



# Improving search engine optimization (SEO) by using hybrid modified MCDM models

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## Abstract

Search engine optimization (SEO) has been considered one of the most important techniques in internet marketing. This study establishes a decision model of search engine ranking for administrators to improve the performances of websites that satisfy users' needs. To probe into the interrelationship and influential weights among criteria of SEO and evaluate the gaps of performance to achieve the aspiration level in real world, this research utilizes hybrid modified multiple criteria decision-making models, including decision-making trial and evaluation laboratory (DEMATEL), DEMATEL-based analytic network process (called DANP), and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). The empirical findings discover that the criteria of SEO possessed a self-effect relationship based on DEMATEL technique. According to the influential network relation map (INRM), external website optimization is the top priority dimension that needs to be improved when implementing SEO. Among the six criteria for evaluation, meta tags is the most significant criterion influencing search engine ranking, followed by keywords and website design. The evaluation of search engine ranking reveals that the website with lowest gap would be the optimal example for administrators of websites to make high ranking website during the time that this study is executed.

**Keywords** SEO · MCDM · DEMATEL · DANP · VIKOR

## 1 Introduction

In modern times, one of the main search engines is the initial step to search for information when people make decisions. Accordingly, for administrators of websites, the forward appearance of the search results is fairly important. However, it is extremely competitive to make a website appear on the foremost page (Dye 2008). Search engine optimization (SEO) is the procedure to advance the ranking of websites on search engines for particular

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searching terms by managing incoming links and characteristics of websites (Malaga 2010). In the detail of search engine, Mavridis and Symeonidis (2015) revealed that search engine returns the most relevant documents determined by complex algorithms that adopt a plethora of criteria or ranking factors constantly changing over the last decade. Though the exact ranking mechanisms algorithms of the search engines are not published, major search engines of Google, Bing and Yahoo provide web content developers with guidelines including the same basics for SEO: qualitative contents, target the users, proper link architecture, suitable keywords, and social media components. However, in the research of Aswani et al. (2018), some of the website administrators try to trick the algorithms by using Black Hat techniques such as posting duplicate content to enhance their content volumes, buying links to increase backlink volumes, keyword spamming to enlarge keyword density in the content and so on. After the unethical practices are detected in few months, such websites are often delisted or banned from search engines, or their quality scores are fairly lowered.

Consequently, administrators of websites are much interested in using ethical strategies for improving SEO, the level of importance of each factor, and reducing the gaps to achieve aspiration level under the consideration of SEO's factors. To provide the solution to these issues, the purpose of this research is to establish decision models of carrying out SEO for administrators of websites to improve the performances of websites for satisfying the users' needs. This paper will indicate, by the proposed hybrid modified multiple criteria decision-making (MCDM) models, the practical sequence of implementing SEO, the influential weights of criteria, and the strategies for evaluating the performance gaps to reach the aspiration level. Amin and Emrouznejad (2011), according to metasearch engine, proposed a linear programming mathematical model for optimizing the ranked list result. Many previous researches assumed the criteria/factors for exploring problems were independent and linear; however, they are interdependent and feedback in real world. Moreover, there are lots of factors influencing SEO; hence, the contributions to administrators of websites are limited. Other preceding researches on SEO were mainly focused on introducing SEO (Yalçın and Köse 2010) and investigating influential factors of SEO (Bar-Ilan et al. 2006; Dye 2008; Xiang and Gretzel 2010; Zhang and Dimitroff 2005). Yet, the messages conveyed, for administrators of websites, merely what the influencing factors of SEO are and whether the influence were positive or negative. Therefore, these findings for constructing a decision model of search engine ranking have little contribution to it. In addition, researches on the interrelationship and influential weights among factors were inadequate.

To supplement previous findings on SEO for establishing a decision model of search engine ranking for administrators of websites to improve website performance for achieving the greatest benefit of internet marketing, this study utilizes hybrid modified MCDM models comprising decision making trial and evaluation laboratory (DEMATEL), DEMATEL-based analytical network process (DANP), and VIse Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) for exploring search engine ranking based on SEO. We recognize the criteria of SEO for building a decision model of search engine ranking by reviewing literatures. According to the survey of experts, this paper uses DEMATEL technique to assess the interdependent and feedback problems among criteria to form the influential network relation map (INRM).

The traditional methods of analytic hierarchy process (AHP) and analytical network process (ANP) proposed by Saaty (1996) assuming that dimensions and criteria are independent, which are not suitable for real world. Therefore, DANP is employed to overcome the problems of dependence and feedback among criteria for obtaining the influential weights of each criterion (Lu et al. 2016) for high ranking on the search engines; subsequently, we rank the data to identify the important criteria. Eventually, VIKOR is adopted to evaluate the perfor-

mance of websites and to reduce gaps based on INRM for achieving the aspiration level. Published work connecting such hybrid MCDM models with improvement strategy of SEO is quite few. This study, to bridge the breach, utilizes an empirical case of technologic companies' websites in Taiwan as an example, and provides the management of search engine ranking with a valuable decision model to improve websites performances.

The remainder of this study is organized as follows: in Sect. 2, the criteria of SEO can be identified based on literature review. In Sect. 3, hybrid modified MCDM models for establishing a decision model of search engine ranking and performance improvement are illustrated. Section 4 reveals an empirical study of improvement strategy for high search engine ranking to demonstrate the usefulness of proposed model. Finally, conclusions and remarks are presented in Sect. 5.

## 2 Criteria of SEO for exploring search engine ranking

SEO is the procedure to improve the ranking of websites for particular searching terms on search engines by managing incoming links and characteristics of websites (Malaga 2010). Based on past literatures, the purpose of this section is to identify the criteria of SEO's two main dimensions: internal and external website optimization. Website design, meta tags, and keywords, for internal website optimization, are necessary for the website, page names, photos, links, content texts in every page and styles that used for the site map, really simple syndication (RSS) feeds, related texts, and pages in different languages. Besides, for external website optimization, joining website to the site guide, utilizing social media factors, and employing links from other optimized websites to the related webpage are included (Yalçın and Köse 2010).

On the dimension of internal website optimization, Bar-Ilan et al. (2006) mentioned that websites can obtain high rankings for specific search terms within specific search engines by designing and redesigning webpages. In the related literatures of meta tags, lots of researchers have proved that it can greatly improve the search effectiveness by associating the results of multiple search engines in the form of a metasearch engines (Amin and Emrouznejad 2011; Bar-Ilan et al. 2006; Spink et al. 2006; Spoerri 2007; Vaughan 2004). As for keywords, Zhang and Dimitroff (2005) found that by increasing the frequency of keywords in the title, in the full-text and in both the title and full-text, webpage visibility can be improved.

On the other dimension of external website optimization, Zhang and Dimitroff (2005) suggested that after the test webpages were ready, they were posted in the public domain so that search engines could crawl and index them for advancing their visibility. In the associated literatures of social media, Xiang and Gretzel (2010) discovered that social media play an important role when using a search engine. With respect to linkage, Zhang and Dimitroff (2005) stated that webpages with high hyperlink were regarded as more significant or influential than those with low hyperlink. Therefore, it was taken into account by some search engine ranking algorithms to let the search results more connected. Namely, webpages with better hyperlink can get higher ranking than other pages (Dye 2008).

According to SEO, two dimensions impact on search engine ranking including internal website optimization and external website optimization. Moreover, by reviewing literature, internal website optimization is affected by three criteria: website design, meta tags, and keywords; external website optimization, on the other hand, is affected by three criteria: public domain, social media, and linkage, which are arranged in Table 1.

**Table 1** Explanation of evaluation criteria

Dimensions	Criteria	Descriptions
Internal website optimization ( $D_1$ )	Website design ( $C_1$ )	A collection of online content comprising applications and documents
	Meta tags ( $C_2$ )	A method for webmasters to supply search engines with information about their websites
	Keywords ( $C_3$ )	A term utilized as a keyword to retrieve documents on a search engine
External website optimization ( $D_2$ )	Site guide ( $C_4$ )	A human-edited directory of the Web
	Social media ( $C_5$ )	The use of web-based and mobile technologies for interactive dialogue
	Linkage ( $C_6$ )	Links from other optimized websites to the related webpage

### 3 Establishing hybrid modified models for search engine ranking and improvement

The main questions of this research are to investigate the improvement strategies for high ranking in search engine, the influential weights of dimensions/criteria when implementing SEO, and the performance gaps for alternatives. As a consequence, MCDM is utilized by this paper to simultaneously consider multiple criteria for providing decision makers with valuable decision models to make the optimal decisions (Tzeng and Huang 2011). The technique of DEMATEL is employed to build the INRM for developing the improvement strategies of SEO. Subsequently, by using DANP, the influential weights of criteria of the structure can be obtained. The method of VIKOR, eventually, is utilized to evaluate compromise ranking and gaps of the alternatives for achieving aspiration level. These principal stages are included in the framework of the hybrid modified MCDM models. The detailed processes of calculation and mathematical equations are illustrated in “Appendix A”.

#### 3.1 Constructing the INRM by DEMATEL

To build the INRM, the DEMATEL technique was utilized to explore the interdependent and feedback problems among criteria (Chen and Tzeng 2011; Fontela and Gabus 1976). The method has been used in diverse fields, such as solar farms, web data, portfolio selection, online reputation, and so on (Chen et al. 2014; Gupta and Kohli 2016; Ho et al. 2011; Hung et al. 2012). The DEMATEL is executed by using questionnaires for experts to point out the influential relationships among criteria indicating the degrees of influence for each criterion.

#### 3.2 The DANP for calculating criteria’s influential weights based on the INRM

Saaty (1996) developed ANP to solve problems with dependence or feedback between criteria. However, Chen et al. (2011) addressed that the traditional survey questionnaire of ANP was too complicated and hard to comprehend. This research, according to Ou Yang et al. (2008), adopts a new method of DANP to conquer the obstruction of carrying out ANP

for calculating the influence weights based on the influential relation matrix of DEMATEL. Hence, hybrid modified MCDM models combining the DEMATEL technique with DANP can deal with the interrelationship (interdependence and feedback) problems among dimensions/criteria, and obtain the influential weights of criteria with dependence and feedback.

### 3.3 Evaluating performance gaps via VIKOR

This research adopts “aspired-worst” benchmark to replace the traditional approach “max–min” for avoiding “choosing the best among inferior alternatives”, meaning preventing from “picking the best apple among a barrel of rotten apples”. The improved way can not only be utilized for ranking and selection, but also can be used to improve the performance gaps based on INRM. The compromise ranking method (VIKOR) as one applicable technique to implement within MCDM model was proposed to determine the compromise solution (Tzeng et al. 2002, 2005). In addition, the solution is feasible for decision-makers, because it supplies a maximum group utility of the majority, and a maximal gap of minimum individuals of the opponent. This hybrid modified MCDM models employ the DEMATEL and DANP processes in Sects. 3.1 and 3.2 to obtain the influential weights of criteria with dependence and feedback, and adopt VIKOR for resolving the compromise solution.

## 4 An empirical case by using websites of technology company

In this section, an empirical study is illustrated to demonstrate the application of the proposed model to evaluate and improve for building the best website of search engine ranking. To solve real-world problems group decision making is a well-known approach for containing comprehensive perspectives and thinking. In this study, experts with related fields are invited to consider any possibilities of situations by group brainstorming and decision making. The hybrid modified MCDM models are utilized to analyze the collected data from experts. Furthermore, the analyzed outcomes are displayed in useful models for administrators to make the best strategies to improve the website performances for reaching the aspiration level.

### 4.1 Background and problem descriptions

Web users browse the few and forward searching results (Jansen and Spink 2005); therefore, the issue of search engine ranking for administrators of websites is very significant. Taiwan Network Information Center (TWNIC) reported that the population of using internet in Taiwan has exceeded 16.95 million (73.57% of total population), and the intensity of accessing internet comes out on top of the world. Looking for information by internet has been a very important tool; however, it is a critical topic for administrators of websites to make websites forward listed on search engine results in the times of information explosion. Moreover, there are numerous factors influencing search engine ranking; therefore, it is a hard problem for administrators of websites to evaluate, improve, and advance search engine ranking. This study applies the knowledge of experts and takes websites of technology companies in Taiwan as an empirical example to establish a suitable decision model to assist administrators of websites in the improvement of SEO.

**Table 2** The initial influence matrix *A*

Criteria	<i>C</i> <sub>1</sub>	<i>C</i> <sub>2</sub>	<i>C</i> <sub>3</sub>	<i>C</i> <sub>4</sub>	<i>C</i> <sub>5</sub>	<i>C</i> <sub>6</sub>
<i>C</i> <sub>1</sub>	0.000	3.733	3.667	2.600	1.533	1.600
<i>C</i> <sub>2</sub>	3.733	0.000	3.933	2.933	1.867	1.933
<i>C</i> <sub>3</sub>	3.667	3.933	0.000	2.867	1.800	1.800
<i>C</i> <sub>4</sub>	2.600	2.867	2.800	0.000	1.733	1.867
<i>C</i> <sub>5</sub>	1.733	1.933	1.733	1.800	0.000	3.867
<i>C</i> <sub>6</sub>	1.600	2.000	1.867	1.800	3.867	0.000

$\frac{1}{n^2} \sum_{i=1}^n \sum_{j=1}^p \frac{|t_{ij}^p - t_{ij}^{p-1}|}{t_{ij}^p} \times 100\% = 2.743\% < 5\%$ , i.e., confidence is 97.257%, where  $p = 15$  denotes the number of experts and  $t_{ij}^p$  is the average influence of  $i$  criterion on  $j$ ;  $n = 6$  denotes number of criteria

## 4.2 Data collection

The experts with specialty of SEO and professional knowledge of internet marketing are the objects of this study, including consultants of SEO, scholars of computer science, and managers of internet marketing. Moreover, the practical experiences of experts are depicted as follows: consultants of SEO are highly skilled in various aspects of technology and web design, scholars of computer science are those who have the specialty of information engineering and the experience of teaching information technology, and managers of internet marketing specialize in marketing and advertising of websites. Information required for sufficient evaluation of SEO procedures and performance is collected utilizing interviews and filled suitable questionnaires. In the DEMATEL questionnaires, a scale of 0, 1, 2, 3, and 4 shows the degree from “no influence (0)” to “very high influence (4)”. As for evaluating performances of websites, a scale of 0, 1, 2, ..., and 10 points representing the range from “the worst (0)” to “the best (10)” is adopted, so we can set the aspiration level as 10 point and the worst as 0 point. The objects of questionnaire are experts, but not consumers for analyzing the consumer behavior. Therefore, the consensus of numbers of experts is needed to be tested. If the samples of experts increase, the degree of consensus will increase; in other words, the difference will decrease. The confidence level, reaching 97.257%, is obtained in this real case of fifteen experts (calculated at the note of Table 2 including: 5 consultants of SEO, 5 scholars of computer science, and 5 managers of internet marketing). The inquisition is implemented in November 2017.

## 4.3 Estimating the relationships among SEO for establishing INRM

DEMATEL technique is used to investigate the problems of interdependence and feedback among six criteria received from literature review. The influence matrix *A* is exhibited in the first place (Table 2). At second, the normalized influence matrix *K* can be calculated utilizing Eq. (1) (Table 3). At third, the total influence matrix *T* is obtained using Eq. (3) (Table 4). The INRM of influential relationship within SEO is finally built by the vectors *r* and *s* (Table 5) from the total influence matrix *T* as shown in Fig. 1. This figure displays that the influential degrees of dimensions/criteria are much higher than others, when the causality is positive. Consequently, it is efficient to improve the dimensions/criteria with positive causality, because the results of it will systematically influence other dimensions/criteria leading the comprehensive promotion of performance.

**Table 3** The normalized direct-influence matrix  $K$ 

Criteria	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$
$C_1$	0.000	0.258	0.253	0.180	0.106	0.111
$C_2$	0.258	0.000	0.272	0.203	0.129	0.134
$C_3$	0.253	0.272	0.000	0.198	0.124	0.124
$C_4$	0.180	0.198	0.194	0.000	0.120	0.129
$C_5$	0.120	0.134	0.120	0.124	0.000	0.267
$C_6$	0.111	0.138	0.129	0.124	0.267	0.000

**Table 4** The total influence matrix  $T$ 

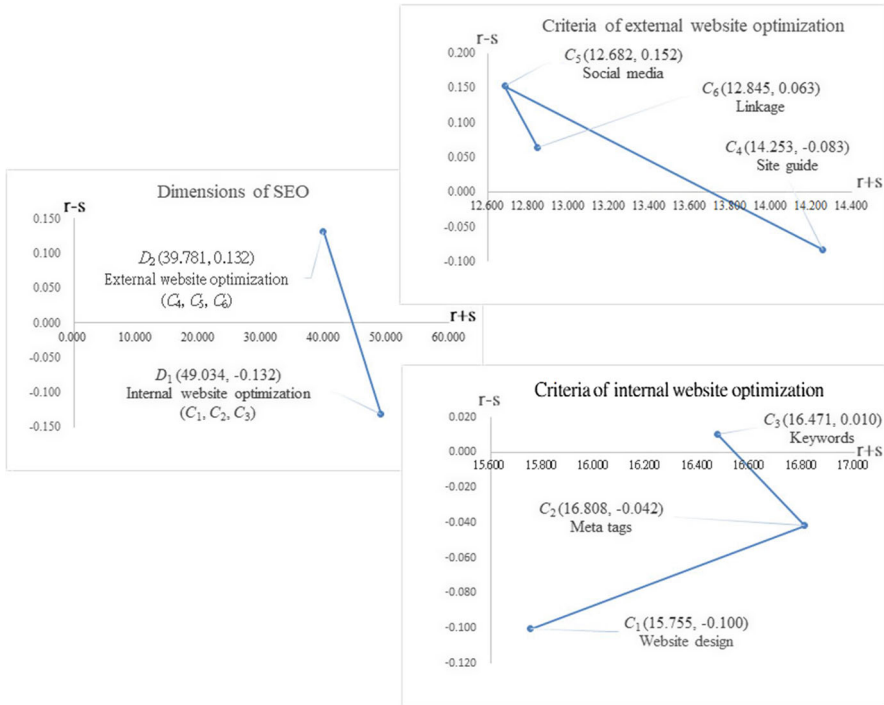
Criteria	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$
$C_1$	1.271	1.554	1.521	1.296	1.081	1.104
$C_2$	1.564	1.442	1.624	1.392	1.169	1.193
$C_3$	1.539	1.632	1.387	1.368	1.147	1.168
$C_4$	1.297	1.380	1.349	1.032	1.001	1.026
$C_5$	1.129	1.204	1.169	1.037	0.826	1.053
$C_6$	1.129	1.214	1.181	1.042	1.042	0.847

**Table 5** The integrated values of influences

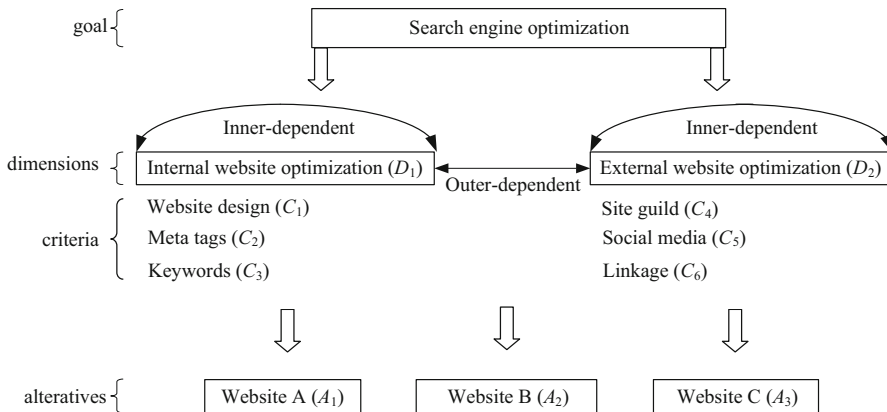
Dimensions/criteria	$r_i$ (influencing)	$s_i$ (influenced)	$r_i + s_i$ (centrality)	$r_i - s_i$ (causality)
Internal website optimization ( $D_1$ )	24.451	24.583	49.034	-0.132
Website design ( $C_1$ )	7.827	7.928	15.755	-0.100
Meta tags ( $C_2$ )	8.383	8.425	16.808	-0.042
Keywords ( $C_3$ )	8.241	8.230	16.471	0.010
External website optimization ( $D_2$ )	19.956	19.824	39.781	0.132
Site guide ( $C_4$ )	7.085	7.168	14.253	-0.083
Social media ( $C_5$ )	6.417	6.265	12.682	0.152
Linkage ( $C_6$ )	6.454	6.391	12.845	0.063

#### 4.4 Finding influential weights and performance gaps

According to the construction of the influence network based on DEMATEL (see Fig. 2), this study utilizes DANP to calculate the influential weights (global weights) of six criteria shown as Tables 6, 7 and 8. The empirical results reveal that experts are much concerned with meta tags and keywords, yet less concerned with linkage and social media. The findings display that the level of influential weights are much higher in meta tags, keywords, and website design. Concretely, meta tags gains the highest point of 0.189, followed by keywords (0.185) and website design (0.179). Moreover, the level of influential weights of linkage and social media is relatively lower averaging 0.143. If comparison is made among dimension,



**Fig. 1** The INRM of influential relationships within SEO



**Fig. 2** Analytic framework for SEO influence network

experts regard meta tags as the most important criterion in the dimension of internal website optimization (D<sub>1</sub>). On the other hand, site guide is considered by experts as the most significant criterion in the dimension of external website optimization (D<sub>2</sub>). Obtained results (ranked top one) show that the criterion of meta tags is the most significant criterion for administrators of websites to implement SEO. As far as dimensions are concerned, experts are much concerned with dimension of internal website optimization (D<sub>1</sub>), because the mean score of it is much higher. In addition, the integrated values are calculated to obtain the total



**Table 6** The unweighted supermatrix  $W = (T_c^\alpha)'$ 

Criteria	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$
$C_1$	0.292	0.338	0.338	0.322	0.322	0.320
$C_2$	0.358	0.311	0.358	0.343	0.344	0.344
$C_3$	0.350	0.351	0.304	0.335	0.334	0.335
$C_4$	0.372	0.371	0.371	0.338	0.356	0.356
$C_5$	0.310	0.311	0.311	0.327	0.283	0.355
$C_6$	0.317	0.318	0.317	0.335	0.361	0.289

**Table 7** The weighted supermatrix  $W^\alpha = T_D^\alpha W$ 

Criteria	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$
$C_1$	0.162	0.187	0.187	0.178	0.178	0.178
$C_2$	0.197	0.172	0.198	0.190	0.191	0.190
$C_3$	0.194	0.194	0.168	0.186	0.185	0.186
$C_4$	0.166	0.166	0.166	0.151	0.159	0.159
$C_5$	0.139	0.139	0.139	0.146	0.126	0.158
$C_6$	0.142	0.142	0.142	0.149	0.161	0.129

**Table 8** The stable matrix of DANP when  $\lim_{z \rightarrow \infty} (W^\alpha)^z$ 

Criteria	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$
$C_1$	0.179	0.179	0.179	0.179	0.179	0.179
$C_2$	0.189	0.189	0.189	0.189	0.189	0.189
$C_3$	0.185	0.185	0.185	0.185	0.185	0.185
$C_4$	0.162	0.162	0.162	0.162	0.162	0.162
$C_5$	0.141	0.141	0.141	0.141	0.141	0.141
$C_6$	0.144	0.144	0.144	0.144	0.144	0.144

performance presented in Table 9. The results confirm that website A, one of the websites of technology company in Taiwan, presents the smallest performance gap (0.277). It is followed by websites B (0.282) and C (0.341) with this regard. Consequently, according to the decision model of search engine ranking provided by this paper, administrators of websites are suggested to take website A as a reference when advancing search engine ranking based on SEO.

#### 4.5 Implications and discussions

The empirical findings are discussed as follows. In the first place, INRM (Fig. 1) of SEO constructed by DEMATEL reveals that administrators of websites should improve first is external website optimization ( $D_2$ ), if the search engine ranking of websites is going down. After providing users with diverse social media ( $C_5$ ) components for the promotion of a content's popularity, making mutual linkage ( $C_6$ ) to the websites for users to find complete

Table 9 Influential weights and performance gaps of selected websites

Dimensions/criteria	Local weight	Global weight	Website A ( $A_1$ )		Website B ( $A_2$ )		Website C ( $A_3$ )	
			Performance	Gap	Performance	Gap	Performance	Gap
Internal website optimization ( $D_1$ )	0.553	–	7.786	0.221	7.894	0.211	7.000	0.300
Website design ( $C_1$ )	0.324	0.179	8.867	0.113	0.087	9.133	0.140	9.133
Meta tags ( $C_2$ )	0.342	0.189	7.400	0.260	7.333	0.267	6.267	0.373
Keywords ( $C_3$ )	0.335	0.185	7.133	0.287	7.267	0.273	6.200	0.380
External website optimization ( $D_2$ )	0.447	–	6.552	0.345	6.293	0.371	6.082	0.392
Site guide ( $C_4$ )	0.362	0.162	3.933	0.607	3.933	0.607	2.467	0.753
Social media ( $C_5$ )	0.315	0.141	7.400	0.260	7.533	0.247	7.800	0.220
Linkage ( $C_6$ )	0.322	0.144	8.667	0.133	7.733	0.227	8.467	0.153
Total	–	–	7.234	0.277	7.178	0.282	6.589	0.341

Performance gap:  $r_{k,j} = (|f_j^{aspired} - f_{k,j}|) / (|f_j^{aspired} - f_j^{worst}|) = (10 - f_{k,j}) / (10 - 0)$

Examples:

Calculate total performance of  $A_1$  by global weights:  $0.179 \times 8.867 + 0.189 \times 7.400 + 0.185 \times 7.133 + 0.162 \times 3.933 + 0.141 \times 7.400 + 0.144 \times 8.667 = 7.234$

Calculate total gap of  $A_1$  by global weights:  $S_{A_1} = d_{A_1}^{p=1} = \sum_{j=1}^6 w_j \left( \frac{f_j^* - f_{A_1,j}}{f_j^* - f_j^-} \right) = 0.179 \times \left( \frac{10 - 8.867}{10 - 0} \right) + 0.189 \times \left( \frac{10 - 7.400}{10 - 0} \right) + 0.185 \times \left( \frac{10 - 7.133}{10 - 0} \right) + 0.162 \times \left( \frac{10 - 3.933}{10 - 0} \right) + 0.141 \times \left( \frac{10 - 7.400}{10 - 0} \right) + 0.144 \times \left( \frac{10 - 8.667}{10 - 0} \right) = 0.277$

information, submitting websites to search engines to be included in the site guides ( $C_4$ ) for been found quickly, internal website optimization ( $D_1$ ) can get following influences: administrators of websites can collect plenty of keywords ( $C_3$ ) from users to improve and redirect the websites, get suitable description for meta tags ( $C_2$ ), and adjust the website design ( $C_1$ ) to satisfy the needs of users.

Secondly, the most significant criterion found by DANP when implementing SEO is meta tags ( $C_2$ ), which weights 0.189. When it comes to search engine ranking, an essential procedure for administrators of websites to consider is that websites should be found by search engines. If meta tags are not described properly, search engines cannot access to the information provided by websites including videos, audios, pictures, webpages, and so forth. Therefore, administrators of websites should give every information appropriate descriptions not only for search engine to find, but also let users easily look for the information that they need to make decisions. Thirdly, the influential weight of keywords ( $C_3$ ) is 0.185 ranked the second among the six criteria of SEO. Once search engines can find the websites, the next cardinal issue for administrators of websites is to let users have the opportunities to search for information by utilizing keywords. Although search engines have started to seriously take some other factors into account apart from meta tags and keywords, "SEO Starter Guide" published by Google has definitely indicated that the two factors are very critical for search engines to produce the abstracts for websites.

Many administrators of websites may set up keywords according to their businesses; however, these websites can be regarded as not existed by decision makers, if they do not show up on the search engine results by the decision makers' keywords. Therefore, administrators of websites should brainstorm for the optimal keywords from the standpoint of decision makers to have their websites appeared on target users. At the last point, VIKOR reveals that administrators of websites can consider the technology website A ( $A_1$ ) as a reference to improve their performances of websites for achieving aspiration level.

The proposed hybrid modified MCDM models based on SEO can be utilized in worldwide websites. Administrators of websites can adjust the influential weights of the six criteria according to the situations of different countries to obtain valuable information for decision making when improving performances of websites. Moreover, they can select the websites of their industries to evaluate and reduce their gaps for advancing search engine ranking.

## 5 Conclusions and remarks

SEO is utilized as a significant technique for high ranking on search engines in the field of internet marketing. It has been developed for decades and examined that the dimensions of internal and external website optimization influence search engine ranking. Nevertheless, it is still vague how the evaluation criteria impact the two dimensions. Although the comprehension of the importance of the criteria can be useful for administrators of websites when implementing SEO, the weights of criteria are seldom investigated.

By utilizing DEMATEL, the criteria are demonstrated having interrelations and self-feedback relationships. Moreover, DANP is employed to obtain influential weights of the six criteria. Empirical findings show that meta tags is the most important criterion, followed by keywords, website design, site guide, linkage, and social media. Experts suggest that administrators of websites put the most emphasis on meta tags, though they must comprehensively take criteria into consideration when making decisions of SEO. As for evaluating SEO, the highest integrated scores is website A, followed by websites of B and C. Therefore, experts

indicate that SEO of website A is an optimal example when implementing SEO for providing administrators of websites to achieve the greatest benefit of internet marketing.

Preceding studies pay most attention to introducing SEO and identifying the criteria that influence it. However, only few past research attempts are concerned about the interrelationship among criteria, the weights of criteria, and the evaluation of website's SEO. This paper thus proposes hybrid modified MCDM models and investigates the perspectives of employing experts for exploring these issues. Associating previous theoretical research with opinions of professional experts, this paper makes contribution to SEO for improving search engine ranking of websites which is not offered by previous research attempts. In conclusion, this research utilizes hybrid modified MCDM models based on SEO to explore the subject for improving and evaluating search engine ranking. As time goes on, search engines will update their machine learning algorithms to diminish low value websites; therefore, further studies can overcome the limitations of this study by taking the latest factors into consideration and inviting various backgrounds of experts to make the research of SEO complete.

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## Appendix A. Hybrid modified MCDM models combined with DEMATEL, DANP, and VIKOR

### A.1. DEMATEL

The method is illustrated as follows: first, we acquire the influence matrix  $A$  by influential scores derived from expert questionnaire survey. Second, the normalized influence matrix  $K$  can be calculated by normalizing  $A$  via Eqs. (1) and (2).

$$K = m \cdot A \quad (1)$$

$$m = \min \left[ \frac{1}{\max_i \sum_{j=1}^n |a_{ij}|}, \frac{1}{\max_j \sum_{i=1}^n |a_{ij}|} \right] \quad (2)$$

Thirdly, derive the total influence matrix  $T$ .  $T$  can be derived by using the formula  $T = K + K^2 + K^3 + \dots + K^h = K(I - K)^{-1}$ , when  $\lim_{h \rightarrow \infty} K^h = [0]_{n \times n}$ , and  $I$  denotes the identity matrix. The fourth step: define the INRM through the vectors  $r$  and  $s$  derived from the sum of the rows and columns separately within the total-influence matrix  $T = [t_{ij}]_{n \times n}$  via the Eqs. (3) and (4), where the superscript  $'$  represents transpose.

$$r = [r_i]_{n \times 1} = \left[ \sum_{j=1}^n t_{ij} \right]_{n \times 1} \quad (3)$$

$$s = [s_j]_{n \times 1} = \left[ \sum_{i=1}^n t_{ij} \right]'_{1 \times n} \quad (4)$$

If  $r_i$  denotes the row sum of the  $i$ th row in matrix  $T$ , then  $r_i$  displays the sum of direct and indirect effects of criterion  $i$  on all other criteria. And, if  $s_j$  denotes the column sum of the  $j$ th column of matrix  $T$ , then  $s_j$  presents the sum of direct and indirect effects that criterion  $j$  receives from all other criteria. Moreover, when  $i = j$  the sums of the row and column aggregate ( $r_i + s_i$ ), it exhibits the giving and received degree of influences; i.e.,  $(r_i + s_i)$  presents the intensity of the significant role that the  $i$ th criterion plays in the problem. When  $(r_i - s_i)$  is positive, the  $i$ th criterion affects other criteria. On the contrary, if  $(r_i - s_i)$  is negative, other criteria influence the  $i$ th criterion (i.e.  $i$ th criterion is affected by other criteria). And thus the INRM can be constructed (Liou et al. 2007).

## A.2. Based on DEMATEL technique to find ANP weights

DANP consists of four steps (Hu et al. 2014), and the first step is to build the construction of the influence network based on DEMATEL. In the second step, the unweighted super-matrix is calculated. The total influence matrix  $T$  is derived from DEMATEL shown in Eq. (5), where  $\sum_{j=1}^m m_j = n$ ,  $m < n$ , and  $T_c^{ij}$  as a  $m_i \times m_j$  matrix.

$$T_c = \begin{matrix} & \begin{matrix} D_1 & & D_j & & D_m \\ c_{11} \dots c_{1m} & \dots & c_{j1} \dots c_{jm} & \dots & c_{m1} \dots c_{mm} \end{matrix} \\ \begin{matrix} D_1 \\ \vdots \\ D_i \\ \vdots \\ D_m \end{matrix} = \begin{matrix} c_{i1} \\ c_{i2} \\ \vdots \\ c_{im} \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm} \end{matrix} & \begin{bmatrix} T_c^{11} & \dots & T_c^{1j} & \dots & T_c^{1m} \\ \vdots & & \vdots & & \vdots \\ T_c^{i1} & \dots & T_c^{ij} & \dots & T_c^{im} \\ \vdots & & \vdots & & \vdots \\ T_c^{m1} & \dots & T_c^{mj} & \dots & T_c^{mm} \end{bmatrix} \end{matrix} \quad (5)$$

$n \times n | m < n, \sum_{j=1}^m m_j = n$

Then, use the total degree of influence to normalize every level of  $T_c$  for acquiring  $T_c^\alpha$  based on Eq. (6).

$$T_c^\alpha = \begin{matrix} & \begin{matrix} D_1 & & D_j & & D_m \\ c_{11} \dots c_{1m} & \dots & c_{j1} \dots c_{jm} & \dots & c_{m1} \dots c_{mm} \end{matrix} \\ \begin{matrix} D_1 \\ \vdots \\ D_i \\ \vdots \\ D_m \end{matrix} = \begin{matrix} c_{i1} \\ c_{i2} \\ \vdots \\ c_{im} \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm} \end{matrix} & \begin{bmatrix} T_c^{\alpha 11} & \dots & T_c^{\alpha 1j} & \dots & T_c^{\alpha 1m} \\ \vdots & & \vdots & & \vdots \\ T_c^{\alpha i1} & \dots & T_c^{\alpha ij} & \dots & T_c^{\alpha im} \\ \vdots & & \vdots & & \vdots \\ T_c^{\alpha m1} & \dots & T_c^{\alpha mj} & \dots & T_c^{\alpha mm} \end{bmatrix} \end{matrix} \quad (6)$$

$n \times n | m < n, \sum_{j=1}^m m_j = n$

For instance,  $T_c^{\alpha 11}$  can be calculated via Eqs. (7) and (8), and we can obtain  $T_c^{\alpha mm}$  by the same way.

$$d_i^{11} = \sum_{j=1}^{m_1} t_{cij}^{11}, \quad i = 1, 2, \dots, m_1 \quad (7)$$

$$T_c^{\alpha 11} = \begin{bmatrix} t_{c11}^{11}/d_1^{11} & \cdots & t_{c1j}^{11}/d_1^{11} & \cdots & t_{c1m_1}^{11}/d_1^{11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{11}/d_i^{11} & \cdots & t_{cij}^{11}/d_i^{11} & \cdots & t_{cim_1}^{11}/d_i^{11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{11}/d_{m_1}^{11} & \cdots & t_{cm_1j}^{11}/d_{m_1}^{11} & \cdots & t_{cm_1m_1}^{11}/d_{m_1}^{11} \end{bmatrix} = \begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{c1j}^{\alpha 11} & \cdots & t_{c1m_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{\alpha 11} & \cdots & t_{cm_1j}^{\alpha 11} & \cdots & t_{cm_1m_1}^{\alpha 11} \end{bmatrix} \quad (8)$$

According to the interdependent relationship in group to array  $T_c^\alpha$ , the unweighted supermatrix can then be obtained by Eq. (9).

$$W = (T_c^\alpha)' = \begin{matrix} & \begin{matrix} D_1 & & D_i & & D_m \\ c_{11} & c_{1m_1} & \cdots & c_{i1} & c_{im_i} & \cdots & c_{m1} & c_{mm_m} \end{matrix} \\ \begin{matrix} D_1 \\ \vdots \\ D_i \\ \vdots \\ D_m \end{matrix} & \begin{bmatrix} W^{11} & \cdots & W^{i1} & \cdots & W^{m1} \\ \vdots & & \vdots & & \vdots \\ W^{1j} & \cdots & W^{ij} & \cdots & W^{mj} \\ \vdots & & \vdots & & \vdots \\ W^{1m} & \cdots & W^{im} & \cdots & W^{mm} \end{bmatrix} \end{matrix} \quad (9)$$

$n \times n | m < n, \sum_{j=1}^m m_j = n$

For example,  $W^{11}$  can be calculated by Eq. (10), and  $W^{nn}$  can be derived by the same way. A blank space or 0 in the matrix show independence of the group of criteria or a single criterion in relation to other criteria.

$$W^{11} = (T^{11})' = \begin{matrix} & c_{11} & \cdots & c_{1i} & \cdots & c_{1m_1} \\ \begin{matrix} c_{11} \\ \vdots \\ c_{1j} \\ \vdots \\ c_{1m_1} \end{matrix} & \begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{c1i}^{\alpha 11} & \cdots & t_{cm_11}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{c1j}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cm_1j}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{c1m_1}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} & \cdots & t_{cm_1m_1}^{\alpha 11} \end{bmatrix} \end{matrix} \quad (10)$$

The third step is dedicated to the derivation of the weighted supermatrix. The total influence matrix of dimensions  $T_D$  is obtained thanks to Eq. (11). Then, utilize the total degree of influence to normalize every level of  $T_D$  for obtaining  $T_D^\alpha$  according to Eq. (12).

$$d_i = \sum_{j=1}^m t_D^{ij}, \quad i = 1, 2, \dots, m$$

$$T_D = \begin{bmatrix} t_D^{11} & \cdots & t_D^{1j} & \cdots & t_D^{1m} \\ \vdots & & \vdots & & \vdots \\ t_D^{i1} & \cdots & t_D^{ij} & \cdots & t_D^{im} \\ \vdots & & \vdots & & \vdots \\ t_D^{m1} & \cdots & t_D^{mj} & \cdots & t_D^{mm} \end{bmatrix}_{m \times m} \quad (11)$$

$$T_D^\alpha = \begin{bmatrix} t_D^{11}/d_1 & \cdots & t_D^{1j}/d_1 & \cdots & t_D^{1m}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_D^{i1}/d_i & \cdots & t_D^{ij}/d_i & \cdots & t_D^{im}/d_i \\ \vdots & & \vdots & & \vdots \\ t_D^{m1}/d_m & \cdots & t_D^{mj}/d_m & \cdots & t_D^{mm}/d_m \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \cdots & t_D^{\alpha 1j} & \cdots & t_D^{\alpha 1m} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha i1} & \cdots & t_D^{\alpha ij} & \cdots & t_D^{\alpha im} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha m1} & \cdots & t_D^{\alpha mj} & \cdots & t_D^{\alpha mm} \end{bmatrix} \quad (12)$$

The weighted super-matrix can thus be calculated by normalizing  $T_D^\alpha$  into the unweighted super-matrix shown in Eq. (13).

$$W^\alpha = T_D^\alpha W = \begin{bmatrix} t_D^{\alpha 11} \times W^{11} & \dots & t_D^{\alpha i1} \times W^{i1} & \dots & t_D^{\alpha m1} \times W^{m1} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1j} \times W^{1j} & \dots & t_D^{\alpha ij} \times W^{ij} & \dots & t_D^{\alpha mj} \times W^{mj} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1m} \times W^{1m} & \dots & t_D^{\alpha im} \times W^{im} & \dots & t_D^{\alpha mm} \times W^{mm} \end{bmatrix}_{n \times n | m < n, \sum_{j=1}^m m_j = n} \quad (13)$$

Fourthly, the limit super-matrix is calculated. The weighted super-matrix multiplies by itself enough times, based on the concept of Markov Chain, to acquire the limit super-matrix. Therefore, the influential weights of criteria are acquired by  $\lim_{z \rightarrow \infty} (W^\alpha)^z$ . The influential weights of DANP can be obtained by means of the limit super-matrix application  $W^\alpha$  with power  $z$ , indicating an adequately large integer, until the super-matrix  $W^\alpha$  has converged and becomes a long-term stable super-matrix to obtain the global priority vectors  $w = (w_1, \dots, w_j, \dots, w_n)$ , called DANP (DEMATEL-based ANP) influential weights. Then local weights  $w^{D_i} = (w_1^{D_i}, \dots, w_j^{D_i}, \dots, w_{m_i}^{D_i})$  of criteria  $j = 1, 2, \dots, m_i$  in dimension  $i$ , and local weights  $w^D = (w_1^D, \dots, w_i^D, \dots, w_m^D)$  of all dimensions in  $i = 1, 2, \dots, m$  also can be obtained respectively.

### A.3. Evaluating the total performance by VIKOR

According to the concept of the positive-ideal point ( $f_j^* = \max_k \{f_{kj} | k = 1, 2, \dots, K\}$ ) and negative-ideal point ( $f_j^- = \min_k \{f_{kj} | k = 1, 2, \dots, K\}$ ), called “max–min” benchmark, the simple additive weighting (SAW) method uses the traditional distance function (Freimer and Yu 1976; Yu 1973). However, the aspiration level ( $f_j^{aspired}$ ) and the worst level ( $f_j^{worst}$ ), called “aspired–worst” benchmark, is adopted by this paper. For example, assume the aspiration level  $f_j^{aspired} = 10$  and the worst level  $f_j^{worst} = 0$  meaning the performance scores are from 0 to 10 (very bad/dissatisfaction  $\leftarrow 0, 1, 2, \dots, 8, 9, 10 \rightarrow$  very good/satisfaction).

By using VIKOR, the modified SAW is suitably utilized for evaluating and improving the performance matrix  $[f_{kj}]_{K \times n}$  of technologic companies’ websites. Moreover, it is developed for exploring the way of reducing the performance gaps in each criterion  $j$  with alternative  $k$  in complex interrelationship systems shown as Eq. (14).

$$r_{kj} = \left\{ \left( \left| f_j^{aspired} - f_{kj} \right| \right) / \left( \left| f_j^{aspired} - f_j^{worst} \right| \right) \middle| k = 1, 2, \dots, K; j = 1, 2, \dots, n \right\} \quad (14)$$

It illustrates the multiple-criteria index by measuring performance gaps to improve each criterion  $r_{kj}$ , dimension  $r_k^{D_i} = \sum_{j=1}^{m_i} w_j^{D_i} r_{kj}^{D_i}$ , as well as alternative  $r_k = \sum_{i=1}^m \sum_{j=1}^{m_i} w_j^{D_i} r_{kj}^{D_i} = \sum_{j=1}^n w_j r_{kj}$  based on INRM for approaching and achieving the aspiration level with zero gap.

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