The Multi-participant Perspective for Evaluating Technology Transfer by Using a Hybrid Multi-Attribute Decision Making Model

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Abstract—Technology transfer (TT) is a process which needs multi-participant including universities, research institutes, enterprises, and intermediary agencies to cooperate that makes it successful. However, it is devoid of the main factors within a systemic perspective to evaluate the priority and influence interrelationship among these participants. This study, therefore, focuses on the multi-participant perspective of the interrelationships of TT and proposes a hybrid multi-attribute decision making model (MADM) combing decision making trial and evaluation laboratory (DEMATEL) and DEMATEL-based-analytic network process (DANP), called D-DANP model. To evaluate the causality and influence interrelationship of successful factors among the multi-participants of TT. Through the linkage effect of causality, the key factor set is identified and the goal of indirectly optimizing the efficiency of multi-participant synergy is achieved. This study first constructs a multi-level network model with the upper layer as the main participants and the lower layer as the influence attributes, applying the experts’ consultant and literature review to collect the influencing factors among participants to construct a hierarchical network for analysis. The results indicate the universities/research institutes are the main participant highly affects the other two participants which are corporations and intermediary agencies. The proposed D-DANP model is effective and can develop and improve the process that prioritizes the weights of attributes as well as makes the decision makers (DMs) have a visual cause-effect diagram for decision making and provide guidance to make sustainable improvement in the current implementation of TT.

Keywords—technology transfer; multi-participant hierarchy network; multiple attribute decision making (MADM); sustainable improvement.

I. INTRODUCTION

Successful technology transfer (TT) has become more important, providing the perspective of developing and promoting the market economy. TT as the transfer of technology know-how or technological process activity from one place to another [1, 2]. The Chinese government in 1996 passed “Law of the PRC on Promoting the Transformation of Scientific and Technological Achievement” has sought to enhance the innovation capacity by encouraging domestic universities and public research institutes to diffuse their inventions to public use. Studies, however, in evaluating the performance and the successful factors of TT are often focus on one “actor” such as corporation, university, research institute, or intermediary agencies [3-8]. In fact, TT as a process begins with innovative conception, design, prototyping, and pretesting stages, with cooperation efforts involves the government, universities, research institutes, corporations and intermediary agencies’ service in the team work so that make the innovative ideas, at the beginning, lead to actual effective products and processes [9]. Therefore, successful TT at a macro level has to generate evolving perspectives on for example to consider the multiple participants’ (i.e., universities, research institutes, corporations and intermediary agencies) internal-external influence relationships [1]. Consequently, the purpose of this study is to propose a hybrid multiple attribute decision making (MADM) model combining decision making trial and evaluation laboratory (DEMATEL) and DEMATEL-based-analytic network process (DANP), called D-DANP model, which can do the analysis of complex influence relationships among hierarchical levels of participants and attributes (i.e., successful factors) simultaneously [10, 11]. The proposed model can overcome the limitations of existing decision models and analyze the main attributes affecting the TT. In particular, this study evaluates the interdependence of the attributes that affect TT as well as to provide sustainable-improvement suggestions to achieve the desired level of TT. The rest of this paper is organized as follows. Section 2 introduces the proposed D-DANP model in terms of DEMATEL and DANP formulations. In Section 3, influential attributes are selected to establish the evaluating model. In section 4, an empirical case to illustrate how D-DANP model identifies the main influence attributes of the TT and analyze the results. Finally, we draw conclusions and remarks in Section 5.

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II. THE D-DANP MODEL FOR EVALUATING INFLUENCE FACTORS OF TT

A. The DEMATEL Technique for Constructing Direct-Influence Matrix and INRM

The DEMATEL technique has been successfully used to identify critical success factors in many situations, such as improving search engine, well-being financial performance, mobile commercial banking service, and information security risk assessment [12-16]. The method can be summarized in the following steps [17]:

Step 1: Calculate the direct-influence matrix by scores.

An assessment of the relationship between each mutual influence attribute is made according to the opinions of knowledge-based experts, using a scale ranging from 0 to 4, with scores represented by natural language: 'absolutely no influence' (0), 'low influence' (1), 'medium influence' (2), 'high influence' (3), and 'very high influence' (4). The knowledge-based experts are required to indicate the direct influence by a pairwise comparison, and if they believe that attribute has an effect and influence on attribute, they should indicate this by Thus, the matrix of direct relationships can be obtained. All diagonal of attributes are zero by pairwise comparison.

Step 2: Normalize the direct-influence matrix $G$.

The normalized matrix $A$ is acquired by using Eq.(1). The maximum total of rows or columns is one.

$$D = vG$$

where $v = \min \left\{ \frac{1}{\max \sum_j g_{ij}}, \frac{1}{\max \sum_i g_{ij}} \right\}, i, j \in \{1, 2, ..., n\}$

Step 3: Find a total-influential matrix $T$.

When the normalized direct-influential matrix $A$ is obtained, the total-influential matrix $T$ can be obtained from Eq.(3), in which $I$ denotes the identity matrix,

$$T = A + A^2 + A^3 + ... + A^k$$

$$= A(I + A + A^2 + ... + A^{k-1})(I - A)(I - A)^{-1}$$

$$= A(I - A^k)/(I - A)^{-1}$$

when $\lim_{k \to \infty} A^k = [0]_{nxn}$

where $A = \left[ a_{ij}^{k} \right]_{nxn}, 0 \leq a_{ij}^{k} < 1, 0 < \sum_j a_{ij}^{k} \leq 1$ and $0 < \sum_i a_{ij}^{k} \leq 1$, and at least one row or column of the summation (but not all) equals one; then, $\lim_{k \to \infty} A^k = [0]_{nxn}$ can be guaranteed. We can denote the row and column sums of the total-influential matrix $T = [t_{ij}^{k}]_{nxn}, i, j \in \{1, 2, ..., n\}$ as column vectors $r$ and $s$ respectively.

Step 4: Analyze the results.

$$r = \sum_j t_{ij}^{k} = [t_{i1}^{k}, ..., t_{in}^{k}] = (r_1, ..., r_n, r)$$

$$s = \sum_i t_{ij}^{k} = [t_{1j}^{k}, ..., t_{nj}^{k}] = (s_1, ..., s_n, s)$$

At this stage, the row sums and the column sums of the matrix components are separately expressed as vector and vector by using Eqs. (3)-(4). Let $i = j$ and $i, j \in \{1, 2, ..., n\}$; the horizontal axis vector $(r_i - s_i)$ is to illustrate the influence of the criterion. Similarly, the vertical axis vector $(r_i - s_i)$ is a causal cluster and an affected cluster. When $(r_i - s_i)$ is positive, the attribute is part of the causal group; i.e., attribute $i$ affects other attributes. By contrast, if $(r_i - s_i)$ is negative, the attribute is part of the affected group; i.e., attribute $i$ is influenced by other attributes. Therefore, a causal graph can be achieved by mapping the data set of $(r_i + s_i, r_i - s_i)$, the so-called influential network relation map (INRM), to provide a valuable approach to decide how the preferred values in each dimension and criterion can be improved.

B. Combine the ANP Method as DANP for Finding the Influence Weights of the Attributes

Step 1: Find the normalized matrix $T_{c}^{nor}$.

Normalize $T_{c}$ with the total degrees of effect and influence of the dimensions and clusters to obtain $T_{c}^{nor}$.

Step 2: Build an unweighted supermatrix $W_{c}$.

The total-influential matrix is normalized into a supermatrix $W_c$ according to the interdependence between the relationships of the dimensions and attributes to obtain an unweighted supermatrix, $W_{c} = \left( T_{c}^{nor} \right)$. If a blank or 0 is shown in the matrix, this means that the dimensions and attributes are independent.

Step 3: Find the normalized total-influential matrix $T_{D}^{nor}$.

The total-influential matrix can be normalized and presented as $T_{D}^{nor}$. Then, the sum of each row can be defined as $t_{i}^{n} = \sum_{j=1}^{m} t_{ij}^{n}$, where $i = 1, ..., m$, and $T_{D}$ can be normalized by the rows of sums by dividing the elements in each row by the sum of the row to obtain as in Eq. (8). Therefore, a total-influential matrix $T_{d}$ can be normalized and represented as $T_{D}^{nor} = \left[ \frac{t_{i}^{n}}{t_{i}^{n}} \right]_{m \times m}$. Then, each row of the normalized $T_{D}^{nor}$ can be summed to equal one, so that $\sum_{j=1}^{m} t_{ij}^{nor} = 1$.

Step 4: Find the influential weights of the DANP.

The total-influential matrix $T$ needs to be normalized by dividing the dimension and cluster, so $T_{c}$ is normalized by summarizing the row by dimensions and clusters to obtain $T_{c}^{nor}$. An unweighted super-matrix $W_{c}$ can be obtained by
transposing $T_c^{nor}$, i.e., $W_c = (T_c^{nor})'$. Then a weighted super-matrix $W_c^*$ can be obtained.

**Step 5: Obtain the DANP.**

Limit the weighted super-matrix by raising it to a sufficiently large power $\varphi$ until it converges and becomes a long-term stable super-matrix to obtain global priority vector, which defines the influential weights $w = (w_1',...,w_k',...,w_n')$ from $\lim_{\varphi \to \infty} (W_c^*)^\varphi$ for the attributes. Consequently, we can obtain DANP.

### III. INFLUENTIAL ATTRIBUTES SET FOR EVALUATING THE IMPLEMENTATION OF TT

Based on Cummings and Teng [18] provided a theoretical model of key factors affecting TT including 9 factors (i.e., influential attributes), and we also consulted the experts with TT experience to modify the attributes descriptions so that have the proposed model adapted to the empirical case in this study. Therefore, the influential attributes are collected as shown in Table I, and there are three participants which is Universities/ research institutes ($P_1$), corporations ($P_2$), and intermediary agencies ($P_3$) within 12 attributes for evaluating TT.

#### IV. AN EMPIRICAL APPLICATION AND ANALYSIS IN CHINA

In this section, an empirical study is to illustrate the application of the proposed D-DANP model for identifying the influential attributes and evaluating the implementation of TT achieving the desired level in China.

**A. Data Collection**

This study reviews the literature of TT issues and asks the seven experts with TT related experience for many years to make the questionnaire with three participants of 12 attributes’ pairwise comparisons. After surveying the nine experts’ perspectives on all attributes via personal interviews and a questionnaire.

**B. Analysis of Results by Using D-DANP Model**

We first apply DEMATEL technique (the steps 1-4 of subsection A) to compute the influence relationship matrix to obtain the cause-effect of the attributes for understanding which are major attributes affecting others. Then the INRM of the DEMATEL technique was obtained in Fig. 1. Having determined the relationship structure of TT attributes, the DANP method (the steps 1-5 of subsection B) was applied to obtain the influential weights of the attributes as shown in Table II.

| TABLE I. THE DESCRIPTIONS OF PARTICIPANTS’ ATTRIBUTES OF TT |
|------------------------------------------------------------|
| **Participants/ Attributes**                               | **Explanation**                                           |
| Universities/ research institutes ($P_1$)                  |                                                           |
| Technology readiness levels ($c_1$)                        | The distance from technology to product                    |
| Technology embeddedness ($c_2$)                            | The difficulty and complexity of TT                       |
| Researchers’ participation ($c_3$)                         | The involvement of researchers in the subsequent transformation activities |
| Institutional arrangements ($c_4$)                         | Researchers’ professional title appraisal system, performance appraisal system, transformation incentive policy, benefit distribution |
| Corporations ($P_2$)                                      |                                                           |
| Demand for new technology ($c_5$)                         | The importance of new technologies to its operations and operations |
| Relationship with technology supplier ($c_6$)              | There is a strategic relationship with supplier or independent |
| Learning ability ($c_7$)                                  | Efficiency in adopting and mastering new technologies      |
| Management ability ($c_8$)                                | Including technical management, resource allocation, organizational management experience, operational capacity, etc. |
| Intermediary agencies service ($P_3$)                      |                                                           |
| Assessment ability ($c_9$)                                | Capacity of accurately evaluating the value of technology  |
| Communication ability ($c_{10}$)                          | Providing trading information platform and assist both parties in connection and negotiation |
| Technical collaboration ability ($c_{11}$)                 | Fund raising; Implementation of site, equipment and supporting collaboration conditions; Supporting recruitment and training of all kinds of personnel. |
| Operational assistance ability ($c_{12}$)                  | New product appraisal and quality certification; Formulation of implementation plans for business development strategies; Technical stability and improvement, equipment maintenance and accessories implementation. |
the interrelationship of each participant and attribute for each embeddedness highest degree in However, the C.

Fig. 1. The INRM of hierarchical levels of participants and attributes.

TABLE II. INFLUENTIAL WEIGHTS BY THE STABLE MATRIX OF DANP

| Attribute Description        | Weight | Ranking |
|------------------------------|--------|---------|
| Researchers’ participation   | 0.094  | 1       |
| Learning ability             | 0.091  | 2       |
| Communication ability        | 0.089  | 3       |
| Technical collaboration ability | 0.089 | 3       |
| Technology embeddedness      | 0.088  | 4       |
| Management ability           | 0.085  | 5       |
| Assessment ability           | 0.081  | 6       |
| Relationship with technology supplier | 0.079 | 7       |
| Technology readiness levels  | 0.077  | 8       |
| Operational assistance ability | 0.077 | 8       |
| Assessment ability           | 0.076  | 9       |
| Institutional arrangements   | 0.073  | 10      |

C. Implications and Discussions

According to the DEMATEL technique, we can recognize the interrelationship of each participant and attribute for each participant and attribute by INRM which is as shown in Fig.1. The \( P_i \) affects the other two participants, namely, \( P_j \) and \( P_k \); obviously, \( P_i \) plays an important role in multi-participant perspective of TT and highly influential in its interrelationship to the others. Therefore, the decision maker(s) (DMs) considering successful process of TT should improve and put the resources in the \( P_i \) first. Besides, in Fig. 1, we can find that the only causal participant is \( P_j \), which is the highest degree of influence affecting \( P_i \) and \( P_k \) in the upper level. Besides, the cause attributes are: technology readiness levels \( (c_1) \), which is the highest degree in \( P_i \) in the local weight. Then, technology embeddedness \( (c_2) \), researchers’ participation \( (c_3) \), institutional arrangements \( (c_4) \) and demand for new technology \( (c_5) \). However, the demand for new technology \( (c_5) \) is in \( P_i \), though it is a direct cause attribute yet vulnerable to the impact of all other attributes. In sum, we used DEMATEL technique to confirm the influential interrelationships and construct INRM so that visualize the cause-effect relationships to assist decision maker(s) easier understand the main attributes to be considered which are cause (i.e., need to improve immediately) and effect (if the cause attributes are improved, the effect attribute would improve indirectly by the cause attributes).

Table II displays the global weight of all the attributes. The top five attributes to improve the process of TT is researchers’ participation \( (c_3) \), followed by learning ability \( (c_4) \) in \( P_2 \), communication ability \( (c_6) \), and technical collaboration ability \( (c_11) \) in \( P_2 \), and technology embeddedness \( (c_2) \) in \( P_1 \). However, in the multi-perspective to the upper and lower level viewpoint (i.e., three participants and 12 attributes), it should evaluate all of the participants and attributes for TT in accordance with Fig. 1 so that the make visible concept for the DMs to evaluate that which would be the first priority at all the begging for successful process of TT.

V. CONCLUSIONS AND REMARKS

TT has played an important role in linking academic and real world needs. However, it always exists gaps from theory and practice so that it is difficult to promote them to the public. Decision-making about its implementations are complicated by the fact that various attributes are distinct and too numerous to evaluate what is “key factor” of TT. Based on the experts’ experience and literature review, we construct a multi-participant perspective of hierarchical network considering participants in the upper level and their attributes in the lower level, and apply the proposed D-DANP model to draw the interrelationship align with the TT process. The main contributions of this study is to evaluate the implementation of improving TT process by a multi-participant perspective dealing with the independent and interactive attributes of the participants. The evaluation attributes selected might miss or not consider due to the purpose of this study; therefore, further research would be verified with another sample or have a longitudinal research of the future can then be compared with this study to exam the attributes which are effective for the TT process.

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REFERENCES

[1] J. D. Roessner, “Technology Transfer Science and Technology Policy in the U.S.A.” Time of Change, Longman, London Hill, 2000.
[2] B. Bozeman, “Technology transfer and public policy: a review of research and theory,” Research policy, 2000, vol. 29, pp.627-655.
[3] T. R. Anderson, “Measuring the efficiency of university technology transfer.” Technovation, 2010, vol. 27, pp.306.
[4] A. Caldera and O. Debande, “Performance of Spanish Universities in Technology Transfer: An Empirical Analysis,” Research Policy, 2010, vol. 39, pp.1160–1173.
[5] V. Costantini, and P. Liberati, “Technology Transfer, Institutions and Development,” Technological Forecasting and Social Change, 2014, vol. 88, pp.26–48.
[6] S. Yusuf, “Intermediating knowledge exchange between universities and business.” Research Policy, 2008, vol.37, pp.1167-1174
[7] J. Zhao, D. Zhu, “Problems and countermeasures of the transformation of scientific and technological achievements in Anhui—taking universities, research institutes and enterprises as examples,” Journal of
Liaoning Technical University (Social Science Edition), 2016, vol. 18, pp.861-865.

[8] D. S. Siegel, D. Waldman, A. Link, “Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study,” Research Policy, 2003, vol. 32, pp.27-48.

[9] R. G. Phillips, “Technology business incubators: How effective as technology transfer mechanisms?” Technology in Society, 2002, vol. 24, pp.299–316.

[10] Y. P. Ou Yang, H. M. Shieh, J. D. Leu, “A novel hybrid MCDM model combined with DEMATEL and ANP with applications,” 2007, vol.5, pp.160-168.

[11] K. H. Peng, G. H. Tzeng, “A hybrid dynamic MADM model for problem-improvement in economics and business,” Technological & Economic Development of Economy, 2013, vol. 19, pp.638-660.

[12] J. J. H. Liou, J. Tamščiūtienė, E. K., Zavadskas, and G. H. Tzeng, “New hybrid copras-g MADM model for improving and selecting suppliers in green supply chain management.” International Journal of Production Research, 2016, vol. 54, pp.114-134.

[13] H. J. Tsuei, W. H. Tsai, F. T., Pan, and G. H. Tzeng, “Improving search engine optimization (seo) by using hybrid modified mcdm models,” Artificial Intelligence Review, 2018, vol.9, pp.1-16.

[14] S. K. Hu, M. T. Lu, and G. H. Tzeng, “Exploring mobile commerce adoption using a new hybrid fuzzy MCDM model,” International Conference on Fuzzy Theory & Its Applications. International Conference on Fuzzy Theory & Its Applications IEEE, 2015.

[15] K. Y. Shen, M. R. Yan, G. H. Tzeng, & K. M. Chien, “Conjoint effects of R&D on the financial performance of semiconductor companies: Rule-based granular computing,” International Symposium on Soft Computing & Intelligent Systems. 2015.

[16] Y. P. Ou Yang, H. M. Shieh, and G. H. Tzeng, “A VIKOR technique based on DEMATEL and ANP for information security risk control assessment,” Information Sciences, 2013, vol. 232, pp.482-500.

[17] G. H. Tzeng, C. H. Chiang, and C. W. Li, “Evaluating intertwined effects in e-learning programs: a novel hybrid MCDM model based on factor analysis and DEMATEL,” Expert Systems with Applications, 2007, vol. 32, pp.1028-1044.

[18] J. L. Cummings, B. S. Teng, “Transferring R&D knowledge: the key factors affecting knowledge transfer success,” Journal of Engineering and Technology Management, 2003, vol. 20, pp.39-68.