Evaluating Industry 4.0 Technology Application in SMEs: Using a Hybrid MCDM Approach

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Abstract: Evaluating Industry 4.0 technology application in small and medium-sized enterprises (SMEs) is an issue that requires a multi-criteria strategy comprising quantitative and qualitative elements. The purpose of this study is to integrate performance estimation of Industry 4.0 technology application using the technology–organization–environment (TOE) framework. Relating TOE to Industry 4.0 technology application evaluation is more multifaceted than other methods and it requires comprehensive analysis. In this study, we applied a multiple-criteria decision-making (MCDM) approach to develop a model which integrates MCDM to perform an assessment that prioritizes the influence weights of Industry 4.0 technology application to SMEs' factors. Firstly, we carried out a review of the literature and the TOE framework was selected to generate nine elements, along with three aspects used to measure Industry 4.0 technology application in SMEs. Secondly, the approach of the decision-making trial and evaluation laboratory (DEMATEL) was set up using an influence network relations digraph (INRD). The DEMATEL-based analytic network process (DANP) was used to indicate the influence weights linking the above aspects and elements. Lastly, the modified VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) technique applied influence weights to assess the aspects/elements in the gaps identified and to investigate how to reduce the gaps so as to estimate the application of Industry 4.0 technology by SMEs. The results show that the technology aspect is the most influential factor.

Keywords: industry 4.0 technology; small and medium-sized enterprises (SMEs); technology–organization–environment (TOE); multiple-criteria decision-making (MCDM)

1. Introduction

Owing to the advancement of science and technology, numerous fields are gradually moving toward automation and intellectualization. The technology of Industry 4.0 represents the convergence of a range of emerging and novel technologies, such as cloud computing, smart sensors, big data, additive manufacturing (AM), robotics, artificial intelligence (AI), machine learning (ML), Internet of Things (IoT), and augmented reality [1–7]. These progressive technologies' participation in Industry 4.0 is reorganizing entire operational structures via centralized workflows and transforming analog to decentralized and digital manufacturing procedures [8–12]. The technologies have a high potential to importantly enhance the manufacturing productivity by converting regular manufacturing to automated production. Industry 4.0 has been beneficial to the production sector in three different ways: End-to-end engineering; vertical integration; and horizontal integration [13–16]. It combines data, machines, and people, thereby establishing more responsive and agile supply chains.

Industry 4.0 is incorporated into smart manufacturing and advanced manufacturing—for example, as an implementable structure where agile lines automatically adjust manufacturing procedures for multiple varying factors and products [17,18]. Industry 4.0 technologies enhance the flexibility, productivity, and quality and are able to assist with

the execution of a broad scope of customized production and sustainable procedures with less resource consumption [18,19].

Existing studies have recorded different definitions of the Industry 4.0 technology model. Some of these studies have examined the sub-domains and contributions of Industry 4.0 technology, including the growth, organization, environment, and technology tendencies of the sub-domains of Industry 4.0 technology [20–23]. Nevertheless, some of these studies have only presented the Industry 4.0 technology application model, and did not evaluate the application of Industry 4.0 technology to strategic models through a systematic and process viewpoint. They also did not determine the influence relations and application models or main strategy of Industry 4.0 technology. Therefore, in this research, we propose a structured perspective for the evaluation of Industry 4.0 technology's application in small and medium-sized enterprises (SMEs).

While IT application in SMEs relates to the combination of the technology–organization–environment (TOE) structure and moves to IT innovation enhancement, managers must improve its application to enhance procedures, practices, designs, and services when they adopt Industry 4.0 technology [19,24]. Owing to the lack of previous studies about the parameters for assessing Industry 4.0 technology application, this study investigates the Industry 4.0 technology application in SMEs to establish the potential for performance progress. The purpose of this research is to propose a fit approach for estimating Industry 4.0 technology's potential to improve the performance in SMEs. Therefore, the paper has two contributions: It develops a theoretical basis linking Industry 4.0 technology application to the business performance in SMEs, and it estimates the influence of Industry 4.0 technology application on diverse aspects of the business performance. In light of hyper-competitive, commerce performance enhancement, SMEs need to formulate and apply schemes that protect their competitive advantage and improve their performances. As the most important sectors in Taiwan, it is especially necessary to notice the improvement of SMEs.

This study examines the effect of aspects of technology (technology readiness, technology security, and technology integration), organization (financial commitment, organization readiness, and top management support), and environmental criteria (regulatory support, competitive pressure, and environmental uncertainty) on Industry 4.0 technology application. The study's model and assumed relations are tested via data collected from top managers and related studies of SMEs in Taiwan. This study's findings contribute to empirical studies on the elements that impact Industry 4.0 technology application decisions. Importantly, this study applies group opinions of experts' practical experience, rather than a few isolated cases. Given the significance of Industry 4.0 technology application in the present and future, this study's findings will help administrators in targeting suitable decision-making models to effectively support Industry 4.0 technology application.

Industry 4.0 technology application strategies are independent and dependent, changing according to specialists' opinions and experience. Some general multiple criteria decision-making (MCDM) prototypes cannot categorize complicated networks in relation to different hierarchical structures of factors in contexts such as SMEs [25]. Furthermore, MCDM models usually employ the average judgement of specialists regarding decision-making procedures [25–28]. Lately, numerous methods have been presented to deal with the performance of Industry 4.0 technology application, such as the analytical network process (ANP) and the analytic hierarchy process (AHP) [29,30]. Nevertheless, these evaluation methods have numerous limitations. First, based on their approaches of only a single element, they are unable to integrate numerous performance elements. Additionally, they are lacking in terms of perceiving the influence weights of sub-elements and main elements and, thus, impartiality when estimating the performance. Therefore, this paper offers an integrated MCDM model which addresses the various problems within aspects of Industry 4.0 technology application and meets administrators' goals.

Most conservative multi-attribute decision analysis approaches cannot deal with the investigation of multifaceted interrelations between dissimilar hierarchical factors [27,28].

Adoption of the application of Industry 4.0 technology involves a decision approach structure that does just that. We can realize this research objective by applying the following methods: We can first build a mixed MCDM approach which integrates the decision-making trial and evaluation laboratory (DEMATEL) to establish an influence network relations digraph (INRD), known as the DEMATEL-based ANP (DANP), to indicate the influence weights of elements and the weights of the modified VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) technique by applying the DANP's influence weights to estimate and combine the gaps in performance. After that, we can study how to reduce these gaps through enhancement to enable the application of Industry 4.0 technology according to the INRD. These mixed techniques overcome the limits of existing evaluation approaches and can be applied to help us investigate the factors that impact the application of Industry 4.0 technology in real life. In this research, we used SMEs in Taiwan as a case study with which to consider the interdependence among factors that impact Industry 4.0 technology application, as well as assess alternative financial and business performances to reduce these gaps in performance among individual aspects in the bid to apply Industry 4.0 technology using an INRD in SMEs.

The study is organized as follows. We review the factors influencing technology, organization, and environmental aspects in the Industry 4.0 technology application model in Section 2. This section draws on the literature to build assessment elements. Section 3 describes the detailed methodology, including the hybrid MCDM method. Next, Section 4 introduces the case study. Lastly, Section 5 presents the study's conclusions.

2. Literature Review

The objective of this section is to study papers related to the Industry 4.0 technology application procedure, to associate and explore numerous assessment contexts, and to classify possible elements that impact the application procedure of Industry 4.0 technology in SMEs. Owing to the shortage of prior studies on the factors applied in assessing Industry 4.0 technology application [31,32], this paper develops an assessment structure applied in other firms and industries, including three primary aspects—technology, organization, and environment—with the goal of recognizing the factors which are most relevant for the application of Industry 4.0 technology.

2.1. Related Literature on the Elements Influencing Industry 4.0 Technology Application in SMEs

Industry 4.0 technology is one of the most promising technologies with the tendency to enhance process effectiveness and increase supply chain visibility [15,16]. Rapid changes in demand and intensified competition in the market have pushed manufacturing industries to implement innovative technology to enhance smart manufacturing. Industry 4.0 is the present data exchange and automation trend in technology of production [33,34]. During the last ten years, future industrial developments have been regularly discussed within academia and industry, whereas numerous viewpoints have emerged to define such developments. The successful growth of such development is considered vital to establishing competitive advantages between national economies and manufacturing firms [35,36]. The most established is Industry 4.0 within Europe [37–40]. Industry 4.0 emerged in Germany and was intended to sustain national growth via promoting the development of manufacturing in 2011. [41]. There are a variety of other initiatives that can be employed to enhance the development, for example, "Future of Manufacturing" in the UK and "Smart Manufacturing" in the USA [13,36].

While Industry 4.0 is well-expected, a major study solving the implementation approaches has been established via multi-national enterprises or larger organizations [42]. Although multi-national enterprises promote the economy in an important way [43], it cannot be neglected that SMEs make up 90% of enterprises operating within the EU [44]. The influence of SMEs is also essential; they ensure social stability, create jobs, and promote economic growth [45,46]. Compared with multi-national enterprises, SMEs tend to face greater knowledge and financial resource constraints [47,48]. This has led to numerous

researchers identifying a mismatch among present Industry 4.0 theory and the particular demands of SMEs [48–51]. Related research is changing in the wake of Industry 4.0 developments in terms of execution, planning, and associated investigation groups [52]. These responses to Industry 4.0 are full of numerous challenges in SMEs, particularly with regards to logistics, technologies, and managerial and organizational perspectives [53]. Fettermann et al. [54] inspected the demands of dissimilar technology, for example, cyber-physical systems, processing in cloud and radio frequency identifiers. Hofmann and Rüsch [55] stated the chances of Industry 4.0 in the logistics context. They stated that management is facing challenges in the adoption of Industry 4.0 because corporations may not detect any short-term financial performance after the adoption of Industry 4.0. In the management context, Barreto et al. [56] investigated the necessities that may enable companies to be more effective at adopting Industry 4.0. Oesterreich and Teuteberg [57] studied the challenges which Industry 4.0 poses for the industry of construction. Ben-Daya et al. [58] expanded the Industry 4.0 conception via the supply chain. Haddud et al. [59] investigated potential challenges and benefits related to the combination of Industry 4.0 from managerial and organizational perspectives.

The challenges associated with Industry 4.0 cause an unbalanced distribution of resources, which is important to and impactive in numerous other sectors of business [60–64]. Without a sufficient comprehension of the concerning Industry 4.0 elements, it is unlikely to exactly apply a suitable approach in response to this tendency [65–68]. Therefore, numerous industries are using Industry 4.0 technology for investigational developments to gain competitive advantages and enhance the operational efficiency through the viewpoint of technology, organization, environment and related business factors [20–23]. Industry 4.0 technology has also been receiving significant consideration in SMEs as it deals with the critical problems of automation and production efficiency in manufacturing operations, as indicated when inspecting the approaches in this study [69–71]. Industry 4.0 technology applications can be divided into several major performances (such as the finance performance, business performance, supply chain management performance, and so on), according to various SME objectives. Nevertheless, we only apply two alternatives ("finance performance (A_1)" and "business performance (A_2)") in our approach as instances to indicate two comparatively good uses for Industry 4.0 technology applications.

The TOE structure illustrates how these contexts influence the implementation and adoption of innovation through three dissimilar factors [20–23,72]. The technology aspect focuses on the technology features that influence corporation implementation, the organization aspect focuses on implementation to the organization's attributes, and the environment aspect reflects the environmental factors [20,21]. Researchers have used the TOE structure to explore the implementation of numerous technologies, such as e-commerce, 3D printing, radio frequency identification (RFID) adoption, and so on [25,73,74]. For example, Lu et al. [74] explored and identified RFID adoption according to the TOE structure and the study demonstrated that RFID adoption had an important influence on each related performance. In addition, Lu et al. [25] extended this generalizability of previous research on business to business implementation to keeping usage. They did this from the perspective of network reliability, data security, top management emphasis, technology complexity, firm size, employees' information system (IS) knowledge, regulatory support, partner support, and competitive pressure. Mostly, the advantage of the TOE structure is its formidable background of theory and possible empirical adoption, which is beneficial in guiding scholars.

Previous researchers on Industry 4.0 technology application have seldom focused on all TOE aspects. Numerous researchers have restricted their argument to only a limited critical element and there is no systemic evaluation strategy in their studies. Therefore, in this study, these elements in each aspect are determined from a review of the related literature and numerous face-to-face interviews with these specialists in SMEs or related industry. Table 1 reviews references for all elements in the research. We state this TOE context as a base, resulting in the three aspects of our study's context–TOE (technology, organization,

and environment). The factors related to the Industry 4.0 technology application within each aspect are subsequently discussed.

Table 1. Clarification of elements and aspects.

Aspects/Element	Descriptions
Technology aspect (*G*1)	
Technology readiness (*g*1)	Technology needs to be organized to make procedure changes, and latent sites must make changes for Industry 4.0 technology if benefits are to accrue.
Technology security (*g*2)	This refers to internet platforms being considered secure for conducting online transactions and exchanging data, including isolated data security and protection in using Industry 4.0 technology.
Technology integration (*g*3)	This refers to improving the responsiveness of information systems and decreasing incompatibility between legacy systems.
Organization aspect (*G*2)	
Financial commitment (*g*4)	This refers to the company that can offer the financial resources for FinTech, and is especially committed to investing in employee training, software, hardware, system development, and system integration.
Organizational readiness (*g*5)	This refers to potential sites having to make decisions and businesses needing to be prepared to make business procedure changes for Industry 4.0 technology if benefits are to accrue.
Top management support (*g*6)	This refers to the top managers offering the support, and a promise to ensure a positive influence on this Industry 4.0 technology application procedure.
Environment aspect (*G*3)	
Competitive pressure (*g*7)	This refers to the adoption of Industry 4.0 technology, so that companies can benefit from more accurate data collection and a greater operational efficiency.
Regulatory support (*g*8)	This refers to elements of conception such as the policies of the government, which impact the diffusion of IT.
Environmental uncertainty (*g*9)	This refers to the environmental uncertainty, and how managers and entrepreneurs tend to act proactively according to well-informed conjectures about the strategic path ahead.

2.2. Elements for Assessing the Industry 4.0 Technology Application Procedure

The factors employed for assessing Industry 4.0 technology application will now be presented.

Technology aspect (G_1): Technology elements are denoted as "innovation characteristics" in numerous studies on administrative application procedures [20,21,75]. Technology readiness, technology security, and technology integration have all been recommended as significant to Industry 4.0 technology applications and are applied in the assessment context [21,22].

Organization aspect (G_2): Organizational features are present when applying novel technologies, as illustrated by Masood and Egger [21], and these are pertinent to the procedure of application. Numerous studies have highly esteemed Industry 4.0 technology application, with factors such as financial commitment, organizational readiness, and top management support considered to have a latent influence [20–23].

Environment aspect (G_3): Masood and Egger [21] have stated the impact of the environment in a management's strategies to implement novel technology. Competitive pressure, regulatory support, and environmental uncertainty are considered as being the most significant external elements [20–23].

This assessment structure focuses on TOE as the three aspects which significantly influence Industry 4.0 technology application in SMEs. Within each aspect, there are

also lower-level factors, considered in former research. Our entire assessment structure, involving both the aspects and elements, is demonstrated in Table 1.

3. Methods

The mixed MCDM model assembled by applying the above mentioned research is considered to be an appropriate method for the prospecting of topics concerning the industry 4.0 technology application in SMEs. It can be employed as a case for managers to enhance TOE estimation approaches for each element. This mixed MCDM with pattern systematic approaches is not only applied for ranking and choosing, but also for explaining the issues among dissimilar elements and the aspects for Industry 4.0 technology application. The tendency in the present method is to divert through ranking and selection to obtain improvement of the commerce performance according to the INRD [1,25–28,75,76].

This DEMATEL approach is used to set up a matrix of total influence relations and to survey this effect and cause inter relations among parameters extracted through distinct criteria and elements. Then, we integrate the influence relations matrix acquired by the DEMATEL approach to set up the fundamental ANP [77] and determine the influence weights for each element.

3.1. DEMATEL Technique

DEMATEL is applied to establish this matrix of effect relations for aspects/elements to calculate the effects and causes for separate factors. The method is broadly used in numerous kinds of multifaceted research to understand the complexity of certain topics. DEMATEL involves five phases.

This primary phase checks the numberer of factors in a structure, n, and advances the gages for determining the influence relations in separate factors, associating aspects/elements in pairs and applying the measure of 0–4, which represents a total lack of effect (0), low effect (1), medium effect (2), high effect (3), and very high effect (4).

The next phase detects a matrix of primary influence, associating effect interplay degree pairs to directly acquire the effect matrix $A = [a_{ij}]_{n \times n}$, where a_{ij} indicates the degree to which element i influences element j. If these i-th elements directly affect the j-th element, then $a_{ij} \neq 0$; then, $a_{ij} = 0$.

The next phase normalizes the matrix of the direct effect to acquire the matrix Z from Equations (1) and (2). The matrix Z for the diagonal is 0, and the largest summation of each column or row is 1.

$$Z = vA \tag{1}$$

$$v = \min_{i,j} \left\{ \frac{1}{\max_i \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n} |a_{ij}|} \right\}, i, j = 1, 2, \ldots, n \tag{2}$$

The fourth phase acquires the total effect matrix G from Equation (3):

$$G = Z + Z^2 + \cdots + Z^h = Z(F - Z)^{-1}, \text{ when } \lim_{h \to \infty} Z^h = [0]_{n \times n}, \tag{3}$$

where $Z = [z_{ij}]_{n \times n}$, $0 \leq z_{ij} < 1, 0 < \sum_{j=1}^{n} z_{ij} \leq 1, 0 < \sum_{i=1}^{n} z_{ij} \leq 1$. If the column or row is equal to 1 for at least some total factors (but not all) in $\sum_{j=1}^{n} z_{ij}$ and $\sum_{i=1}^{n} z_{ij}$, then we are able to determine that F is the identity matrix and $\lim_{h \to \infty} Z^h = [0]_{n \times n}$.

The final phase acquires the relations and prominence of these variables. Through all individual columns and rows of the total effect matrix $G = [g_{ij}]$, we can acquire the summation of all column and row vectors as follows:

$$e = [e_i]_{n \times 1} = \left[\sum_{j=1}^{n} g_{ij} \right]_{n \times 1} = (e_1, \ldots, e_i, \ldots, e_n)',$$

$$\boldsymbol{o} = [o_j]'_{1 \times n} = \left[\sum_{i=1}^{n} g_{ij}\right]'_{1 \times n} = (o_1, \ldots, o_j, \ldots, o_n)'.$$

The value e_i, which is the summation of all rows in the total influence matrix G, denotes the degree to which this element indirectly or directly impacts other elements. The value v_j, which s the summation of all columns in G, indicates the degree that the element is influenced by other elements. Based on this explanation, $e_i + o_j$ indicates the degree of the total relations among the elements, meaning "prominence", whilst $e_i - o_i$ shows the degree of the impact and other elements, illustrating the "net influence relations". If $(e_i - o_i)$ is positive, then element *i* influences the other elements, and if $(e_i - o_i)$ is negative, then element *i* is affected by other elements.

3.2. DANP Method

DEMATEL is not only used to build the interplay relations between each element, but also to acquire the most exact weight of the impact. The traditional ANP resolves these issues through the feedback and interdependence of elements. Therefore, we apply these fundamental ANP conceptions [77] as a foundation and associate them with the DEMATEL to resolve these problems [1,25,28,77,78]. In this way, DANP covers the next phases.

The first phase builds the framework of the specialist influence survey. The survey is broken down and divided into components.

The next phase uses an unweighted supermatrix $\boldsymbol{B} = (G_c^\alpha)'$, transposing separate normalized characteristics with the total degree of influence G_c^α achieved by the matrix $\boldsymbol{G}_c$ of the total effect by applying the DEMATEL, as illustrated in Equation (4).

$$
G_c = \begin{array}{c}
\\
\\
E_1 \\
\\
\\
\vdots \\
\\
\\
G_c = \quad E_i \\
\\
\\
\vdots \\
\\
\\
\\
E_n
\end{array}
\begin{array}{c}
\\
\\
c_{11} \\
c_{12} \\
\vdots \\
c_{1m_1} \\
\vdots \\
c_{i1} \\
c_{i2} \\
\vdots \\
c_{im_i} \\
\vdots \\
c_{n1} \\
c_{n2} \\
\vdots \\
c_{nm_n}
\end{array}
\overset{\begin{array}{ccc} E_1 & E_j & E_n \\ c_{11}\ldots c_{1m_1} & \cdots \quad c_{j1}\ldots c_{jm_j} \quad \cdots & c_{n1}\ldots c_{nm_n} \end{array}}{
\left[\begin{array}{ccccc}
G_c^{11} & \cdots & G_c^{1j} & \cdots & G_c^{1n} \\
& & & & \\
\vdots & & \vdots & & \vdots \\
& & & & \\
G_c^{i1} & \cdots & G_c^{ij} & \cdots & G_c^{in} \\
& & & & \\
\vdots & & \vdots & & \vdots \\
& & & & \\
G_c^{n1} & \cdots & G_c^{nj} & \cdots & G_c^{nn}
\end{array}\right]}
\quad (4)
$$

The normalized G_c with a total degree of effect offers the G_c^α of the aspects illustrated in Equation (5).

$$
G_c^\alpha =
\begin{array}{c}
\\
\\
E_1 \\
\\
\\
\\
E_i \\
\\
\\
\\
E_n \\
\\
\end{array}
\begin{array}{c}
c_{11} \\
c_{12} \\
\vdots \\
c_{1m_1} \\
\vdots \\
c_{i1} \\
c_{i2} \\
\vdots \\
c_{im_i} \\
\vdots \\
c_{n1} \\
c_{n2} \\
\vdots \\
c_{nm_n}
\end{array}
\begin{array}{ccccc}
\overset{E_1}{c_{11}\dots c_{1m_1}} & & \overset{E_j}{c_{j1}\dots c_{jm_j}} & & \overset{E_n}{c_{n1}\dots c_{nm_n}} \\
\left[\begin{array}{ccccc}
G_c^{\alpha 11} & \dots & G_c^{\alpha 1j} & \dots & G_c^{\alpha 1n} \\
\\
\vdots & & \vdots & & \vdots \\
\\
G_c^{\alpha i1} & \dots & G_c^{\alpha ij} & \dots & G_c^{\alpha in} \\
\\
\vdots & & \vdots & & \vdots \\
\\
G_c^{\alpha n1} & \dots & G_c^{\alpha nj} & \dots & G_c^{\alpha nn}
\end{array}\right]
\end{array}
\tag{5}
$$

We use $G_c^{\alpha 11}$ to indicate the fundamental conception in Equations (6) and (7).

$$
e_i^{11} = \sum_{j=1}^{m_1} g_{Cij}^{11}, i = 1, 2, \dots, m_1
\tag{6}
$$

$$
G_c^{\alpha 11} =
\begin{bmatrix}
g_{c11}^{11}/e_1^{11} & \cdots & g_{c1j}^{11}/e_1^{11} & \cdots & g_{c1m_1}^{11}/e_1^{11} \\
\vdots & & \vdots & & \vdots \\
g_{ci1}^{11}/e_i^{11} & \cdots & g_{cij}^{11}/e_1^{11} & \cdots & g_{cim_1}^{11}/e_1^{11} \\
\vdots & & \vdots & & \vdots \\
g_{cm_11}^{11}/e_{m_1}^{11} & \cdots & g_{cm_1j}^{11}/e_{m_1}^{11} & \cdots & g_{cm_1m_1}^{11}/e_{m_1}^{11}
\end{bmatrix}
=
\begin{bmatrix}
g_{c11}^{\alpha 11} & \cdots & g_{c1j}^{\alpha 11} & \cdots & g_{c1j_1}^{\alpha 11} \\
\vdots & & \vdots & & \vdots \\
g_{ci1}^{\alpha 11} & \cdots & g_{cij}^{\alpha 11} & \cdots & g_{cim_1}^{\alpha 11} \\
\vdots & & \vdots & & \vdots \\
g_{cm_11}^{\alpha 11} & \cdots & g_{cm_11}^{\alpha 11} & \cdots & g_{cm_1m_1}^{\alpha 11}
\end{bmatrix}
\tag{7}
$$

Then, it normalizes the matrix G_c of the total influence into the matrix G_c^α applying its aspects; formerly, the unweighted supermatrix B is attained via transposing G_c^α, i.e., $B = (G_c^\alpha)'$, according to the fundamental ANP conception in an unweighted supermatrix B, as illustrated in Equation (8).

$$
\boldsymbol{B} = (\boldsymbol{G}_\alpha^c)' =
\begin{array}{c}
\\
E_1 \\
\\
\\
\\
\\
E_j \\
\\
\\
E_n
\end{array}
\begin{array}{c}
c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \\ \vdots \\ c_{j1} \\ c_{j2} \\ \vdots \\ c_{jm_j} \\ \vdots \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n}
\end{array}
\begin{bmatrix}
\boldsymbol{B}^{11} & \cdots & \boldsymbol{B}^{i1} & \cdots & \boldsymbol{B}^{n1} \\
\vdots & & \vdots & & \vdots \\
\boldsymbol{B}^{1j} & \cdots & \boldsymbol{B}^{ij} & \cdots & \boldsymbol{B}^{nj} \\
\vdots & & \vdots & & \vdots \\
\boldsymbol{B}^{1n} & \cdots & \boldsymbol{B}^{in} & \cdots & \boldsymbol{B}^{nn}
\end{bmatrix}
\tag{8}
$$

with column headings E_1 ($c_{11}\ldots c_{1m_1}$), $\ldots$, E_i ($c_{i1}\ldots c_{im_i}$), $\ldots$, E_n ($c_{n1}\ldots c_{nm_n}$).

This produces matrix $\boldsymbol{B}^{11}$, as shown in Equation (9). If these clusters or elements are independent, the consistent item in this matrix is zero or blank. The matrix $\boldsymbol{B}^{nn}$ is attained in a similar way.

$$
\boldsymbol{B}^{11} = (\boldsymbol{G}^{11})' =
\begin{array}{c}
c_{11} \\ \vdots \\ c_{1j} \\ \vdots \\ c_{1m_1}
\end{array}
\begin{bmatrix}
g_{c11}^{\alpha11} & \cdots & g_{ci1}^{\alpha11} & \cdots & g_{cm_11}^{\alpha11} \\
\vdots & & \vdots & & \vdots \\
g_{c1j}^{\alpha11} & \cdots & g_{cij}^{\alpha11} & \cdots & g_{cm_1j}^{\alpha11} \\
\vdots & & \vdots & & \vdots \\
g_{c1m_1}^{\alpha11} & \cdots & g_{cim_1}^{\alpha11} & \cdots & g_{Cm_1m_1}^{\alpha11}
\end{bmatrix}
\tag{9}
$$

The third phase acquires the weight of the supermatrix, aspectualizing the matrix $\boldsymbol{G}_e$ of the total influence relations matrix $\boldsymbol{G}_e$ (as shown in Equation (10)). Agreement per aspect of matrix $\boldsymbol{G}_e$ is normalized by the full effect to acquire $\boldsymbol{G}_E^\alpha$. Equation (11) illustrates the outcome:

$$
e_i = \sum_{j=1}^{n} g_E^{ij}, i = 1, 2, \ldots, n \text{ and } g_E^{\alpha ij} = g_E^{ij}/e_i, i = 1, 2, \ldots, n
$$

$$
\boldsymbol{G}_E =
\begin{bmatrix}
g_E^{11} & \cdots & g_E^{1j} & \cdots & g_E^{1n} \\
\vdots & & \vdots & & \vdots \\
g_E^{i1} & \cdots & g_E^{ij} & \cdots & g_E^{in} \\
\vdots & & \vdots & & \vdots \\
g_E^{n1} & \cdots & g_E^{nj} & \cdots & g_E^{nn}
\end{bmatrix},
\tag{10}
$$

$$
\boldsymbol{G}_E^\alpha =
\begin{bmatrix}
g_{11}^E/e_1 & \cdots & g_E^{1j}/e_1 & \cdots & g_E^{1n}/e_1 \\
\cdots & & \cdots & & \cdots \\
g_E^{i1}/e_i & \cdots & g_D^{ij}/e_i & \cdots & g_E^{in}/e_i \\
\cdots & & \cdots & & \cdots \\
g_E^{n1}/e_n & \cdots & g_D^{nj}/e_n & \cdots & g_E^{nn}/e_n
\end{bmatrix}
=
\begin{bmatrix}
e_E^{\alpha11} & \cdots & e_E^{\alpha1j} & \cdots & e_E^{\alpha1n} \\
\cdots & & \cdots & & \cdots \\
e_E^{\alpha i1} & \cdots & e_E^{\alpha ij} & \cdots & e_E^{\alpha in} \\
\cdots & & \cdots & & \cdots \\
e_E^{\alpha n1} & \cdots & e_E^{\alpha nj} & \cdots & e_E^{\alpha nn}
\end{bmatrix}.
\tag{11}
$$

Multiplying the normalized matrix $\boldsymbol{G}_E^{\alpha}$ via the unweighted supermatrix $\boldsymbol{B}$ offers the normalized supermatrix $\boldsymbol{B}^{\alpha}$, as illustrated in Equation (12).

$$\boldsymbol{B}^{\alpha} = \boldsymbol{G}_E^{\alpha} \boldsymbol{B} = \begin{bmatrix} g_E^{\alpha 11} \times \boldsymbol{B}^{11} & \cdots & g_D^{\alpha i1} \times \boldsymbol{B}^{i1} & \cdots & g_D^{\alpha n1} \times \boldsymbol{B}^{n1} \\ \vdots & & \vdots & & \vdots \\ g_E^{\alpha 1j} \times \boldsymbol{B}^{1j} & \cdots & g_D^{\alpha ij} \times \boldsymbol{B}^{ij} & \cdots & g_D^{\alpha nj} \times \boldsymbol{B}^{nj} \\ \vdots & & \vdots & & \vdots \\ g_E^{\alpha 1n} \times \boldsymbol{B}^{1n} & \cdots & g_D^{\alpha in} \times \boldsymbol{B}^{in} & \cdots & g_D^{\alpha nn} \times \boldsymbol{B}^{nn} \end{bmatrix} \tag{12}$$

The fourth phase acquires the normalized supermatrix $\boldsymbol{B}^{\alpha}$. The supermatrix limitation can be acquired by multiplying this supermatrix $\boldsymbol{B}^{\alpha}$ with normalization via itself numerous times, until the supermatrix has become and converged into a long-term stabilizing supermatrix to provide a big enough power t. Hence, these weights of the effect of individual elements are attained via $\lim_{t \to \infty} (\boldsymbol{W}^{\alpha})^t$, where t indicates any numeral for the exponent. We apply these procedures to acquire the influence weights.

3.3. Modified VIKOR

The VIKOR technique, established by Opricovic and Tzeng [78,79], resolves MCDM issues with inconsistent elements. The technique is associated with negative-ideal and positive-ideal resolutions, with a preference for being close to the point of positive-ideal, that is, the fundamental plan of accustomed thinking. The conception of gap procedures indicates the closeness to the point of positive-ideal [78,79]. We will now define this modified VIKOR technique.

The primary phase indicates the values u_j^* and u_j^- in valuable element evaluation elements. The value u_j^* denotes the positive-ideal point, that is, the best score for element j, and u_j^- denotes the point of the negative-ideal, representing the worst score for element j. u_{pj} represents the score of the performance of the p alternative for j. This evolution of the VIKOR technique starts with the following procedure of Q_p_metric:

$$Q_p^k = \left\{ \sum_{j=1}^n [b_j(|u_j^* - u_{pj}|)/(|u_j^* - u_j^-|)]^k \right\}^{1/k}, \tag{13}$$

where $1 \leq k \leq \infty$; $p = 1, 2, \ldots, m$ and the influence of weight w_j is derived through the DANP. In this study, we applied the conceptions of Equations (14) and (15) to acquire the next outcomes for enhancement of the gap of each aspect/element according to feedback and interdependence issues:

$u_j^* = \max_p x_{pj}, j = 1, 2, \ldots, n$ (traditional approach)

We built the aspiration levels (modified approach) via the following vector:

$$\boldsymbol{u}^* = (u_1^*, u_2^*, \cdots, u_n^*). \tag{14}$$

$u_j^- = \min_p u_{pj}, j = 1, 2, \ldots, n$ (traditional approach)

We built the worst values (modified approach) via the following vector:

$$\boldsymbol{u}^- = (u_1^-, u_2^-, \cdots, u_n^-). \tag{15}$$

The fundamental aspect of the modified method is that we apply the scores of the performance from 0 to 4 in surveys so that the aspired value can be established at 4 and the worst value at zero. Therefore, in this study, we established $u_j^* = 10, j = 1, 2, \ldots, n$ as the aspired value and $j = 1, 2, \ldots, n, u_j^- = 0$ as the worst level, representing a difference when compared to the traditional method. In the study, we established u_j^* as the aspired value

and u_j^- as the worst value, and were able to prevent selection of the best among lower alternatives.

The second phase analyses the minimal mean of the group utility I_p and maximal regret L_p.

$$Q_p^{k=1} = I_p = \sum_{j=1}^{n} b_j r_{pj} = \sum_{j=1}^{n} b_j \left(\left| u_j^* - u_{kj} \right| \right) / \left(\left| u_j^* - u_j^- \right| \right), \tag{16}$$

$$Q_p^{k=\infty} = Q_p = \max_j \{ r_{pj} | j = 1, 2, \ldots, n \}, \tag{17}$$

where $r_{pj} = \left(\left| u_j^* - u_{pj} \right| \right) / \left(\left| u_j^* - u_j^- \right| \right)$ indicates the gap ratio; I_p indicates the ratios of the average gap through the aspired level u_j^* to the value of performance u_{pj} in element j of alternative p in the study, and we focus on how to minimize this gap r_{pj} for the element $j = 1, 2, \ldots, n$. Formerly, b_j indicates the respective influence weight of element j; b_j can be obtained from the DANP according to the DEMATEL technique. L_p indicates the maximum gap for all elements.

The last phase attains the overall factor R_p and its sorted outcomes. Equation (17) computes the values. As shown in Equation (17), we can detect how to enhance the application of Industry 4.0 technology to decrease the gaps in reaching the desired value according to the influence network relation map.

$$R_p = s(I_p - I^*) / (I^- - I^*) + (1 - s)(L_p - L^*) / (P^- - P^*) \tag{18}$$

The derived values are $I^* = 0$ (as the gap is zero, achieving the desired level), $I^- = 1$ (the worst situation)m $L^* = 0$ (desired level), and $L^- = 1$ (the worst situation). Therefore, in this study, we employed the gap for $V^* = 0$ and $I^- = 1$, $L^* = 0$, and $L^- = 1$, and modified Equation (17) as $R_p = sI_p + (1 - s)L_p$. The weight $s = 1$ only indicates how we are able to minimize this average gap, and the weight $s = 0$ only indicates how to choose the maximum gap for previous enhancement. Generally, $s = 0.5$, which can be regulated, depending on the circumstances.

According to the above conceptions, we could simply attain how to enhance these gaps r_{kj} ($p = 1, 2, \ldots, m;$), that is, the precedence for enhancement of the achieved aspired value.

4. Case Analysis

This empirical case focused on SMEs in Taiwan and is provided to show the application of the recommended MCDM pattern with the goal of choosing and evaluating the best approaches. The approach is able to help managers better handle matters of Industry 4.0 technology through the TOE structure and to realize their goals for distinct aspects/elements. A map of this study is shown in Figure 1.
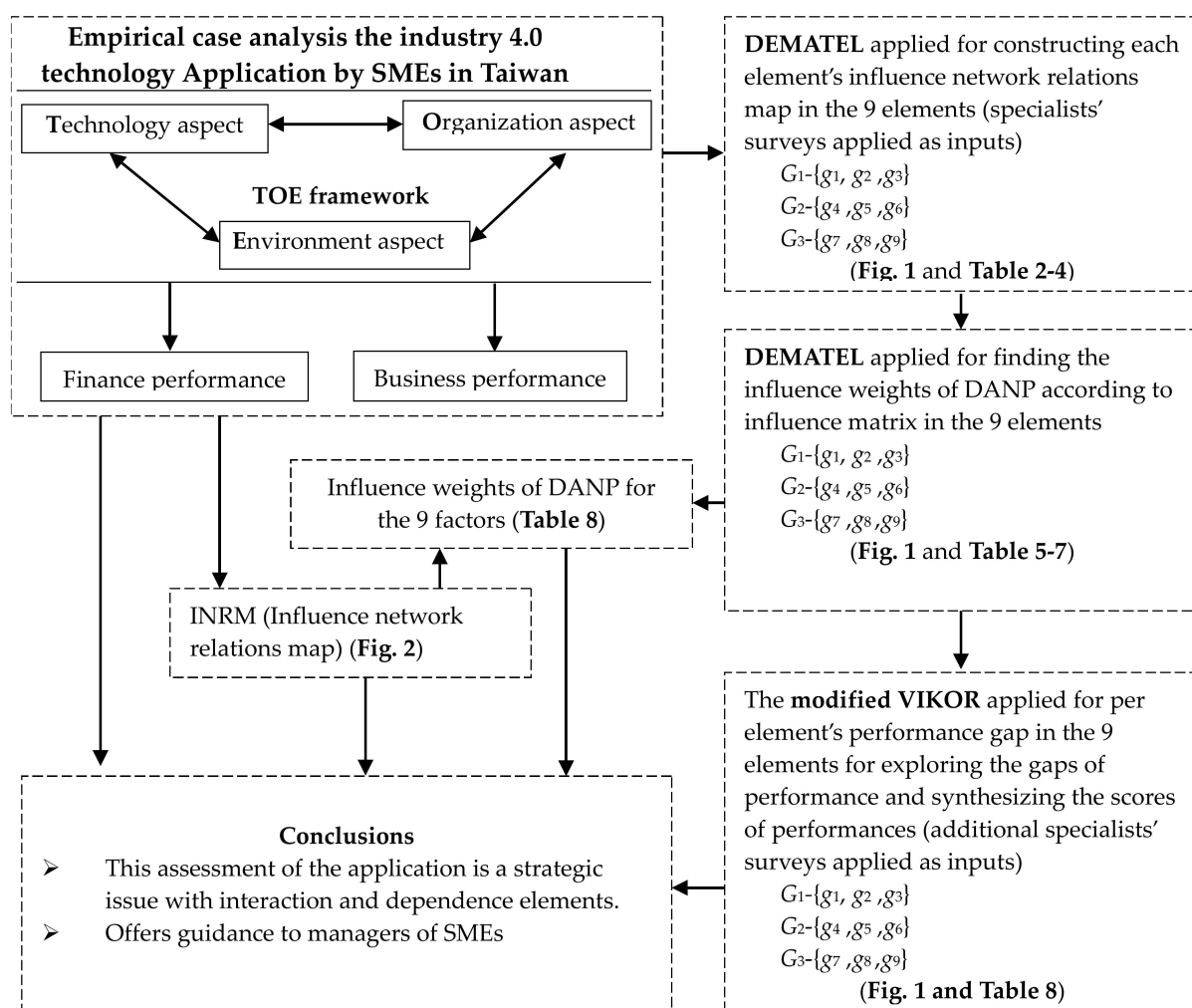
Figure 1. A map of the empirical case.

4.1. Data Collection

This study reviewed literature on Industry 4.0 technology and the application of information technology/information systems to SMEs, and relied on the context of TOE to choose Industry 4.0 technology application elements. The questionnaire was provided to specialists in the assessment of information technology application within associated fields. Firstly, the investigation applied a 5-point scale from 4 (very high effect) to 0 (completely no effect) to indicate the elements of impact of each aspect on the others. For these performance assessments, 12 specialists were questioned to assess their value of fulfillment for each element (see Table 2 in Note 1, where the gap error is 1.973%; the significant confidence is 98.027%, and it is more than 95%). Most of these specialists had more than 12 years' experience as managers in SMEs. Professional viewpoints on all elements within the elements were gathered by a survey and individual interviews. The interviews with the specialists were carried out in December 2020, and they lasted for 25 to 30 min per session for the whole survey.

Table 2. The total influence relationship matrix of G_C for elements.

	Elements	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9
g_1	Technology readiness	0.443	0.565	0.560	0.529	0.538	0.582	0.475	0.560	0.484
g_2	Technology security	0.496	0.409	0.502	0.470	0.488	0.526	0.419	0.496	0.455
g_3	Technology integration	0.458	0.458	0.357	0.385	0.441	0.449	0.376	0.432	0.388
g_4	Financial commitment	0.488	0.510	0.495	0.386	0.500	0.533	0.461	0.483	0.432
g_5	Organizational readiness	0.565	0.607	0.601	0.575	0.465	0.621	0.528	0.588	0.518
g_6	Top management support	0.320	0.317	0.335	0.309	0.315	0.268	0.270	0.301	0.270
g_7	Competitive pressure	0.548	0.570	0.554	0.537	0.526	0.570	0.395	0.578	0.501
g_8	Regulatory support	0.475	0.466	0.461	0.451	0.451	0.470	0.425	0.375	0.385
g_9	Environmental uncertainty	0.504	0.515	0.497	0.489	0.486	0.527	0.444	0.527	0.358

Note 1: It is an $n \times n$ matrix and $n = 9$. $\frac{1}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{\left| t_{ij}^p - t_{ij}^{p-1} \right|}{t_{ij}^p} \times 100\% = 1.973\% < 5\%$, and significant confidence is 98.027%, as $p = 12$ represents the number of specialists and t_{ij}^p is the average effect of the i element on j; n represents the number of elements.

4.2. Results Analysis

In this research, we applied the strategic framework of DEMATEL and investigated it through nine (9) elements and three (3) aspects of the TOE context viewpoint on Industry 4.0 technology. By applying the expert surveys, we acquired the matrix **G** of the total influence of aspects and elements illustrated in Tables 2 and 3. We examined the opinions and thoughts of the specialists in terms of three (3) aspects, and the relations between the scopes of influence, which are compared to other aspects in Table 3.

Table 3. The summation of the effects on the aspects and total influence relations matrix of **G**.

Aspects	G_1	G_2	G_3	e_i	o_i	$e_i + o_i$	$e_i - o_i$
Technology aspect	0.472	0.490	0.454	1.415	1.453	2.868	−0.037
Organization aspect	0.471	0.441	0.428	1.340	1.432	2.772	−0.092
Environment aspect	0.510	0.501	0.443	1.454	1.325	2.779	0.129

Based on the total influence prominence ($e_i + o_j$), the "technology aspect (G_1)" has the maximum influence of the relations detected; the "organization aspect (G_2)" includes all of the aspects which influence the others at the most basic level. Based on the influence relations ($e_i - o_i$), we can also observe that the "environment aspect (G_3)" has the maximum level of impact in relation to other aspects calculated. Additionally, the "organization aspect (G_2)" has the weakest influence in comparison to other aspects. Based on Table 4, we can acquire data on the relational influence among elements. Table 4 illustrates the direct and indirect relations among the aspects in relation to other elements. "Organizational readiness (g_5)" is the most significant element considered; in addition, "top management support (g_6)" influences all other elements at the most basic level. Moreover, Table 4 illustrates that "competitive pressure (g_7)" has the maximum influence level in relation to the other elements. Moreover, "technology integration (g_3)" has the weakest influence in relation to the other elements.

Table 4. The sum of the effects on the elements.

	Aspects/Elements	e_i	o_i	$e_i + o_i$	$e_i - o_i$
G_1	Technology aspect				
g_1	Technology readiness	4.736	4.298	9.033	0.438
g_2	Technology security	4.260	4.417	8.676	−0.157
g_3	Technology integration	3.744	4.360	8.104	−0.617
G_2	Organization aspect				
g_4	Financial commitment	4.289	4.131	8.420	0.158
g_5	Organizational readiness	5.067	4.209	9.277	0.858
g_6	Top management support	2.706	4.546	7.252	−1.841
G_3	Environment aspect				
g_7	Competitive pressure	4.780	3.794	8.573	0.986
g_8	Regulatory support	3.959	4.340	8.299	−0.382
g_9	Environmental uncertainty	4.347	3.791	8.138	0.556

Previously, we applied DEMATEL to approve the relational influence for the elements, and we aimed to obtain the most precise influenced weights. DANP was used to resolve the interdependence and feedback issues of separate elements [25–28]. Therefore, we assembled the quality estimation model via DEMATEL, combined with DANP to acquire the weights of influence for the individual elements, as indicated in Tables 5–7.

Table 5. The unweighted supermatrix $\boldsymbol{B} = (G_c^\alpha)'$.

	Elements	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9
g_1	Technology readiness	0.283	0.360	0.357	0.321	0.326	0.353	0.313	0.369	0.319
g_2	Technology security	0.352	0.291	0.357	0.317	0.329	0.354	0.306	0.362	0.332
g_3	Technology integration	0.360	0.360	0.280	0.302	0.346	0.352	0.314	0.362	0.324
g_4	Financial commitment	0.327	0.341	0.332	0.272	0.352	0.375	0.335	0.351	0.314
g_5	Organizational readiness	0.319	0.342	0.339	0.346	0.280	0.374	0.323	0.360	0.317
g_6	Top management support	0.329	0.326	0.344	0.346	0.353	0.300	0.321	0.358	0.321
g_7	Competitive pressure	0.328	0.341	0.331	0.329	0.322	0.349	0.268	0.392	0.340
g_8	Regulatory support	0.339	0.332	0.329	0.329	0.329	0.343	0.359	0.316	0.325
g_9	Environmental uncertainty	0.333	0.340	0.328	0.325	0.324	0.351	0.334	0.397	0.269

Table 6. The normalized supermatrix $\boldsymbol{B}^\alpha = G_D^\alpha \boldsymbol{B}$.

	Elements	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9
g_1	Technology readiness	0.094	0.118	0.120	0.115	0.112	0.116	0.115	0.119	0.117
g_2	Technology security	0.120	0.097	0.120	0.120	0.120	0.115	0.119	0.117	0.119
g_3	Technology integration	0.119	0.119	0.094	0.117	0.119	0.121	0.116	0.115	0.115
g_4	Financial commitment	0.111	0.110	0.104	0.090	0.114	0.114	0.113	0.113	0.112
g_5	Organizational readiness	0.113	0.114	0.120	0.116	0.092	0.116	0.111	0.113	0.111
g_6	Top management support	0.122	0.123	0.122	0.124	0.123	0.099	0.120	0.118	0.121
g_7	Competitive pressure	0.100	0.098	0.101	0.107	0.103	0.102	0.082	0.109	0.102
g_8	Regulatory support	0.118	0.116	0.116	0.112	0.115	0.114	0.120	0.096	0.121
g_9	Environmental uncertainty	0.102	0.106	0.104	0.100	0.101	0.102	0.104	0.099	0.082

Table 7. The stable matrix of the decision-making trial and evaluation laboratory-based analytic network process (DANP) with the power limit of $\varphi \to \infty$, i.e., $\lim_{\varphi \to \infty}(\boldsymbol{B}^{\alpha})^{\varphi}$.

	Elements	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9
g_1	Technology readiness	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
g_2	Technology security	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
g_3	Technology integration	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115
g_4	Financial commitment	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
g_5	Organizational readiness	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112
g_6	Top management support	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
g_7	Competitive pressure	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101
g_8	Regulatory support	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
g_9	Environmental uncertainty	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100

We defined the key elements in the application of Industry 4.0 technology to SMEs as top management support (g_6), technology security (g_2), and technology integration (g_3). DEMATEL was integrated with the influence weights to estimate the precedence of resolving issues, according to the gaps determined through the modified VIKOR and the influence network relations map.

In this research, a case study relating the Industry 4.0 technology application to SMEs was used to estimate and enhance approval gaps by applying the modified VIKOR technique, as shown in Table 8. Managers can detect problems through the values of gaps, either from the viewpoint of the element or separate aspects.

Table 8. A gap evaluation of the application of Industry 4.0 technology by modified VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR).

	Aspects/Elements	Local Weights	Global Weights	Industry 4.0 Technology Gap	
				FP	BP
G_1	Technology aspect	0.345		0.428	0.254
g_1	Technology readiness	0.330	0.114	0.280	0.140
g_2	Technology security	0.337	0.116 (2)	0.560	0.360
g_3	Technology integration	0.333	0.115 (3)	0.440	0.260
G_2	Organization aspect	0.340		0.317	0.392
g_4	Financial commitment	0.321	0.109	0.427	0.240
g_5	Organizational readiness	0.329	0.112	0.420	0.320
g_6	Top management support	0.350	0.119 (1)	0.120	0.600
G_3	Environment aspect	0.315		0.360	0.295
g_7	Competitive pressure	0.320	0.101	0.387	0.300
g_8	Regulatory support	0.362	0.114	0.320	0.320
g_9	Environmental uncertainty	0.318	0.100	0.380	0.260
SA_1		Total gaps		0.258	0.228

By applying these elements and aspects, the performances of the gap can be indicated by the enhancement of precedence arrangements to achieve the desired values. In the application of Industry 4.0 technology, technology security (g_2), with a high gap value of 0.560, is the primary element to be enhanced for the financial performance; top management support (g_6), with a high gap value of 0.600, is the primary element to be enhanced for the business performance. The enhancement precedence is also able to be used in separate aspects for the financial performance and business performance. In terms of the financial performance, for the technology aspect (G_1), for example, the precedence gap values are ordered as follows: Technology security (g_2), technology integration (g_3), and technology readiness (g_1). For the organization aspect (G_2), the precedence values of the gap are ordered as follows: Financial commitment (g_4), organizational readiness (g_5), and management support (g_6). For the environment aspect (G_2), the enhancement

precedencies are ordered as follows: Competitive pressure (g_7), environmental uncertainty (g_9), and regulatory support (g_8). For the business performance, in terms of the technology aspect (G_1), improvement priorities are ordered as follows: (g_2), (g_3), and (g_1). The order is (g_6), (g_5), and (g_4) within the organization aspect (G_2) and (g_8), (g_7), and (g_9) for the environment aspect (G_3). When applying the gap values offered by the specialists, the comprehensive priority systems of enhancement for the disparate aspects and for the general array of elements are obvious, as illustrated in Table 8. For managers, realizing the enhancement precedence of the application of Industry 4.0 technology for clients' needs to be simpler to realize than these performance gaps in the SMEs.

4.3. Implications and Discussion

The outcomes of this paper will now be discussed. Initially, based on the DEMATEL, we can identify the interrelationship among separate elements and aspects from the influence relations network map for each element and aspect. In Figure 2, the "environment aspect (G_3)" impacts other aspects, specifically, the "technology aspect (G_1)" and "organization aspect (G_2)"; visibly, the environment aspect (G_3) is a significant feature, and it has maximum strength impact in relation to other aspects. Therefore, the managers of SMEs need to prioritize enhancing this aspect. This is to be followed by the technology aspect (G_1) and the organization aspect (G_2) in assessing and enhancing the application of Industry 4.0 technology via SMEs.
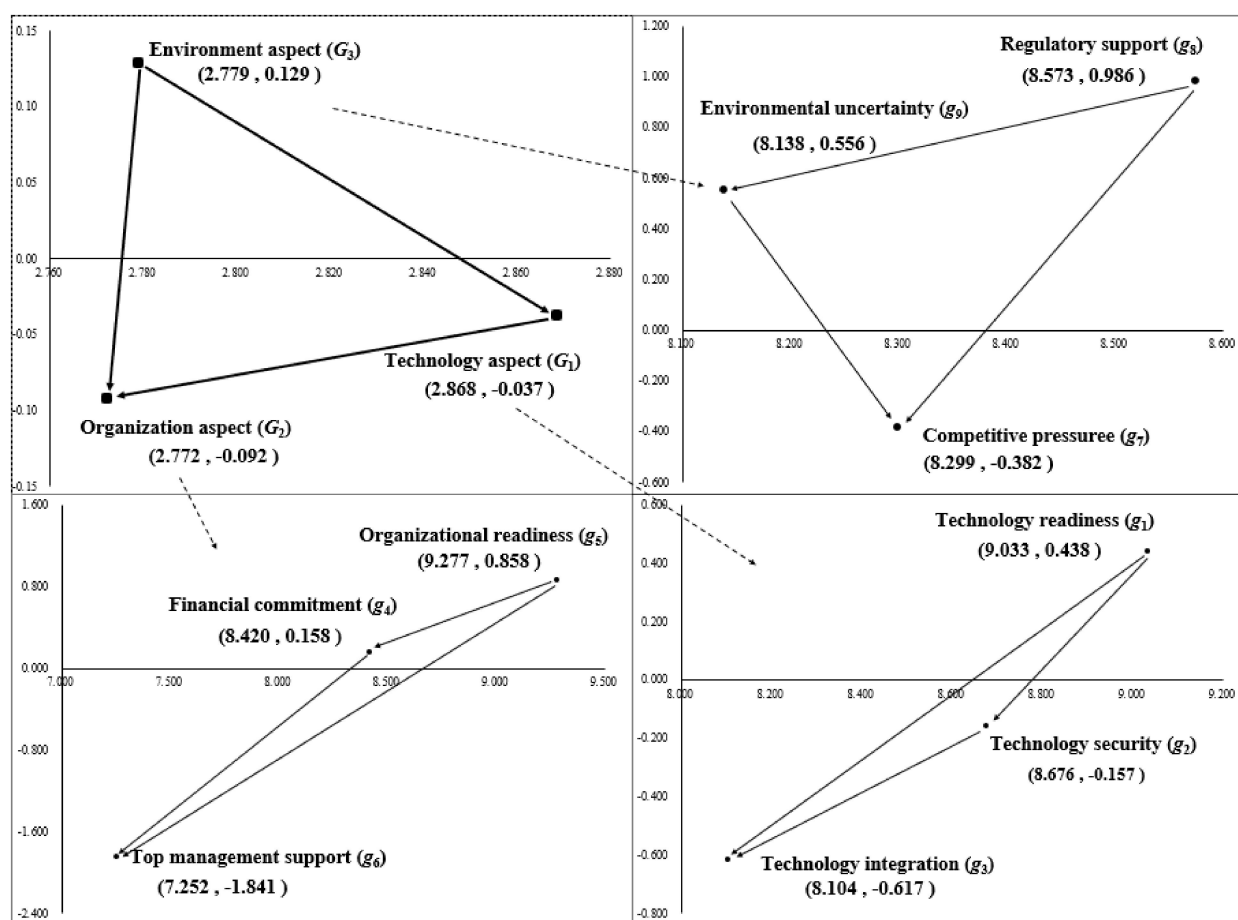

Figure 2. The influence network relations digraph (INRD) of each aspect and element.

Next, after inspecting these aspects, we focused on the elements, considered per aspect. Based on the findings, we developed a map of the influence relations of the elements in Figure 2. Therefore, for the effect relations among the elements, technology readiness

(g_1) was the most influential element in the technology aspect (G_1) and thus needs to be prioritized for enhancement. This is to be followed by technology security (g_2) and technology integration (g_3) (check Figure 2 on the causal relations between (G_1), (G_2), and (G_3) for more details). Each of the assessment elements and aspects comprise the necessities for influencing the Industry 4.0 technology application in SMEs. Therefore, SME managers need to assess all of the aspects and elements for Industry 4.0 technology in accordance with Figure 2. This assessment approach is applicable to most SMEs. Nevertheless, SME managers need to pay attention to the fact that, when using the approach, some modifications exist. The significance level for the nine (9) elements might change based on the characteristic of each firm or industry, and SME managers need to compare the assessment approaches for each Industry 4.0 technology model before determining the best application technique.

Lastly, the value of the gap is 0.258 (i.e., the distance to 0) for the finance performance and 0.228 for the business performance for the application of Industry 4.0 technology, as shown in Table 8, demonstrating room for enhancement. From the TOE viewpoint, the technology aspect (G_1), presenting the largest value of the gap of 0.428 for the finance performance and 0.392 for the organization aspect (G_2) in terms of the business performance, needs to be the primary precedence for enhancement if managers of SMEs wish to attain the desired value. For long-term enhancement, managers need systematic and sensible administration, as stated above. With our empirical findings, as formulated in Table 9, we were able to realize the objective of this paper. The assessment pattern for the application of Industry 4.0 technology offered in this research is applicable to most SMEs. However, SME managers must be cautious when using the approach. The importance of the nine (9) elements might change based on different circumstances, and managers need to employ the application of Industry 4.0 technology to explain gaps before developing strategies on the best technology to apply.

Table 9. Scheme of enhancement precedence for Industry 4.0 technology application.

Scheme	Array of Enhancement Precedence
F1: Influence network of aspects	$(G_3),(G_1),(G_2)$
F2: Influence network of elements within individual aspects	$(G_1):(C_2),(C_3),(C_1)$ $(G_2):(C_5),(C_4),(C_6)$ $(G_3): (C_9),(C_8),(C_7)$
F3: Array of aspects required to rise to aspired value (through high to low, via the value of the gap)	Financial performance $(G_1),(G_3),(G_2)$
	Business performance $(G_2),(G_3),(G_1)$
F4: Array of elements required to rise to aspired value by individual aspects (through high to low, via the value of gap)	Financial performance $(G_1): (g_2),(g_3),(g_1)$ $(G_2): (g_4),(g_5),(g_6)$ $(G_3): (g_7),(g_9),(g_8)$
	Business performance $(G_1): (g_2),(g_3),(g_1)$ $(G_2): (g_6),(g_5),(g_4)$ $(G_3): (g_8),(g_7), (g_9)$

5. Conclusions

This paper has examined issues surrounding the application of Industry 4.0 technology, and proposes a beneficial approach for the estimation and choice of elements for Industry 4.0 technology application using the TOE structure. To the best of our knowledge, that is one of the approaches dictating the Industry 4.0 technology application for SMEs in Taiwan. Industry 4.0 technology application is generally limited to certain fields in Taiwan, rather than within multifaceted topics encompassing technology, organization, and environmental

elements. Therefore, the approach is important for presenting Industry 4.0 technology application findings on SMEs. These contributions are threefold. First, the assessment of Industry 4.0 technology application is a decision-making issue which is composed of multifaceted interactions and dependences. Next, the Industry 4.0 technology application technique is used to assess the performance and significance values that are alternated into the scores of performances. Lastly, a mixed method is devised to determine the hierarchical structure process and interdependence relationships among the Industry 4.0 technology application aspects and elements. Therefore, as the SMEs help to make use of more technological patterns like the research proposes, technological usages ought to be planned to enhance advantages in the target market. This pattern can be used in various kinds of instances to generate distinct results. These results can also support Industry 4.0 technology application to fit target areas.

There are numerous limitations to this study that require further inspection. Primarily, this study was conducted via surveying a comparatively restricted number of specialists. A greater sample could have allowed for a more multifaceted study of assessment methods, which could have generalized the outcomes of the paper. Next, these TOE assessment elements are concluded from prior literature on TOE assessment, which excluded several possible impacts on the Industry 4.0 technology assessment procedure. Future research can apply dissimilar approaches, such as longitudinal or fuzzy theory research, to detect other elements. Lastly, to offer more objective data on the applicability of the future TOE assessment pattern, future research can use specific performance assessments, such as, finance or the economy, and thus demonstrate the practicality of the general assessment context for the business assessment and Industry 4.0 technology application proposed in this paper.

Further research should focus on learning particular clusters or pairs of Industry 4.0 technology application that are more advantageous. As an approach, it can raise awareness on aspects where improvements are necessary. Additionally, different approaches can be applied, such as the entropy technique, to analyze the weights of the elements. Finally, to offer more objective information on the suitability of the stated Industry 4.0 technology application assessment model, future efforts could be made to use data mining approaches, for example, the support vector machine or random forest, to mention the most essential elements and enhance the feasibility of the universal assessment framework. The consequences of future study can then be associated with those stated here.

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