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A Hybrid MCDM Model for Improving the Electronic Health Record to Better Serve Client Needs

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Abstract: Although the electronic health record (EHR) is a promising innovation in the healthcare industry, the implementation of EHR has been relatively slow. A theoretical structure for the exploration and improvement of this usage of EHR is proposed. Incorporating the theoretical structure of TOE (technology-organization-environment), we apply the DEMATEL (decision-making trial and evaluation laboratory) technique to illustrate the influence-matrix and to construct the INRM (influential network relationship map). Based on this DEMATEL influence matrix and the fundamental concepts of ANP (Analytic Hierarchy Process), we derive influential weights for the criteria. These influential weights are then combined with the modified VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method to find ways to understand and enhance the usage of EHR technology. The outcome demonstrates that our model can not only be used for implementation of EHR technology, but can also be applied to analyze the gaps in performance between the aspiration level and present performance values in individual criterion/dimension.

Keywords: electronic health record (EHR); technology-organization-environment (TOE); MCDM; DEMATEL; DANP; VIKOR; healthcare industry

1. Introduction

Electronic health record (EHR) technology is one of the most promising innovations for sustainable development in the healthcare industry [1]. An EHR is defined as an electronic health-related record of an individual's health history that accords with nationally recognized interoperability principles and that can be consulted, managed, and created by staff members and authorized clinicians in more than one healthcare institution [2,3]. EHRs allow healthcare providers to exchange and store health information using computers rather than keeping the records on paper [1,4]. The current focus in Taiwan is a reduction in healthcare costs and improvement in quality, which has led both practitioners and policymakers to advocate for the implementation of health information technology (IT). EHR could provide a solid foundation for change and sustainable improvement in the Taiwanese healthcare systems. Anecdotal evidence suggests that it is concerns for privacy protection that partially explain the slow pick-up rate for EHR. However, EHR technology has the potential to drastically change healthcare by making services more efficient while also ensuring better healthcare quality by automating procedures, providing more detailed documentation, and disseminating individual health records for sustained development [1,5].

Despite these advantages, the adoption of EHR has been slow. Barriers to implementation could include concerns with privacy and finances, and resistance from physicians [1,3,6,7].

Even in surroundings where EHR implementation has spread beyond the earliest adopters to over half the healthcare industry, little is known about organizational perspectives on EHR implementation and application. The adoption of EHRs has substantially changed practices for most physicians, with early evidence of improvements as well as difficulties [8,9]. Documenting visits, gathering patient study results, entering orders, and communicating with colleagues and with patients are all very different with EHR [8–11]. Although there are many advantages to this system, adoption rates have been fairly low in community clinics [8–11] in the face of a number of obstacles [8–13]. One major factor is the financial cost of the system [12,13]. Other issues relate to technology, organization, and environment. Hence, the most important question that must be answered when evaluating EHR implementation for the sustained development of a healthcare system is which criteria should be emphasized. In practice, there are many different criteria, of varying importance, which interrelate with each other. Conventional decision models do not consider the interrelationships between different criteria with different levels of relative importance. To solve the aforementioned problems, we recommend an integrated approach using a multiple criteria decision making (MCDM) model with the DEMATEL (decision-making trial and evaluation laboratory) to build an influential network relationship map (INRM), DANP (DEMATEL-based ANP) to determine the influential weights of the dimensions/criteria, and a modified VIKOR method to examine how to reduce the gaps to sustainable performance for the entire systems to achieve the aspiration level. These issues are addressed while also considering implementation measures and how to improve the EHR for the entire healthcare systems to better serve client needs. This paper outlines a theoretical structure for examination of the prevalence of the technological, organizational, and environmental (TOE) dimensions/criteria associated with the EHR, to meet client needs in the healthcare industry. The fact that the EHR adoption rate is not growing as quickly as expected suggests that additional efforts are needed in order to understand what affects innovation implementation and specifically to identify the criteria affecting EHR [4,14]. The TOE framework forms a theoretical basis for the application of information technology and innovation adoption for sustained development [15,16]. Applying the TOE structure, we have developed a model for the implementation of EHR in the healthcare industry.

In the Section 2, we review the literature related to TOE and discuss our conceptual model. In Section 3, the hybrid MCDM model is described. In Section 4, we report on the application of an empirical case and discuss the analysis of the outcome. In Section 5, some conclusions are presented and suggestions are made for future research.

2. Literature Review on EHR and the TOE Framework

This section examines and evaluates the EHR criteria related to its impact on performance (financial management and human resource management) in the healthcare industry. Evaluation of implementation problems is determined by analysis of expert questionnaires combined with a review of the technological, organizational, and environmental literature. Subsequently, the TOE framework is used to explore the related evaluation criteria, which are integrated with an IT review and verification in order to assess performance in the healthcare industry.

2.1. The TOE Dimensions of EHR

It has been proposed in prior studies that the TOE structure provides a good beginning for information system research [14]. A theoretical model must account for the criteria that affect a firm's predisposition to apply EHR, which is rooted in the organization's specific technological, organizational, and environmental conditions. This TOE structure identifies the three dimensions which influence the adoption, implementation, and usage of IT innovation in the healthcare industry: the technological dimension defines both new technologies and the present technologies in use related to this organization; the organizational dimension mentions descriptive measures regarding this organization, including the amount of resources and size internally available; and the

environmental dimension is the arena in which the corporation executes its commerce—its organizations, competitors, and relationship through management authorities [14].

Investigators have successfully used the TOE framework. Zhu et al. [17] investigated how the TOE criteria affected the influence of an information system and subsequent firm performance. They tested the model using a questionnaire distributed to the South African retail sector. Their analysis indicated the value of applying this TOE structure in order to realize how to adopt an intricate information system innovation. Chau and Tam [18] suggested that future studies are needed to extend the TOE structure to other innovation characteristics. As a generic technology diffusion theory, the TOE structure can help research different innovations [16]. Hence, we propose a conceptual model for EHR evaluation using dimensions/criteria for understanding the impact of performance in the healthcare industry based on the TOE framework.

The three dimensions specified in the TOE framework—technological, organizational and environmental—are discussed below.

2.2. Technological Dimension

The technological dimension relates to the technologies pertaining to EHR implementation in the healthcare industry—both technology available to the firm with existing equipment and in the market. The judgement as to whether to implement a technology depends not only on how the technology fits with what that corporation already possesses, but also what is available on the market [15,18–20]. Some of these technological aspects mentioned in the literature are technology integration, readiness, and security [4,17,21,22]. Technology integration is "the level of interconnectivity among back-office databases and information system inside corporations and these externally combined with databases and interdependent system" [17]. Technology integration is a critical factor for EHR adoption, given that EHR requires simplified data flowing throughout the value chain, and should automatically respond to alterations in downstream systems or procedures [21,22]. Technology readiness refers to "IT human resources and technology structure… IT human resources means IT professionals possessing the skills and knowledge to adopt Internet-related uses… and technology infrastructure refers to technologies that enable Internet-related businesses" [17]. The EHR system is an information system which the healthcare industry can adopt with greater technological readiness. One of the important impact issues for EHR is technological security; that is, the extent to which the network is considered safe for protecting privacy and exchanging data.

EHR technology is still new in comparison to other technologies, such as electronic data interchange, which has been in use for two decades. Generally, EHR faces a less ripe institutional structure regarding data exchange and privacy protection. Because of these issues, EHR exchangers are likely to be particularly concerned about technological security.

2.3. Organizational Dimension

The organizational dimension relates to the internal influences on a business which influence innovation implementation and adoption [15,20,21]. Some of the organizational issues noted in the literature are financial commitment, firm size, and managerial obstacles [23–26]. Financial commitment constitutes another criterion recognized in the IT adoption literature [24,25]. In this study, we restrict this criterion to financial resources specifically assigned to EHR. Applying an EHR system requires investing in software, hardware, employee training, and integrating this into an existing system. Firm size is normally cited as a criterion when discussing innovation diffusion and IT adoption [20,21,23]. However, there is tension between organizational inertia and the availability of resources, and different views exist concerning this role of a firm's size in the innovation diffusion procedure [27,28]. Large firms tend to have the resources for the promotion of usage and implementation [15], but large firm size is often associated with inertia—a tendency to be less adaptable than smaller firms. Firm size is a significant organizational attribute for the diffusion of innovation [9,13]. Addressing this barrier to EHR, Chang et al. [14] proposed examining the influence of managerial obstacles such as the lack of managerial ability and know-how for administering the adaptations of business to better accommodate EHR. Mata et al. [29] offer insight into the underlying

issues: "This heart of a corporation's abilities to assimilate information technology is the skills of IT and the ability to blend managerial."

2.4. Environmental Dimension

The environmental dimension relates to the arena within which business is conducted. The three key environmental pressures in EHR implementation are environmental uncertainty [1,21,30,31], competition [20,32], and the regulatory environment [27,33]. Uncertainty refers to "the inability to allocate probabilities to future incidents or to accurately forecast the results of judgements" [33,34]. In this study, we focus on the uncertainty stemming from a given organization's external environment. Environmental uncertainty can be the motivation for a strategy or actions taken by the organization [20,34]. Corporations tend to find competitive advantages via innovation [32]. They concluded that the introduction of innovation such as EHR may change the rules of competition, influence the firm's arrangement, and produce novel ideas leading to outperforming competitors, therefore altering the competitive landscape. These results can also be applied to the adoption of EHR in the healthcare industry. Regulatory support is another critical environmental factor that affects the implementation of EHR technology [33,35]. The latter study investigated what would happen for firms operating in environments with restrictive government policies [36]. Hence, governments could encourage EHR adoption by instituting supportive healthcare laws to defend data exchange and use, adjust the Internet to make reliable (e.g., confirming the patient's medical records and medication use), and providing incentives to the healthcare providers that are willing to use EHR systems.

Based on the TOE framework, we invited 20 experts to participate in a Delphi survey. The experts suggested criteria, from which we obtained a consensus for ranking the criteria on a scale from 1 to 5 (1 = irrelevant and 5 = essential). After obtaining this consensus from the experts, we identified three dimensions that may significantly affect EHR in the healthcare industry. The technological, organizational, and environmental dimensions are highlighted as the main evaluation dimensions. Three criteria which affect the technological dimension are technology integration, technology readiness, and technology security. The three criteria for the organizational dimension are financial commitment, firm size, and managerial obstacles, while the three criteria affecting the environmental dimension are environmental uncertainty, competitive pressure, and regulatory support. We summarize these basic concepts and the EHR evaluation system in Figure 1.

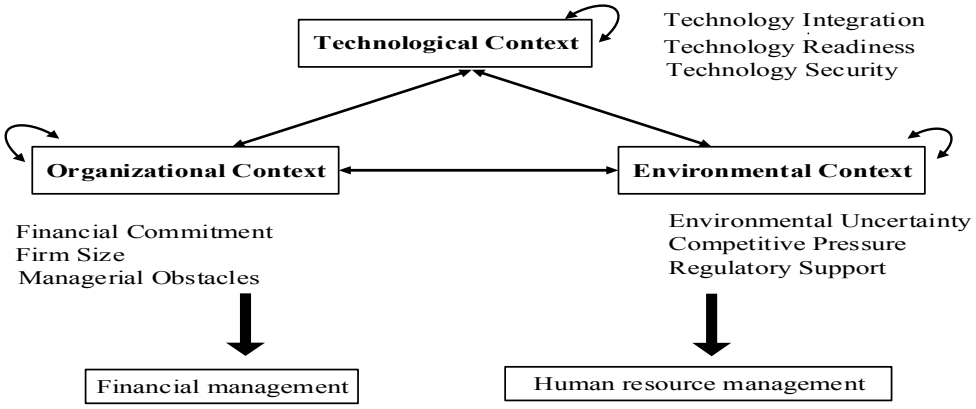

Figure 1. Impactful criteria and electronic health record (HER) evaluation system.

3. Method: DEMATEL-DANP-mVIKOR Model

The MCDM method was developed to take multiple goals into account, has a robust theoretical basis, and has been used for decision-making in different domains. This study proposes an integrated MCDM methodology which includes the DEMATEL method, DANP, and modified VIKOR. The traditional MCDM ignores some important new concepts, and some additional assumptions (limitations/defects) are needed to solve real-world issues. Our proposed model adopts new trends and concepts [37–39] for solving real issues for the implementation of EHR in the healthcare industry.

The new integrated MCDM model proposed in this paper can resolve complex issues. First, in the typical MCDM model, it is supposed that the criteria are hierarchical and independent within the framework. However, in real-life situations one must deal with feedback effects. To reflect real-world situations, our model considers the interdependence between dimensions/criteria. Second, the relative favorable solution method of choosing from the existing alternatives is changed to consideration of the aspiration levels for some critical issues. The modified VIKOR method [37–39] is applied to rectify the Max-Min typically used as a negative ideal point and the ideal point is changed to the aspiration level and the worst value to prevent one from "choosing the best apple among a bucket of bad apples" [39]. Third, except for the selection and ranking of alternatives, these hybrid analytical tools can be applied to develop the gaps to sustainable performance among the relevant criteria/dimensions. The different methods applied for different purposes in each stage are combined to form the hybrid model applied in our analysis.

3.1. DEMATEL Technique

The DEMATEL technique has been widely used to resolve complex network problems. The INRM is constructed to address the relationships between the criteria. The DEMATEL technique involves four steps. The first step is to construct a system with n elements/indicators (also called criteria), using pairwise comparisons to develop a five-point assessment scale with choices in natural language ranging from 0 (absolutely no influence) to 4 (very high influence). This scale is used for pairwise comparison based on the perceptions/opinions of experts. In the second step, the influence matrix is calculated from the preliminary matrix. In the third step, the matrix is normalized to obtain a relationship matrix where the sum of at least one column or row equals one, but not all. Finally, in the fourth step, the total influence relationship matrix is exported to map out the influential network relationship map (INRM) [37–39].

3.2. DANP Technique

DANP (DEMATEL-based ANP) is applied to solve non-linear and complex relations and to obtain the relative influence weights of the criteria. The DANP has been applied to solve practical decision-making problems, for performance evaluation/improvement [19,20,37,39], supplier selection, and internal control. The DANP approach is based on the influence relationship matrix of the DEMATEL technique, and the basic concept of ANP can be used to produce the unweighted super-matrix and weighted super-matrix. The global vectors of the DANP influence weights can then be found, which represent a sufficiently large power. Therefore, these methods can be used to solve the problems of dependence and feedback among criteria [39].

3.3. Modified VIKOR

The traditional VIKOR method was introduced by Opricovic and Tzeng [38]. Its basic concept of compromise solution could be implemented to resolve the problem of the criterion conflict encountered in the MADM model. Thus, the best alternative in the MADM framework would be selected when managing a multiple-criteria decision-making problem. In this study, the most suitable alternatives (criteria) are extracted by the modified VIKOR method, using the "Aspiration-Worst" as to replace the "Max-Min" benchmark in the traditional VIKOR approach (at least two or more alternatives). Consequently, the modified VIKOR method can not only be used for ranking and selection among the alternatives, but can also be used for performance gap improvement, moving it closer to zero to reach the aspiration level—even for only a single alternative.

The procedures for the integrated MCDM are illustrated in Figure 2, and detailed mathematical formulations can be found in [37–39].

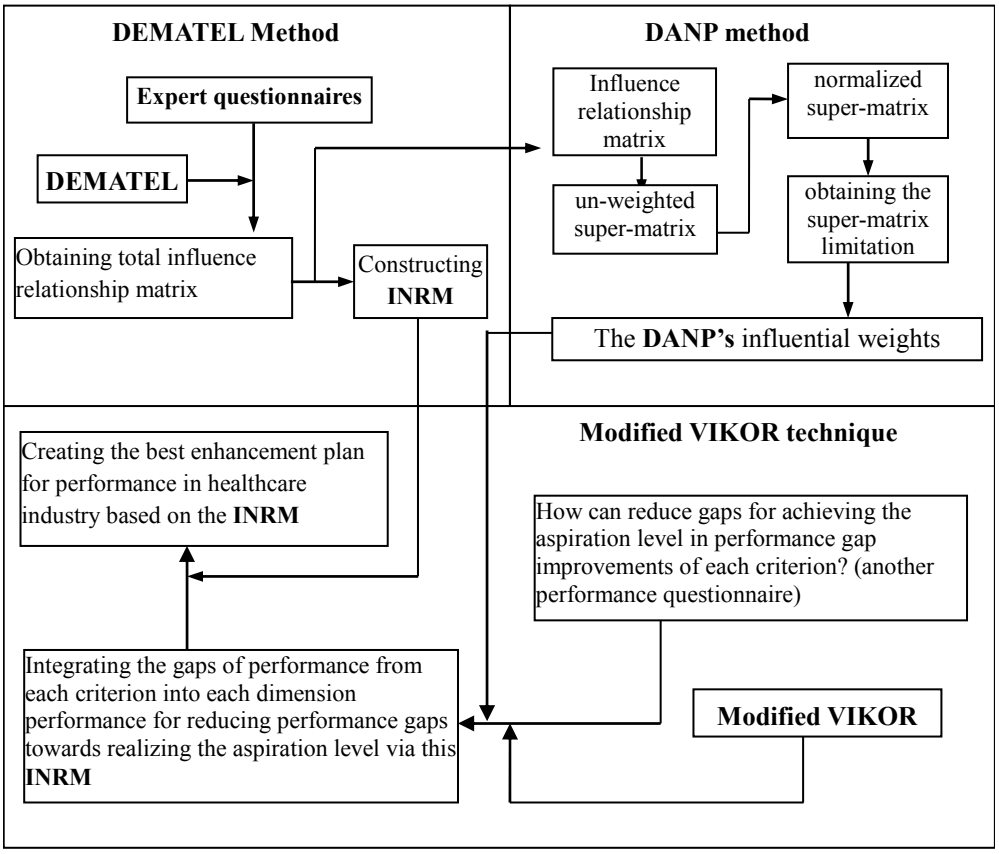

Figure 2. Procedures of the hybrid multiple criteria decision making (MCDM) model. DANP: DEMATEL-based ANP; DEMATEL: decision-making trial and evaluation laboratory; INRM: influential network relationship map.

4. Empirical Study: EHR Implementation in the Healthcare Industry

This section explores the TOE framework for EHR in an empirical study of the healthcare industry. We evaluate the degree of preference to determine the influential weight of various criteria and to find those critical for EHR implementation. We also discuss the performance gaps to the aspiration levels for each criterion and dimension. Finally, we investigate to find problems with the implementation of EHR. This study provides some managerial suggestions for improving the usage of EHR in Taiwan.

4.1. Description of Data Collection

We collected data from 20 experts in the healthcare industry (for consensus, significant confidence is 98.30%, gap error = 1.70%, more than 95%). The majority of experts had worked for at least ten years as managers in the healthcare industry. We collected expert perspectives on all criteria via questionnaires and personal interviews. Interviews were conducted in July 2017, and 50 to 60 min were required to fill out a survey.

4.2. Assembling the Influence Network via the DEMATEL Method

In the study, the DEMATEL method is used to build the administrative framework and analyze data from three dimensions and nine criteria for EHR. According to the questionnaire responses from the experts, we obtained these total influence matrix of criteria and dimensions (Tables 1–3).

In the dimension level (Table 2), "organizational dimension (A_2)" has the highest positive value (net effect), indicating that it is a causal dimension. The operational situation of the organizational dimension affects others more than it is affected by them. However, the "technological dimension (A_1)" has the highest value in terms of prominence, meaning that it has the highest total influence-

degree of strength among the dimensions. In addition, in terms of the criterion level (Table 3), "technology readiness (B_2)", "financial commitment (B_4)", and "regulatory support (B_9)" had the highest degree of net effect within the technological dimension (A_1), organizational dimension (A_2), and environmental dimension (A_3). Conversely, "technology integration (B_1)", "financial commitment (B_4)", and "regulatory support (B_9)" had the highest value of prominence within their dimensions.

Table 1. The total influence matrix of criteria.

Criteria	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
B_1 Technology integration	0.421	0.466	0.534	0.533	0.381	0.538	0.463	0.517	0.477
B_2 Technology readiness	0.513	0.366	0.559	0.538	0.365	0.522	0.492	0.482	0.522
B_3 Technology security	0.493	0.436	0.423	0.538	0.355	0.480	0.455	0.466	0.529
B_4 Financial commitment	0.629	0.529	0.639	0.515	0.463	0.636	0.550	0.566	0.593
B_5 Firm size	0.453	0.397	0.465	0.461	0.268	0.452	0.398	0.403	0.425
B_6 Managerial obstacles	0.484	0.419	0.505	0.508	0.378	0.404	0.449	0.484	0.486
B_7 Environmental uncertainty	0.419	0.368	0.434	0.456	0.329	0.442	0.314	0.393	0.378
B_8 Competitive pressure	0.498	0.444	0.514	0.496	0.354	0.486	0.470	0.371	0.435
B_9 Regulatory support	0.548	0.439	0.558	0.564	0.411	0.541	0.483	0.505	0.415

Note: significant confidence is 98.30%.

Table 2. The total effect matrix and sum of dimension effects.

Dimensions	A_1	A_2	A_3	Influence Given	Influence Received	Prominence	Net Effect
A_1 Technological dimension	0.468	0.472	0.489	1.429	1.439	2.868	−0.010
A_2 Organizational dimension	0.502	0.454	0.484	1.440	1.379	2.819	0.061
A_3 Environmental dimension	0.469	0.453	0.418	1.340	1.391	2.731	−0.051

Table 3. The sum of effects, rankings of each criterion, and influential weights.

	Dimensions/Criteria	Influence Given	Influence Received	Prominence	Net Effect	Degree of Importance (Global Weights)
A_1	Technological dimension					0.342
B_1	Technology integration	4.329	4.457	8.787	−0.128	0.118
B_2	Technology readiness	4.358	3.865	8.223	0.493	0.102
B_3	Technology security	4.174	4.632	8.806	−0.458	0.122
A_2	Organizational dimension					0.328
B_4	Financial commitment	5.120	4.607	9.727	0.513	0.122
B_5	Firm size	3.722	3.304	7.025	0.418	0.087
B_6	Managerial obstacles	4.118	4.501	8.619	−0.382	0.118
A_3	Environmental dimension					0.330
B_7	Environmental uncertainty	3.532	4.074	7.606	−0.541	0.107
B_8	Competitive pressure	4.067	4.186	8.253	−0.119	0.111
B_9	Regulatory support	4.464	4.259	8.724	0.205	0.112

Figure 3 further illustrates influence priority, which can be sequenced as follows: organizational dimension (A_2), technological dimension (A_1), environmental dimension (A_3). When considering improvement, the experts all considered the organizational dimension to be first and agreed that it had the highest priority for improvement, because it can affect the remaining dimensions (i.e., the

technological and environmental dimensions). This finding suggests that the healthcare industry administrators' main concern is organizational improvement, including financial commitment, firm size, and managerial obstacles. The experts believed that improving these criteria first would be better than focusing on the other dimensions.

In the organizational dimension (A_2), financial commitment (B_4) exerts a direct effect on the remaining criteria, including firm size (B_5) and managerial obstacles (B_6). Healthcare industry administrators agreed that financial commitment has the most influence and is the best way to improve an organization. Greater "financial commitment" contributes more resources and financial support to the industry. Furthermore, "managerial obstacles (B_6)" was deemed the least influential criterion or the last criterion that should be improved, from the viewpoint of the surveyed experts. Therefore, the general improvement priority can be sequenced as (B_4), (B_5), (B_6) in the organizational dimension (A_2).

There are also sub-networks within the individual dimensions. For instance, technology readiness (B_2) directly affects technology integration (B_1) and technology security (B_3), indicating that the priority for improvement should be (B_2), (B_1), (B_3) in the technological dimension (A_1). Regulatory support (B_9) directly affects competitive pressure (B_8) and environmental uncertainty (B_7), indicating that the priority for improvement should be (B_9), (B_8), (B_7) in the environmental dimension (A_3). Such an influential sub-network emerges in the individual dimension, as illustrated in Figure 3. For the administrators, the result is not only clear, but also simplifies the identification of priorities for improvement given complex criteria.

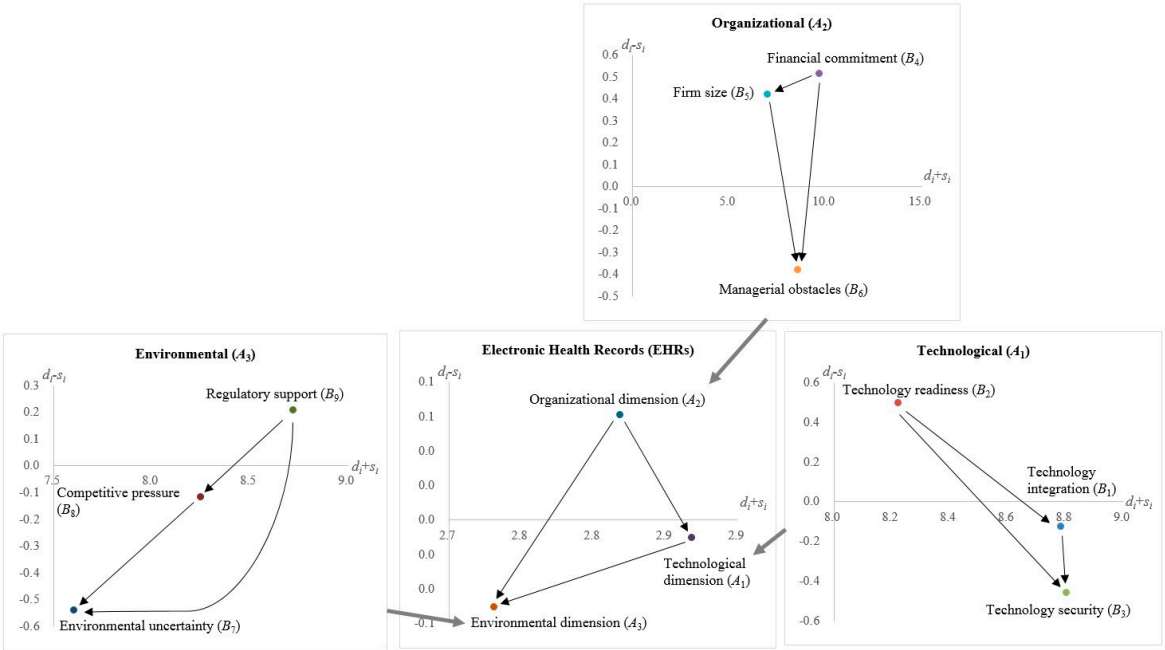

Figure 3. The influential network relationship map.

4.3. Finding the DANP's Influential Weights

The DEMATEL method is applied to determine the interdependence of the criteria and to obtain the most accurate influence weights. Hence, we assemble a quality assessment model by integrating DEMATEL with ANP (to form the DANP model), which can be used to obtain the weight of the influence of each criterion (as shown in Table 3).

Furthermore, we identify the most critical criterion in each dimension, which are technology security (B_3), financial commitment (B_4), and regulatory support (B_9). Then, we rank the influence weights in non-cross-dimensional degrees. Finally, we combine the weight of influence (DANP) with the modified VIKOR method to evaluate the priority for problem-solving needed to reduce the performance gaps for each criterion/dimension followed by an influential relationship map (Figure 3).

4.4. Integrating/Evaluating the Gaps by the Modified VIKOR Method

Integrating the influential weights, the modified VIKOR method can provide the overall gaps in financial management and HR (human resources) management for EHR (as shown in Table 4). Administrators can use this integrated index to assist with problem-solving issues based on each dimension or from the perspective of the criteria as a whole.

Applying the dimension/criteria overall, the gap values can be determined by priority sequence enhancement to achieve the desired aspiration level. For financial management, managerial obstacles (B_6), with a higher gap value of 0.636, are the first criterion that needs to be enhanced. This criterion is followed by environmental uncertainty (B_7) and firm size (B_5). Technology integration (B_1) is the last criterion, as indicated by the gap value of 0.091. In HR management, firm size (B_5), with a higher gap value of 0.532, is the first criterion that needs to be enhanced. This criterion is followed by environmental uncertainty (B_7), technology readiness (B_2), and so on. Technology integration (B_1) is the last criterion, as indicated by its gap (0.114). These outcomes indicate the priority for enhancement needed overall to reach the aspired/desired level, from the most to the least key criteria.

Enhancement priority can also be used in the each dimension. In the technological dimension (A_1) for financial management performance, the priority values are ordered as follows: technology readiness (B_2), technology security (B_3), technology integration (B_1). In the organizational dimension (A_2), the priority values are ordered as follows: managerial obstacles (B_6), firm size (B_5), financial commitment (B_4). In the environmental dimension (A_3), the priorities for enhancement priorities are as follows: environmental uncertainty (B_7), competitive pressure (B_8), regulatory support (B_9). On the other hand, in terms of HR management performance, the priorities for improvement are sequenced as follows: (B_2), (B_3), (B_1) in the technological dimension (A_1); (B_5), (B_4), (B_6) in the organizational dimension (A_2); and (B_7), (B_8), (B_9) in the environmental dimension (A_3). Applying the gap values obtained from the panel of experts as described above, the priority for enhancement is comprehensive and unique—both for the separate dimensions and from the overall points of view (Table 4).

Table 4. Gap evaluation of EHR through the modified VIKOR and traditional VIKOR methods.

Dimensions/Criteria		Local Weight	Global Weight (DANP)	Performance of EHR Gap (r_{ij})			
				Financial Management		HR Management	
				Modified	Traditional	Modified	Traditional
A_1	Technological dimension	0.342 (1)		0.134	0.000	0.220	0.228
B_1	Technology integration	0.344	0.118 (4)	0.100	0.000	0.120	0.120
B_2	Technology readiness	0.299	0.102 (8)	0.200	0.000	0.400	0.400
B_3	Technology security	0.357	0.122 (2)	0.110	0.000	0.165	0.165
A_2	Organizational dimension	0.328 (3)		0.404	0.657	0.377	0.390
B_4	Financial commitment	0.372	0.122 (1)	0.115	0.000	0.370	0.370
B_5	Firm size	0.267	0.087 (9)	0.520	0.970	0.525	0.525
B_6	Managerial obstacles	0.361	0.118 (3)	0.615	1.000	0.275	0.275
A_3	Environmental dimension	0.330 (2)		0.352	0.393	0.374	0.375
B_7	Environmental uncertainty	0.325	0.107 (7)	0.540	1.000	0.485	0.485
B_8	Competitive pressure	0.335	0.111 (6)	0.300	0.179	0.275	0.275
B_9	Regulatory support	0.341	0.112 (5)	0.225	0.000	0.365	0.365
	Total gap S_k			0.290	0.350	0.314	0.466

4.5. Discussion and Implications

First, on the basis of the influential degrees, as shown in the Figure 3, the priority for improvement is sequenced as follows: organizational dimension, technological dimension, and environmental dimension. This array is a key point for healthcare industry administrators. Specialist healthcare administrators recognize that organizational issues should be enhanced first. Efforts in

this direction will yield the network effects on the other dimensions and simultaneously solve multiple problems. The INRM shown here allows us to demonstrate the influential networks beyond a linear relation, from either criteria or dimensional points of view.

Second, these criteria—including financial commitment (B_4), technology readiness (B_2) and regulatory support (B_9)—influence the other criteria in the individual dimensions (as shown in Figure 3). Notably, financial commitment (B_4) has the highest priority, because implementing sufficient financial resources to the implementation of an EHR system will allow the healthcare industry to develop superior systems and obtain necessary resources [16]. Financial commitment must therefore improve before other actions are taken. Technology readiness (B_2) also deserves further attention. EHR systems are information systems; therefore, greater technological readiness can make it easier to initiate, adopt, and routinize EHR. Furthermore, additional attention should be given to regulatory support (B_9). Governments could establish laws to protect EHR data exchange, regulating the internet to make it a trustworthy platform for EHR. Regulatory support is also an important criterion.

Third, the most significant criterion calculated by DANP for EHR decisions is financial commitment, weighted at 0.122 (as shown in Table 4). The greatest barrier to the adoption of EHR by the healthcare industry is the cost of implementation and maintenance. With adequate financial resources, the healthcare industry can purchase often expensive EHR systems and equipment. Implementing EHR also demands investment in software, hardware, employee training, and system integration. Dedicating sufficient financial resources to assist the healthcare industry to acquire these essential technological resources is necessary to reach their full potential. Administrators expect greater financial commitment to lead to successful implementation, and thus to greater use. Financial commitment is therefore the most significant criterion for EHR implementation in the healthcare industry. To demonstrate the advantages of the proposed method, we also compared our results with those obtained with the traditional VIKOR method, as shown in Table 4. The gap for financial management in the technological dimension is zero when using traditional VIKOR, which would indicate there is nothing to improve in this dimension. However, our proposed method shows that the gap is 0.134, which is more reasonable than the gap obtained with the traditional VIKOR method. This result is because in the modified VIKOR method we replace the "Max-Min" of the traditional VIKOR method with an "Aspiration-Worst" benchmark.

For long-term enhancement, administrators should supervise motivation sensibly, as noted above. Given the empirical results, our outcomes—as summarized in Table 5—achieve this objective of the study. The EHR implementation model provided in the study can be adapted for most healthcare providers using EHR technology implementation. However, decision-makers should be cautious when using this model. The significance of the nine criteria may vary based on these outcomes, and decision-makers should compare the EHR and define the performance gap before making choices on optimal EHR.

Table 5. Priorities for enhancement of EHR performance.

Scheme	Array of Improvement Priorities
F1: Influential relationship network of dimensions	(A_2), (A_1), (A_3)
F2: Influential relationship network of criteria within respective dimensions	(A_1): (B_2), (B_1), (B_3) (A_2): (B_4), (B_5), (B_6) (A_3): (B_9), (B_8), (B_7)
F3: Array of dimension to promote to desired/aspired level in each performance (from low to high by gap value)	In financial management (A_2), (A_3), (A_1) In HR (human resources) management (A_3), (A_2), (A_1)
F4: Array of criteria to promote to desired/aspired level within respective dimension (from low to high by gap value)	In financial management (A_1): (B_2), (B_3), (B_1) (A_2): (B_6), (B_5), (B_4) (A_3): (B_7), (B_8), (B_9) In HR management

(A_1): (B_2), (B_3), (B_1)
(A_2): (B_5), (B_4), (B_6)
(A_3): (B_7), (B_9), (B_8)

5. Conclusions

The criteria and dimensions discussed in this study serve as bridging mechanisms that are useful in adapting EHR for client needs and for the estimation of performance gaps. The core contributions of the research are twofold: first, the estimation of performance gaps is a management problem considering the interaction and interdependent criteria/dimensions. According to the TOE structure, this research generates three dimensions and nine criteria to measure EHR estimations for client needs in the healthcare industry. Second, the study combines the DEMATEL method, DANP method, and modified VIKOR to improve an EHR estimation model that prioritizes relative weightings of TOE dimensions and criteria, and finds the gaps in performance for improvement. The proposed method not only deals with the dependence and interaction within dimensions and factors, but also yields more valuable information with which to construct a visual diagram of cause-and-effect for improved strategies. This empirical outcomes illustrate that the proposed model for EHR improvement is effective.

However, there are several limitations requiring further investigation. First, the research was conducted by sampling a group with comparatively high levels of familiarity with and knowledge of technology. Our results could be validated through larger samples to enhance the findings. Second, the TOE framework was applied for the estimation model. Further research can implement other multiple criteria models to evaluate the relative-weights of the effects on EHR client needs. Finally, these criteria for estimation were deduced from a review of the TOE estimation literature which could preclude some possible effects on EHR estimation, including privacy protection. Future research could apply different methods, such as interviews and longitudinal studies to include the other factors.

References

1. Heart, T.; Ben-Assuli, O.; Shabtai, I. A review of PHR, EMR and EHR integration: A more personalized healthcare and public health policy. *Health Policy Technol.* **2017**, *6*, 20–25.
2. Office of the National Coordinator for Health Information Technology (ONC). Defining Key Health Information Technology Terms April 28, 2008. Available online: http://www.hitechanswers.net/wp-content/uploads/2013/05/NAHIT-Definitions2008.pdf (accessed on 30 June 2017).
3. Ben-Zion, R.; Pliskin, N.; Fink, L. Critical Success Factor for Adoption of Electronic Health Record Systems: Literature Review and Prescriptive Analysis. *Inf. Syst. Manag.* **2014**, *31*, 296–312.
4. Miller, A.R.; Tucker, C. Privacy protection and technology diffusion: The case of electronic medical records. *Manag. Sci.* **2007**, *55*, 1077–1093.
5. Jha, A.; Ferris, T.; Donelan, K.; DesRoches, C.; Shields, A.; Rosenbaum, S.; Blumenthal, D. How common are electronic health records in the United States? A summary of the evidence. *Health Aff.* **2006**, *25*, 496–507.
6. Miller, R.H.; Sim, I. Physicians' Use of electronic medical records: Barriers and solutions. *Health Aff.* **2004**, *23*, 116–126.
7. Behkami, N.A.; Daim, T.U. Research Forecasting for Health Information Technology (HIT), using technology intelligence. *Technol. Forecast. Soc. Chang.* **2012**, *79*, 498–508.
8. Jones, S.S.; Rudin, R.S.; Perry, T.; Shekelle, P.G. Health information technology: An updated systematic review with a focus on meaningful use. *Ann. Intern. Med.* **2014**, *160*, 48–54.
9. Shanafelt, T.D.; Dyrbye, L.N.; Sinsky, C.; Hasan, O.; Satele, D.; Sloan, J.; West, C.P. Relationship between clerical burden and characteristics of the electronic environment with physician burnout and professional satisfaction. *Mayo Clin. Proc.* **2016**, *91*, 836–848.
10. Fletcher, G.S.; Payne, T.H. Selection and Implementation of an Electronic Health Record. *PMR* **2017**, *9*, S4–S12.
11. Penrod, E.L. Electronic Health Record Transition Considerations. *PMR* **2017**, *9*, S13–S18.
12. Lau, F.; Price, M.; Boyd, J.; Partridge, C.; Bell, H.; Raworth, R. Impact of electronic medical record on physician practice in office settings: A systematic review. *BMC Med. Inform. Decis. Mak.* **2012**, *12*, 1–10.

13. Boonstra, A.; Broekhuis, M. Barriers to the acceptance of electronic medical records by physicians from systematic review to taxonomy and interventions. *BMC Health Serv. Res*. **2010**, *10*, 231–247.
14. Chang, I.C.; Hwang, H.G.; Hung, M.C.; Kuo, K.M.; Yen, D.C. Factor affecting cross-hospital exchange of Electronic Medical Records. *Inf. Manag.* **2009**, *46*, 109–115.
15. Tornatzky, L.G.; Fleischer, M. *The Processes of Technological Innovation*; Lexington Books: Lexington, MA, USA, 1990.
16. Corrocher, N. The diffusion of Internet telephony among consumers and firms: Current issues and future prospects. *Technol. Forecast. Soc. Chang.* **2003**, *70*, 525–544.
17. Zhu, K.; Kraemer, K.L.; Xu, S.; Dedrick, J. Information technology payoff in e-business environments: An international perspective on value creation of e-business in the financial services industry. *J. Manag. Inf. Syst.* **2004**, *21*, 17–54.
18. Chau, P.Y.K.; Tam, K.Y. Factor affecting the adoption of open systems: An exploratory study. *MIS Q.* **1997**, *21*, 1–24.
19. Jeyaraj, A.; Rottman, J.; Lacity, M.J. A review of the predictors, linkages, and biases in IT innovation adoption research. *J. Inf. Technol.* **2006**, *21*, 1–23.
20. Jia, Q.; Guo, Y.; Barnes, S.J. Enterprise 2.0 post-adoption: Extending the information system continuance model based on the technology-Organization-environment framework. *Comput. Hum. Behav.* **2017**, *67*, 95–105.
21. He, C.; Fan, X.; Li, Y. Toward ubiquitous healthcare services with a novel efficient cloud platform. *IEEE Trans. Biomed. Eng.* **2013**, *60*, 230–234.
22. Scheurwegs, E.; Luyckx, K.; Luyten, L.; Daelemans, W.; Vanden Bulcke, T. Data integration of structured and unstructured sources forassigning clinical codes to patient stays. *J. Am. Med. Inform. Assoc.* **2016**, *23*, e11–e19.
23. Damanpour, F. Organizational size and innovation. *Organ. Stud.* **1992**, *13*, 375–402.
24. Iacovou, C.L.; Benbasat, I.; Dexter, A.S. Electronic data interchange and small organizations: Adoption and impact of technology. *MIS Q.* **1995**, *19*, 465–485.
25. Ramamurthy, K.; Premkumar, G.; Crum, M.R. Organizational and interorganizational determinants of EDI diffusion and organizational performance: A cause model. *J. Organ. Comput. Electron. Commer.* **1999**, *9*, 253–285.
26. Chatterjee, D.; Grewal, R.; Sambamurthy, V. Shaping up for e-commerce: Institutional enablers of the organizational assimilation of Web technologies. *MIS Q.* **2002**, *26*, 65–89.
27. Zhu, K.; Kraemer, K.L.; Xu, S. The process of innovation assimilation by firms in different countries: A technology diffusion perspective on e-business. *Manag. Sci.* **2006**, *52*, 1557–1576.
28. Lu, M.T.; Lin, S.W.; Tzeng, G.H. Improving RFID adoption in Taiwan's healthcare industry based on a DEMATEL technique with a hybrid MCDM model. *Decis. Support Syst.* **2013**, 56, 259–269.
29. Mata, F.; Fuerst, W.; Barney, J. Information technology and sustained competitive advantage: A resource-based analysis. *MIS Q.* **1995**, *19*, 487–505.
30. Duncan, R.B. Characteristics of organizational environments and perceived environmental uncertainty. *Adm. Sci. Q.* **1972**, *17*, 313–327.
31. Downey, H.K.; Hellriegel, D.; Slocum, J.W. Environmental uncertainty: The construct and its application. *Adm. Sci. Q.* **1975**, *20*, 613–629.
32. Gatignon, H.; Robertson, T.S. Technology Diffusion: An Empirical Test of Competitive Effects. *J. Mark.* **1989**, *53*, 35–49.
33. Umanath, N.S.; Campbell, T.L. Differential diffusion of information systems technology in multinational enterprises: A research model. *Inf. Resour. Manag. J.* **1994**, *7*, 6–18.
34. Hatch, M.J. *Organizational Theory Modern, Symbolic, and Postmodern Perspectives*; Oxford University Press: Oxford, UK, 1997.
35. Dasgupta, S.; Agarwal, D.; Ioannidis, A.; Gopalakrishnan, S. Determinants of information technology adoption: An extension of existing models to firms in a developing country. *J. Glob. Inf. Manag.* **1999**, *7*, 41–49.
36. Williamson, O.E. Organizational Innovation: The Transaction Cost Approach. In *Entrepreneurship*, Ronen, J., Ed.;. Lexington Books: Lexington, MA, USA, 1983.
37. Lu, M.T.; Tzeng, G.H.; Cheng, H.; Hsu, C.C. Exploring mobile banking services for user behavior in intention adoption: Using new hybrid MADM model. *Serv. Bus.* **2015**, *9*, 541–565.

38. Opricovic, S.; Tzeng, G.H. Extended VIKOR method in comparison with outranking methods. *Eur. J. Oper. Res.* **2007**, *178*, 514–529.
39. Liou, J.J.H.; Tamošaitienė, J.; Zavadskas, E.K.; Tzeng, G.H. New hybrid COPRAS-G MADM Model for improving and selecting suppliers in green supply chain management. *Int. J. Prod. Res*. **2016**, *54*, 114–134.