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# Analyzing determinants for promoting emerging technology through intermediaries by using a DANP-based MCDA framework

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ABSTRACT

Multiple Criteria Decision Analysis (MCDA) has been widely considered a useful tool for evaluating decision making. Several derivatives of MCDA, including AHP, ANP, DANP, have been implemented in previous studies to construct real-world applications. However, literature combining a systematic introduction on methodological developments of MCDA with an empirical implementation in promoting technology through intermediaries is still rare. To fill in this gap, this paper begins with introducing the methodological development of MCDA to set out an analytical framework, namely DANP for the empirical analysis. Consequently, this paper applied DANP to analyze multiple determinants and five dimensions that we summarized from existing literature to find out the key determinants and the interdependent relationship for promoting the emerging sector through institutional intermediaries. While conducting empirical implementation, 33 experts from major intermediaries involved in promoting the biotechnology sector were visited. 7 out of 33 of these experts were further visited for interview to verify our analysis. Based on our MCDA analysis, we found that government policies and regulations are the most influential determinates while promoting emerging sectors through intermediaries. This paper contributes to the literature in several ways including highlighting methodological improvements of DANP, improving approaches on empirical data collection, and implementing an empirical MCDA analysis by applying an influential network relation map (INRM) to construct useful policy suggestions for real-world applications.

## 1. Introduction

Innovation studies initially focused on firm-based studies and subsequently moved into analysis of systematic social and economic activities embedded in the networks and sectors, especially in the case of the biotechnology innovation system (Wield et al., 2013). In East Asia, especially Taiwan and Korea, intermediaries play crucial roles in implementing public policies for developing emerging technologies. On the other strand, the innovation network literature (Powell et al., 1996) maintains that innovation is embedded in inter-organizational collaborations rather than any single actor, especially in the biotech sector (Gilsing and Nooteboom, 2006; Powell et al., 1999; Powell et al., 2005). Etzkowitz (2002) emphasizes the crucial role of laboratory and university research in knowledge production networks of incubating emerging technologies. The technologies can also be transferred from the knowledge owners, such as universities or organizations, to the acquirers, such as firms, for manufacturing new products or through new processes (Guan et al., 2006; Lee et al., 2010). The specific technology in the labs could also be commercialized to the practical products or services (Sung, 2009).

Nevertheless, technology transfer does not always reach the firms' strategic objectives due to the complex and dynamic interactions in the technology transfer process (Lichtenthaler and Lichtenthaler, 2010). Technology transfer processes involve technologies, firms' capabilities and interrelationships between the technology providers and recipients (Guan et al., 2006; Lai, 2011; Lee et al., 2010). The process also needs efforts and resources to reduce the structural, cultural, and organizational boundaries (Sung, 2009). Thus, intermediaries constantly take charge of bridging this kind of communication gap (Yusuf, 2008) while transferring knowledge and technologies from knowledge providers into industry (Caldera and Debande, 2010; Kirkels and Duysters, 2010). An increasing number of intermediaries, such as university Technology Transfer Offices (TTOs), incubators, and research centres have been established in the past three decades worldwide (Villani et al., 2016). In particular, in the emerging high-tech sectors, firms heavily rely on external knowledge in the innovation process (Kirkels and Duysters, 2010; Leydesdorff and Meyer, 2006; Powell and Grodal, 2005; Weckowska, 2015).

Existing literature has suggested several key determinants of

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intermediaries while promoting emerging technologies, such as policies (Aldridge and Audretsch, 2011; Kalar and Antoncic, 2015), government supports (Kalar and Antoncic, 2015; Weckowska, 2015), characters of technologies and products (Lai, 2011; Sung, 2009), geographic proximity (D'Este and Iammarino, 2010; Kalar and Antoncic, 2015), relationships with other organizations (Weckowska, 2015), professions of staff (Villani et al., 2016), resources (Lai, 2011), and incentives (Siegel et al., 2003b). However, the interdependence relationships among the above-mentioned key determinants are less clear. To fill in this gap in the existing literature this paper firstly will introduce the methodological developments in MCDA and where DANP comes from. This study took the biotechnology sector as the example which is an emerging sector which received longitudinal policy attention in many countries, in particular in Taiwan. The main research question this paper attempts to answer is what are the key determinants for incubating technologies and enhancing technology transfer through intermediaries in the emerging biotechnology sector?

This main research question can be broken down into three sub questions:

(1) How did the MCDA methods develop for analyzing independent determinants?
(2) How are main institutional intermediaries in the biotechnology sector involved? What roles are they playing while facilitating technology transfer and technology incubation?
(3) What are the key determinants for incubating technologies and enhancing technology transfer in the emerging biotechnology sectors?

In response to the above-mentioned questions, this paper begins with introducing an MCDA framework which integrates a Decision-Making Trial and Evaluation Laboratory (DEMATEL) and the Analytical Network Process (ANP), to form a framework namely DANP (Hsu et al., 2012). The DANP framework is established for building a visual influential relationship map among dimensions and criteria with DEMATEL (Chiu et al., 2013), and using the basic concept to evaluate the key determinants by considering the influential and priority weights based on the influence matrix by DEMATEL (Ou Yang et al., 2007; Tsui et al., 2015).

The rest of this paper is organized as follows: Section 2 introduces the recent developments of the DANP-based MCDA framework for setting out the analytical framework of this paper. Section 3 reviews recent literature regarding intermediaries and the key determinants for promoting the emerging technology industry. This will form the basis for our empirical analysis in Section 5. The methods and data are explained in Section 4. Our implementations of DANP on our empirical data are presented in Section 5. Conclusions and suggestions are in Section 6.

## 2. The development of a DANP-based MCDA framework

Literature indicates that over the past two decades, multi-criteria decision making and analysis has been increasingly applied in real world problems (Yang and Tzeng, 2011). Among the MCDM and MCDA methods, some procedures are based on an aggregating function representing the closeness to the ideal points, such as VIKOR and TOPSIS. Some methods such as the Analytic Hierarchy Process (AHP), Analytical Network Process (ANP), DEMATEL, and DEMATEL-based ANP (DANP) mainly focus on determining the evaluation criteria and the decision structures based on decision-makers' preference weights. During the decision making process, the measurement of criteria importance and

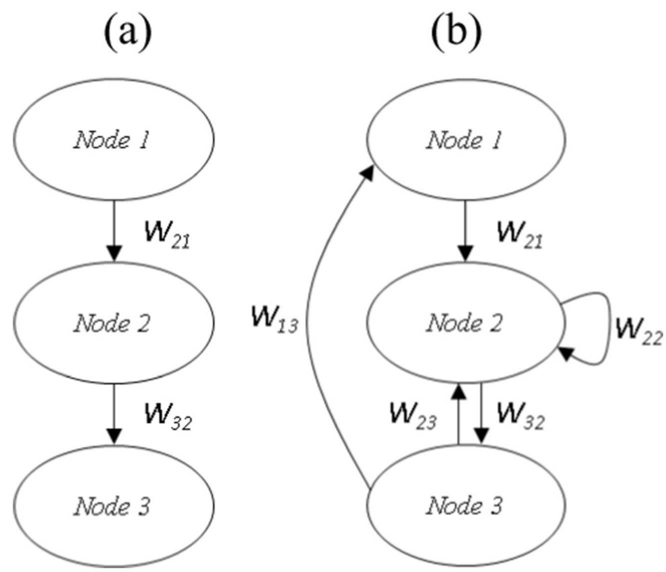


**Fig. 1.** The decision structure of (a) AHP and (b) ANP.
Source: Wei and Chang (2008).

structures is very important for enhancing the quality of decision making (Yang and Tzeng, 2011). Different from the traditional statistical factor analysis which commonly divides criteria into groups and assumes independent equal criteria weights to sum up factor effectiveness (Tzeng et al., 2007), the ANP and DANP methods were developed for considering the interdependent relationship between the influential criteria in the system. In this section, we introduce the concept and the development of AHP, ANP, and DANP before bringing them together to set out our analytical framework.

Among the MCDM or MCDA methods, the AHP proposed by Satty (1980) has been widely applied to solve multi-criteria decision-making problems, including in the relevant emerging technology and biomedical fields (Chen and Huang, 2004; Danner et al., 2011; Erensal et al., 2006; Liberatore and Nydick, 2008; Lin and Juang, 2008; Sloane et al., 2001). The concept of AHP is to decompose a decision problem to a set of manageable clusters and sub-clusters into several levels for establishing a decision model for selecting alternatives (Cheng and Li, 2007). The structure of AHP is hierarchical and linear, which represents a goal at the top and some alternatives on the bottom. The process contains several levels of criteria, as shown in Fig. 1-(a).

$$AW = \begin{array}{c} \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{ccccc} \mathrm{A}_1 & & \mathrm{A}_j & & \mathrm{A}_n \end{array} \\ \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_j & \cdots & w_1/w_n \\ \vdots & & \vdots & & \vdots \\ w_i/w_1 & \cdots & w_i/w_j & \cdots & w_j/w_n \\ \vdots & & \vdots & & \vdots \\ w_n/w_1 & \cdots & w_n/w_j & \cdots & w_n/w_n \end{bmatrix} \end{array} \begin{bmatrix} w_1 \\ \vdots \\ w_i \\ \vdots \\ w_n \end{bmatrix} = nW \tag{1}$$

See an example of AHP on the above Eq. (1). By solving the Eigen vector $\boldsymbol{W}$ from the pairwise relation matrix $\boldsymbol{A}$, we can obtain the priority weights of the criteria, where $n$ is the number of criteria. However, the significant limitations include the restriction that the AHP decision models must be hierarchical, and the independency of each element in the hierarchy, that is, the higher-level elements from lower-level elements and also of the elements within their own level are assumed independent (Jharkharia and Shankar, 2007). In the real world, the criteria would be dependent and would also have feedback among