistency ratio (C.R.).

Based upon the C.I. and R.I. from step (b) and (c), consistency ratio (C.R.) was calculated by the following formula:

$$C.R. = \frac{C.I.}{R.I.} \quad (5)$$

Suggested by Saaty [12], if C.R. ≦ 0.1, bias of judgment of each criterion weight in setting up pairwise comparison matrix was acceptable, indicating that the consistency was achieved.

7. Did supermatrix calculation. After checking consistency, eigenvector of trust dimension indexes impacted by single indexes of consistency were integrated into a large matrix, which was so called unweighted supermatrix represented by W' in the following form:

$$W' = \begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & & C_N \\ e_{11}\, e_{12} \cdots e_{1n1} & e_{21}\, e_{22} \cdots e_{2n2} & \cdots\ \cdots & e_{m1}\, e_{m2} \cdots e_{mnm} \end{array} \\ \begin{array}{c} C_1 \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n1} \end{array} \\ C_2 \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n2} \end{array} \\ \vdots\ \vdots \\ C_m \begin{array}{c} e_{m1} \\ e_{m1} \\ \vdots \\ e_{mnm} \end{array} \end{array} & \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1m} & \cdots \\ W_{21} & W_{22} & \cdots & W_{2m} & \cdots \\ W_{m1} & W_{m2} & \cdots & W_{mm} & \cdots \end{bmatrix} \end{array}$$

of which the Cm means the dimension m, and Wij means index j of dimension i. Then multiplied unweighted matrix by pairwise comparison matrix of evaluation dimension to achieve eigenvector to get weighted supermatrix represented by W. If the trust indexes depended on each other, a fixed convergence limit would be obtained after multiplying W several times without any changing. The $\lim_{k\to\infty} W^{2k+1}$ was an achievable weight of trust indexes.

**Combining DEMATEL-based Relational Grade with ANP-based Weight**

The initial ANP may calculate weight of each element but not considering impacts of relational grade on the element. This step was hereby conducted to cover the result from DEMATEL and took it as strength of impacts among the elements. In this step, composite important DEMATEL proposed by Tamura et al. (2003) was applied to improve the limitation of the initial ANP.

1. Listed weight matrix calculated from ANP

Through calculating the weight after mutual impacts among trust indexes by ANP, $w_i$ was applied as the weight of index. Set

$$Y^{*} = \begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix} \quad (6)$$

and calculated

$$Y = \lambda^{*} \cdot Y^{*} \text{ of which the } \lambda^{*} = \frac{1}{\max\limits_{1\le i\le n}(w_i)} \quad (7)$$

2. Calculated relation matrix Z after compositing weight

Z=Y+TY (8)

In the formula, T was index direct/indirect-relation matrix calculated by DEMATEL and Z represented dimension. The $z_i$ means dispersion of the other weighted index caused by changes of index.

**Finding out Improvable Performance Indexes**

Under the circumstance of multi criteria decision making, the research calculated total performance of supplier based upon the weight theory and composite weight combing with relational grade. Improvable performance index can be found out according to the following information:

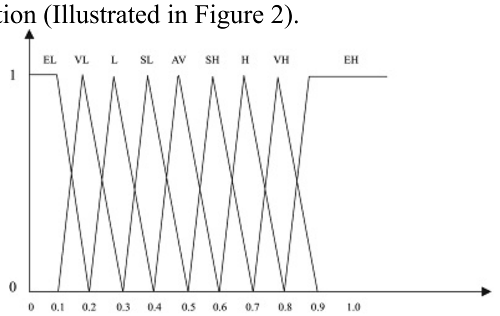
1. Sequence of index relational grade combining with weight.
2. Causal diagram.

**Setting up the Fuzzy Value of Trust Threshold**

Reviewing the methodology, an inaccurate measurement could be managed in the following steps:

1. Collected all trust dimension indexes of the will of information sharing.
2. Converted collected trust dimension data by means of fuzzy logic methodology. Fuzzy technology was used to calculate threshold of model of trust function on the basis of accurate value derived from trust dimension indexes.
3. Did Data collection and defuzzification. All the trust dimension indexes were evaluated by the following

linguistic terms scored within a certain range respectively: extremely low (EL), very low (VL), low (L), slightly low (SL), average (AV), slightly high (SH), high (H), very high (VH) and extremely high (VH). Most of these terms have applied triangular membership function to describe the evaluation (Illustrated in Figure 2).




Source: Barry Shore et al.[14]

Figure 2 Triangular Membership Function for Infrastructure Capability

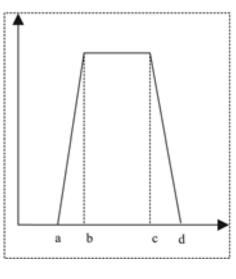
Trust dimension indexes were requested to be evaluated by experts involved in the research by the linguistic terms stated above. Given that the evaluation was conducted relying on the range of these terms, the global trust function score shall be converted to crisp, which was completed in the course of defuzzification on the basis of the conversion formula proposed by Chen and Hwang [1]. Crisp number was then calculated by triangular member function M= (a, b, c, d) as follows:

$$C = \frac{1}{2}\left(\frac{d}{1-c+d} + \frac{b}{b-a+1}\right) \tag{9}$$

In Figure 3, the [b; c] interval represented a membership degree of 1 for M; values below a and above d represent membership degrees of 0 for M. Between the range [a; b] and [c; d] the membership degrees vary linearly. For a triangular membership function the values of b and c were the same.

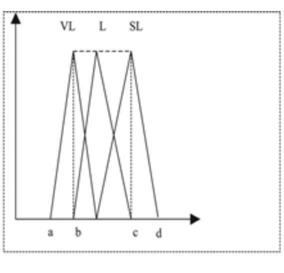
When a single linguistic term was used to assess a capability, the above formula (as a triangular function) was used to convert the fuzzy assessment into a crisp value. When a range of terms were used, a trapezoidal equivalent of the triangular membership functions (see Figure 4) representing the range of linguistic terms were derived before the conversion formula is applied.

Figure 3. Trapezoidal Membership Function




Source: Barry Shore et al.[14]

Figure 4. Conversion of A Range of Linguistic Terms




Source: Barry Shore et al.[14]

## IV. A model of Trust Function

To study will of information sharing between partners was established based on the research structure proposed in the section III.

**Establishing Trust Dimension Indexes**

This step is based on the section "Methods to Construct Trust Dimension Indexes" to establish.

Table 2. Integrate the Dimensions of Trust Function Model

| Dimension(T) | Indexes |
|---|---|
| Competent(C) | 1.Operational(C1); 2.Competitive(C2)<br>3.Information System Competent(C3)<br>4.Control Competent(C4) |
| Predictable(P) | 1.Predictable(P1) |
| Relationship (R) | 1.Goodwill(R1); 2.Benevolent(R2)<br>3.Fair and Reciprocal(R3); 4.Estimate(R4) |
| Integrity(I) | 1.Integrity(I1); 2.Honest(I2); 3.Open(I3) |

Directors/staffs in purchase department of corporations were interviewed in the research. While filling up the questionnaire, the respondents were first invited to comment on 12 indexes of the four trust dimensions. Then, integrated dimensions of model of trust function on the basis of literature review and questionnaire responded by experts (Table 2).

**Establishing Trust Relational Structure of Trust Dimension Indexes**

This step is based on the section "Using DEMATEL to Determine Relational Grade of Trust Dimensions" to establish. After analyzing relationship matrix of trust dimension indexes, the research found that all trust dimension indexes were of relational grade

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**Establishing Trust Weight of Trust Dimension Indexes**

This step is based on the section "Using ANP to Determine Weight of Trust Dimension Indexes" to establish. Weight of trust dimension indexes of information sharing was achieved by means of ANP (Illustrated in Table 3).

Table 3. Operational Results

| T | Index | Relative weight | Order | Mixing relative weight | Order | Threshold |
|---|---|---|---|---|---|---|
| C | C1 | 0.09238 | 3 | 0.0697 | 7 | 67 |
| | C2 | 0.08737 | 5 | 0.0637 | 9 | 73 |
| | C3 | 0.07846 | 6 | 0.0435 | 12 | 73 |
| | C4 | 0.08790 | 4 | 0.0600 | 11 | 66 |
| P | P1 | 0.25526 | 1 | 0.1328 | 1 | 64 |
| R | R1 | 0.06319 | 8 | 0.0713 | 6 | 73 |
| | R2 | 0.02730 | 12 | 0.0679 | 8 | 64 |
| | R3 | 0.03497 | 11 | 0.0603 | 10 | 64 |
| | R4 | 0.03928 | 10 | 0.0740 | 5 | 64 |
| I | I1 | 0.07604 | 7 | 0.1196 | 3 | 67 |
| | I2 | 0.09556 | 2 | 0.1294 | 2 | 70 |
| | I3 | 0.06237 | 9 | 0.1078 | 4 | 70 |

**Calculating the Matrix which Mixed the Weight and Relational Grade**

This step is based on the section "Combining DEMATEL-based Relational Grade with ANP-based Weight" and "Finding out Improvable Performance Indexes" to establish.

DEMATEL-based direct/indirect-relation matrix shall be combined with ANP-based weight to indicate the impacts of improvement of an index on the others' improvement and global score calculation after the improvement. Weight of each trust index in formula 1, the mixing of the weight of dispersion was obtained (Illustrated in Table 3).

Composite dispersion was different from the original sequence in the research. Both the indexes and dimensions still ranked at top 1 and 2 but changed significantly then. So, suppliers might improve the most efficient index on these calculations.

**Setting up the Value of Trust Threshold**

This step is based on the section "Setting up the Fuzzy Value of Trust Threshold" to set up the value of trust threshold. Converted collected trust dimension data by means of methodology of fuzzy logic. On the basis of conversion criteria, indexes of model of trust function can be converted into crisp number (Illustrated in Table 3).

A crisp number representing the global trust function was integrated based upon the four crisp numbers and essential consideration of weight of various indexes. As stated above, converted trust dimension indexes into crisp number by fuzzy linguistic, followed by multiplying by ANP-based weight of trust dimension indexes to convert qualitative weight into quantitative value [12] as follows:

$F_{TRU} = \alpha F_C + \beta F_P + \delta F_R + \varepsilon F_I$

$= 16.4545 + 8.49938 + 18.14555 + 24.61776$

$= 67.7172$

Threshold of model of trust function was then generated as 67.712 by combining DEMATE-based and ANP-based results. If $F_{TRU} > 67.7172$, the value of trust threshold was achieved, meaning that the will of information sharing between transaction partners was improved; whereas if $F_{TRU} < 67.7172$, the threshold wasn't achieved, which means the party may improve the trust indexes with relative significant dispersion from DEMATEL to achieve the value of trust threshold efficiently and further promote the will of information sharing.

## V. Validating the Results

In the research, safety of supply chain was particularly considered to generate results for the purpose of comparison. By referring relevant literature and using concept of risk, the trust was relative higher under the low risk circumstance.

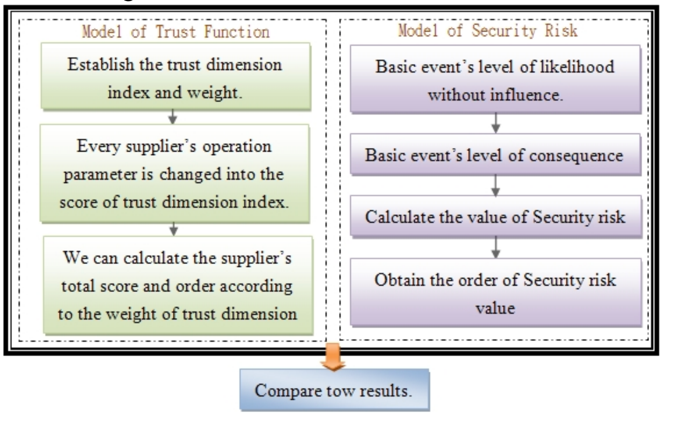
**Validation Process**

Firstly, safety risk was defined as results of probability of event occurrence multiplying with consequences severity:

$$SR = \sum_{i=1}^{36} P_i \times R_i , i \in N \qquad (10)$$

Of which SR means security risk, Pi means events occurrence probability, and Ri means severity level of consequence (Illustrated in Figure 5).

Figure 5. Authentication Model Flowchart




**Validation Results**

Sequence of relative trust and safety grade among factories were obtained based upon trust function values from the model of trust function and relevant literature-defined risk consequences. Then use statistic method to check discrepancy of sequences according to consequences properties.

Table 6. Contrast of Sequences

| Validation | The level of trust | | The value of Security Risk | |
|---|---|---|---|---|
| 1 | Supplier#05 | 88.5513 | Supplier#05 | 10.300 |
| 2 | Supplier#32 | 86.9575 | Supplier#31 | 10.900 |
| 3 | Supplier#31 | 86.2225 | Supplier#09 | 11.600 |
| 4 | Supplier#04 | 84.9348 | Supplier#21 | 15.800 |
| 5 | Supplier#21 | 81.8111 | Supplier#06 | 16.200 |
| 6 | Supplier#10 | 80.0365 | Supplier#32 | 18.900 |
| 7 | Supplier#25 | 78.3757 | Supplier#29 | 19.600 |
| 8 | Supplier#30 | 78.0221 | Supplier#25 | 20.900 |
| 9 | Supplier#34 | 77.4936 | Supplier#10 | 21.400 |
| 10 | Supplier#18 | 76.7495 | Supplier#04 | 21.500 |
| 11 | Supplier#06 | 75.7835 | Supplier#33 | 25.900 |
| 12 | Supplier#07 | 75.2079 | Supplier#27 | 27.800 |
| 13 | Supplier#28 | 75.1942 | Supplier#30 | 27.800 |
| 14 | Supplier#09 | 73.9853 | Supplier#07 | 29.600 |
| 15 | Supplier#11 | 73.2728 | Supplier#36 | 32.900 |
| 16 | Supplier#29 | 73.1072 | Supplier#34 | 34.400 |
| 17 | Supplier#20 | 72.5099 | Supplier#20 | 38.300 |
| 18 | Supplier#15 | 72.2523 | Supplier#35 | 38.600 |
| 19 | Supplier#33 | 72.2523 | Supplier#18 | 40.200 |
| 20 | Supplier#35 | 70.3025 | Supplier#12 | 42.000 |
| 21 | Supplier#36 | 68.3669 | Supplier#11 | 43.700 |
| 22 | Supplier#23 | 66.9496 | Supplier#28 | 47.300 |
| 23 | Supplier#17 | 65.473 | Supplier#15 | 50.300 |
| 24 | Supplier#19 | 65.1837 | Supplier#17 | 51.200 |
| 25 | Supplier#14 | 64.9568 | Supplier#19 | 52.000 |
| 26 | Supplier#12 | 64.1706 | Supplier#23 | 53.300 |
| 27 | Supplier#26 | 62.0864 | Supplier#01 | 54.600 |

| | | | | |
|---|---|---|---|---|
| **28** | Supplier#27 | 61.7006 | Supplier#24 | 55.600 |
| **29** | Supplier#24 | 59.6369 | Supplier#22 | 56.400 |
| **30** | Supplier#01 | 57.6401 | Supplier#14 | 60.300 |
| **31** | Supplier#02 | 57.6401 | Supplier#26 | 61.800 |
| **32** | Supplier#03 | 53.6627 | Supplier#02 | 113.200 |
| **33** | Supplier#16 | 51.0145 | Supplier#03 | 115.600 |
| **34** | Supplier#22 | 50.3505 | Supplier#16 | 123.200 |
| **35** | Supplier#13 | 49.8523 | Supplier#13 | 130.500 |
| **36** | Supplier#08 | 45.8264 | Supplier#08 | 137.900 |

Table 6 is sequenced of 36 suppliers in terms of trust and safety grade by two methods. For the research, evaluation was assumed as rational without any significant distinction between the two sequences, which were achieved only by statistic hypothesis test.

Before the validation, null hypothesis ($H_0$) and alternative hypothesis ($H_1$) had to be defined first, which were set to「ρ ＝0」 and 「ρ＞0」respectively for the validation purpose (ρ: the population correlation coefficient), and the level of significance was set to 0.05 (α=0.05). Second, according to the formula of rank correlation coefficient, corresponded necessary parameters with research data and defined (see as follows). Last, introduce actual data into the formula to calculate the two sets of sequence for subsequent test. The rank correlation coefficient was defined as follows:

$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2-1)}, i = 1,2,...,36, -1 \le r_s \le 1 \qquad (11)$$

Of which: rs : Rank correlation between each other's， Ranging from -1 (negative correlation) to 1 (positive correlation); xi, yi : The level of trust, the value of Security Risk; Rank xi, Rank yi: Level of trust rankings, Security Risk Value Rank; di: Rank xi - Rank yi; n: Number of samples (Certification: n<30 can be directly look-up table, n.>30 are closer to normal distribution).

Rank correlation value (rs) was obtained after calculating the formula. Then, calculated P-value assuming approximate normal distribution while there were more than 30 samples ( $n$ ). Compared P-value with the level of significance (α) (See Table 5), presenting that any null hypothesis conclusion ($H_0$) shall be rejected.

Table 5. Test Results

| rs | Z* | P-Value | α = 0.05 |
|---|---|---|---|
| 0.8589447 | 5.0815851 | 0.00000019 | P-Value < α |

Hence, the alternative hypothesis ρ > 0 was established, indicating that the two sequences were derived to be positive related to each other. This consequence further confirmed results originated from the model of trust function proposed by the research were rational and hereby provided reference for the future study and practice.

## VI. Conclusions

From the trust mode among partners in this study, we verify the accuracy through simulation test and have the following conclusions:

1. For mutual influence among indexes of trust among partners, we collect relational grade among trust indexes with DEMATEL.
2. ANP is applied to determine the weight of supplier trust indexes.
3. We propose a new performance evaluation model in combination with DEMATE and ANP to sort trust indexes and find out the maximum index that affect the overall performance. 4. The supplier's trust level evaluation value and suggested corresponding from the study is referable.

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