探討成功開發新產品的關鍵因素

Investigate the Critical Factors of Successful New Product Development

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Abstract

New product (NP) plays a crucial role in enhancing a company's competitiveness and performance. Unlike past researches, this paper employs a set of more comprehensive factors and focuses on the viewpoints of senior managers, adopts the DANP method proposed by Ou Yang et al. (2008) which are integrated by DEMATEL and ANP to investigate the critical factors of successful new product development (NPD). The set of fifteen criteria of is extracted from past literature and then classifies them into six clusters. For consolidating the research structure, this paper consults ten scholars/experts who are excellent in production domain to advise and revise the fifteen criteria and six clusters. Then, interviews ten senior managers to collect their opinions to decide the relative importance of each criterion while developing new products. The research results show that the External Factors Cluster is the main influence source and the Strategy Cluster plays as the central role among the six clusters. It implies that the companies must firstly consider outer operation environment on unpredictable risks and opportunities, then deploy resources in innovation or exploit their existed products in NPD. The top three priority criteria exhibit that senior NPD managers believe innovation strategy can assist companies to develop differentiated NPs, process management will help the companies to allocate and utilize resources effectively, and gating system can help to filter NPD projects to reduce the risk. The last three priority criteria indicate that government's policies and regulations may impede or slow down NPD, the economic conditions will impact on each company without discrimination, and due to most of the interviewed companies are relatively small to medium size enterprises, they are not necessary or affordable to establish CFTs.

Keywords: MCDM (Multi-Criteria Decision Making), DEMATEL, ANP, DANP, New Product Development (NPD)

1. Introduction

Innovation is the major driving force for every country's economic development. The major indicator of innovation is patents. According to the World Intellectual Property Organization (WIPO). New products (NPs), which are mostly composed by creative ideas and inventions with patents, refer to those that are new to the companies/markets/consumers, encompassing improved products, modified products, and innovative products (Kotler, 1991). NPs are beneficial for the companies and the world. To create NPs, companies need to engage in new product development (NPD). For exploring successful NPD, most of the past researchers were confined on limited number of variables/factors in specific area or only conducted from the perspective of consumer. Considering the limitations of research results in previous NPD literature, this paper stands on the top management perspective and incorporates a broader range of factors to develop a new viewpoint and create a more comprehensive exploration for successful NPD determinates.

We find that while engaging in NPD, companies cannot ignore the influence of External Factors Cluster due to the outer unpredictable risks and opportunities. Companies also have to focus on the Strategy Cluster to deploy resources in innovation or exploit their existed products. Senior NPD managers consider that companies need to formulate and implement innovative strategy to stimulate NP ideas and thinking, regular review and improve NPD process to ensure its effectiveness, and establish suitable filter standards for NPD projects. On the contrary, the research findings indicate that the government needs to gain a deeper understanding of the current industry situation and proposes relevant policies timely to effectively assist companies in NPD. In addition, the economic conditions do not have differentiated effect on each company, and not all companies need to immediately adopt new technology for NPD. Finally, companies interviewed by this paper are not necessary or afford to establish CFTs because their company size are relative small to medium.

The remaining of this paper is organized as follows: Section 2 reviews the past literature and extracts the criteria for successful NPD; The adopted research methodology is described in Section 3; The research results and explanation are expressed in Section 4; Section 5 is the conclusion and discussion.

2. Literature Review

In the highly competitive environment with constantly changing consumer demands, NPD has become crucial strategies for companies to achieve survival and growth. In such circumstances, gaining a profound understanding and identifying the factors that influence the success of NPD is important. This paper adopts the frame of Cooper (2019) and reviews relative literature, fifteen criteria are extracted and classified into six clusters, namely Organization Cluster, Strategy Cluster, Product Characteristics Cluster, Processes and Methodologies Cluster, Go-to-Market Cluster, and External Factors Cluster.

2.1 Organization Cluster

Organization is a structured group of individuals who share one or more common goals (Boella & van der Torre, 2006). Its capabilities, resources, and culture are essential means to help achieve NPD projects (Johnson et al., 2020). In addition, the positive attitude of top management and the collaboration among NPD team members can help to smooth the progress of NPD projects (Tang, Mu, & Thomas, 2015). This subsection will discuss how can the organization contribute to implement NPD projects by Internal Strength Criterion, Organizational Culture Criterion, Top Management Support (TMS) Criterion, and Cross-Functional Teams (CFTs) Criterion.

2.1.1 Internal Strength Criterion: In order to develop NPs quickly and achieve market competition successfully, the companies need to effectively utilize their capabilities (Azanedo, et al., 2020) and concentrate their resources on the most promising NPD projects to increase their success rate (Cooper & Kleinschmidt, 2007).

2.1.2 Organizational Culture Criterion: For developing NPs, the company need to foster an innovative culture to inspire employees' innovative behaviors, guide them to embrace innovation as a core organizational value (Hartmann, 2006). A company with innovative culture, its employees can mutually share information to raise new ideas (Hanifah et al., 2020) and promote the ability to develop NPs (Aksoy, 2017).

2.1.3 Top Management Support (TMS) Criterion: While engage in NPD, top management should provide opportunities for improving NPD (Kleinschmidt, De Brentani, & Salomo, 2010), understand NPD team's needs to provide right resources (Felekoglu et al., 2022), and enable the NPD team to resist the pressure of resource reallocation to other projects (Wheelwright & Clark, 1992) to ensure the success of NPD.

2.1.4 Cross-Functional Teams (CFTs) Criterion: For developing NPs, personnel from different fields or business departments are reassembled into cross-functional teams (CFTs) (Gemser & Leenders, 2011) to integrate perspectives on the compatibility of objectives from diverse domains (Dyson, 2020) and fully leverage each member's unique expertise and skills (Slotegraaf & Atuahene-Gima, 2011) for NPD.

2.2 Strategy Cluster

Strategy refers to the plans or methods that determine how the company to obtain/utilize resources to achieve its goals/objectives (Davies, 2000). For better accomplishing the objective of NPD, it is crucial for the companies to incorporate innovation into their strategy (Hsu, 2017). Companies can also increase the diversity of NPs by exploiting the proliferation strategy based on existed products to enhance market competitiveness (Zhao et al., 2020). Strategy Cluster comprise the criteria of Innovation Strategy Criterion and Product Proliferation Criterion in this subsection.

2.2.1 Innovation Strategy Criterion: Companies should formulate and implement innovation strategies based on their unique market environment and objectives (Yang, 2014) as a guideline for NPD. Innovation strategies can help the companies to expand markets (Nugraheni & Muhammad, 2020), develop NPs or new services (Kahn, 2018), meet the needs of consumers and stakeholders (Cillo et al., 2019), comply with international standards (Manders, de Vries, & Blind, 2016), and adapt to external environmental changes (Wang & Ellinger, 2011).

2.2.2 Product Proliferation Criterion: Apply product proliferation, companies can exploit current technologies or modify existing products in NPD (Eggers, 2012). By conducting product proliferation to NPD, companies can better cater to a wide range of consumer preferences (Huang & Su, 2013; Lyons, Um, & Sharifi, 2020), help companies to expand their market share, and increase profitability (Wan & Sanders, 2017).

2.3 Product Characteristics Cluster

Product characteristics are the attributes and features of a product, aim at conveying the messages of product to consumers (Hassenzahl, 2018). When choosing NPs, the consideration of consumers focuses on the uniqueness, exceptional value offered, and needs satisfaction (Jung, Choi, & Oh, 2020; Childs et al., 2020). For ensuring that NPs will meet consumer needs, the companies should identify customers' opinions and expectations (Mahdiraji et al., 2022). In addition, the companies also need to gather market intelligence to understand the needs, wants, and demands of the market for better responding to the market (Udriyah, Tham, & Azam, 2019). This subsection will discuss the related factors on Product Advantage Criterion, Voice of Customer (VoC) Criterion, and Market Orientation Criterion.

2.3.1 Product Advantage Criterion: NP with advantage can help the company to offer consumers unique features compared to other products, demonstrate excellent price/performance ratio, deliver good value, meet customers' needs (Cooper, 2019) and make difficulties for competitors to develop similar products (Potter & Lawson, 2013). Product advantage leads to outstanding financial performance (Fahy, 2000; Falahat et al., 2020), enhances brand recognition and reputation (Roberts & Dowling, 2002)."

2.3.2 Voice of Customer (VoC) Criterion: While engaging in NPD, the company has to adopt customer-focused policies (Cooper & Kleinscmidt, 1994) to collect and analyze market information from voice of customers to align with market demands and customer's expectations for achieving higher levels of consumer satisfaction, loyalty, and performance (Kirca et al., 2005; Mahdiraji et al., 2022)."

2.3.3 Market Orientation Criterion: The company must satisfy the explicitly expressed needs and the latent needs of customers for creating and delivering superior value to customers (Agarwal, Erramilli, & Dev, 2003; Narver, Slater, & MacLachlan, 2004). The development of NPs requires to understand the market and consumer needs to deliver rare and difficult-to-imitate value for customers (Lonial et al., 2008; Ali, Hilman, & Gorondutse, 2020).

2.4 Processes and Methodologies Cluster

The establishment and implement of processes and methodologies enable companies' NPD projects to move quickly and effectively from idea stage to commercialization stage (Cubero, Gbadegeshin, & Consolación, 2021). For developing NPs quickly and effectively, the Processes and Methodologies Cluster will discuss the related factors on Gating System Criterion and Process Management Criterion.

2.4.1 Gating System Criterion: For reducing risk and properly use the scarce resources, it is necessary to screen and select potential NPD projects. Company may establish Stage-Gate approach with clearly defined gates between each stage of the NPD process (Marion, Friar, & Simpson, 2012; Nicholas & Steyn, 2012) as standards for assessing NPD projects (Bansal & Grewatsch, 2020).

2.4.2 Process Management Criterion: For developing NPs, company must create NPD process that aligns with market and technical demands (Bruni & Verona, 2009; Masyhuri, 2022) in the most efficient manner to ensure that NPD is under expected timeframe, budget, quality guarantee, and customer expectations (Cooper, 2001).

2.5 Go-to-Market Cluster

Go-to-market refers to the strategy that company uses to introduce NPs to the market (Schuhmacher, Kuester, & Hultink, 2018) with the goal to ensure that NPs can enter the market quickly and effectively (Friedman, 2012). For successfully introduce NPs, Market Testing Criterion and Launch Criterion are discussed in this subsection.

2.5.1 Market Testing Criterion: After completing NPD, the company have to engage in market testing to confirm market demands, market response, and collect more detailed and precise solution-oriented feedback (Sarstedt & Mooi, 2014; Dash, Kiefer, & Paul, 2021) to better adjust the NP and develop appropriate marketing mix strategies (Henard & Szymanski, 2001).

2.5.2 Launch Criterion: For successfully launch NPs in the stage of NPD, top management should ensure relevant personnel and necessary resources should participate in the launch plan (Cooper, 2019). Also, companies must consider the timing of launch NPs to cope with increased competition, ever-changing consumer preferences, shortened product life cycles, and accelerated product obsolescence (Khinvasara, Ness, & Tzenios, 2023), but cannot compromise with the quality of NPs (Sethi, 2000).

2.6 External Factors Cluster

External factors lead to unpredictable risks and opportunities in NPD (Rastogi & Trivedi, 2016). For mitigating risks and grasping opportunities, companies must acquire government supports (Zhu et al., 2012), adopt advanced technologies, and adjust their NPD strategies to align with the economic environment (Hendrasetyawan & Yunus, 2022). This subsection will discuss the External Factors Cluster on Government Policy Criterion and Economic Conditions and Technology Trend Criterion.

2.6.1 Government Policy Criterion: The government must adopt policies to bridge the companies' financing gap (Almus & Czarnitzki, 2003), encourage innovation and R&D activities, and protect intellectual property rights (Chundakkadan & Sasidharan, 2020) to reduce NPD costs and risks. The government should also provide employee training support (Nguyen et al., 2023), establish infrastructure (Hnatenko et al., 2020), and setup industrial zones or science parks for creating industrial clusters (Lai et al., 2014) to enhance companies' ability to develop NPs (Casanueva et al., 2013).

2.6.2 Economic Conditions and Technology Trend Criterion: When engaging in NPD, the companies must consider economic conditions (e.g., interest rates and inflation rate) to ensure that NPD projects can bring reasonable returns (Hemmati, Taghizad, & Mahmoudi, 2017; Beladi, Deng, & Hu, 2021). The companies should also examine technology trend to accumulate existing knowledge for creating new knowledge (Aydin, 2021) and enhance the flexibility of rapid redefinition and reconfiguration for NPD options (Dai et al., 2018) for developing NPs to come across shorter product lifecycle (Aytac & Wu, 2013) and meet customers' dynamic demands (Ma, Wu, & Liu, 2021), derived from the change of population structure (Liu et al., 2023).

2.7 The Summation of Clusters and Criteria

In order to explore successful NPD, this paper extracts fifteen criteria from past relative literature and consults ten scholars/experts in the field of NPD to supplement and revise these criteria. The Structure of successful NPD includes six clusters and fifteen criteria, i.e. Organization (O1 to O4), Strategy (S1 and S2), Product Characteristics (P1 to P3), Processes and Methodologies (M1 and M2), Go-to-Market (G1 and G2), and External Factors (E1 and E2), shown as Table 2.1.

3. Research Methodology

This paper adopts the DANP model proposed by Ou Yang et al. (2008) integrated by DEMATEL and ANP. DEMATEL is used to determine the degree of mutual influence among clusters, then ANP is weighted according to the degree of mutual influence created by DEMATEL to further evaluate the prioritization of NPD criteria. Based on the data processing steps of Ou Yang et al. (2008) and Khan et al. (2020), the flowchart of DANP is depicted as Fig. 3.1. The detail description of each step will be shown in the following subsections.

Table 2.1 The Structure of Successful NPD Criteria

Clusters	Criteria	Sources
(O) Organization	(O1) Internal Strength	Azanedo, et al., 2020; Cooper & Kleinschmidt, 2007
	(O2) Organizational Culture	Hartmann, 2006; Hanifah et al., 2020; Aksoy, 2017
	(O3) Top Management Support	Kleinschmidt, De Brentani, & Salomo, 2010; Felekoglu et al., 2022; Wheelwright & Clark, 1992
	(O4) Cross-Functional Teams	Gemser & Leenders, 2011; Dyson, 2020; Slotegraaf & Atuahene-Gima, 2011
(S) Strategy	(S1) Innovation Strategy	Yang, 2014; Nugraheni & Muhammad, 2020; Kahn, 2018; Cillo et al., 2019; Manders, de Vries, & Blind, 2016; Wang & Ellinger, 2011
	(S2) Product Proliferation	Eggers, 2012; Huang & Su, 2013; Lyons, Um, & Sharifi, 2020; Wan & Sanders, 2017
(P) Product Characteristics	(P1) Product Advantage	Cooper, 2019; Potter & Lawson, 2013; Fahy, 2000; Falahat et al., 2020; Roberts & Dowling, 2002
	(P2) Voice of Customer	Cooper & Kleinscmidt, 1994; Kirca et al., 2005; Mahdiraji et al., 2022
	(P3) Market Orientation	Agarwal, Erramilli, & Dev, 2003; Narver, Slater, & MacLachlan, 2004; Lonial et al., 2008; Ali, Hilman, & Gorondutse, 2020
(M) Processes and Methodologies	(M1) Gating System	Marion, Friar, & Simpson, 2012; Nicholas & Steyn, 2012; Bansal & Grewatsch, 2020
	(M2) Process Management	Bruni & Verona, 2009; Masyhuri, 2022; Cooper, 2001
(G) Go-to-Market	(G1) Market Testing	Dash, Kiefer, & Paul, 2021; Sarstedt & Mooi, 2014; Henard & Szymanski, 2001
	(G2) Launch	Cooper, 2019; Khinvasara, Ness, & Tzenios, 2023; Sethi, 2000
(E) External Factors	(E1) Government Policy	Almus & Czarnitzki, 2003; Chundakkadan &; Sasidharan, 2020; Nguyen et al., 2023; Hnatenko et al., 2020; Lai et al., 2014; Casanueva et al., 2013
	(E2) Economic Conditions and Technology Trend	Hemmati, Taghizad, & Mahmoudi, 2017; Beladi, Deng, & Hu, 2021; Aydin, 2021; Dai et al., 2018; Aytac & Wu, 2013; Ma, Wu, & Liu, 2021

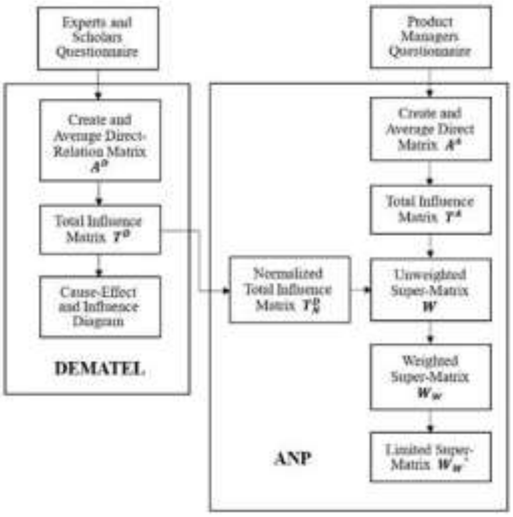

Fig. 3.1 The Flowchart of DANP Steps. (Source: Rearranged by This Paper)

3.1 The Steps of DEMATEL Procedure

Step D1: Calculate Average Direct-Relation Matrix $\boldsymbol{A^D}$

Each respondent questionnaire will generate a direct-relation matrix $\boldsymbol{D_k}$, $k = 1, 2, \cdots, n$, where n represents the number of respondents. Each element of $\boldsymbol{D_k}$, denoted by d_{ij}^k, expresses the influence cluster i impacts on cluster j, shown as Eq. (1).

$$\boldsymbol{D_k} = \begin{bmatrix} d_{11}^k & \cdots & d_{1j}^k & \cdots & d_{1n}^k \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ d_{i1}^k & \cdots & d_{ij}^k & \cdots & d_{in}^k \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ d_{n1}^k & \cdots & d_{nj}^k & \cdots & d_{nn}^k \end{bmatrix} \quad (1)$$

The average direct-relation matrix $\boldsymbol{A^D}$ is calculated by averaging the corresponding elements from the direct-relation matrix $\boldsymbol{D_k}$. Each element in the average direct-relation matrix $\boldsymbol{A^D}$, denoted by a_{ij}^D, is calculated by Eq. (2), where n indicates the number of direct-relation matrices $\boldsymbol{D_k}$ and m expresses the number of clusters.

$$a_{ij}^D = \frac{\sum_{k=1}^{n} d_{ij}^k}{n} \quad (2)$$

Then, $A^D = \begin{bmatrix} a_{11}^D & \cdots & a_{1j}^D & \cdots & a_{1m}^D \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{i1}^D & \cdots & a_{ij}^D & \cdots & a_{im}^D \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{m1}^D & \cdots & a_{mj}^D & \cdots & a_{mm}^D \end{bmatrix}$

Step D2: Derive the Total Influence Matrix $\boldsymbol{T^D}$

Normalizing $\boldsymbol{A^D}$ by Eqs. (3) and (4) to obtain the normalized average direct-relation matrix $\boldsymbol{X^D}$, and all the principal diagonal factors equal to zero. The total influence matrix $\boldsymbol{T^D}$ can be acquired through Eq. (5), where $\boldsymbol{I}$ denotes identity matrix. The elements t_{ij}^D of $\boldsymbol{T^D}$ is expressed as the direct or indirect influence from cluster *i* to cluster *j*.

$$s^D = min\left[\frac{1}{max\sum_{j=1}^{n}\left[a_{ij}^D\right]}, \frac{1}{max\sum_{i=1}^{n}\left[a_{ij}^D\right]}\right] \quad (3)$$

$$\boldsymbol{X^D} = s^D \times \boldsymbol{A^D} \quad (4)$$

$$\boldsymbol{T^D} = \lim_{k\to\infty}\left(\boldsymbol{X^D} + \boldsymbol{X^D}^2 + \boldsymbol{X^D}^3 + \cdots + \boldsymbol{X^D}^k\right) = \boldsymbol{X^D}(\boldsymbol{I} - \boldsymbol{X^D})^{-1} \quad (5)$$

Then, $\boldsymbol{T^D} = \begin{bmatrix} t_{11}^D & \cdots & t_{1j}^D & \cdots & t_{1n}^D \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{i1}^D & \cdots & t_{ij}^D & \cdots & t_{in}^D \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{n1}^D & \cdots & t_{nj}^D & \cdots & t_{nn}^D \end{bmatrix}$

Step D3: Analyze the Results of Influences and Relationships

In $\boldsymbol{T^D}$, r and c respectively denote the row sum and column sum, which can be calculated by Eqs. (6) and (7).

$$r = (r_i)_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \quad (6)$$

$$c = \left(c_j\right)_{1\times n} = \left(c_j\right)'_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{n\times 1} \quad (7)$$

where r_i is the sum of the i^{th} row of $\boldsymbol{T^D}$, represents the total of direct and indirect impacts of cluster i on the other clusters. Similarly, c_j is the sum of the j^{th} column of $\boldsymbol{T^D}$ and represents the total of direct and indirect influences that cluster j received from the other clusters. When $i = j$, the $r_i + c_i$ indicates the "degree of importance" of cluster i that the strength of the total influence gives to and receives from the other clusters (Kuo, Hsu, & Li, 2015). The higher the value of $r_i + c_i$, the stronger the connections among cluster i and the other clusters which means that cluster i plays a central role with a higher priority (Wang et al., 2018). On the other hand, the $r_i - c_i$ refers as "net effect" that signifies the prioritization of cluster i. If $r_i - c_i > 0$, then cluster i has a net affecting to the other clusters; if $r_i - c_i < 0$, then cluster i is net influenced by the other clusters (Qu et al., 2019; Hsu, Shih, & Pai, 2020). A higher value of $r_i - c_i$ means that the influence of cluster i on the other clusters is stronger than it received from the other clusters, it implies a higher priority to cluster i (Peng et al., 2022).

The original version of Ou Yang et al. (2008) established a threshold (α) to screen and eliminate minor influence clusters in the matrix $\boldsymbol{T^D}$. Considering the difference between significant influence clusters and minor influence clusters may be minimal, this paper follows the suggestion of Chiu, Tzeng, & Li (2013) and Yang et al. (2020) to mark the upper-right corner of minor influence clusters with an asterisk "*" to indicate that the values which are below α rather than to remove them. For example, the values of elements t_{11}^D, t_{12}^D, t_{21}^D, and t_{33}^D are smaller than α in $\boldsymbol{T^D}$, thus marking them with asterisk "*", shown as Fig. 3.2.

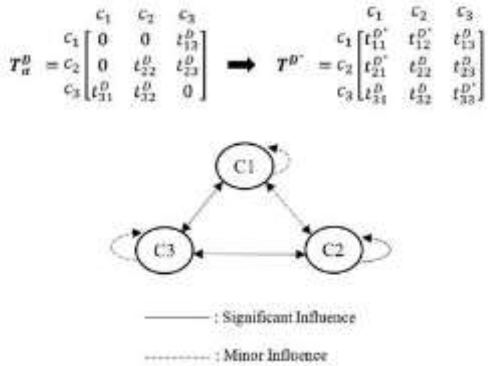

Fig. 3.2 The Revised Edition of $\boldsymbol{T_{\alpha}^{D}}$ and Influence Diagram. (Source: Revised by This Paper)

3.2 The Steps of ANP Procedure

Step A1: Collect and Average the Direct Matrix $\boldsymbol{A_y}$

This paper collects the data by interviewing with ten senior NPD managers to generate ten direct matrices $\boldsymbol{A_y}$, $y = 1, 2, \cdots, 10$, shown as Eq. (8).

$$\boldsymbol{A_y} = \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{bmatrix} \boldsymbol{H_{11}^y} & \boldsymbol{H_{12}^y} & \cdots & \boldsymbol{H_{1n}^y} \\ \boldsymbol{H_{21}^y} & \boldsymbol{H_{22}^y} & \cdots & \boldsymbol{H_{2n}^y} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{H_{n1}^y} & \boldsymbol{H_{n2}^y} & \cdots & \boldsymbol{H_{nn}^y} \end{bmatrix} \quad (8)$$

In Eq. (8), n represents the number of respondents, C_n indicates the n^{th} cluster, and e_{nm_i} indicates the m_i element in n^{th} cluster. $\boldsymbol{H_{ij}^y}$ are the submatrices of $\boldsymbol{A_y}$, signify the influence of the elements in the j^{th} cluster compared to the i^{th} cluster. Each element of $\boldsymbol{H_{ij}^y}$, denoted by η_{ij}^y, expresses the initial direct effects that each criterion gives and receives from the other criteria.

The average matrix $\boldsymbol{A^A}$ is generated by calculating the average of the same elements in each direct matrix $\boldsymbol{A_y}$. Each element of $\boldsymbol{A^A}$ is expressed as a_{ij}^A, denoted as Eq. (9), where n represents the number of direct matrices $\boldsymbol{A_y}$ and m expresses the number of criteria.

$$a_{ij}^A = \frac{\sum_{y=1}^{m} \eta_{ij}^y}{n} \quad (9)$$

Then, $\boldsymbol{A^A} = \begin{bmatrix} a_{11}^A & \cdots & a_{1j}^A & \cdots & a_{1m}^A \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{i1}^A & \cdots & a_{ij}^A & \cdots & a_{im}^A \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{m1}^A & \cdots & a_{mj}^A & \cdots & a_{mm}^A \end{bmatrix}$

Step A2: Derive the Total Influence Matrix $\boldsymbol{T^A}$

Normalizing $\boldsymbol{A^A}$ by Eqs. (10) and (11) obtains the initial direct-relation matrix $\boldsymbol{X^A}$. All the principal diagonal elements in $\boldsymbol{X^A}$ are equal to zero.

$$s^A = min\left[\frac{1}{max\sum_{j=1}^{n}\left[a_{ij}^A\right]}, \frac{1}{max\sum_{i=1}^{n}\left[a_{ij}^A\right]}\right] \quad (10)$$

$$\boldsymbol{X^A} = s^A \times \boldsymbol{A^A} \quad (11)$$

Calculate the total influence matrix $\boldsymbol{T^A}$ by Eq. (12), where $\boldsymbol{I}$ denotes the identity matrix. In $\boldsymbol{T^A}$, the element t_{ij}^A represents the direct or indirect influence from criterion i to criterion j.

$$\boldsymbol{T^A} = \lim_{k\to\infty}\left(\boldsymbol{X^A} + \boldsymbol{X^A}^2 + \boldsymbol{X^A}^3 + \cdots + \boldsymbol{X^A}^k\right) = \boldsymbol{X^A}(\boldsymbol{I} - \boldsymbol{X^A})^{-1} \quad (12)$$

Then, $\boldsymbol{T^A} = \begin{bmatrix} t_{11}^A & \cdots & t_{1j}^A & \cdots & t_{1n}^A \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{i1}^A & \cdots & t_{ij}^A & \cdots & t_{in}^A \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{n1}^A & \cdots & t_{nj}^A & \cdots & t_{nn}^A \end{bmatrix}$

Step A3: Obtain the Unweighted Super-Matrix $\boldsymbol{W}$

Normalizing $\boldsymbol{T^A}$ to obtain the normalized total influence matrix $\boldsymbol{T_N^A}$, shown as Eq. (13).

To calculate $\boldsymbol{T_N^A}$, divide each element in $\boldsymbol{T^A}$ into submatrices firstly. In each submatrix, calculate the sum of all the elements, and finally divide every element by the summation. For instance, the calculation process of the submatrix $\boldsymbol{T_N^{A^{11}}}$ is shown as Eqs. (14) and (15).

$$\boldsymbol{T_N^A} = \begin{matrix} & & \begin{matrix} C_1 & C_2 & \cdots & C_n \\ e_{11}\cdots e_{1m_1} & e_{21}\cdots e_{2m_2} & \cdots & e_{n1}\cdots e_{nm_n} \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} & \begin{matrix} e_{11}\cdots e_{1m_1} \\ e_{21}\cdots e_{2m_2} \\ \vdots \\ e_{n1}\cdots e_{nm_n} \end{matrix} & \begin{bmatrix} \boldsymbol{T_N^A}^{11} & \boldsymbol{T_N^A}^{12} & \cdots & \boldsymbol{T_N^A}^{1n} \\ \boldsymbol{T_N^A}^{21} & \boldsymbol{T_N^A}^{22} & \cdots & \boldsymbol{T_N^A}^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{T_N^A}^{n1} & \boldsymbol{T_N^A}^{n2} & \cdots & \boldsymbol{T_N^A}^{nn} \end{bmatrix} \end{matrix} \tag{13}$$

$$s_{e_1}^{11} = \sum_{i=1}^{m_1} t_{e_{1i}}^{A^{11}} \tag{14}$$

$$\boldsymbol{T_N^{A^{11}}} = \begin{bmatrix} t_{11}^{A^{11}}/s_{e_1}^{11} & t_{12}^{A^{11}}/s_{e_1}^{11} & \cdots & t_{1m_1}^{A^{11}}/s_{e_1}^{11} \\ \vdots & \vdots & \ddots & \vdots \\ t_{21}^{A^{11}}/s_{e_2}^{11} & t_{22}^{A^{11}}/s_{e_2}^{11} & \cdots & t_{2m_1}^{A^{11}}/s_{e_2}^{11} \\ \vdots & \vdots & \ddots & \vdots \\ t_{m_11}^{A^{11}}/s_{em_1}^{11} & t_{m_12}^{A^{11}}/s_{em_1}^{11} & \cdots & t_{m_1m_1}^{A^{11}}/s_{em_1}^{11} \end{bmatrix} = \begin{bmatrix} t_{N_{11}}^{A^{11}} & t_{N_{12}}^{A^{11}} & \cdots & t_{N_{1m_1}}^{A^{11}} \\ \vdots & \vdots & \ddots & \vdots \\ t_{N_{21}}^{A^{11}} & t_{N_{22}}^{A^{11}} & \cdots & t_{N_{2m_1}}^{A^{11}} \\ \vdots & \vdots & \ddots & \vdots \\ t_{N_{m_11}}^{A^{11}} & t_{N_{m_12}}^{A^{11}} & \cdots & t_{N_{m_1m_1}}^{A^{11}} \end{bmatrix} \tag{15}$$

Transpose $\boldsymbol{T_N^A}$ to obtain the unweighted super-matrix $\boldsymbol{W}$ as Eq. (16) for the preparation to calculate the weighted super-matrix $\boldsymbol{W_W}$.

$$\boldsymbol{W} = \begin{matrix} & & \begin{matrix} C_1 & C_2 & \cdots & C_n \\ e_{11}\cdots e_{1m_1} & e_{21}\cdots e_{2m_2} & \cdots & e_{n1}\cdots e_{nm_n} \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} & \begin{matrix} e_{11}\cdots e_{1m_1} \\ e_{21}\cdots e_{2m_2} \\ \vdots \\ e_{n1}\cdots e_{nm_n} \end{matrix} & \begin{bmatrix} \boldsymbol{W_{11}} & \boldsymbol{W_{12}} & \cdots & \boldsymbol{W_{1n}} \\ \boldsymbol{W_{21}} & \boldsymbol{W_{22}} & \cdots & \boldsymbol{W_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{W_{n1}} & \boldsymbol{W_{n2}} & \cdots & \boldsymbol{W_{nn}} \end{bmatrix} \end{matrix} \tag{16}$$

Step A4: Obtain the Weighted Super-Matrix $\boldsymbol{W_W}$

To modify the original assumption of each cluster with equal weight in ANP proposed by Saaty (1996), this paper introduces cluster weights $\boldsymbol{T^D}$ established in DEMATEL. Normalize $\boldsymbol{T^D}$ by Eqs. (17) and (18) to obtain the normalized total influence matrix $\boldsymbol{T_N^D}$.

$$d_i = \sum_{j=1}^{n} t_{ij}^D \tag{17}$$

$$\boldsymbol{T_N^D} = \begin{bmatrix} t_{11}^D/d_1 & \cdots & t_{1j}^D/d_1 & \cdots & t_{1n}^D/d_1 \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{i1}^D/d_i & \cdots & t_{ij}^D/d_i & \cdots & t_{in}^D/d_i \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{n1}^D/d_n & \cdots & t_{nj}^D/d_n & \cdots & t_{nn}^D/d_n \end{bmatrix} = \begin{bmatrix} t_{N_{11}}^D & \cdots & t_{N_{1j}}^D & \cdots & t_{N_{1n}}^D \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{N_{i1}}^D & \cdots & t_{N_{ij}}^D & \cdots & t_{N_{in}}^D \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{N_{n1}}^D & \cdots & t_{N_{nj}}^D & \cdots & t_{N_{nn}}^D \end{bmatrix} \tag{18}$$

Multiply the unweighted super-matrix $\boldsymbol{W}$ by the transposed normalized total influence matrix $\boldsymbol{T_N^D}'$, i.e. $\boldsymbol{T_N^D}' \times \boldsymbol{W}$ to obtain the weighted super-matrix $\boldsymbol{W_W}$ as Eq. (19).

$$\boldsymbol{W_w} = \begin{bmatrix} t_{N_{11}}^D \times W_{11} & \cdots & t_{N_{j1}}^D \times W_{1j} & \cdots & t_{N_{n1}}^D \times W_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{N_{1i}}^D \times W_{i1} & \cdots & t_{N_{ji}}^D \times W_{ij} & \cdots & t_{N_{ni}}^D \times W_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{N_{1n}}^D \times W_{n1} & \cdots & t_{N_{jn}}^D \times W_{nj} & \cdots & t_{N_{nn}}^D \times W_{nn} \end{bmatrix} \tag{19}$$

Step A5: Rank the Global Weights

By Eq. (20), raise the weighted super-matrix $\boldsymbol{W_W}$ to a sufficiently large power k until it converges to a long-term stable super-matrix, namely limited super-matrix $\boldsymbol{W_W}^*$ to obtain the global weights (Shao et al., 2018).

$$\lim_{k\to\infty} \boldsymbol{W_W}^k \tag{20}$$

Based on $\boldsymbol{W_W}^*$, the rank of global weights can be used to determine overall priorities of criteria (Ou Yang et al., 2008).

4. Research Results and Explanation

Follow the data processing steps in section 3.3, this paper analyzes the data collected from ten scholars/experts by DEMATEL and ten senior NPD managers by ANP to investigate the influence relationships among six clusters and rank the priority of the fifteen criteria for NPD.

4.1 The Relationships among Clusters

In DEMATEL, this paper collects the opinions of ten scholars/experts on the influence relationships among six clusters by questionnaires. Based on Eq. (2), obtains the average direct-relation matrix $\boldsymbol{A^D}$, shown as Table 4.1.

Table 4.1 The Average Direct-Relation Matrix $\boldsymbol{A^D}$

Cluster	O	S	P	M	G	E
O	0	3.6	2.2	3.3	2.2	1.2
S	3.5	0	3	3.4	2.9	1.4
P	2.6	2.8	0	1.7	1.4	1
M	3	2.6	2.8	0	1.6	0.9
G	1.8	2.7	1.2	2.8	0	1.8
E	3.2	3.2	2	2.3	2.3	0

Normalize the average direct-relation matrix $\boldsymbol{A^D}$ by Eqs. (3) and (4), the normalized average direct-relation matrix $\boldsymbol{X^D}$ is obtained as Table 4.2.

Table 4.2 The Normalized Average Direct-relation Matrix $\boldsymbol{X^D}$

Cluster	O	S	P	M	G	E
O	0	0.24161	0.14765	0.22148	0.14765	0.08054
S	0.2349	0	0.20134	0.22819	0.19463	0.09396
P	0.1745	0.18792	0	0.11409	0.09396	0.06711
M	0.20134	0.1745	0.18792	0	0.10738	0.0604
G	0.12081	0.18121	0.08054	0.18792	0	0.12081
E	0.21477	0.21477	0.13423	0.15436	0.15436	0

The total influence matrix $\boldsymbol{T^D}$ can be acquired by Eq. (5), shown as Table. 4.3.

Table 4.3 The Total Influence Matrix $\boldsymbol{T^D}$

Cluster	O	S	P	M	G	E
O	0.63529	0.85419	0.6657	0.80735	0.61557	0.37977
S	0.88685	0.72475	0.75461	0.87187	0.69613	0.42089
P	0.65246	0.68168	0.42541	0.59905	0.47447	0.30576
M	0.72716	0.73001	0.63157	0.54886	0.52552	0.32658
G	0.64913	0.71268	0.53231	0.68985	0.4154	0.36762
E	0.84169	0.86806	0.67602	0.78662	0.645	0.32015

Calculating the values of $r_i + c_i$ and $r_i - c_i$ by Eqs. (6) and (7) to show the gives and received influences among six clusters, shown as Table 4.4.

Table 4.4 The Gives and Received Influences of the Six Clusters

Cluster	r_i	c_i	$r_i + c_i$	$r_i - c_i$
O	3.95787	4.39258	8.35045	-0.43471
S	4.35509	4.57138	8.92647	-0.21628
P	3.13883	3.68563	6.82446	-0.54680
M	3.48970	4.30359	7.79329	-0.81388
G	3.36700	3.37209	6.73909	-0.00509
E	4.13755	2.12078	6.25833	2.01677

For filtering the minor influence clusters in matrix $\boldsymbol{T^D}$, this paper creates a threshold value α and marks the value of elements in $\boldsymbol{T^D}$ that are lower than α with an asterisk "*" in the upper-right corner, shown as Table 4.5.

Table 4.5 The Total Influence Matrix $\boldsymbol{T^D}$ (α)

Cluster	O	S	P	M	G	E
O	0.63529	0.85419	0.6657	0.80735	0.61557*	0.37977*
S	0.88685	0.72475	0.75461	0.87187	0.69613	0.42089*
P	0.65246	0.68168	0.42541*	0.59905*	0.47447*	0.30576*
M	0.72716	0.73001	0.63157	0.54886*	0.52552*	0.32658*
G	0.64913	0.71268	0.53231*	0.68985	0.4154*	0.36762*

E	0.84169	0.86806	0.67602	0.78662	0.645	0.32015*

Based on Table 4.4 and Table 4.5, this paper depicts the causal-effect diagram to understand the interactions and net fects among six clusters, shown as Fig. 4.2.

At the first glance on Fig. 4.2, there exists two parts along $r_i - c_i = 0$. The upper side is the External Factors Cluster with $r_i - c_i > 0$; the lower side includes the other clusters with $r_i - c_i < 0$. The External Factors Cluster has the highest $r_i - c_i$ value which indicates that it has the greatest net positive influence effect and can be seen as the main cause-factor for successful NPD. At the same time, the External Factors Cluster also has the lowest $r_i + c_i$ value, this result signifies that the External Factors Cluster has minimal total influence. Therefore, the External Factors Cluster with highest $r_i - c_i$ and lowest $r_i + c_i$ infers that it influences the other clusters more than affected by them, it implies that the External Factors Cluster plays a distinct role compared with the other clusters while developing NP. It means that the companies have to consider the External Factors Cluster firstly before other clusters when they engage in NPD.

Observes Fig. 4.2 in more detail, there can be seen that the Strategy Cluster has the highest $r_i + c_i$ value (the largest total influence), it indicates that the Strategy Cluster is located in the central role among the six clusters for successful NPD and must be focused in NPD. As for the Organization Cluster has the second-highest $r_i + c_i$ value and a medium $r_i - c_i$ value indicates that it has high total influence and is more influenced by the other clusters. It implies that the Organization Cluster needs to pay more attention in NPD. Whereas, the Processes and Methodologies Cluster has the lowest $r_i - c_i$ value, the least net negative influence effect expresses that the Processes and Methodologies Cluster is the main effect-factor for successful NPD. It implies that the Processes and Methodologies Cluster is not the primary consideration in NPD.

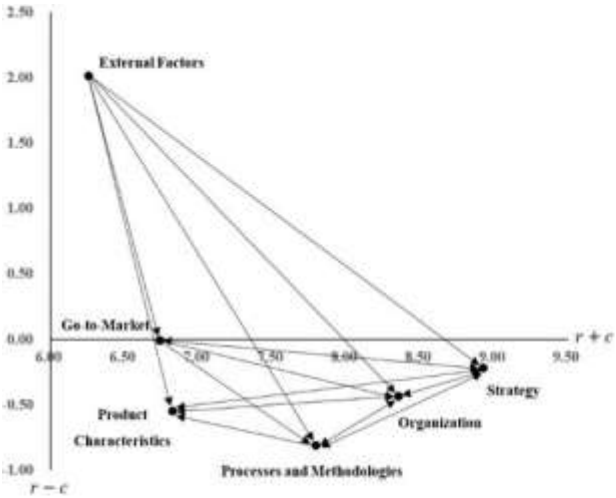

Fig. 4.2 Cause-Effect Diagram of the Six Clusters

This paper further draws the influence diagram of six clusters for evaluating successful NPD, shown as Fig. 4.3.

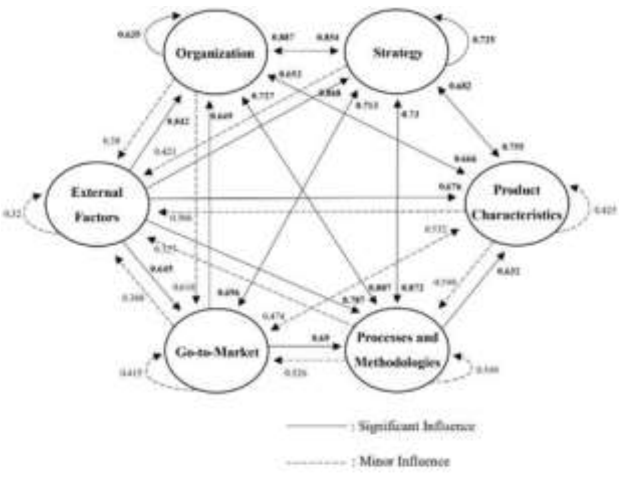

Fig. 4.3 Influence Diagram of the Six Clusters

Observes Fig. 4.3, the influences of External Factors Cluster are radiant to the other clusters significantly. Therefore, the External Factors is the main influence source cluster. It means that the other clusters are constrained by the External Factors Cluster in NPD. On the other hand, the Organization Cluster and the Strategy Cluster are heavily influenced by the other clusters which show that the Organization Cluster and the Strategy Cluster are the sunk clusters. It indicates that the Organization Cluster and the Strategy Cluster do not be considered immediately in NPD. In addition, the External Factors Cluster, the Go-to-Market Cluster, the Processes and Methodologies Cluster, and the Product Characteristics Cluster have minor influence loops (weak self-influence effect). It shows that each criterion in those four clusters is relatively independent. On the contrary, the Organization Cluster and the Strategy Cluster have significant influence loops (strong self-influence effect), expressing that the criteria in the two clusters are mutual dependency.

4.2 Measure the Priority of Criteria by ANP

In ANP, this paper interviews ten senior NPD managers with extensive experience in NPD, aim at gathering messages for successful NPD in real world. To determine the relative importance of criteria, each interviewee was asked to fill a ANP questionnaire of pairwise comparisons problems, results the ten direct matrices $\boldsymbol{A_y}$, y = 1, 2, ⋯, 10.

4.2.1 Average the Direct Matrix $\boldsymbol{A^A}$

Average the ten direct matrices by Eq. (9) to acquire the average direct matrix $\boldsymbol{A^A}$, shown as Table 4.6.

Table 4.6 The Average Direct Matrix $\boldsymbol{A^A}$

Criteria	O1	O2	O3	O4	S1	S2	P1	P2	P3	M1	M2	G1	G2	E1	E2
O1	1.00	0.67	0.36	0.39	0.37	0.26	0.22	0.22	0.28	0.19	0.19	0.18	0.16	0.15	0.14
O2	4.05	1.00	0.19	0.20	0.18	0.19	0.21	0.21	0.18	0.20	0.19	0.21	0.21	0.14	0.13
O3	5.30	6.50	1.00	0.14	0.14	0.15	0.15	0.14	0.15	0.15	0.14	0.16	0.15	0.15	0.14
O4	4.50	5.80	7.10	1.00	3.65	1.44	1.89	1.97	1.95	2.07	2.50	1.09	1.20	0.17	0.19
S1	4.60	6.00	7.30	0.58	1.00	0.44	0.34	0.88	0.70	0.55	0.49	0.63	1.07	0.16	0.22
S2	6.20	6.20	6.80	3.26	4.10	1.00	2.60	2.90	3.50	3.23	3.23	2.25	1.95	0.24	0.28
P1	6.30	5.60	6.70	3.08	4.10	0.54	1.00	1.45	2.07	2.25	3.16	0.55	0.53	0.18	0.19
P2	5.30	5.60	7.20	2.68	2.28	0.52	1.48	1.00	2.05	1.90	2.21	0.75	0.98	0.23	0.20
P3	6.00	6.00	6.70	2.86	2.55	0.42	0.97	0.74	1.00	1.50	1.63	0.48	0.75	0.22	0.21
M1	5.80	5.60	7.00	1.89	3.35	0.75	1.63	1.49	1.69	1.00	2.70	2.22	2.15	0.18	0.26
M2	6.20	6.10	7.20	0.90	2.70	0.70	0.95	1.42	1.38	0.54	1.00	1.65	1.71	0.19	0.18
G1	7.10	5.70	6.30	4.17	3.73	0.73	2.55	2.60	2.80	1.76	2.38	1.00	1.25	0.27	0.22
G2	7.00	5.70	6.80	2.71	3.71	0.72	3.35	2.57	3.13	1.91	2.68	1.81	1.00	0.17	0.23
E1	7.00	7.20	6.90	6.30	6.60	4.90	5.80	5.30	4.90	5.90	5.60	4.10	5.90	1.00	0.33
E2	7.70	7.90	7.50	6.10	5.80	5.00	5.90	6.10	5.30	6.00	6.30	5.00	5.60	3.50	1.00

4.2.2 Derive the Total Influence Matrix $\boldsymbol{T^A}$

Firstly, utilize Eqs. (10) and (11) to normalize the average direct matrix $\boldsymbol{A^A}$ and gain the initial direct-relation matrix $\boldsymbol{X^A}$, shown as Table 4.7. Then, substitute $\boldsymbol{X^A}$ into Eq. (12), the total influence matrix $\boldsymbol{T^A}$ can be obtained as Table 4.8.

Table 4.7 The Initial Direct-Relation Matrix $\boldsymbol{X^A}$

Criteria	O1	O2	O3	O4	S1	S2	P1	P2	P3	M1	M2	G1	G2	E1	E2
O1	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O3	0.06	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O4	0.05	0.07	0.08	0.01	0.04	0.02	0.02	0.02	0.02	0.02	0.03	0.01	0.01	0.00	0.00
S1	0.05	0.07	0.09	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
S2	0.07	0.07	0.08	0.04	0.05	0.01	0.03	0.03	0.04	0.04	0.04	0.03	0.02	0.00	0.00
P1	0.07	0.07	0.08	0.04	0.05	0.01	0.01	0.02	0.02	0.03	0.04	0.01	0.01	0.00	0.00
P2	0.06	0.07	0.08	0.03	0.03	0.01	0.02	0.01	0.02	0.02	0.03	0.01	0.01	0.00	0.00
P3	0.07	0.07	0.08	0.03	0.03	0.00	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.00
M1	0.07	0.07	0.08	0.02	0.04	0.01	0.02	0.02	0.02	0.01	0.03	0.03	0.03	0.00	0.00
M2	0.07	0.07	0.08	0.01	0.03	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.00	0.00
G1	0.08	0.07	0.07	0.05	0.04	0.01	0.03	0.03	0.03	0.02	0.03	0.01	0.01	0.00	0.00
G2	0.08	0.07	0.08	0.03	0.04	0.01	0.04	0.03	0.04	0.02	0.03	0.02	0.01	0.00	0.00
E1	0.08	0.08	0.08	0.07	0.08	0.06	0.07	0.06	0.06	0.07	0.07	0.05	0.07	0.01	0.00
E2	0.09	0.09	0.09	0.07	0.07	0.06	0.07	0.07	0.06	0.07	0.07	0.06	0.07	0.04	0.01

Table 4.8 The Total Influence Matrix $\boldsymbol{T^A}$

Criteria	O1	O2	O3	O4	S1	S2	P1	P2	P3	M1	M2	G1	G2	E1	E2
O1	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O3	0.07	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O4	0.09	0.10	0.11	0.02	0.05	0.02	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.00	0.00
S1	0.07	0.09	0.10	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.00

S2	0.12	0.11	0.12	0.05	0.06	0.02	0.04	0.04	0.05	0.05	0.05	0.03	0.03	0.00	0.01
P1	0.11	0.10	0.10	0.04	0.06	0.01	0.02	0.02	0.03	0.03	0.04	0.01	0.01	0.00	0.00
P2	0.09	0.09	0.11	0.04	0.04	0.01	0.02	0.02	0.03	0.03	0.03	0.01	0.02	0.00	0.00
P3	0.10	0.09	0.10	0.04	0.04	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00
M1	0.10	0.10	0.11	0.03	0.05	0.01	0.03	0.02	0.03	0.02	0.04	0.03	0.03	0.00	0.00
M2	0.10	0.10	0.10	0.02	0.04	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.00	0.00
G1	0.12	0.10	0.11	0.06	0.06	0.01	0.04	0.04	0.04	0.03	0.04	0.02	0.02	0.00	0.00
G2	0.12	0.10	0.11	0.04	0.06	0.01	0.05	0.04	0.05	0.03	0.04	0.03	0.02	0.00	0.00
E1	0.16	0.16	0.16	0.10	0.11	0.07	0.09	0.08	0.08	0.09	0.09	0.06	0.08	0.01	0.01
E2	0.18	0.18	0.17	0.10	0.11	0.07	0.09	0.09	0.09	0.09	0.10	0.08	0.08	0.05	0.02

4.2.3 Obtain the Unweighted Super-Matrix $\boldsymbol{W}$

Employ Eqs. (14) and (15) to normalize the total influence matrix $\boldsymbol{T^A}$, receive the normalized total influence matrix $\boldsymbol{T_N^A}$, then transpose $\boldsymbol{T_N^A}$ by Eq. (16), the unweighted super-matrix $\boldsymbol{W}$ is obtained as Table 4.9.

Table 4.9 The Unweighted Super-Matrix $\boldsymbol{W}$

Criteria	**O1**	**O2**	**O3**	**O4**	**S1**	**S2**	**P1**	**P2**	**P3**	**M1**	**M2**	**G1**	**G2**	**E1**	**E2**
O1	0.38	0.68	0.41	0.27	0.27	0.29	0.30	0.28	0.29	0.30	0.31	0.31	0.32	0.28	0.29
O2	0.28	0.20	0.48	0.31	0.33	0.29	0.27	0.28	0.29	0.29	0.30	0.26	0.27	0.28	0.28
O3	0.19	0.07	0.09	0.35	0.36	0.30	0.30	0.32	0.30	0.32	0.33	0.27	0.30	0.27	0.27
O4	0.14	0.05	0.02	0.06	0.04	0.13	0.12	0.12	0.12	0.09	0.05	0.15	0.11	0.17	0.16
S1	0.62	0.57	0.57	0.73	0.70	0.79	0.86	0.80	0.83	0.80	0.78	0.82	0.82	0.62	0.60
S2	0.38	0.43	0.43	0.27	0.30	0.21	0.14	0.20	0.17	0.20	0.22	0.18	0.18	0.38	0.40
P1	0.31	0.35	0.34	0.32	0.22	0.29	0.24	0.32	0.34	0.33	0.27	0.32	0.36	0.35	0.34
P2	0.31	0.34	0.32	0.34	0.41	0.32	0.32	0.25	0.29	0.31	0.36	0.33	0.29	0.33	0.34
P3	0.38	0.32	0.35	0.34	0.36	0.38	0.43	0.43	0.37	0.35	0.37	0.36	0.35	0.32	0.32
M1	0.49	0.49	0.49	0.45	0.50	0.49	0.42	0.46	0.47	0.31	0.39	0.43	0.42	0.50	0.48
M2	0.51	0.51	0.51	0.55	0.50	0.51	0.58	0.54	0.53	0.69	0.61	0.57	0.58	0.50	0.52
G1	0.52	0.49	0.51	0.48	0.40	0.52	0.50	0.45	0.42	0.50	0.49	0.46	0.60	0.43	0.47
G2	0.48	0.51	0.49	0.52	0.60	0.48	0.50	0.55	0.58	0.50	0.51	0.54	0.40	0.57	0.53
E1	0.51	0.53	0.52	0.49	0.46	0.48	0.50	0.52	0.52	0.45	0.52	0.53	0.46	0.68	0.75
E2	0.49	0.47	0.48	0.51	0.54	0.52	0.50	0.48	0.48	0.55	0.48	0.47	0.54	0.32	0.25

4.2.4 Obtain the Weighted Super-Matrix $\boldsymbol{W_W}$

Adopt the weights of six clusters established in DEMATEL to normalize $\boldsymbol{T^D}$ by Eqs. (17) and (18), the normalized total influence matrix $\boldsymbol{T_N^D}$ is gained as Table 4.10. Follow Eq. (19), multiply $\boldsymbol{W}$ by the transposed normalized total influence matrix $\boldsymbol{T_N^{D'}}$ and get the weighted super-matrix $\boldsymbol{W_W}$, shown as Table 4.11.

Table 4.10 The Normalized Total Influence Matrix $\boldsymbol{T_N^D}$

Cluster	O	S	P	M	G	E
O	0.161	0.216	0.168	0.204	0.156	0.096
S	0.204	0.166	0.173	0.200	0.160	0.097
P	0.208	0.217	0.136	0.191	0.151	0.097
M	0.208	0.209	0.181	0.157	0.151	0.094
G	0.193	0.212	0.158	0.205	0.123	0.109
E	0.203	0.210	0.163	0.190	0.156	0.077

Table 4.11 The Weighted Super-Matrix $\boldsymbol{W_W}$

Criteria	**O1**	**O2**	**O3**	**O4**	**S1**	**S2**	**P1**	**P2**	**P3**	**M1**	**M2**	**G1**	**G2**	**E1**	**E2**
O1	0.06	0.11	0.07	0.04	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.06	0.06
O2	0.05	0.03	0.08	0.05	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.06	0.06
O3	0.03	0.01	0.01	0.06	0.07	0.06	0.06	0.07	0.06	0.07	0.07	0.05	0.06	0.05	0.06
O4	0.02	0.01	0.00	0.01	0.01	0.03	0.03	0.02	0.02	0.02	0.01	0.03	0.02	0.03	0.03
S1	0.13	0.12	0.12	0.16	0.12	0.13	0.19	0.17	0.18	0.17	0.16	0.17	0.17	0.13	0.13
S2	0.08	0.09	0.09	0.06	0.05	0.03	0.03	0.04	0.04	0.04	0.05	0.04	0.04	0.08	0.08
P1	0.05	0.06	0.06	0.05	0.04	0.05	0.03	0.04	0.05	0.06	0.05	0.05	0.06	0.06	0.05
P2	0.05	0.06	0.05	0.06	0.07	0.06	0.04	0.03	0.04	0.06	0.07	0.05	0.05	0.05	0.06
P3	0.06	0.05	0.06	0.06	0.06	0.07	0.06	0.06	0.05	0.06	0.07	0.06	0.06	0.05	0.05
M1	0.10	0.10	0.10	0.09	0.10	0.10	0.08	0.09	0.09	0.05	0.06	0.09	0.09	0.09	0.09
M2	0.11	0.10	0.10	0.11	0.10	0.10	0.11	0.10	0.10	0.11	0.10	0.12	0.12	0.10	0.10
G1	0.08	0.08	0.08	0.07	0.06	0.08	0.08	0.07	0.06	0.08	0.07	0.06	0.07	0.07	0.07
G2	0.07	0.08	0.08	0.08	0.10	0.08	0.08	0.08	0.09	0.07	0.08	0.07	0.05	0.09	0.08
E1	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.05	0.06	0.05	0.05	0.06
E2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.02	0.02

4.2.5 Rank the Global Weights

Raise $\boldsymbol{W_W}$ by Eq. (20) until it converges to a long-term stable situation, the limited super-matrix $\boldsymbol{W_W}^*$ is received as Table 4.12.

In $\boldsymbol{W_W}^*$, stable row values denote the global weights of criteria. Rank the global weights results in the priority of each criterion for successful NPD. The local weights of each criterion is calculated by summing up the global weights of criteria within the same cluster firstly to obtain the local weight of that cluster, then, divides the local weight by the global weights of criteria, yields the criteria's local weights which reflect the relative importance in the clusters. The weights and rank of criteria is demonstrated as Table 4.13.

Table 4.12 The Limited Super-Matrix $\boldsymbol{W_W}^*$

Criteria	O1	O2	O3	O4	S1	S2	P1	P2	P3	M1	M2	G1	G2	E1	E2
O1	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
O2	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
O3	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
O4	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
S1	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149
S2	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
P1	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
P2	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
P3	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
M1	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.086
M2	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
G1	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
G2	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079
E1	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
E2	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047

Table 4. 13 Weights and Rank of the Evaluation Criteria

Cluster	Criteria	Local Weight	Global Weight	Rank
Organization	**Subtotal**	**0.19517**		
	(O1) Internal Strength	0.32260	0.06296	6
	(O2) Organizational Culture	0.29559	0.05769	8
	(O3) Top Management Support	0.28524	0.05567	9
	(O4) Cross-Functional Teams	0.09658	0.01885	15
Strategy	**Subtotal**	**0.20352**		
	(S1) Innovation Strategy	0.73408	0.14940	1
	(S2) Product Proliferation	0.26592	0.05412	11
Product Characteristics	**Subtotal**	**0.16433**		
	(P1) Product Advantage	0.30341	0.04986	12
	(P2) Voice of Customer	0.33512	0.05507	10
	(P3) Market Orientation	0.36147	0.05940	7
Processes and Methodologies	**Subtotal**	**0.19094**		
	(M1) Gating System	0.45197	0.08630	3
	(M2) Process Management	0.54803	0.10464	2
Go-to-Market	**Subtotal**	**0.14996**		
	(G1) Market Testing	0.47653	0.07146	5
	(G2) Launch	0.52347	0.07850	4
External Factors	**Subtotal**	**0.09608**		
	(E1) Government Policy	0.51176	0.04917	13
	(E2) Economic Conditions and Technology Trend	0.48834	0.04692	14

4.3 Explanation

Observes the local weight of Table 4.15, the respondents of product development manager expressed that the most important criterion in each cluster from the perspective of local weights are as follows: Internal Strength Criterion in the Organization Cluster; Innovation Strategy Criterion in the Strategy Cluster; Market Orientation Criterion in the Product Characteristics Cluster; Process Management Criterion in the Processes and Methodologies Cluster; Launch Criterion in the Go-to-Market Cluster; and Government Policy Criterion in the External Factors Cluster. From the perspective of global weight of Table 4.15, the respondents of product development manager revealed that the top three priority criteria are Innovation Strategy Criterion, Process Management Criterion, and Gating System Criterion, while the last three priority criteria are Government Policy Criterion, Economic Conditions and Technology Trend Criterion, and Cross-Functional Teams (CFTs) Criterion, respectively.

To investigate the rationale of those research results, this paper concludes and cites the viewpoints of respondents to explain the meanings behind the top three and last three priority criteria.

The explanation of the top three priority criteria are expressed as follows:

(1) Innovation Strategy Criterion:

Innovation strategy is the foundation of successful NPD and the main source of enhancing competitiveness and efficiency for companies. Respondents R3, R5, and R6 pointed out that if companies do not incorporate innovation into their strategy, they will be constrained by existing ideas and thinking, which makes them difficult to develop competitive NPs, thereby leading to decline market position and decreased profitability in the future. Respondents R1, R4, and R8 believed that innovation strategy can bring differentiation to NPs to compartmentalize companies from their competitors, and thus enhancing competitiveness of companies. Respondents R7 and R9 emphasized that innovation is not only limited to NPD, but also includes technology and process. Through new technologies and processes, companies can boost the efficiency of NPD, thus accelerating the launch speed of NPs. In order to stand out in an ever-changing market, companies need to adopt innovation strategy to increase the differentiation of NPs and enhance their market competitiveness to avoid being eliminated in market competition. This is reason why Innovation Strategy Criterion is ranked at the first priority in successful NPD.

(2) Process Management Criterion:

Process management is a crucial means for companies to ensure smoothness and efficiency of NPD process, and is the key to produce high-quality NPs as well. Respondents R2, R5, and R10 indicated that by establishing clear standard operating procedures and processes for NPD, companies can ensure that NPD is carried out according to the scheduled plan to improve work efficiency of NPD and speed up the launch of NPs. Respondents R4 and R7 believed that process management can assist companies to allocate resources effectively, including manpower, materials, and time, so that these resources can be fully utilized and used for the most critical development and production activities to increase the efficiency of NPD and the quality of NPs. Respondents R1, R8, and R9 stated that regular maintenance of process management helps companies to establish comprehensive quality control mechanisms, including monitoring, detecting, evaluation, and improving NPD process, thereby reducing the defect rate and uncertainty of NPs to ensure that NPs can meet consumer expectations and requirements. Therefore, companies should review process management regularly to sustain the good condition of NPD process and make sure the high quality of NPs. This is the reason why Process Management Criterion is ranked at the second priority in successful NPD.

(3) Gating System Criterion:

Gating system is one of the important tools for companies in NPD. By dividing NPD projects into multiple stages and establishing gates between stages as standards for evaluating NPD projects. Gating system reduces the risk and increases the success rate of NPD. Respondents R3, R7, and R10 believed that incorporating filter standards into the evaluation of NPD projects provides companies with the opportunity to assess the feasibility of NPD projects. Filter standards allow companies to identify potential issues with NPD projects early to adjust/terminate inappropriate NPD projects to avoid investing resources in NPD projects that lack of economic benefits. Thereby reducing the risk of loss and failure. Respondents R5, R6, and R9 indicated that the establishment of filter standards enables companies to decide whether to continue NPD projects and allow them to allocate limited resources to NPD projects with potential performance to avoid wasting resources on NPD projects with low value or low success rate. However, respondent R2 pointed out that establishing universal filter standards is not easy because different NPD projects may require different evaluation standards. Despite the gating system effectively assists companies in successful NPD, different NPs may involve different markets, technologies, and consumer demands, thus make it difficult to establish universal standards for NPD projects. Therefore, the Gating System Criterion is ranked at the third priority in successful NPD.

The explanation of the last three priority criteria are expressed as follows:

(1) Government Policy Criterion:

Unless the NPD projects specifically supported by the government, government policy can only provide limited assistance to companies in NPD. Respondents R3 and R4 stated that the cost of NPD can be reduced by government support, but it does not mean that the companies can successfully develop NPs. Companies mainly rely on their own capabilities, resources, and processes in NPD. Respondents R2, R7, and R9 believed that government supports for NPD target and only prioritize in specific industries or technology areas. Respondents R1 and R5 pointed out that companies must comply with government policies and regulations in the process of NPD. Companies have to invest a great amount of time and resources to ensure that their NPs will meet the standards of the relevant policies and regulations. But the government often fails to revise appropriate policies and regulations timely because it does not understand the current status of industries and the actual needs of companies, thereby restricting NPD implementation. In addition, the government also enacts policies and regulations to protect consumers and the environment, which may impede or slow down NPD for companies. Therefore, Government Policy Criterion is ranked at the last third (thirteenth) priority in successful NPD.

(2) Economic Conditions and Technology Trend Criterion:

When economic conditions are prosperous, consumer's disposable income will increase and lead to higher demand for NPs, thereby making companies more willing to engage in NPD. However, economic conditions can also lift the cost of NPD for companies. According to respondents R9 and R10, if interest rate and inflation rate rise due to economic growth, the cost of financing and raw material will surge and inhibit the willingness of companies to develop NPs. Respondents R1, R2, and R5 believed that economic fluctuations are a common situation faced by every company and do not have differentiated effect on individual company. Instead, the influence of technology trend on NPD is greater for companies. Respondents R6, R7, and R8 stated that companies with the ability to adopt appropriate new technology can enhance their innovation capabilities and expedite the NPD process. Respondents R3 and R4 pointed out that new technology may not be suitable for every company, so not all companies need to immediately adopt new technology for NPD. Therefore, whether companies should follow technology trend for NPD depends on their industry and the properties of the NPs. This is reason why Economic Conditions and Technology Trend Criterion is ranked at the second lowest (fourteenth) priority in successful NPD.

(3) Cross-Functional Teams (CFTs) Criterion:

CFTs are the drivers of NPD by integrating knowledge and skills from different areas within the company. However, CFTs establishment is constrained by the structure of companies, and it is not easy for the companies to manage CFTs. Respondent R7 stressed out that CFTs members from different professional disciplines can share their specialized ideas and experiences to address the problems of NPD from a more comprehensive perspective. Respondents R2 and R3 pointed out that CFTs members come from different professional disciplines, their working methods, thinking patterns, and communication styles fields have nothing in common with each other. If the companies cannot effectively coordinate communication and collaboration among members, it is hard to reach consensus on decisions, thereby affecting the progress of NPD. Respondent R6 indicated that the requirement of companies to establish CFTs only when their size is large enough. Although the companies can better handle NPD by CFTs, they need to ensure that CFTs can be effectively managed. In addition, most of the companies interviewed in this paper have difficult to build CFTs due to their relatively small size. Therefore, Cross-Functional Teams (CFTs) Criterion is ranked at the last (fifteenth) priority in successful NPD.

5. Conclusion and Discussion

NPD is a critical strategy for companies to enhance competitiveness and also contributes to the economic growth of the national economy. Companies can adopt the newly developed technology to develop their NPs, they also have the opportunity to establish or improve their own technological capabilities through technical R&D while developing NPs. In addition, companies usually need to hire employees for developing or producing NPs, thereby creating job opportunities and raising people's income. Most past literature had explored the critical determinants of successful NPD, but they were confined on limited variables/factors in specific area or only focused on the perspective of consumers. In order to investigate successful NPD determinants in more comprehensively, this paper adopts DANP which combines DEMATEL and ANP as research methodology, extracts fifteen criteria from relative literature, and classifies them into six clusters, then ranks the criteria priority from the perspective of ten senior NPD managers in ten excellent companies.

DANP is used to improve the unreasonable assumption that each cluster has the same weight in ANP and aims to obtain more realistic results. In DEMATEL, the research results show that the External Factors Cluster is the main influence source and the Strategy Cluster plays as the central role among the six clusters. It means that when the companies engage in NPD, they cannot ignore the impact of External Factors Cluster and they also have to pay more attention on the Strategy Cluster. These findings imply that the companies must firstly consider outer operation environment on unpredictable risks and opportunities, then deploy resources in innovation or exploit their existed products in NPD. In ANP, the findings reveal that the top three priority criteria are Innovation Strategy Criterion, Process Management Criterion, and Gating System Criterion. It exhibits that senior NPD managers believe innovation strategy can assist companies to develop differentiated NPs and increase market competitiveness to avoid being eliminated in market competition. Process management will help the companies to allocate and utilize resources effectively to smooth NPD progress. In addition, adopting gating system can help to filter NPD projects to reduce the risk and guarantee the limited resources can be devoted in the appropriate potential NPD projects assuredly. In brief, the companies should formulate and implement innovative strategy to stimulate NP ideas and thinking, regular review and improve NPD process to ensure its effectiveness, and establish suitable filter standards for NPD projects. On the other hand, the last three priority criteria are Government Policy Criterion, Economic Conditions and Technology Trend Criterion, and Cross-Functional Teams (CFTs) Criterion, respectively. These results indicate that government's policies and regulations may impede or slow down NPD, the government needs to understand in depth about current situation of the industry and timely propose relevant policies and regulations to effectively assist companies in NPD. As for the economic conditions, they will impact on each company without discrimination, and not all companies need to immediately adopt new technology for NPD. Finally, due to most companies interviewed are relatively small to medium size enterprises, they are not necessary or affordable to establish CFTs.

Since the industry environment is dynamic, researches investigate this topic at different times and market conditions may yield different results. Thus, it is worthwhile for future researchers to reexplore the critical factors of successful NPD at that time.

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