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EXPLORING THE BEST STRATEGY PLAN FOR IMPROVING THE DIGITAL CONVERGENCE BY USING A HYBRID MADM MODEL

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Abstract. This study proposes a new hybrid MADM model that can explore the best strategy plan according to the environmental attributes that influence digital convergence, with the additional consideration of societal and individual needs for improving the digital convergence toward satisficing users' needs. The proposed hybrid MADM model employs the DEMATEL method to construct an influential network relationship map (INRM), and find the influential weights of DANP (DEMATEL-based ANP). Next, a modified VIKOR method is employed to assess the weighting of identified attributes to integrate the performance gap for each criterion into dimensions and the overall. Finally, this paper presents Taiwan as an empirical case to demonstrate the effectiveness of the proposed model in practically improving laws and regulations to plan for digital convergence. The contributions of our proposed model can be summarized as follows: (1) The INRM can be used to assist government bodies in understanding the influence and relationships of digital convergence development; (2) The modified VIKOR can be employed to reduce performance-gap towards achieving the aspiration level; (3) The model can help decision-makers to avoid choosing the optimal inferior alternative for reaching a certain aspiration level through continuous improvement.

Keywords: digital convergence development, multiple-attribute decision-making (MADM), DEMATEL (decision-making trial and evaluation laboratory), influential network relation map (INRM), DEMATEL-based analytic network process (DANP), modified VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje).

JEL Classification: C18, C210, C44, C520, C540, C60, L96, O00, O210, O38.

Introduction

The invention and popularization of smartphones and tablet computers (e.g., the iPhone and iPad) have considerably influenced the lifestyles and life patterns of many people, such as regarding banking, information acquisition, and communication. The integration of tele-

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communication devices, video and media devices, and networks into compact mobile devices has made communication more convenient for numerous people. However, various problems emerge when these innovations and inventions are developed faster than policy making can keep up with. For instance, the iPhone 6, released in late 2014, features a mobile payment system. However, governments must integrate various relevant banking regulations and administrative measures to enable people to use this and similar systems, which are designed without consideration for the unique conditions of every country. In light of such problems, digital convergence has become a critical research topic. By using appropriate research methods, we attempted to determine the applicable policies and devise a new hybrid research model to provide recommendations to governments and relevant institutions to enable them to rapidly fulfill the related requirements for accelerating digital convergence in development, which is expected to enhance public convenience considerably.

At present, nearly every new electronic device contains digital technology in some form. Therefore, because these products have become increasingly integrated with digital components, boundaries between distinct industries have become ambiguous, causing industry overlap. A vivid example of this is the merging of the information and communications industries into a single industry. People worldwide are still struggling with awkward combinations of terms such as "telecommunications", "information", and "computing" when discussing the basic technologies of the information economy. The progress of digital convergence concerns the initial implementation and eventual voidance of specific standards designed to combine various media forms.

Digital convergence can be categorized into various types such as network, market, product, service, industry, and technological convergence (Curran 2013; Kim *et al.* 2010). However, an interrelationship between these types already exists in the real world. The concept of digital convergence was established several decades ago (Kaluza *et al.* 1999), though it only recently began to gain practical importance. The convergence of audio, video, and data was found to be the current trend in the digital content industry (Liu 2013). Digital convergence is an ongoing phenomenon, and it particularly affects the digital content industry, the telecommunications market, consumers, and related policies (Fransman 2000). The key driving force in the digital content industry is the rapid progress in the field of digital and related technologies. This digital revolution has become an inseparable part of people's lives (Utschig 2001; Vasmatics 2010; Government Office for Science 2014). For example, people currently use smartphones to access the Internet, watch videos, play games, and monitor the stock market while commuting. Scientists in various fields have attempted to evaluate and predict the influence of this digital revolution on society and various industries (Baldwin *et al.* 1996). The trend of digital convergence is driven by three major forces: (1) semiconductors, software, and digital communication technologies; (2) government deregulation policies; and (3) innovative management (Yoffie 1997). In addition to digital technology, government strategies for accelerating digital convergence have become critical in the growth of this trend because they affect overall trends concerning national development.

In numerous countries, the main tendency in recent years has been to shift the balance between government and society away from the public sector and toward the private sector (Kooiman 1993). Numerous people have argued that new electronic technology has the potential to transform how governments relate to users of public services (Dutil *et al.* 2007). To promote the Digital Convergence, Government needs to satisfy the needs in society (or called "satisfy the social needs"), and the Business (enterprise) needs to provide products or services that meet user's or customer's needs. Because government policies are a central concern and often foundational for subsequent planning and execution efforts (Dutil *et al.* 2007). Presently, governments worldwide are faced with the challenge of redesigning digital convergence development programs to deliver efficient and cost-effective digital services and hardware through an optimal strategy development mode. Therefore, scholarly thinking on the impact and implications of using new digital forms of citizen identity management in public service environments has been further explored (Lips 2010).

Studies on digital convergence have recently been conducted from various perspectives and with multiple considerations. Shin (2010) investigated the gap between technological convergence and regulatory divergence in South Korea. Kim (2011) used South Korea as a case study to address the convergence of regulatory institutions for broadcasting and telecommunications. Mithas *et al.* (2013) examined how the competitive environment for industries shapes the manner in which the digital strategic posture (i.e., a focal firm's degree of engagement in a particular category of digital business practices involving the industry norm) influences the actualization of digital business strategies for firms. Lin (2013) addressed the emergence of complex convergence and regulatory issues resulting from the establishment of cross-platform audiovisual services, and analyzed the multiscreen television experience (e.g., a traditional TV set and a tablet) in Singapore. Few studies on digital convergence policy management have been conducted, mainly because government is responsible for addressing this. Moreover, policies on digital convergence vary across countries, and few studies have established a management decision-making model for accelerating digital convergence in the interrelationship of multiple-user needs to facilitate the creation of relevant administrative bodies and enforcement of related policies. The extant complex policies and directions (i.e., dimensions and guidelines) were suitable for devising a management decision-making model through the use of a hybrid multiple-attribute decision-making (MADM) model. The MADM method has been widely used recently for establishing decision-making management models (Tzeng, Huang 2011, 2013; Liou, Tzeng 2012; Liou 2013; Peng, Tzeng 2013; Chen, Tzeng 2015).

MADM refers to the decision-making methods used in realistic and common scenarios in which multiple and often extant interrelationships (i.e., dependence and feedback) among criteria must be considered to more accurately reflect the real world (Tzeng, Huang 2011, 2013; Liou, Tzeng 2012; Liou 2013; Peng, Tzeng 2013). In recent years, several critical concepts and trends regarding hybrid MCDM methods have been established for solving real-world problems. MCDM methods can be classified into two main categories according to purpose and data type: MADM and multiple-objective decision-making (MODM). Multiple criteria or attributes can be considered simultaneously in MADM, and the method facilitates the conducting of evaluations and estimations of the best (ideal) conditions by decision makers. The traditional MADM method not only considers ranking and selection, but is based on the characteristics of a limited number of alternative cases, and the proposed novel method also considers performance improvements. The modern hybrid MADM method is used for solving five major problems, (1) The traditional MADM method assumes that the criteria are independently, linearly, and hierarchically structured; however, in actuality, real problems frequently include interdependent criteria and/or dimensions, and may even exhibit feedback-like effects, which could lead to statistical and economic suppositions that are considered unrealistic, e.g., assumptions and hypotheses in SEM (Structural Equation Modeling), etc. Comparisons of statistical methods (regression or SEM) and MCDM techniques are ideal in real-world situations. Additionally, to solve the traditional MADM model, we adopted a new hybrid MADM model through the DEMATEL technique to construct an influential network relation map (INRM) and determine the influential weights of the DEMATEL-based map (DANP) to avoid supporting the notion that "some statistics and economics are unrealistic in the real world". (2) The solutions obtained using the max-min concept from the existing alternatives are replaced by "aspiration levels" to fit today's competitive markets and avoid "picking the best apple among a barrel of rotten apples" (Herbert A. Simon received the Nobel Prize in Economics in 1978 for his work discussing the basic concept of aspiration levels). (3) The emphasis in the field has been shifted away from ranking and selection by using "aspired-worst" as a benchmark. For determining the ideal approaches to systematically improving the performance of existing methods, "max–min" was employed as a benchmark to avoid "stop-gap and piecemeal problems" and the selection of the optimal choice among inferior options. In other words, this benchmark can be used to avoid "picking the best apple from a barrel of rotten apples" (Lu *et al.* 2013, 2015a). (4) Information integration techniques, including the fuzzy integral method, have been developed to aggregate non-additive (or called super-additive) performances (Kahneman and Tversky developed the concept of non-additive value-function aggregation in multicriteria problems in 1973). Finally, (5) the classical MODM methods are used to determine an optimal solution in a fixed region (i.e., objective space) according to fixed conditions or resources (i.e., decision space). The modern consideration of MODM models incorporating changeable spaces can aid decision makers in devising plans and designs and in reaching a desired point (i.e., aspiration level); this is a superior approach for only reaching the ideal point or attaining a Pareto optimal solution (Tzeng, Huang 2011, 2013; Liou, Tzeng 2012; Liou 2013; Huang, Tzeng 2014; Tzeng *et al.* 2014). The present study focuses on solving the first three of these problems.

The proposed a hybrid MADM model can be used to translate the performance values of each criterion into dimensions, and generally, it can include them in each alternative for ranking and selection. Moreover, the model can also be employed to assist decision makers in systematically establishing the best management decision-making model to attenuate such problems (e.g., the performance gaps of the criteria and dimensions or use of the modified VIKOR method according to the influential network relation map (INRM)). Thus, the proposed model includes three features based on the aforementioned concepts and trends. (1) The decision-making trial and evaluation laboratory (DEMATEL) method was used to construct an INRM, instead of relying on traditional statistical and economic approaches (e.g., structural equation modeling and linear regression), for reducing the potential emergence of unreasonable assumptions. (2) The DEMATEL technique was combined with the basic concept of analytic network process (ANP; Saaty 1996) to form a

DEMATEL-based analytic network process (DANP) for determining the influential weights of DANP (or called DANP-weighted attributes), thereby reducing the likelihood of unreasonable assumptions. (3) The VIKOR method was modified using the DANP-weighted attributes to integrate the overall performance gap as well as that of each criterion into dimensions. Afterward, a best improvement strategy plan based on the INRM can be devised systematically to achieve the aspiration level, which, in this study, was the fulfillment of social needs in each measurement criterion. These combined processes comprise the proposed a hybrid MADM model. This model has numerous applications such as exploring smart phone improvement (Hu *et al.* 2014), evaluating suppliers (Liou *et al.* 2014), probing organization performance (Chen, Tzeng 2015), implementing business-to-business m-commerce (Lu *et al.* 2015b), e-commerce (Chiu *et al.* 2013, 2014), outsourcing providers (Hsu *et al.* 2013, 2012), glamor stock (Shen *et al.* 2014), RFID (Lu *et al.* 2013), and tourism development, including metro–airport connection services(Liu *et al.* 2013b), increasing cruise ticket sales by travel agencies (Liu *et al.* 2013a), and improving tourism policies (Liu *et al.* 2012). These types of integrated models can facilitate decision-making, be used to identify ineffective policies and directions, and improve causality so that mistakes resulting from the pursuit of incorrect improvement directions can be avoided. These advantages are unique to these types of integrated methods by systematics.

The remainder of this paper is organized as follows. Section 1 reviews policies on digital convergence. Section 2 presents the procedure of DEMATEL used to construct the INRM, and discusses how DANP was used to determine DANP-weighted attributes (or called the influential weights of DANP). This section also includes a description of the modified VIKOR method. Section 3 demonstrates the advantages of the proposed model by adopting Taiwan as an empirical case study of the process of implementing digital convergence policies. This section also includes a discussion on the results. Finally, last Section provides conclusions and closing remarks.

1. Review of digital convergence policies

Network communications technology has undergone rapid development, resulting in the convergence of various industries, particularly those in telecommunications and broadcasting; digital convergence emerged from this trend. In 1992, the Organization for Economic Cooperation and Development (OECD) provided the first definition of digital convergence, indicating that the convergence of telecommunications and broadcasting occurred mainly at the network, service, and corporate organization levels. In 1997, the European Union defined convergence as "the ability of different network platforms to carry essentially similar kinds of services, or the coming together of consumer devices such as the telephone, television and personal computer". In addition, regarding techniques, platforms, services, and devices for exploring digital convergence, originally distinct fields related to commerce and technology were found to have converged (OECD 2004). Advances in digital technology have resulted in the merging of three communication media (i.e., telecommunications, the Internet, and broadcasting) – a clear example of digital convergence. This convergence appears in various areas (e.g., regulatory, platform, terminal-device, application-service, and diverse-content convergence). The areas differ but are interrelated through dependence and feedback. Because digital convergence involves numerous areas, it requires national integration and management.

The United States has begun adjusting policies for the gradual expansion of digital convergence. For instance, the Telecommunications Act replaced the Communications Act. In the Telecommunications Act, services are categorized as information services, telecommunication services, broadcasting services, cable television, or value-added network services. In 2010, the U.S. Federal Communications Commission (FCC) presented Congress with a proposal entitled Connecting America: The National Broadband Plan. This plan includes six objectives concerning household broadband services, mobile innovation, personal Internet access, digital skills, public safety network establishment, and energy-saving schemes for the Internet. The plan also includes four policy priorities: broadband-service market competition, the effective application and allocation of a frequency spectrum, the promotion of broadband services, and the development of broadband applications at national levels. The time frame for the plan ends in 2020. In late 2010, the FCC passed the Open Internet Order, which proposed three rules (i.e., no throttling, no blocking, and no paid prioritization). Furthermore, the FCC announced that a Super Wi-Fi network would be established, and that the standard design was expected to be completed by the end of 2014. This Super Wi-Fi network would be more powerful than the existing network, with the range-coverage and transmission speed increasing by nine and three times, respectively.

The European Union has adhered to previously published green papers in developing and implementing relevant policies, regulations, and projects. The decision-making parties are involved in electronic communications, wireless frequency spectra, and the digital agenda. The main objectives of the EU legislation are connecting the policy implementations of different countries and standardizing all relevant laws and regulations. Furthermore, in 2013, the European Union announced its media policies, aimed at stabilizing the progression of media service convergence and merging the traditional broadcasting industry with the Internet to ensure access to media services without limitations caused by geographic location or telecommunications carriers (European Commission 2013).

In 2009, the U.K. government published the Digital Britain Report, which includes 86 recommendations concerning "the utilization of digital technology to economically enhance the digital industry and enter the digital era" (Digital Economy Act 2010). Two crucial recommendations were included in the priority list: (1) recover from the recession and devise a plan for the future establishment of a powerful economic system, and (2) reprioritize the objectives of U.K. public services. These recommendations were highly pertinent to the orientation and development of the public broadcasting and communications industries. The report also listed five critical goals: (1) the completion of comprehensive network links, (2) the enhancement of wired and wireless Internet access, (3) the use of the digital and knowledge-based economies to secure foreign investment, (4) the provision of high-quality programs and online services for British citizens and the creation of international value, and (5) the transformation of public services through the use of digital technology. The year following the Digital Britain Report, the 2010 Digital Economy Bill detailed relevant laws and regulations (Digital Economy Act 2010).

The growth of digital technology has led to the convergence of three independent industries: the digital, electronic communications, and news media industries. However, this convergence brings problems in different areas, such as the converged entity's regulations, transmission platform, operating platform, terminal carrier, application service, and multi-content convergence at different levels. In addition, as digital convergence-related technologies and business models evolve, they in turn bring change to consumer electronic products (e.g., tablet computers, smart phones), digital video, video games, information technology, and other areas. The quality of governmental progress also influences people's quality of life and the development of relevant industries. Moreover, the quality of related government policy can be viewed as indicating the quality of life in a country. Several major countries and unions that are devising strategies for digital convergence (i.e., the United States, European Union, and United Kingdom) have established respective development procedures and objectives concerning the online environment, spectrum management, and market mechanisms. They have also implemented major policies concerning digital convergence, which have contributed toward the development of relevant policy tools (e.g., the U.S. national broadband plan and the Digital Britain Report). These examples indicate that digital convergence is a crucial topic of discussion worldwide.

2. Methodology

This section comprises two main parts. The first part details the procedure followed in this study to establish a hybrid MADM model (Fig. 1); and the second part introduces the process of implementing this model (Sections 2.1, 2.2, and 2.3).

The proposed research model is based on the hybrid MADM methodological framework. First, DEMATEL technique was used to determine the influence-related matrix,

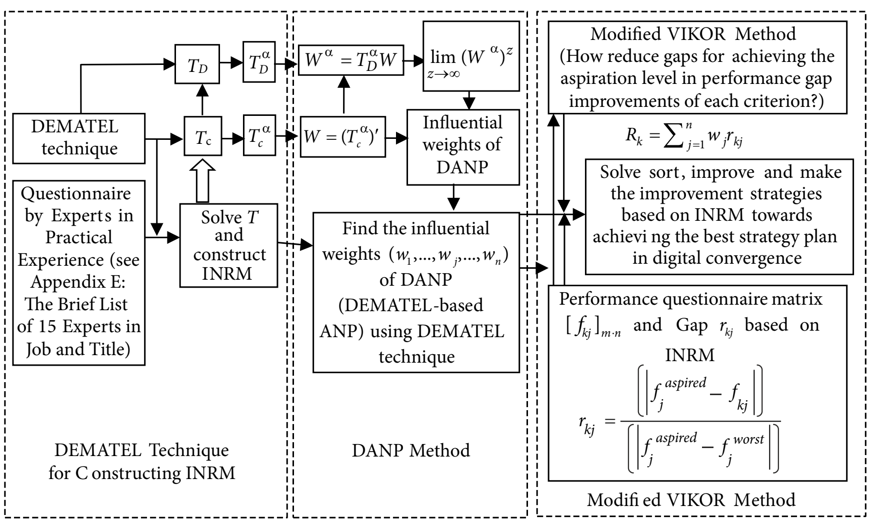

Fig. 1. Model procedures of new hybrid MADM

so that the properties of the INRM could be constructed (Section 2.1). Afterward, DANP was used to identify the influential weighted attributes, as shown in Section 2.2. Finally, the aspiration-worst level (called "aspired-worst") was sought as a benchmark for the measurement scale (see modified VIKOR method in Fig. 1); the traditional max-min points as the positive and negative ideal points were replaced by using the modified VIKOR method based on "aspired-worst" as benchmark to evaluate and improve the performance gap in each criterion and dimension, and to determine how the aspiration level can be attained by using the INRM (Section 2.3). Each stage of the method is described as follows.

2.1. Using DEMATEL to construct the INRM

DEMATEL technique is a method used for constructing a structural model for clarifying and solving complex problems. DEMATEL technique was developed between 1972 and 1976 by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva (United Nations). During its development, the program was being focused on resolving complex and intertwined sets of global issues (Fontela, Gabus 1974; Warfield 1976), which can now be accomplished by determining the mutual influence among factors or criteria within a model based on matrices and relevant mathematical operations to calculate the causality of each element. DEMATEL technique can be employed widely for solving a various complex problems and gain an understanding of complex structures as well as establish practical problem-solving approaches. DEMATEL comprises five steps (Appendix A) (Tzeng *et al.* 2007; Huang *et al.* 2007; Tzeng, Huang 2012; Lu *et al.* 2013; Liou *et al.* 2014, 2015; Hu *et al.* 2014). For the first step, a system with n elements must be constructed, and a measurement scale from 0 (*no influence whatsoever*) to 1 (*low influence*), 2 (*medium influence*), 3 (*high influence*), and 4 (*extremely high influence*) must be developed by experts of knowledge domain in practical experience by their native language to conduct pairwise comparisons. In the second step, the initial matrix $\boldsymbol{A} = [a_{ij}]_{n \times n}$ is calculated to determine the influence-related matrix directly (Chen *et al.* 2011). In the third step, the influence-related matrix is normalized, such that at least one column or row – but not all of them – is summed to one, thereby obtaining the normalized direct influence-related matrix $\boldsymbol{X} = [x_{ij}]_{n \times n}$. In the fourth step, the total influence-related matrix $\boldsymbol{T} = [t_{ij}]_{n \times n}$ is obtained. Finally, the fifth step involves devising the INRM, as shown in Figure 3 and Section 3.3.

2.2. Determining the DANP-weighted attributes

In addition to using DEMATEL technique to construct a dynamic interrelationship among the dimensions and criteria (total influence-related matrices $\boldsymbol{T_D}$ and $\boldsymbol{T}_c$), the most suitable weighted attributes can be found using $\boldsymbol{T}_c$ and $\boldsymbol{T_D}$. In this paper, we use DEMATEL technique based on the basic concept of ANP (Saaty 1996) to construct the influential weights (called "DEMATEL-based ANP", abbreviated as "DANP"), which can be used to overcome the limitations of independent assumptions based on returned AHP questionnaires; it can also be applied for clarifying nonlinear and complex network relationships (Lu *et al.* 2013; Peng, Tzeng 2013; Hu *et al.* 2014; Shen *et al.* 2014). Saaty (1996) proposed an ANP to solve the dependence and feedback problems only between dimensions (or called clusters), criteria (inner dimension/cluster) in diagonal matrix until assumed to be independent (zero matrix, $\boldsymbol{W}^{ii} = \boldsymbol{0}$) or assumed self-relation (Identity matrix, $\boldsymbol{I}$), and the weighted super-matrix obtained by using equal weights; Saatys' ANP eliminates the limitations of the Analytic Hierarchy Process (AHP) assumed criteria (inner and outer dimension/cluster) are all independent. Ou Yang *et al.* (2008) replaced equal weights with the normalized total influence-related matrix $\boldsymbol{T}_c^{\alpha}$, which was obtained using $\boldsymbol{T}_D^{\alpha}$ (DEMATEL in dimensions). Their results are highly accurate for the unweighted super-matrix $W = (\boldsymbol{T}_c^{\alpha})'$ and the weighted super-matrix $\boldsymbol{W}^{\alpha} = \boldsymbol{T}_D^{\alpha}\boldsymbol{W}$. The present study followed these steps accordingly, after which the influential weights $\boldsymbol{w} = (w_1, ..., w_j, ..., w_n)$ of the DANP can be established. The DANP is a new method that was developed in the MADM field for weighting the performance integration from each criterion into dimensions and overall performance in interrelationship problem from research group of Tzeng (Liou, Tzeng 2012; Liou 2013). This method is used to convert the DEMANTEL-produced total influence-related matrix $\boldsymbol{T}$ into the weighted attributes of the DANP in each criterion, and can be used effectively for integration-weighting by employing the modified VIKOR method to conduct performance evaluations. Therefore, the DANP calculations comprise three steps (Appendix B). First, the total influence-related matrix $\boldsymbol{T}$ (including $\boldsymbol{T}_C$ according to the dimensional criteria, and $\boldsymbol{T}_D$ according to the overall dimensions) is determined using DEMATEL, and $\boldsymbol{T}_C$ and $\boldsymbol{T}_D$ are converted into the normalized influence-related matrix $\boldsymbol{T}_C^{\alpha}$ and $\boldsymbol{T}_D^{\alpha}$, respectively. Second, the basic concept of ANP method (Saaty 1996) is used to construct the unweighted super-matrix $W = (\boldsymbol{T}_c^{\alpha})'$ and weighted (or normalized) super-matrix $\boldsymbol{W}^{\alpha} = \boldsymbol{T}_D^{\alpha}\boldsymbol{W}$ by DEMATEL technique. Third, $\boldsymbol{W}^{\alpha}$ is adopted to calculate the DANP-weighted attributes of the criteria $\boldsymbol{w} = (w_1, ..., w_j, ..., w_n)$ (i.e., global weights) and dimensions (i.e., local weights) by considering a sufficiently large self-multiplied power z (using the Markov chain), after which the DANP-weighted attributes can be obtained by solving $\lim_{z\to\infty}(\boldsymbol{W}^{\alpha})^z$. Ou Yang *et al.* (2008, 2013) have proposed these approaches for resolving the criteria dependence and feedback problems and increase practicality for use in real-world applications.

2.3. Using the modified VIKOR method for improving the performance gap

The traditional VIKOR method was developed for multiple-criteria optimization in complex systems. The method is used to produce a multiple-criteria ranking index, which is based on a measure of proximity to the ideal solution (Opricovic 1998; Opricovic, Tzeng 2004, 2007). The VIKOR method relies on the class distance function (Yu 1973), which is based on the concept of the positive ideal solution (this study adopted the aspiration level instead) and the negative ideal solution (this study adopted the worst level instead), and organizes the results. In other words, this traditional approach involves selecting the optimal option from among a set of inferior choices. Thus, in contrast to the VIKOR method, we used the ideal values of the measurement range as the aspiration level and worst value (called "aspired-worst" as benchmark). This new concept is not limited to the use of performance ranking and selection, but can be applied to improve performance gaps in replacements (i.e., the modified VIKOR method) (Appendix C). To normalize the class distance function, it is preferable to be near the aspiration level and far from the worst level; our modified VIKOR approach thus shifts focus from ranking and selection to systematic improvements in the performance gap, which is based on the INRM, thereby not only can be for avoiding the "stop-gap piecemeal", piecemeal problem and the selection of the least poor choice among inferior options; i.e., but also can be for avoiding "Picking the best apple among a barrel of rotten apples" (Lu *et al.* 2013, 2015a). Opricovic and Tzeng (2004) suggested that the compromise ranking method (VIKOR) is suitable for implementation within MADM (Tzeng *et al.* 2002a, 2002b, 2005; Opricovic, Tzeng 2002, 2003, 2007; Lu *et al.* 2013). To address these problems and improve the performance gaps, we included the following three steps in the proposed modified VIKOR method. (1) Check the best (aspiration) level and the worst level of each evaluation criterion in the performance matrix of each alternative k (k = 1, 2, …, m) for each criterion j (j = 1, 2, …, n; called "each attribute j" in real-world situations), a shift from ranking and selection when determining the most preferable approaches to improvements in the performance gaps of INRM-based methods (Fig. 3) established using a systematic approach for avoiding the stop-gap, piecemeal problem. (2) Calculate the mean group utility according to the sum of the regrets (i.e., gaps) of all the criteria (i.e., average overall performance gaps, which are the gaps in the criteria and dimensions established using a systematic approach, and creative innovations that lead to planning the best strategies aimed at closing these gaps as much as possible), and calculate the maximal regret (i.e., the maximal gap) for a single criterion for confirmation; this criterion should be selected by considering the overall priority improvement as well as that for each dimension. Consequently, the modified VIKOR method, represented as $r_{kj} = \left(\left|f_j^{aspired} - f_{kj}\right|\right) \Big/ \left(\left|f_j^{aspired} - f_j^{worst}\right|\right)$, can be used to attain the expected results, where represents the gap ratio according to the normalization scale (using the aspiration level $f_j^{aspired}$ and the worst level f_j^{worst}). From the aspiration level that is farther to the actual performance value f_{kj} in alternative k on criterion j, the minimal average gaps $S_k = L_k^{p=1} = \sum_{j=1}^{n} w_j r_{kj}$ can be found to close the gap as much as possible. Moreover, the maximal individual regret (gap) is written as $Q_k = L_k^{p=\infty} = \max_j \left\{ r_{kj} \,\middle|\, j = 1,2,...,n \right\}$ for the INRM-based priority improvement (Fig. 3). (3) Obtain the comprehensive/integration indicators and provide the obtained results to the decision maker, who implements the improvement strategies and reduces the competitiveness gaps for both overall performance and in each dimension and criterion pertaining to the performance gap.

By relying on these concepts combined with the INRM (Fig. 3), an improvement strategy aimed at closing to zero of performance gaps $\{r_{kj} | k = 1,2,...,K; j = 1,2,...,n\}$ of the criteria as much as possible (i.e., towards reaching the aspiration level through innovations and creativity and thereby reducing the performance gap) can be devised easily through a systematic approach. Identifying the criteria should be prioritized to improve the performance gap, so that the aspiration level can be reached for overall performance. Thus, the best strategy-planning program can be developed for implementation and enforcement using the proposed a hybrid MADM model.

3. Empirical case study for devising development strategies to improve digital convergence

To demonstrate the effectiveness of the hybrid MADM model, this section presents an empirical case, thereby showing the analytical process of substantially improving the laws and regulations established in preparation for digital convergence. Section 3.1 provides a description of the problems faced by the study target. Section 3.2 details the origin of development criteria for digital convergence. In Section 3.3, the establishment of an INRM by using DEMATEL is discussed. Section 3.4 details the weighted attributes of the criteria that were determined using the DANP. In Section 3.5, VIKOR was used to conduct a performance evaluation of the case study. Section 3.6 provides a discussion and implications.

3.1. Description of problems

Most countries have devised strategies for the development of digital convergence. These strategies generally include various types of development items that may in turn contain numerous development programs. Most countries have devised strategies for the development of digital convergence. These strategies generally include various types of development items that may in turn contain numerous development programs. In real-world situations, such programs are often interdependent relationship structures, which should be considered in the model-building process. Therefore, a clear development policy regarding digital convergence would contribute to the integration of resources across government sectors and to the development of digital media-related industries in Taiwan. Therefore, a clear development policy regarding digital convergence would contribute to the integration of resources across government sectors and to the development of digital media-related industries in Taiwan. The Taiwan government's approaches to communication issues and technological convergence effectuate changes to the industry structure and market. However, the government began actively devising policies addressing digital convergence in 1998, such as by establishing an independent administrative agency tasked with integrating telecommunications and communication information. In 2004, basic regulations for national communication were enacted (i.e., the Fundamental Communications Act) (NCC 2004). In the following year, the National Communications Commission Organization Act was enacted. Furthermore, in accordance with this act, the government established the National Communications Commission (NCC) (NCC 2015). The government regards the development of digital convergence as an important future direction for national development. In 2010, the Taiwan government launched the Digital Convergence Policy Initiative, and proposed six major policy directions, with a seventh added in 2012. The original six policies were as follows: (1) maintain a high-speed broadband network, (2) advance telecommunications convergence services, (3) accelerate the switchover to digital television, (4) promote innovative video services, (5) improve the communications industry, and (6) harmonize the regulatory environment of convergence. The policy content contains extensive details on the policy direction and objectives, as well as on the project implementation and the responsibilities of the government unit in charge of the initiative. Digital convergence entails a highly complex network of relationships between each deposit development project content. Therefore, an effective decision-making model can assist a decision-making body by providing an in-depth understanding of policy considerations and decisions. All development items and methods are mutually influential in the interrelationship. For example, the poor performance of item/method A affects the performance of item/method B, inevitably resulting in a poor overall performance throughout the entire process of digital convergence development. Therefore, the MADM structure was adopted in this study to establish a hybrid MADM model with integrated functions for performance evaluation and improvement. When development strategies lead to poor performance in digital convergence, the MADM structure can be used to assist the policy development team in gaining a comprehensive understanding of the influences and interrelationships between the development strategy and the resultant performance. Thus, an improvement strategy with a causal influence or interrelationship can be achieved, thereby ensuring the best performance for digital convergence resulting from development strategies. Figure 2 presents the procedure for our empirical analysis of the Taiwan case study.

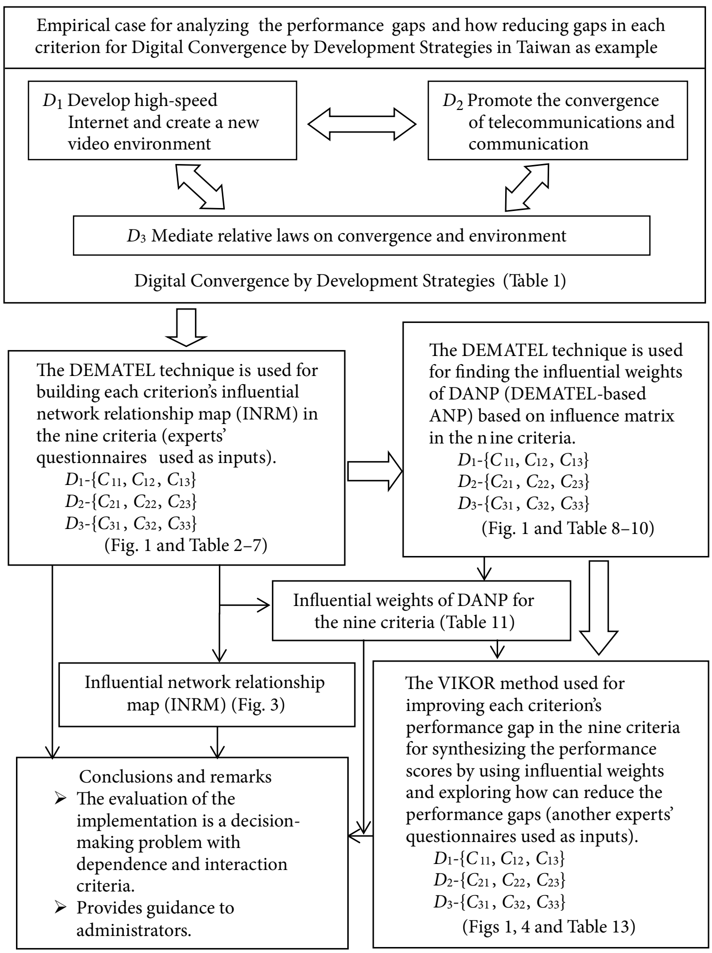

Fig. 2. The diagram of empirical case

3.2. Digital convergence through development strategies

This study examined the contents of public and social digital convergence development as proposed by the government of Taiwan, which was selected as an empirical case to show how such strategies actually develop over time. Questionnaires with answers given on an 11-point scale from 0 to 10 were used to assess the importance of whether (for all criteria, the average importance was found to be greater than 7), and as a response of satisfaction/good level for obtaining performance value in perception/feeling. These questionnaires were used to collect the opinions of experts in their native language. Fifteen experts (five from government sectors, five from the media industry, and five from academia) evaluated the importance of these methods. We regarded an average score higher than 7.0 as indicating the selection of digital convergence development strategies of greater importance, in accordance with the orientation (dimensions) and methods (criteria). They can be generalized as three major development orientations (dimensions) and nine development methods (criteria) in the real world (Table 1).

3.3. Using DEMATEL to establish an influential network relationship map

The 15 experts each evaluated the degree of influence of the criteria on a scale ranging from 0 (*no influence*) to 4 (*very high influence*) in their native language. In accordance with the questionnaires completed by the experts (15 samples of experts), the initialization of the influence-related matrix (Table 2) was obtained through pairwise comparisons. To obtain a high-quality consensus result, we used the equation ($\frac{1}{n(n-1)}\sum_{i=1}^{n}\sum_{j=1}^{n}\left(\left|a_{ij}^{p}-a_{ij}^{p-1}\right|\Big/a_{ij}^{p}\right)\times 100\% = 2.4\%$) to test for significance among experts in pairwise comparison in an $n \times n$ matrix (i.e., $n^2 - n = n(n-1)$). The result was highly significant in confidence and very reliable, with a high consensus ratio of 97.6% (higher than 95%; the error consensus ratio in the gap was only equal to 0.024 (2.4% < 5%), as stated in the footnote of Table 2).

Subsequently, the influence-related matrix $\boldsymbol{A}$ (Table 2) was initialized and normalized using Equations (A1) and (A2), thereby obtaining a normalized influence-related matrix $\boldsymbol{X}$ (Table 3). The row and column sums of this matrix were between 0 and 1, and $0 < \sum_{j=1}^{n} x_{ij} \leq 1$, $0 < \sum_{i=1}^{n} x_{ij} \leq 1$. This enabled the calculation of the total influence-related matrix $\boldsymbol{T}$ (also referred to as $\boldsymbol{T}_C$) (Table 4) and the total influence-related matrix $\boldsymbol{T}_D$ (Table 5).

Tables 6 and 7 list the information of each dimension regarding the influence on the network relationship model as follows. (1) Influence relationship (r_i): if r_i denotes the row sum $\sum_{j=1}^{n} t_{ij}$ of the *ith* row of matrix $\boldsymbol{T}$ (also referred to as $\boldsymbol{T}_C$), then r_i denotes the sum of the direct and indirect influences of criterion i on all of the other criteria. (2) Influenced relationship (s_i): if s_i denotes the column sum from matrix $\boldsymbol{T}$, then s_i denotes the sum of the direct and indirect effects on criterion i by all of the other criteria. (3) Influence intensity ($r_i + s_i$): ($r_i + s_i$) represents an index of the strength of the influences given and received (i.e., the relationship between the influence and influenced in criterion i); that is, ($r_i + s_i$) shows the degree of the total influence of criterion i in the system. (4) Net-difference relationship ($r_i - s_i$): If ($r_i - s_i$) is positive, then criterion i has a net influence on the other criteria; conversely, if ($r_i - s_i$) is negative, then criterion i is generally influenced by the other criteria.

Table 1. Digital convergence development strategies in Taiwan

Objective	Orientations/ dimensions	Methods/criteria	Meanings/definitions
Digital convergence development strategies	D_1 Develop high-speed Internet and create a new video environment	C_{11} Promote the next-generation network	1. Expedite the establishment of optical networks 2. Promote the establishment of wireless broadband networks
		C_{12} Create a new video environment	1. Expand the service market for creating a new video environment 2. Effectively manage new media service industries
		C_{13} Create a comprehensive video environment with integrated access	1. Integrate new types of access 2. Comprehensively manage video content
	D_2 Promote the convergence of telecommunications and communication	C_{21} Promote mobile value-added services	1. Promote innovative mobile value-added applications and services 2. Innovative telematics application
		C_{22} Expedite the digitization of cable and wireless television	1. Establish a comprehensive mechanism for operating digital cable television 2. Promote digitization services for cable television 3. Expedite the digitization of wireless television 4. Increase the use of digital wireless television
		C_{23} Promote investments and development in the convergence industry	1. Encourage the innovative development of the content of digital television 2. Create an ideal environment for industry investments
	D_3 Mediate relative laws on convergence and the environment	C_{31} Adjust regulations on telecommunications and broadcasting	1. Promote the effective management of communications resources 2. Establish competition, comprehensive regulations, rates, and key facility management
		C_{32} Establish a comprehensive legal framework and related legislation for convergence	The increased use of digital convergence has caused single Internet providers to transform their services from a single service to diverse services. Therefore, amendments in the legal structure and the addition of related legislation are necessary to accommodate the development demands of the industry.
		C_{33} Decrease the digital gap and increase the use of related services	Complete the installation of broadband networks in remote regions and increase the use of cable television funds.

Source: Digital Convergence Policy Initiative (2010–2015) 2nd.

Table 2. Initializing the influence-related matrix ***A***

A	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}
C_{11}	0.000	3.467	3.000	2.467	2.667	3.267	2.467	2.533	2.667
C_{12}	2.200	0.000	3.333	2.400	2.400	2.667	2.200	2.267	2.267
C_{13}	2.067	3.333	0.000	2.333	2.600	2.467	2.067	2.400	2.467
C_{21}	2.267	2.467	2.400	0.000	1.467	2.067	2.333	2.067	2.467
C_{22}	2.600	2.533	2.933	2.133	0.000	2.333	2.400	2.333	2.400
C_{23}	2.400	2.400	2.800	2.533	2.200	0.000	2.267	2.333	2.667
C_{31}	2.667	2.933	3.000	2.400	2.667	3.067	0.000	3.133	2.533
C_{32}	2.733	3.000	2.867	2.600	2.933	3.200	3.133	0.000	3.067
C_{33}	2.467	2.067	2.267	2.000	2.333	2.600	2.467	2.400	0.000

Notes: Gap ratio $= \frac{1}{n(n-1)}\sum_{i=1}^{n}\sum_{j=1}^{n}\left(\left|a_{ij}^{p}-a_{ij}^{p-1}\right|/a_{ij}^{p}\right)\times 100\% = 2.4\% < 5\%$, i.e., significant confidence in consensus is 97.6%, where $p = 15$ and $p - 1 = 14$ denote the number of experts and a_{ij}^{p} is the 5average influence of *i* criterion on *j*; and *n* denotes number of criteria, here $n = 9$ and $n \times n$ matrix.

Table 3. Normalized influence-related matrix ***X***

X	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}
C_{11}	0.000	0.147	0.127	0.105	0.113	0.139	0.105	0.108	0.113
C_{12}	0.093	0.000	0.142	0.102	0.102	0.113	0.093	0.096	0.096
C_{13}	0.088	0.142	0.000	0.099	0.110	0.105	0.088	0.102	0.105
C_{21}	0.096	0.105	0.102	0.000	0.062	0.088	0.099	0.088	0.105
C_{22}	0.110	0.108	0.125	0.091	0.000	0.099	0.102	0.099	0.102
C_{23}	0.102	0.102	0.119	0.108	0.093	0.000	0.096	0.099	0.113
C_{31}	0.113	0.125	0.127	0.102	0.113	0.130	0.000	0.133	0.108
C_{32}	0.116	0.127	0.122	0.110	0.125	0.136	0.133	0.000	0.130
C_{33}	0.105	0.088	0.096	0.085	0.099	0.110	0.105	0.102	0.000

Table 4. The total influence-related matrix ***T*** (or called $\boldsymbol{T}_C$).

$\boldsymbol{T}_C$	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}
C_{11}	0.649	0.865	0.863	0.731	0.750	0.842	0.742	0.750	0.787
C_{12}	0.661	0.653	0.788	0.656	0.667	0.739	0.659	0.666	0.695
C_{13}	0.656	0.777	0.664	0.653	0.674	0.732	0.654	0.670	0.701
C_{21}	0.606	0.683	0.690	0.507	0.577	0.655	0.607	0.602	0.642
C_{22}	0.676	0.751	0.776	0.647	0.576	0.729	0.667	0.670	0.700
C_{23}	0.665	0.742	0.766	0.657	0.657	0.634	0.658	0.666	0.706
C_{31}	0.751	0.847	0.862	0.728	0.751	0.835	0.648	0.771	0.782
C_{32}	0.781	0.880	0.889	0.762	0.787	0.870	0.793	0.681	0.830
C_{33}	0.645	0.704	0.721	0.616	0.639	0.708	0.643	0.645	0.580

Table 5. The total influence-related matrix $\boldsymbol{T}_D$

$\boldsymbol{T}_D$	D_1	D_2	D_3
D_1	0.731	0.716	0.703
D_2	0.706	0.627	0.658
D_3	0.787	0.744	0.708

Table 6. The influential network relation on criteria

Criteria	r_i	s_i	$r_i + s_i$	$r_i - s_i$
C_{11}	6.978	6.091	13.070	0.887
C_{12}	6.184	6.902	13.086	-0.718
C_{13}	6.181	7.020	13.201	-0.839
C_{21}	5.571	5.958	11.529	-0.387
C_{22}	6.192	6.078	12.270	0.114
C_{23}	6.151	6.743	12.894	-0.592
C_{31}	6.976	6.070	13.046	0.906
C_{32}	7.273	6.121	13.394	1.152
C_{33}	5.900	6.423	12.323	-0.523

Table 7. The influential network relationships on dimensions

Dimensions	r_i	s_i	$r_i + s_i$	$r_i - s_i$
D_1	2.149	2.224	4.373	-0.074
D_2	1.990	2.087	4.077	-0.096
D_3	2.239	2.068	4.307	0.171

As shown in Figure 3, D_3 (Mediate relative laws on convergence and the environment) had the greatest influence on developing strategies for accelerating digital convergence because it affected D_1 (Develop high-speed Internet and create a new video environment), which in turn influenced D_2 (Promote the convergence of telecommunications and communication). Further analysis on the cause of this influence implied that the government must comply with relevant laws because Taiwan has an effective legal system. Convergence laws have established the foundation for the development of digital convergence. Therefore, the structure and orientation of these laws affect the developmental progress of high-speed broadband and the types of services (including innovative interactive video services) offered by the relevant industries. In other words, relevant laws and regulations are the key for the development of digital convergence.

In the D_1 orientation (dimension), the C_{11} method (criterion) for real-world application was influenced chiefly by the criterion for developing next-generation networks (NGNs). Moreover, C_{11} influenced C_{12} (create a new video environment), which in turn influenced C_{13} (create a comprehensive video environment with integrated access). Further analysis on the cause of this influence suggested that the Internet is a standard medium for disseminating information and offering services. The convergence of new service types depends on the NGN. New video services are unachievable without the NGN. In other words, enhancing the NGN is a key factor in establishing new video services, because such enhancements affect the convergence and integration of video content and access.

In D_2, C_{22} (expedite the digitalization of cable and wireless television) was the criterion with the largest influence. C_{22} affected C_{21} (promote mobile value-added services), which in

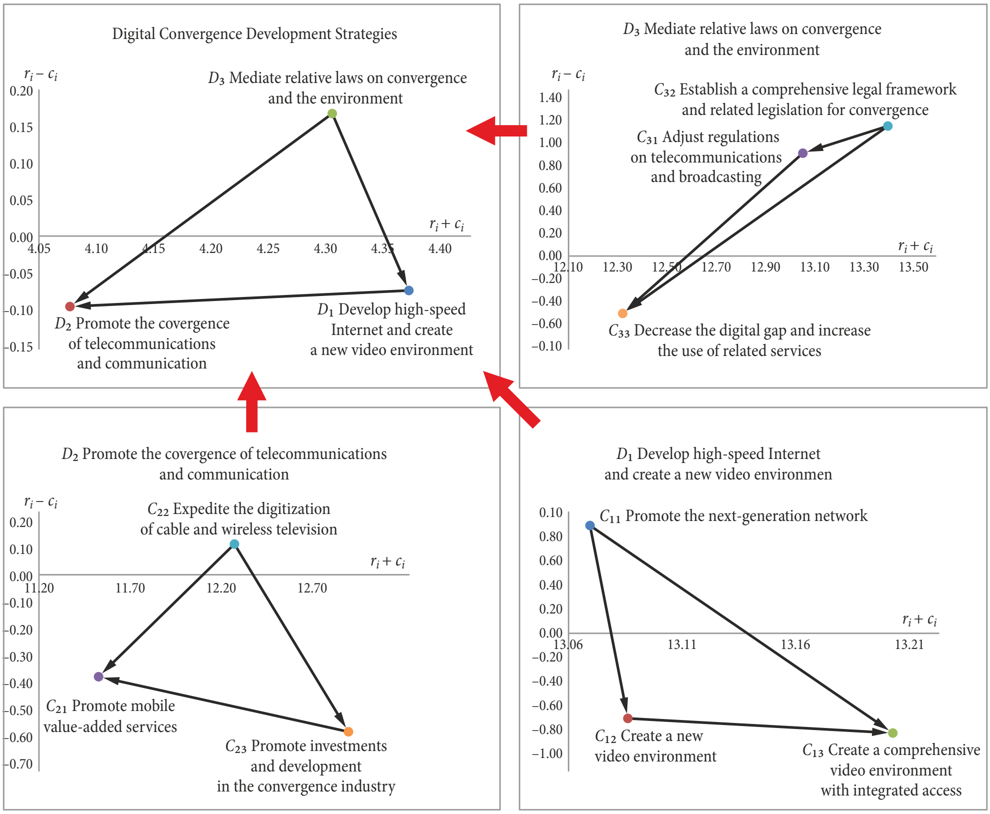

Fig. 3. Influential-network relationship map (INRM) of digital convergence for improvement strategies

turn influenced C_{23} (promote investments and development in the convergence industry). Between August and October 2013, 82.9% and 30.9% of households in Taiwan had cable and digital television, respectively (data obtained from the Directorate-General of Budget, Accounting, and Statistics, Executive Yuan, Taiwan). This indicates that cable television is accessible in most remote areas of Taiwan. Digital networks are a basic facility for providing various mobile value-added services. The digitalization of cable television is essential for increasing the accessibility of multiple digital channels and related services (e.g., education, shopping, and online platforms), which have considerable business potential. Thus, the digitalization progress for cable and wireless television has a major influence on the promotion of telecommunication and mobile value-added services. Furthermore, business opportunities offered by these services can benefit efforts expended in convergence development.

In D_3, C_{32} (establish a comprehensive legal framework and legislation pertaining to convergence) was the criterion with the greatest influence. C_{32} affected C_{31} (adjust regulations on telecommunications and broadcasting), which in turn influenced C_{33} (decrease the digital gap and increase the use of related services). Further analysis on the cause of this influence suggested that the government must comply with relevant laws because of

Taiwan's working legal system. Convergence laws act as indicators for establishing an environment conducive to convergence and related services. A complete legal framework and a formal legislative process are essential for supervisory authorities, and effectively combine broadcasting, telecommunications, and information. Without a comprehensive legal framework, the executive power of the supervisory authorities is limited, and developing convergence becomes difficult. The resultant digital convergence should benefit all people, including those in remote areas. A comprehensive legal framework and strong executive power for supervisory authorities are indispensable for guaranteeing equal accessibility. The Taiwan Telecommunications Act stipulates that the primary purposes of the Regulations on Telecommunications Universal Service are to supervise telecommunication carriers and ensure that the cost is not used to justify charging higher rates for clients in remote areas. If losses are incurred, carriers can apply for compensation from the central government. The enactment of the Regulations on Telecommunications Universal Service under the Telecommunications Act can effectively reduce the digital gap.

3.4. Using the DANP to establish weighted attributes for the criteria

An unweighted super-matrix $\boldsymbol{W}$ was established by transposing the normalized matrix $\boldsymbol{T}_C^{\alpha}$ (i.e., $\boldsymbol{W}=(\boldsymbol{T}_C^{\alpha})'$), the total influence-related matrix $\boldsymbol{T}_C$ of the criteria by dimension (Table 5) into Equations (B7) to (B11) (Appendix B, Step 1) (Table 8). Subsequently, Equations (B13) to (B15) (Appendix B, Step 2) were used to establish a weighted super-matrix $\boldsymbol{W}^{\alpha}=\boldsymbol{T}_D^{\alpha}\boldsymbol{W}$ (Table 9). Finally, a limitation, super-matrix $\lim_{z\to\infty}(\boldsymbol{W}^{\alpha})^z$ (Table 10), was employed to determine the weighted attributes $\boldsymbol{w}=(w_1,\ldots,w_j,\ldots,w_n)$ as the global weights of each criterion (Table 11). Table 12 lists the weighted attributes of the orientations (dimensions) and methods (criteria). The table shows that the weighted attributes in the orientation (dimensions) were ranked $D_1 > D_2 > D_3$. The influential weight ranking for the methods in D_1, D_2, and D_3 was $C_{13} > C_{12} > C_{11}$, $C_{23} > C_{22} > C_{21}$, and $C_{22} > C_{32} > C_{31}$, respectively.

Table 8. The un-weighted super-matrix $\boldsymbol{W}=(\boldsymbol{T}_C^{\alpha})'$

$\boldsymbol{W}$	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}
C_{11}	0.273	0.314	0.313	0.306	0.307	0.306	0.305	0.306	0.311
C_{12}	0.364	0.311	0.370	0.345	0.341	0.341	0.344	0.345	0.340
C_{13}	0.363	0.375	0.317	0.349	0.352	0.353	0.350	0.349	0.348
C_{21}	0.315	0.318	0.317	0.292	0.332	0.337	0.315	0.315	0.314
C_{22}	0.323	0.324	0.327	0.332	0.295	0.337	0.324	0.325	0.325
C_{23}	0.362	0.358	0.355	0.377	0.373	0.325	0.361	0.360	0.361
C_{31}	0.326	0.326	0.323	0.328	0.327	0.324	0.294	0.344	0.344
C_{32}	0.329	0.330	0.331	0.325	0.329	0.328	0.350	0.296	0.345
C_{33}	0.345	0.344	0.346	0.347	0.344	0.348	0.356	0.360	0.310

Table 9. The weighed super-matrix $\boldsymbol{W}^{\alpha} = \boldsymbol{T}_D^{\alpha}\boldsymbol{W}$

$\boldsymbol{W}^{\alpha}$	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}
C_{11}	0.093	0.107	0.106	0.109	0.109	0.109	0.107	0.108	0.109
C_{12}	0.124	0.106	0.126	0.122	0.121	0.121	0.121	0.121	0.120
C_{13}	0.123	0.128	0.108	0.124	0.125	0.125	0.123	0.123	0.122
C_{21}	0.105	0.106	0.106	0.092	0.104	0.106	0.105	0.105	0.104
C_{22}	0.108	0.108	0.109	0.104	0.093	0.106	0.108	0.108	0.108
C_{23}	0.121	0.119	0.118	0.119	0.118	0.102	0.120	0.120	0.120
C_{31}	0.106	0.107	0.106	0.108	0.108	0.107	0.093	0.109	0.109
C_{32}	0.108	0.108	0.108	0.107	0.109	0.108	0.111	0.093	0.109
C_{33}	0.113	0.112	0.113	0.115	0.114	0.115	0.112	0.114	0.098

Table 10. Limited super-matrix $\lim_{z\to\infty}(\mathbf{W}^{\alpha})^{z}$

Criteria	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}
C_{11}	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106
C_{12}	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120
C_{13}	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
C_{21}	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
C_{22}	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106
C_{23}	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117
C_{31}	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106
C_{32}	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
C_{33}	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112

Table 11. Influential weights (global weights) for each criterion (called DANP)

Criteria	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}
Influential weights	0.106	0.120	0.122	0.104	0.106	0.117	0.106	0.107	0.112

Table 12. Influential weights for global weights and local weights

Orientations/ Dimensions	Local weights	Ranking	Methods/ Criteria	Local weights	Ranking	Global weights	Ranking
D_1	0.348	1	C_{11}	0.305	3	0.106	6
			C_{12}	0.345	2	0.120	2
			C_{13}	0.350	1	0.122	1
D_2	0.327	2	C_{21}	0.317	3	0.104	9
			C_{22}	0.324	2	0.106	8
			C_{23}	0.359	1	0.117	3
D_3	0.325	3	C_{31}	0.326	3	0.106	7
			C_{32}	0.329	2	0.107	5
			C_{33}	0.345	1	0.112	4

3.5. Use of the modified VIKOR method for calculating performance gaps

The aspiration level can be defined as the presumption of future accomplishments. Although the set point of the aspiration level is a goal that is generally impossible to achieve, it can drive companies and governments wanting to become leaders in a specific area to actively conduct improvements. Therefore, the performance value of each criterion can be determined by distributing questionnaires with a scale ranging from 0 (*complete dissatisfaction/bad*) to 10 (*complete satisfaction/good*). The result of this performance value f_{kj} can initially be obtained using the simple additive weighting (SAW) method to assign each criterion to the most appropriate dimension, including even the overall performance value ($R_k = \sum_{j=1}^{n} w_j f_{kj}$; Table 13). We could also check the relationship between the performance value f_{kj} and performance gap ratio $r_{kj} = \left(\left|f_j^{aspired} - f_{kj}\right|\right) / \left(\left|f_j^{aspired} - f_j^{worst}\right|\right)$ (i.e., $f_{kj}=(1-r_{kj})\times 10$ in this instance). Thus, for this case, the aspiration level can be set as $f_j^{aspired} = 10$, and the worst value can be set as $f_j^{worst} = 0$ in $j = 1,2,...,n$. Consequently, we can set $f_j^{aspired} = 10$ as the aspiration level and $f_j^{worst} = 0$ as the worst value for normalization, in contrast to the traditional approach, which sets $f_j^* = \max_k f_{kj}$ and $f_j^- = \min_k f_{kj}$, respectively. We propose this new concept for improving the performance gap to avoid the traditional approach of selecting the best option among a set of inferior choices; i.e., avoid "pick the best apple among a barrel of rotten apples". The performance and differences in the case study can be calculated using Equations (C16) to (C21) (Appendix C). The results are shown in Table 13 and Figure 4.

Table 13 lists the ranking of the orientations (dimensions) from highest to lowest, which are as follows: D_3 (mediate laws pertaining to convergence and the environment); D_2 (promote the convergence of telecommunications and traditional communication mediums); and D_1 (develop high-speed Internet connections and create an innovative video environment). In D_1 (develop high-speed Internet connections and create an innovative video environment), C_{12} (create an innovative video environment) and C_{13} (create a comprehensive video environment with integrated access) exhibited the greatest difference (0.340). In D_2 (promote the convergence of telecommunications and traditional modes of communication), C_{23} (promote relevant investments and the acceleration of industrial convergence) exhibited the greatest difference (0.373). In D_3 (mediate laws on convergence and the environment), C_{33} (reduce the digital gap and increase the use of related services) exhibited the greatest difference (0.420). For greater clarity, these results are shown in Figure 4.

3.6. Discussion and implications

This study proposed an assessment model that provided an integrated perspective to assist decision makers in determining the reciprocal influence-relationship structure of all policies relating to digital convergence. When government decision makers can identify the weakest policies, the assessment model can assist them in proposing appropriate improvement strategies according to causality viewpoints.

Of all the orientations (dimensions), D_3 (Mediate relative laws on convergence and the environment) had the lowest performance. However, D_3 exerted the greatest influence on all the development strategies for digital convergence (Fig. 3). Therefore, despite the excel-

Table 13. Performance evaluation for the case study

Dimensions/criteria (orientations/dimensions)	Local weights (DANP)	Global weights (DANP)	Performance (SAW)	Gap (VIKOR)
D_1 Develop high-speed Internet and create a new video environment	0.348		6.986	0.301
C_{11} Promote the next-generation network	0.305	0.106	7.867	0.213
C_{12} Create a new video environment	0.345	0.120	6.600	0.340
C_{13} Create a comprehensive video environment with integrated access	0.350	0.122	6.600	0.340
D_2 Promote the convergence of telecommunications and communication	0.327		6.822	0.318
C_{21} Promote mobile value-added services	0.317	0.104	7.133	0.287
C_{22} Expedite the digitization of cable and wireless television	0.324	0.106	7.133	0.287
C_{23} Promote investments and development in the convergence industry	0.359	0.117	6.267	0.373
D_3 Mediate relative laws on convergence and the environment	0.325		6.215	0.379
C_{31} Adjust regulations on telecommunications and broadcasting	0.326	0.106	6.667	0.333
C_{32} Establish a comprehensive legal framework and related legislation for convergence	0.329	0.107	6.200	0.380
C_{33} Decrease the digital gap and increase the use of related services	0.345	0.112	5.800	0.420
Overall Total Performance and Gap	1.000	1.000	6.682	0.330

lent performance of D_1 (Develop high-speed Internet and create a new video environment) and D_2 (Promote the convergence of telecommunications and communication), D_3 had a negative effect on overall performance. Further analysis of the performance of the various dimensions and criteria (Table 13) revealed that the majority of internal criteria differences in D_3 exceeded those in D_1 and D_2, which is in agreement with the analytical results shown in Figure 3.

Overall improvements should be initiated using the internal criteria of D_3 (mediate laws on convergence and the environment). In D_3, C_{33} (reduce the digital gap and increase the use of related services) had the lowest performance (difference = 0.420). However, the criteria that influenced C_{33} were C_{32} (establish a comprehensive legal framework and related legislation for convergence) and C_{31} (adjust regulations on telecommunications and broadcasting). The difference between C_{32} and C_{33} was low; therefore, by enhancing the performance of both criteria, that of C_{33} can be raised further, thereby enhancing the overall performance of D_3.

According to the findings obtained using the proposed model, the case subjects should be improved using D_3 (Mediate relative laws on convergence and the environment). An increase in model performance was beneficial for improving the developments of all relevant policies.

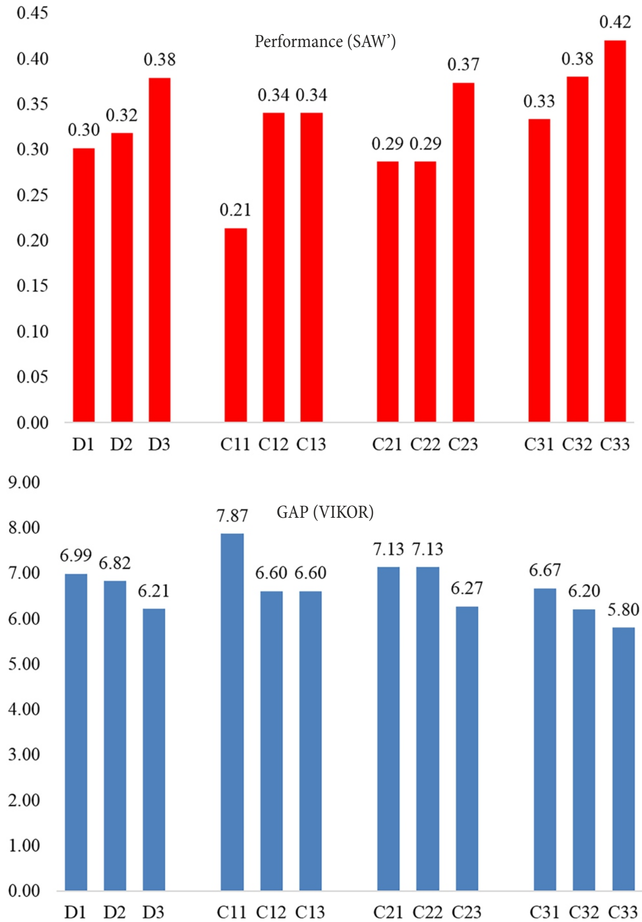

Fig. 4. The performance and gap of digital convergence strategies

Conclusions

The Internet is a virtual platform that provides convenient transaction services to people from different countries, enabling transaction-related actions and information (regardless of whether the transaction involves cash, logistics, or information) can be executed and acquired online, respectively. The rapid advancement of Internet-related software and hardware (e.g., mobile-payment functions and smartphones, respectively) was one of the most critical developments in the past decade. Hundreds of millions of people now own a smartphone, which they use to make payments on public transport, the Internet, in brick-and-mortar stores, and elsewhere. Transactions conducted using smartphones can be considered one of the main transaction methods for this generation. These emerging modes of electronic transactions have developed because of digital convergence. Every developed country and union (e.g., the United States, Japan, South Korea, and the European Union) have been actively developing policies relating to digital convergence, which will facilitate the future switchover to borderless e-transaction modes.

The Digital Convergence Policy Initiative (2010–2015) was passed by the Executive Yuan of Taiwan in December 2010. Aimed at promoting an ideal environment conducive for digital convergence, the initiative has gained considerable recognition, indicating the rapid advancement of communication technology in Taiwan. To further refine Taiwan's digitalization agenda and provide high-speed and high-quality digital services, the Executive Yuan of Taiwan in May 2012 authorized and approved the second edition of the Digital Convergence Policy Initiative, which was aimed at making the environment more conducive for digital convergence in Taiwan.

All countries have a specific policy orientation for accelerating digital convergence. These policies include various development approaches that are used to accelerate digital convergence. However, these methods are interrelated, and the poor performance of one method affects the performance of others. To resolve this problem, this study proposed a hybrid MCDM model.

DEMATEL technique was employed to examine the causality and relationship of the methods (dimensions and criteria). The DANP was then used to determine the weighted attributes, and we used the ANP for our calculations. The results were used to facilitate performance evaluations by employing VIKOR, so that we could transform the influential relationship problems to more accurately reflect real issues. The aspiration level concept was employed to explore the difference between each solution (dimensions and criteria) and the aspired solution. Once the poorly performing methods (dimensions and criteria) were determined, an INRM, established using DEMATEL, was used to identify the method (dimensions and criteria) with the lowest performance, and proposed improvement strategies with causality or relationships.

In this study, the development strategies for digital convergence used by the Taiwan government were examined by 15 experts with practical experience in developing the dimensions and criteria (i.e., orientations and methods, respectively) for evaluating case studies. The results revealed that the overall performance of the environment for digital convergence development was poor, thus necessitating substantial improvements. Among the dimensions examined, the legal environment for digital convergence was found to require the most attention. Furthermore, the legal environment was found to exert a major influence in the model. Therefore, such improvements can be achieved through the prompt establishment of a comprehensive legal framework and related legislation pertaining to convergence, followed by adjusting regulations on telecommunications and broadcasting, and finally by reducing the digital gap and increasing the use of related services.

The contributions of our proposed model can be summarized as follows: (1) The INRM can be used to assist government bodies in understanding the influence and relationships of digital convergence development; (2) The modified VIKOR can be employed to determine the disparity between development standards and ideal solutions by considering the aspiration level, thereby enabling the minimization of differences in digital convergence development; (3) The model can help decision makers to avoid choosing the optimal inferior alternative, even though the optimal alternative can be employed to achieve a certain aspiration level through continuous improvement. These contributions are crucial practices in strategic development because expert knowledge is frequently ambiguous. When experts complete questionnaires, their judgments and preferences are difficult to quantify in exact numerical values because of the inherent vagueness of human language in perception and feeling. Therefore, we recommend that future researchers include fuzzy logic in their research procedures.

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APPENDIX

Appendix A. DEMATEL technique for building the influence-related matrix and constructing the influential network relation map (INRM)

Step 1: Calculating the direct influence-related matrix using scores.

Experts were asked to indicate the direct effect that they believed factor i would have on factor j, which is denoted as a_{ij}. The matrix $\boldsymbol{A} = [a_{ij}]_{n \times n}$ of direct relations can thus be obtained. In the DEMATEL formulation, respondents indicate the degree of direct influence on a scale of 0 to 4: "*No influence*" (0), "*Low influence*" (1), "*Medium influence*" (2), "*High influence*" (3), and "*Very high influence*" (4).

Step 2: Normalizing the direct influence-related matrix A.

Based on the direct influence-related matrix $\boldsymbol{A} = [a_{ij}]_{n \times n}$, the normalized direct influence-related matrix $\boldsymbol{X} = [x_{ij}]_{n \times n}$ is acquired using Eqs (A1) and (A2):

$$\boldsymbol{X} = k\boldsymbol{A}; \tag{A1}$$

$$k = \min\left\{1 / \max_i \sum\nolimits_{j=1}^{n} a_{ij}, 1 / \max_j \sum\nolimits_{i=1}^{n} a_{ij}\right\}, \ i, j \in \{1, 2, ..., n\}. \tag{A2}$$

Step 3: Attaining the total influence-related matrix T.

Once the normalized direct influence-related matrix $\boldsymbol{X}$ is obtained, the total influence-related matrix $\boldsymbol{T}$ to construct the influential network relation map (INRM) can be obtained using Eq. (A3), where $\boldsymbol{I}$ denotes the identity matrix:

$$\boldsymbol{T} = \boldsymbol{X} + \boldsymbol{X}^2 + \boldsymbol{X}^3 + ... + \boldsymbol{X}^h = \boldsymbol{X}(\boldsymbol{I} + \boldsymbol{X} + \boldsymbol{X}^2 + ... + \boldsymbol{X}^{h-1})[(\boldsymbol{I} - \boldsymbol{X})(\boldsymbol{I} - \boldsymbol{X})^{-1}] = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X}^h)(\boldsymbol{I} - \boldsymbol{X})^{-1}.$$

$$\text{Then, } \boldsymbol{T} = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})^{-1}, \text{ when } k \to \infty \text{ and } \lim_{h \to \infty} \boldsymbol{X}^h = [0]_{n \times n}, \tag{A3}$$

where $\boldsymbol{X} = [x_{ij}]_{n \times n}$, $0 \le x_{ij} < 1$, $0 < \sum\nolimits_{j=1}^{n} x_{ij} \le 1$, $0 < \sum\nolimits_{i=1}^{n} x_{ij}$. If the summation of at least one row or column is equal to 1 (but not all) in $\sum\nolimits_{j=1}^{n} x_{ij}$ and $\sum\nolimits_{i=1}^{n} x_{ij}$, then $\lim_{h \to \infty} \boldsymbol{X}^h = [0]_{n \times n}$ is guaranteed.

Step 4: Analyzing the results.

At this stage, the sum of rows $\sum\nolimits_{j=1}^{n} t_{ij} = t_i = r_i$ and the sum of columns $\sum\nolimits_{i=1}^{n} t_{ij} = t_j = s_j$ are separately expressed as vector $\boldsymbol{r} = (r_1, ..., r_i, ..., r_n)'$ and vector $\boldsymbol{s} = (s_1, ..., s_j, ..., s_n)'$ by using Eqs. (A4)–(A6). Let $i = j$ and $i, j \in \{1, 2, ..., n\}$; the horizontal axis vector ($r_i + s_i$) is then created by adding r_i to s_i, which reveals the importance of the criterion. Similarly, the vertical axis vector ($r_i - s_i$) is constructed by subtracting r_i from s_i, which may separate criteria into a cause group and an effect group. In general, when ($r_i - s_i$) is positive, the criterion belongs to the cause group. By contrast, if vector ($r_i - s_i$) is negative, the criterion is part of the effect group. Therefore, the causal graph can be achieved by mapping the dataset of vectors ($r_i + s_i$, $r_i - s_i$), thus providing a valuable approach to decision making.

$$\boldsymbol{T}=[t_{ij}]_{n\times n},\ \ i,j=1,2,...,n; \tag{A4}$$

$$\boldsymbol{r}=[r_i]_{n\times 1}=\left[\sum\nolimits_{j=1}^{n}t_{ij}\right]_{n\times 1}=(r_1,...,r_i,...,r_n)'; \tag{A5}$$

$$\boldsymbol{s}=[s_j]'_{1\times n}=\left[\sum\nolimits_{i=1}^{n}t_{ij}\right]'_{1\times n}=(s_1,...,s_j,...,s_n)', \tag{A6}$$

where vector $\boldsymbol{r}$ and vector $\boldsymbol{s}$ express the sum of rows and the sum of columns from total influence-related matrix $\boldsymbol{T}$, respectively, and the use of sup superscript $'$ denotes transpose.

Appendix B. Finding the influential weights of DANP (or called DANP-weights attributes) method from total influence-related matrix T_C and T_D

Step 1: Determining the influential weights by using the DANP based on total influence-related matrix $\boldsymbol{T}_C$ and $\boldsymbol{T}_D$.

At this step, the un-weighted super-matrix is constructed. First, each level is normalized to the total degree of effect based on the total influence-related matrix $\boldsymbol{T}_C$ by using the DEMATEL, as shown in Eq. (B7), where $\sum\nolimits_{j=1}^{m}m_j=n$, $m<n$, and $\boldsymbol{T}_c^{ij}$ as a $m_i \times m_j$ matrix:

$$\boldsymbol{T}_C=\begin{array}{c} \\ \\ D_1 \\ \vdots \\ D_i \\ \vdots \\ D_m \end{array}\begin{array}{c} \\ \\ c_{11}\, c_{12} \cdots c_{1m_1} \\ \vdots \\ c_{i1}\, c_{i2} \cdots c_{im_i} \\ \vdots \\ c_{m1}\, c_{m2} \cdots c_{mm_m} \end{array}\overset{\begin{array}{ccccc} D_1 & & D_j & & D_m \\ c_{11}...c_{1m_1} & \cdots & c_{j1}...c_{jm_j} & \cdots & c_{m1}...c_{mm_m} \end{array}}{\begin{bmatrix} \boldsymbol{T}_c^{11} & \cdots & \boldsymbol{T}_c^{1j} & \cdots & \boldsymbol{T}_c^{1m} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{i1} & \cdots & \boldsymbol{T}_c^{ij} & \cdots & \boldsymbol{T}_c^{im} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{m1} & \cdots & \boldsymbol{T}_c^{mj} & \cdots & \boldsymbol{T}_c^{mm} \end{bmatrix}}_{n\times n|m<n,\ \sum_{j=1}^{m}m_j=n.} \tag{B7}$$

Next, $\boldsymbol{T}_C$ is normalized to the total degree of influence, then $\boldsymbol{T}_C^{\alpha}$ is obtained, as shown in Eq. (B8):

$$\boldsymbol{T}_C^{\alpha}=\begin{array}{c} \\ \\ D_1 \\ \vdots \\ D_i \\ \vdots \\ D_m \end{array}\begin{array}{c} \\ \\ c_{11}\, c_{12} \cdots c_{1m_1} \\ \vdots \\ c_{i1}\, c_{i2} \cdots c_{im_i} \\ \vdots \\ c_{m1}\, c_{m2} \cdots c_{mm_m} \end{array}\overset{\begin{array}{ccccc} D_1 & & D_j & & D_m \\ c_{11}...c_{1m_1} & \cdots & c_{j1}...c_{jm_j} & \cdots & c_{m1}...c_{mm_m} \end{array}}{\begin{bmatrix} \boldsymbol{T}_c^{\alpha 11} & \cdots & \boldsymbol{T}_c^{\alpha 1j} & \cdots & \boldsymbol{T}_c^{\alpha 1m} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha i1} & \cdots & \boldsymbol{T}_c^{\alpha ij} & \cdots & \boldsymbol{T}_c^{\alpha im} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha m1} & \cdots & \boldsymbol{T}_c^{\alpha mj} & \cdots & \boldsymbol{T}_c^{\alpha mm} \end{bmatrix}}_{n\times n|m<n,\ \sum_{j=1}^{m}m_j=n.} \tag{B8}$$

Then, $\boldsymbol{T}_C^{\alpha 11}$ is normalized using Eqs. (B9) and (B10), and the process is repeated to obtain $\boldsymbol{T}_C^{\alpha mm}$:

$$d_i^{11}=\sum\nolimits_{j=1}^{m_1}t_{c^{ij}}^{11},\ \ i=1,2,\cdots,m_1; \tag{B9}$$

$$T_C^{\alpha 11} = \begin{bmatrix} t_{c11}^{11}/d_1^{11} & \cdots & t_{c1j}^{11}/d_1^{11} & \cdots & t_{c1m_1}^{11}/d_1^{11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{11}/d_i^{11} & \cdots & t_{cij}^{11}/d_i^{11} & \cdots & t_{cim_1}^{11}/d_i^{11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{11}/d_{m_1}^{11} & \cdots & t_{cm_1j}^{11}/d_{m_1}^{11} & \cdots & t_{cm_1m_1}^{11}/d_{m_1}^{11} \end{bmatrix} = \begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{c1j}^{\alpha 11} & \cdots & t_{c1m_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{\alpha 11} & \cdots & t_{cm_11}^{\alpha 11} & \cdots & t_{cm_1m_1}^{\alpha 11} \end{bmatrix}. \tag{B10}$$

The total influence-related matrix $\boldsymbol{T}$ match and fill into the interdependence clusters which can be normalized as the normalized matrix $\boldsymbol{T}_C^{\alpha}$ (as Eq. (B8)). It will be called an un-weighted super-matrix $\boldsymbol{W}$ as shown as Eq. (B11), which is based on transposing the normalized influence-related matrix $\boldsymbol{T}_C^{\alpha}$ by dimensions (clusters), i.e. $\boldsymbol{W} = (\boldsymbol{T}_c^{\alpha})'$:

$$\boldsymbol{W} = (\boldsymbol{T}_c^{\alpha})' = \begin{array}{c} D_1 \\ \vdots \\ D_j \\ \vdots \\ D_m \end{array} \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \\ \vdots \\ c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_i} \\ \vdots \\ c_{m1} \\ c_{m2} \\ \vdots \\ c_{mm_m} \end{array} \overset{\begin{array}{ccc} D_1 & D_i & D_m \\ c_{11}\ldots c_{1m_1} \cdots & c_{i1}\ldots c_{im_i} \cdots & c_{m1}\ldots c_{mm_m} \end{array}}{\begin{bmatrix} \boldsymbol{W}^{11} & \cdots & \boldsymbol{W}^{i1} & \cdots & \boldsymbol{W}^{m1} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1j} & \cdots & \boldsymbol{W}^{ij} & \cdots & \boldsymbol{W}^{mj} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1m} & \cdots & \boldsymbol{W}^{im} & \cdots & \boldsymbol{W}^{mm} \end{bmatrix}}_{n \times n | m < n, \sum_{j=1}^{m} m_j = n.} \tag{B11}$$

In addition, $\boldsymbol{W}^{11}$ can be obtained using Eq. (B12). A blank space or **0** in the matrix indicates that the group or criterion is independent and with no interdependence. And other $\boldsymbol{W}^{mm}$ can be obtained similarly:

$$\boldsymbol{W}^{11} = (\boldsymbol{T}^{11})' = \begin{array}{c} \boldsymbol{c}_{11} \\ \vdots \\ \boldsymbol{c}_{1j} \\ \vdots \\ \boldsymbol{c}_{1m_1} \end{array} \overset{\begin{array}{ccccc} \boldsymbol{c}_{11} & \cdots & \boldsymbol{c}_{1i} & \cdots & \boldsymbol{c}_{1m_1} \end{array}}{\begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{ci1}^{\alpha 11} & \cdots & t_{cm_11}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{c1j}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cm_1j}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{c1m_1}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} & \cdots & t_{cm_1m_1}^{\alpha 11} \end{bmatrix}}. \tag{B12}$$

Step 2: Obtaining the weighted super-matrix.

This step is used to obtain the weighted super-matrix $\boldsymbol{W}^{\alpha}$ using the total influence-related matrix $\boldsymbol{T}_D$ by dimensions, as shown in Eq. (B13). Each level and the dimensions of influence-related matrix $\boldsymbol{T}_D$ are normalized to the total degree of influence relation by dimension as $\boldsymbol{T}_D^{\alpha}$, as shown in Eq. (B14).

$$\boldsymbol{T}_D = \begin{bmatrix} t_D^{11} & \cdots & t_D^{1j} & \cdots & t_D^{1m} \\ \vdots & & \vdots & & \vdots \\ t_D^{i1} & \cdots & t_D^{ij} & \cdots & t_D^{im} \\ \vdots & & \vdots & & \vdots \\ t_D^{m1} & \cdots & t_D^{mj} & \cdots & t_D^{mm} \end{bmatrix}_{m \times m}. \tag{B13}$$

We normalized the total influence-related matrix $\boldsymbol{T}_D$, and obtained a normalized matrix $\boldsymbol{T}_D^{\alpha}$, as shown as Eq. (B14), where $d_i = \sum_{j=1}^{n} t_D^{ij}$ and $t_D^{\alpha ij} = t_D^{ij} / d_i$:

$$\boldsymbol{T}_D^{\alpha} = \begin{bmatrix} t_D^{11}/d_1 & \cdots & t_D^{1j}/d_1 & \cdots & t_D^{1m}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_D^{i1}/d_i & \cdots & t_D^{ij}/d_i & \cdots & t_D^{im}/d_i \\ \vdots & & \vdots & & \vdots \\ t_D^{m1}/d_m & \cdots & t_D^{mj}/d_m & \cdots & t_D^{mm}/d_m \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \cdots & t_D^{\alpha 1j} & \cdots & t_D^{\alpha 1m} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha i1} & \cdots & t_D^{\alpha ij} & \cdots & t_D^{\alpha im} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha m1} & \cdots & t_D^{\alpha mj} & \cdots & t_D^{\alpha mm} \end{bmatrix}_{m \times m}. \tag{B14}$$

We use $\boldsymbol{T}_D^{\alpha}$ to normalize the un-weighted super-matrix, then the weighted super-matrix $\boldsymbol{W}^{\alpha}$ can be obtained, as shown in Eq. (B15), where $t_D^{\alpha ij}$ is a scalar and $\sum_{j=1}^{m} m_j = n$:

$$\boldsymbol{W}^{\alpha} = \boldsymbol{T}_D^{\alpha}\boldsymbol{W} = \begin{bmatrix} t_D^{\alpha 11} \times \boldsymbol{W}^{11} & \cdots & t_D^{\alpha i1} \times \boldsymbol{W}^{i1} & \cdots & t_D^{\alpha m1} \times \boldsymbol{W}^{m1} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1j} \times \boldsymbol{W}^{1j} & \cdots & t_D^{\alpha ij} \times \boldsymbol{W}^{ij} & \cdots & t_D^{\alpha mj} \times \boldsymbol{W}^{mj} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1m} \times \boldsymbol{W}^{1m} & \cdots & t_D^{\alpha im} \times \boldsymbol{W}^{im} & \cdots & t_D^{\alpha mm} \times \boldsymbol{W}^{mm} \end{bmatrix}_{n \times n | m < n,\ \sum_{j=1}^{m} m_j = n.} \tag{B15}$$

Step 3: Limiting the weighted super-matrix.

This step is used to obtain the limit super-matrix. The weighted super-matrix is multiplied by itself multiple times to a sufficiently large power z based on the concept of Markov Chain, until the super-matrix has converged and become a long-term stable super-matrix to obtain the global influential weights $(w_1,...,w_j,...,w_n)$, called DANP (DEMATEL-based ANP), such as $\lim_{z\to\infty}(\boldsymbol{W}^{\alpha})^z$, where z represents any number of power.

Appendix C: Modified VIKOR method

Step 1: Set f_j^{aspire} as the aspiration level and f_j^{worst} as the worst value in the performance matrix.

We use the performance scores with measuring range from 0 to 10 in questionnaires of each criterion as: *Complete dissatisfaction/bad ← 0,1,2,..,4,5,6,…,8,9,10 → Extreme sat-*

isfaction/good. So the aspiration level and the worst value can be set as $f_j^{aspired} = 10$ and $f_j^{worst} = 0$ in each criterion *j*, *j* = 1, 2,…, *n* respectively. Then in this real research case, we conduct to modify the traditional VIKOR approach, which sets the positive ideal point $f_j^{*} = \max_k f_{kj}$ and the negative ideal point $f_j^{-} = \min_k f_{kj}$ in alternatives with *k* = 1, 2,…, *K*, changing to set the aspiration level as $f_j^{aspired} = 10$ and the worst value as $f_j^{worst} = 0$, called "modified VIKOR method" for normalizing the performance matrix $[f_{kj}]_{m \times n}$ into the performance gap ratios in $[r_{kj}]_{m \times n}$ as follow:

$$[r_{kj}]_{m \times n} = \left[\left(\left| f_j^{aspired} - f_{kj} \right| \right) \Big/ \left(\left| f_j^{aspired} - f_j^{worst} \right| \right) \right]_{m \times n}. \quad \text{(C16)}$$

We propose this new idea, not only for using performance ranking and selection, but also for using performance-gap improvement in alternatives to avoid the traditional approach "choosing the best among the inferior choices/options/alternatives, i.e., pick the best apple in a barrel of rotten apples".

The aspiration levels, vector $\boldsymbol{f}^{aspired} = (f_1^{aspired}, \ldots, f_j^{aspired}, \ldots, f_n^{aspired})$. (C17)

The worst values, vector $\boldsymbol{f}^{worst} = (f_1^{worst}, \ldots, f_j^{worst}, \cdots, f_n^{worst})$. (C18)

Step 2: calculate the minimal mean of the group utility F_k (minimal average gap) and maximal regret Q_k (maximal gap for all criteria or for each aspect of criteria to give the improvement priority).

$$L_k^{p=1} = F_k = \sum_{j=1}^{n} w_j r_{kj} = \sum_{j=1}^{n} w_j \left(\left| f_j^{aspired} - f_{kj} \right| \right) \Big/ \left(\left| f_j^{aspired} - f_j^{worst} \right| \right); \quad \text{(C19)}$$

$$L_k^{p=\infty} = Q_k = \max_j \left\{ r_{kj} \mid j = 1, 2, \ldots, n \right\}, \quad \text{(C20)}$$

where $r_{kj} = \left(\left| f_j^{aspired} - f_{kj} \right| \right) \Big/ \left(\left| f_j^{aspired} - f_j^{worst} \right| \right)$ represents the gap ratio (i.e., by normalization scale); F_k represents the ratios of the average gap from aspiration level $f_j^{aspired}$ to performance value f_{kj} in criterion *j* of alternative *k* in this article, we focus on how to minimalize the performance gap ratios r_{kj} for all criteria *j* = 1, 2,…, *n*. We also can check the relationship between performance value f_{kj} and performance gap ratio, i.e., $(1 - r_{kj}) \times 10$ of modified VIKOR in this case by $(1 - r_{kj}) \times 10 = \left[1 - \left(\left| f_j^{aspired} - f_{kj} \right| \right) \Big/ \left(\left| f_j^{aspired} - f_j^{worst} \right| \right) \right] \times 10 = f_{kj}$, when scale $f_j^{aspired}$=10 and f_j^{worst}=0. Then, w_j represents the relative influential weight (from DANP) of criterion *j* (*j* = 1, 2,…, *n*).Q_k represents the maximum gap for all criteria (or the dimension of each criterion of the *k* -th alternative for improvement priority).

Step 3: obtains the comprehensive indicator R_k and its sorted results.

Eq. (C20) can compute R_k integrated value. From Eq. (C20), we observe how we can improve the implementation of improving the digital convergence in contemporary information-oriented society to reduce the gaps in achieving the desired level based on the INRM.

$$R_k = v\left(F_k - F^{aspired}\right) \Big/ \left(F^{worst} - F^{aspired}\right) + (1 - v)\left(Q_k - Q^{aspired}\right) \Big/ \left(Q^{worst} - Q^{aspired}\right). \quad \text{(C21)}$$

Using the values derived from $F^{aspired} = 0$ (achieving the desired level where the gap is zero), $F^{worst} = 1$ (the worst situation); $Q^{aspired} = 0$ (achieving the aspiration level), $Q^{worst} = 1$ (the worst situation). Thus, we can re-write Eq. (C21) as $R_k = vF_k + (1-v)Q_k$. The weight $v = 1$ only considers how we can minimize the average gap (average regret), and the weight $v = 0$ only determines how to select the maximum gap for prior improvement. In general, $v = 0.5$, which can be adjusted depending on the situation.

Appendix D: the questionnaire

AD.1 The questionnaire for Survey of the level of importance and satisfaction of the performance evaluation standard

Completely unimportance or completely dissatisfaction ← 0,1,2,3,4,5,6,7,8,9,10 →Very importance or very satisfaction

Dimensions	Criteria	Very unimportance ← 0,1,2,.., 8,9,10 → Very importance	Very dissatisfaction/poor ← 0,1,2,.., 8,9,10 → Very satisfaction/good
D_1 Develop high-speed Internet and create a new video environment	C_{11} Promote the next-generation network		
	C_{12} Create a new video environment		
	C_{13} Create a comprehensive video environment with integrated access		
D_2 Promote the convergence of telecommunications and communication	C_{21} Promote mobile value-added services		
	C_{22} Expedite the digitization of cable and wireless television		
	C_{23} Promote investments and development in the convergence industry		
D_3 Mediate relative laws on convergence and the environment	C_{31} Adjust regulations on telecommunications and broadcasting		
	C_{32} Establish a comprehensive legal framework and related legislation for convergence		
	C_{33} Decrease the digital gap and increase the use of related services		

AD.2 The questionnaire of DEMATEL technique

No.1	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}
C_{11}									
C_{12}									
C_{13}									
C_{21}									
C_{22}									
C_{23}									
C_{31}									
C_{32}									
C_{33}									

Note: the degree of direct influence on a scale of 0 to 4: "No influence" (0), "Low influence" (1), "Medium influence" (2), "High influence" (3), and "Very high influence" (4).

Appendix E: the brief list of fifteen experts

Category	No.	Job Title
Official unit	1	Transport Minister
	2	Ministry of Transportation special committee
	3	Ministry of Transportation special committee
	4	Members of the Executive Yuan
	5	Deputy Secretary Ministry of Economic Affairs
Academic institutions	6	Professor
	7	Professor
	8	Professor
	9	Associate Professor
	10	Associate Professor
Business institutions	11	Technologies Board of Directors
	12	Department Manager of Smartphone
	13	Vice General Manager Telecommunications
	14	Digital network manager
	15	Digital audio and video multimedia department manager

Wan-Chi Jackie HSU is a doctoral candidate at the Department of Business Administration of National Central University in Taiwan. She had worked in Ministry of Transportation Department over 15 years. In past, she was an executive secretary in Ministry of Transportation Department, and was also a vice director in Yang Ming Shipping Company. Currently, she is a Chief Executive Officer in ChenXin International Company Limited. Her research interest is applying hybrid MCDM method to solve some problems in digital convergence.

Ming-Hone TSAI received his PhD degree from the Department of Business Administration of Cheng-Chi University in Taiwan. Currently, he is an Association Professor in the Department of Business Administration of National Central University in Taiwan. He has published in numerous journals, including *International Journal of Electronic Business Management, Journal of Consumer marketing, Journal of Consumer marketing, International Journal of Management and Decision Making, Annals of Tourism Research, Management Science, Journal of Business Venturing*, etc. His research interest in business policy and organization theory.

Gwo-Hshiung TZENG, in 1967, he received the Bachelor's degree in Business Management from the Tatung Institute of Technology (now Tatung University) in Taiwan; in 1971, he received the Master's degree in Urban Planning from National Chung Hsing University (now National Taipei University), Taiwan; and in 1977, he received the PhD degree course at Graduate School of Economics (major in management science) from Osaka University, Osaka, Japan. He was an Associate Professor at National Chiao Tung University, Taiwan (1977–1981), a Research Associate at Argonne National Laboratory (July 1981–January 1982), a Visiting Professor in the Department of Civil Engineering at University of Maryland, College Park (August 1989–August 1990), a Visiting Professor in the Department of Engineering and Economic System, Energy Modeling Forum at Stanford University (1997 August–1998 August), a Professor at National Chaio Tung University (1981–2003) and a Chair Professor at National Chiao Tung University (2003–lifelong), a President (2004–2005) and Distinguished Chair Professor (2004–2013) at Kainan University, and a Distinguished Chair Professor at National Taipei University (from 2013–present). He received the MCDM Edgeworth-Pareto Award from the International Society on Multiple Criteria Decision Making (June 2009), the world Pinnacle of Achievement Award in 2005, and the National Distinguished Chair Professor Award (highest honor offered) of the Ministry of Education Affairs of Taiwan in 2000–2003; additionally, he received three times of a distinguished research award and twice named a distinguished research fellow (highest honor offered) of the National Science Council of Taiwan (now MOST of Taiwan). His current research interests include statistics, multivariate analysis, econometrics, network, routing and scheduling, multiple criteria decision making, fuzzy theory, hierarchical structure analysis for applying the real cases to economics and business, technology management, energy conservation, environment management, transportation systems and management, transportation planning and investment, logistics, location, urban planning, tourism management, electronic commerce, global supply chain, etc.; in recent he created and developed "New Concepts and Trends of New Hybrid MCDM (MRDM, MADM, and MODM) Methods for Tomorrow" for solving the real world problems.