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A Multicriteria Selection Model for Developing New Color Calibration Device

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Abstract

Color Calibration Device is a key component for the performance of Medical Display Monitor (MDM). MDMs have been extensively used in hospitals in the past decades. The technological requirements of MDMs are higher than those of general purpose display monitors, but the gross profit margins of MDMS are larger as well. The purpose of this research is to build a hybrid multiple criteria decision making (MCDM) model useful in developing new color calibration device for the MDM industry. The proposed MCDM model uses fuzzy Kano method to filter the performance criteria, and then apply the analytic network process (ANP) in selecting the best alternative among three new products. In this study, gray relation analysis (GRA) is used to build a relations-structure for ANP criteria. The paper also presents a case study on model implementation in a LCD high-tech company.

Keywords: *fuzzy Kano model, analytic network process, medical display monitor, color calibration device, GRA*

1. Introduction

Technological innovations and business environments are changing rapidly nowadays, particularly in the electronic product industry. In order to maintain competitiveness in their business environment, companies require effective and efficient research and development (R&D) capabilities to develop new products, strong marketing power, and competent organizational integration [1]. In recent years, Medical Display Monitors (MDMs) have been widely used in medical centers. The technological requirements of MDMS are higher than those of display monitors used for general purposes, but their gross profit margins are larger as well. Mathematical modeling approach is frequently adopted to solve such decision problems. However, surveys in the literature and collected data from industrial practitioners indicate that few modeling techniques of this approach were applied in practice. Major criticisms of these techniques involve their inability to deal with strategic factors, mathematical complexity, and implementation flexibility [2, 3].

Multiple criteria decision making (MCDM) is one of appropriate approaches dealing with the new product development selection problem. The MCDM approach enables experts and decision makers to simultaneously consider the relevant factors or criteria, and then integrate their opinions in building an MCDM model. Subsequently, the model is applied to weight the alternatives and select the best. Among various MDCM methods, analytic hierarchy process (AHP) [4] is a common and practical method. The AHP copes with the use of applicable information and experience, allowing decision makers to model a complex problem in a hierarchical structure. A simple AHP model consists of a goal, criteria and alternatives. The hierarchical structure shows the relationships of the three levels from top to bottom. The modeling process consists of three phases: decomposition, comparative judgment, and synthesizing [5]. The decomposition phase constructs a hierarchical structure based on experts' and decision-makers' opinions. The hierarchical structure of the basic AHP allows dependencies among elements of consecutive levels within the hierarchy, and the only possible direction of impact is downward towards the bottom of the hierarchy. Also, the elements of a given level are assumed to be mutually independent. Concepts and techniques, such as pairwise comparisons and eigenvector method, are used in the comparative judgment phase to

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derive criteria weights and check consistency. The synthesizing phase ranks the elements at the lowest level, which are classified as subcriteria or alternatives.

The Analytic Network Process (ANP), introduced in [6], is a generalization of the AHP. Whereas AHP represents a decision-making framework with a unidirectional hierarchical relationship, ANP allows for complex interrelationships among decision clusters and their elements. Many decision problems cannot be structured hierarchically, since they involve interdependencies of both the elements within the same clusters (innerdependence), and the elements between clusters at the same or different levels (outerdependence or feedback). Therefore, ANP represents a decision model by a network, rather than a hierarchy. Although ANP and AHP are similar in the comparative judgment phase, there are differences in the synthesizing phase. In the ANP, ratio scale priority vectors derived from pairwise comparison matrices are not synthesized linearly, as with AHP. Saaty [6] proposed “supermatrix” technique, which uses Markov chain convergence theory to synthesize ratio scale.

There are many studies in literature using ANP to solve decision making problems. In two separate studies, [7, 8] used ANP to prioritize interdependent information system projects. The studies [9-11] also employed ANP to solve R&D project selection problems. Hu et al. [12] also used ANP to evaluate the homestay industry in north Taiwan. Recently, hybrid MCDM models are commonly used to solve complex decision problems. Shyur [13] combined ANP and modified TOPSIS to evaluate and select the commercial-off-the-self (COTS) products in software development projects. In this study, the ANP is used to obtain the relative weights of the criteria, but not for the alternatives to reduce large numbers of pairwise comparisons. The modified TOPSIS uses a newly defined weighted Euclidean distance to rank competing products in terms of overall evaluation results on multiple criteria. Dağdeviren [14] also adopted the same approach to solve personnel selection problems in manufacturing systems. Liou and Chuang [15] studied the outsourcing provider selection problem, and developed a hybrid MCDM model consisting of DEMATEL, ANP, and VIKOR to prioritize the alternatives. In their model, the DEMATEL builds a relations-structure among criteria, the ANP determines the relative weights of criteria with dependence and feedback, and the VIKOR ranks the alternatives. Fazli and Jafari [16]) applied the same hybrid model to solve the investment decision problem in the Iranian stock exchange. Hsu [17] presented a selection model combining ANP and GRA (gray relational analysis) for independent media agencies, where GRA performs a role similar to TOPSIS in [13, 14].

The purpose of this paper is to present a solution model for the decision problem on developing new color calibration device, allowing the consideration of interactions among decision levels and criteria. The device is used in medical display monitors. The fuzzy Kano method [18, 19] is utilized to filter the elements of “criteria”, whereas GRA is used to build a relations-structure among elements of the model. The Kano model was first developed by Kano et al. [20] to categorize the features of a product or service, based on how well they satisfy customers’ needs. Compared to the traditional Kano model, the fuzzy Kano method allows the respondents to express their ideas in a more flexible and reasonable manner. The Kano model has been applied in new product development [21], new service creation [22], internet community [23], logistics customer service [24], etc.

The paper is structured as follows: Section 2 describes the process for establishing the hybrid MCDM model; Section 3 presents the numerical results of a case study utilizing this model; Section 4 concludes the paper.

2. Proposed Model

This paper presents a model developed from the literature, and adapted for a LCD high-tech company. The company acts as the case study to validate the model. To build the model, ten experts and decision-makers are invited to participate. All are members of high management, including Departments of R&D, Marketing, Production, Information Technology, and Product Planning. Subsequently, a four-level hierarchical model with inner- and outer-dependence is proposed. We shall refer to the top element as the goal, the clusters at the second level as “perspectives”, the clusters at the third level as “criteria”, and the elements at the lowest level as “alternatives”.

The evaluation process consists of the following steps:

Step 1: Form an expert/decision-maker group for this problem.
Step 2: Establish a preliminary evaluation framework via literature review and discussion with the group.
Step 3: Apply fuzzy Kano method to filter the elements in the framework, including the perspectives and their respective criteria.
Step 4: Employ GRA to identify the relationships between elements in the framework, and finalize the ANP.
Step 5: Perform ANP calculations to prioritize the criteria and the alternatives.

2.1. Fuzzy Kano Model (FKM)

The FKM adopted for screening the criteria is based on [18, 19] with modifications. The Kano model illustrates the relationship between customer satisfaction and product or service quality. The model divides product or service features into five categories, as shown below:

(a) Must-be attributes: These attributes are considered to be necessary by customers. Their sufficiency will not result in higher satisfaction for customers, but insufficiency will dissatisfy customers.

(b) One-dimensional attributes: These attributes are “the more the better” and “the less the worse”. The effects may only go in one direction.

(c) Attractive attributes: Customers will feel more satisfaction as the performance of these attributes improves. However, customers will still deem them acceptable if they are not sufficient.

(d) Indifferent attributes: These attributes will not affect customer satisfaction, whether they are sufficient or not.

(e) Reverse attributes: These attributes have effects on customer satisfaction inverse to One-dimensional attributes; that is, “the more the worse” and “the less the better”.

Kano et al. [20] used functional (positive) and dysfunctional (negative) questionnaires, which form a 5 x 5 evaluation table to determine distinct attributes. This is achieved by asking two questions:

(a) If the product/service provided to you functions well, how do you feel?

(b) If the product/service provided to you functions unsatisfactorily, how do you feel?

Table 1 shows the Kano’s evaluation table, where symbol “M” stands for “must-be”, “O” for “one dimensional”, “A” for “attractive”, “Q” for “questionable”, “I” for indifferent”, and “R” for reverse”. Table 2 provides an answer sheet for the traditional Kano questionnaire. If a respondent marks “Like” for Functional and “Live-with” for Dysfunctional, then the conclusion is “A” from Table 1. Table 3 presents an example of the fuzzy Kano questionnaire (FKQ). The FKQ allows a respondent to give a fuzzy evaluation when he feels uncertainty. Thus, the FKQ is superior to TKQ, since the former is more accurate in securing a respondent’s authentic opinion. In the case of Table 3, the 5 x 5matrix generated by $[0.9\ 0.1\ 0\ 0\ 0]^T \cdot [0\ 0\ 0.1\ 0.4\ 0.5]$, the resulting value that corresponds to “A” is 0.09+0.36=0.45, to “O” is 0.45, to “I” is 0.05, to “M” is 0.05, and to “Q” is zero. If the significance classification level (also known as α-cut) is set to 0.4, then the respondent will give 1 to both “A” and “O”, and give 0 to the others.

Table 1 Kano’s evaluation table

	Dysfunctional				
Functional	Like	Must-be	Neutral	Live-with	Dislike
Like	Q	A	A	A	O
Must-be	R	I	I	I	M
Neutral	R	I	I	I	M
Live-with	R	I	I	I	M
Dislike	R	R	R	R	Q

Source by Matzler and Hinterhuber (1998)

Table 2 Traditional Kano’s questionnaire (TKQ)

TKQ	Like	Must-be	Neutral	Live-with	Dislike
Fuctional	v				
Dysfunctional				v	

Table 3 Fuzzy Kano’s questionnaire (FKQ)

FKQ	Like	Must-be	Neutral	Live-with	Dislike
Fuctional	0.9	0.1			
Dysfunctional			0.1	0.4	0.5

The preliminary decision framework considers three perspectives and fifteen criteria. After applying the modified FKM, eleven criteria are considered for the studied problem. Table 4 shows the FKQ results of the group for the eleven criteria, where each criterion has weighted frequency greater than 7.493, which is the average of the initial fifteen criteria. In order to utilize the modified FKM, preprocessing is performed to assign the weights of the six quality attributes. Three attributes, “M”, “A”, and “O”, are regarded as positive elements, whereas the other three attributes, “R”, “I”, and “Q”, are considered to be undetermined or negative. By observing the characteristics of these attributes in a two-dimensional Kano model, and after discussion with the group, a weight vector for the six attributes is given as follows: $[W_O, W_A, W_M, W_I, W_R, W_Q]$ = [1, 0.6, 0.8, -1, -1, 0]. This estimate is conservative, as it stresses the negative effects. For example, “M” is assigned a value of 0.8, “A” a value of 0.6, and both “I” and “R” a value of “-1”. The criteria screening process is illustrated as follows:

Step 1: For each criterion C_{ij}, calculate frequencies for each attribute based on the group’s FKQ results, $\{F_{ijk}$: k = O, A, M, I, R, Q$\}$, where F_{jk} is the sum of “1’ appearing in ten FKQ results for C_{ij}.

Step 2: For each $C_{ij,}$ calculate weighted frequency using the formula, $WF_{ij} = W_O \cdot F_{ijO} + W_A \cdot F_{ijA} + W_M \cdot F_{ijM} + W_I \cdot F_{ijI} + W_R \cdot F_{ijR} + W_Q \cdot F_{ijQ}$.

Step 3: Compute the average of WF_{ij} for all j. If $WF_{ij} \geq$ average value, retain criterion C_{ij}; delete if otherwise.

Table 4. Criterion Frequency List of Fuzzy Kano Model and Resulting Average Weighted Frequency

$W_{(M \sim Q)}$	0.8	1	0.6	-1	-1	0	Average_WF_{ij} 7.493
	M	**O**	**A**	**I**	**R**	**Q**	WF_{ij}
C_{11}	2	5	4	0	0	0	9
C_{12}	5	4	1	0	0	0	8.6
C_{13}	2	8	0	0	0	0	9.6
C_{14}	3	3	5	0	0	0	8.4
C_{21}	3	6	1	0	0	0	9
C_{22}	3	4	4	1	0	0	7.8
C_{23}	3	6	2	0	0	0	9.6
C_{24}	4	4	3	1	0	0	8
C_{31}	3	6	1	1	0	0	8
C_{32}	1	7	2	1	0	0	8
C_{33}	4	4	2	0	0	0	8.4

The resulting decision framework contains the following:

Level 1: Goal (G) – determine the device to be developed.

Level 2: Perspectives (P) – Technical Capability (P_1), Marketing Environment (P_2), Organizational Management (P_3).

Level 3: Criteria for each perspective;

P_1 : Technical Capability

C_{11} – Technology patent;

C_{12} – Product accreditation

C_{13} – Customization capacity

C_{14} – R&D capability

P_2 : Marketing Environment

C_{21} – Product profitability

C_{22} – Competitiveness

C_{23} – Consumer preference

C_{24} – Brand image

P_3: Organizational management

C_{31} – Relations & corporate support

C_{32} –Integration ability

C_{33} – Marketing capability

Level 4: Three alternatives;

A_1: Front sensor – size: 18 x 10 mm; weight: 30g; imbedded USB; automatic control; technical difficulty: high; current market share: 30%; precision: ±15%; applicable MDM: 19-27 inch; investment: USD100000; estimated selling price: USD1000; warranty: 3 years.

A_2: Color sensor – size: 68 x 41 mm; weight: 140g; external USB; manual control; technical difficulty: medium; current market share: 60%; precision: ±5%; applicable MDM: 19-60 inch; investment: USD60000; estimated selling price: USD300; warranty: 1 year.

A_3: Swing sensor – size: 117 x 29 x 96 mm; weight: 160g; external USB; automatic control; technical difficulty: very high; current market share: 10%; precision: ±10%; applicable MDM: 19-27 inch; estimated selling price: USD1200; warranty: 2 years.

2.2. Relations among Elements at Each Level

A modified gray relation analysis method is applied to determine the dependence between any two elements at the perspective and criteria levels. For simplicity, we illustrate the method using three perspectives. Let R_{n1k} denote the influential or relational value of P_1 on P_k given by the n-th member of the group, k = 1, 2, 3 and n = 1,…, 10; $0 \le R_{n1k} \le 1$. Note that R_{n11} = 1 for all n. Define $\Delta_{nik} = | R_{n1k} - R_{n11}|$ for all n and k. $\Delta\max = \max\{\Delta_{nik} \mid n = 1,\ldots, 10; k = 2, 3\}$ and $\Delta\min = \min\{\Delta_{nik} \mid n = 1,\ldots, 10; k = 2, 3\}$. Then the gray relation coefficient (GRC) of the n-th member can be calculated via the following formula:

$$\gamma_{n1k} = (\Delta\min + \xi\cdot\Delta\max)/(\Delta_{n1k} + \xi\cdot\Delta\max) \quad (1)$$

Where ξ, is termed a distinguishing coefficient and usually takes a value of 0.5 for objective purposes. The GRC of P_1 on P_k is the average value of γ_{n1k} for n = 1,…, 10. In this study, the threshold value is set to 0.6 for identifying the influence of P_1 on P_k. In other words, if the average is larger than the threshold, then the influence is accepted. This same method is applied to P_2 and P_3. The group's scoring results indicate that the three perspectives are mutually dependent. By applying pairwise comparisons and then synthesizing the group's evaluation results, we obtain the relative correlation strengths shown in Table 6. The same process is applied to every element at the criteria level. The interdependencies and relative correlation strengths among the elements at this level are shown in Table 8. For instance, criterion C_{11} is correlated to criteria {C_{12}, C_{14}, C_{21}, C_{22}, C_{23}, C_{24}, C_{31}} with the following correlation strengths {0.209, 0.276, 0.138, 0.124, 0.139, 0.047, 0.066}.

2.3. Analytic Network Process (ANP)

From sections 2.1 and 2.2, an ANP model can be established for the studied problem. The left side of Figure 1 displays the ANP in graphical form, and the right side of Figure 1 presents the corresponding unnormalized supermatrix M_S. Figure 2 shows the detailed network structure of the ANP. Matrix W_{21} is 3 x 1, which indicates the relative weights (importance) of the three perspectives with respect to the Goal. Matrix W_{22} is 3 x 3, which shows the influential strength among the three perspectives. Matrix W_{32} is 11 x 3, which specifies the relative importance of the criteria with respect to their individual perspectives. Matrix W_{33} is 11 x 11, which signifies the dependencies for criteria within the same cluster and between two distinct clusters. Matrix W_{43} is 3 x 11, which shows the relative weights of the three alternatives for each criterion. I is a 3 x 3 identity matrix, which implies that the three alternatives are independent.

3. Numerical Results

Table 5 illustrates the calculated results for W_{21}. The other matrices can be similarly obtained. First, arithmetic mean is used to integrate the pairwise comparisons of group members. For example, a_{12} = 2.800 in W_{21} is the mean of the values in the same position given by the group members. Afterwards, the geometric mean method is used to calculate the relative weights: $2.098 = (1\cdot 2.8\cdot 3.3)^{1/3}$, $0.950 = (0.357\cdot 1\cdot 2.4)^{1/3}$, and $0.502 = (0.303\cdot 0.417\cdot 1)^{1/3}$. The weight of P_1 in W_{21} is 2.098/(2.098+0.950+0.502) = 0.591. By similar calculations, we obtain that the weights of P_2 and P_3 are respectively 0.268 and 0.141. Further calculations indicate that CR = 0.049, which confirms the consistency of the group's evaluations.

Similar calculations produce the matrices W_{ij} in Tables 6-9. ANP uses limiting or convergent weights to rank the perspectives, criteria, and alternatives. To calculate the limiting supermatrix, we apply the Markov chain theory [6]. A Markov chain requires the sum of each column to be 1. Thus, the supermatrix M_S in Figure 1 needs to be normalized for the column sum requirement. A normalized supermatrix M_w can be obtained by dividing any column in P

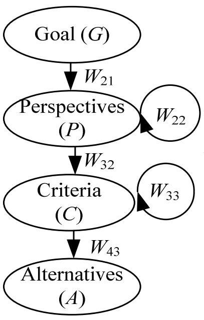
and C by 2, as shown in Figure 3. The details of the normalized supermatrix M_w is provided in Table 10.

The limiting weight vectors of the respective three perspectives, eleven criteria, and three alternatives can be obtained by a series of matrix computations on the three matrices in Figure 3 until they converge.

For perspectives: Compute $(M_1^T)^n$ for large n, where T represents matrix transpose. As a result, the limiting weight vector (P_1, P_2, P_3) = (0.402, 0.319, 0.279). Technical capacity ranks first, Product profitability second, Organizational management third.

For criteria: Compute $(M_{w2}^T)^n$ for large n; (C_{11}, C_{12}, C_{13}, C_{14}, C_{21}, C_{22}, C_{23}, C_{24}, C_{31}, C_{32}, C_{33}) = (0.209, 0.174, 0.067, 0.154, 0.058, 0.096, 0.076, 0.059, 0.048, 0.027, 0.032). Among the eleven criteria, Technical patent and Product accreditation are deemed the most important by the group, whereas System integration ability and Marketing capacity are least important. These results may be attributed to the status and capacity of the case company. The company has strong relations & corporate support, as it is a subsidiary of a worldwide famous LCD producer, which also owns a large medical center in Taiwan. The group members are confident of their marketing ability and organizational integration ability, but believe that technical innovation and related certificates are the most crucial factors for success of new product.

For alternatives: Compute $(M_w^T)^n$ for large n; (A_1, A_2, A_3) = (0.525, 0.349, 0.126). Product A_1 has the advantage of compactness and long warranty. All other features are between A_2 and A_3. The group regards Product A_1 as the best option.



$$
M_S = \begin{array}{c} \\ G \\ P \\ C \\ A \end{array}
\begin{array}{c} \begin{array}{cccc} G & P & C & A \end{array} \\
\begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & W_{22} & 0 & 0 \\ 0 & W_{32} & W_{33} & 0 \\ 0 & 0 & W_{43} & I \end{bmatrix} \end{array}
$$

Fig. 1 Graphical form and supermatrix of ANP

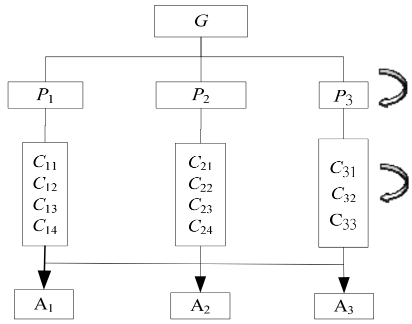


Fig. 2 ANP decision framework

$$
M_1 = \begin{bmatrix} 0 & 0 \\ W_{21} & W_{22} \end{bmatrix} \quad
M_{w2} = \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22}/2 & 0 \\ 0 & W_{32}/2 & W_{33} \end{bmatrix} \quad
M_w = \begin{array}{c} \\ G \\ P \\ C \\ A \end{array}
\begin{array}{c} \begin{array}{cccc} G & P & C & A \end{array} \\
\begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & W_{22}/2 & 0 & 0 \\ 0 & W_{32}/2 & W_{33}/2 & 0 \\ 0 & 0 & W_{34}/2 & I \end{bmatrix} \end{array}
$$

Figure 3. Normalized Matrices

Table 5. Pairwise Comparisions and Weight Matrix W_{21}

	P_1	P_2	P_3	GM	W_{21}
P_1	1.000	2.800	3.300	2.098	0.591
P_2	0.357	1.000	2.400	0.950	0.268
P_3	0.303	0.417	1.000	0.502	0.141

λ_{max}: 3.056 ; CI: 0.028 ; RI: 0.058 ; CR: 0.049

Table 6 Interdependence weight matrix W_{22}

W_{22}	P_1	P_2	P_3
P_1		0.630	0.722
P_2	0.600		0.278
P_3	0.400	0.370	

Table 7. Weight Matrix W_{31}

W_{31}	P_1	P_2	P_3
C_{11}	0.498		
C_{12}	0.286		
C_{13}	0.112		
C_{14}	0.104		
C_{21}		0.462	
C_{22}		0.248	
C_{23}		0.166	
C_{24}		0.124	
C_{31}			0.603
C_{32}			0.273
C_{33}			0.124

Table 8. Interdependence Weight Matrix W_{33}

W_{33}	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}
C_{11}		0.302	0.249	0.372	0.276	
C_{12}	0.209		0.136	0.232	0.178	0.266
C_{13}		0.169				0.128
C_{14}	0.276	0.191	0.131		0.113	0.188
C_{21}	0.138		0.140			
C_{22}	0.124	0.087	0.126	0.155	0.154	
C_{23}	0.139	0.107			0.098	0.134
C_{24}	0.047	0.065	0.082	0.095	0.083	0.080
C_{31}	0.066		0.053	0.080		0.093
C_{32}		0.046	0.048		0.059	0.060
C_{33}		0.034	0.035	0.066	0.038	0.052

	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}
C_{11}	0.340	0.320	0.247	0.357	
C_{12}	0.247		0.216	0.243	0.426
C_{13}		0.258		0.124	0.211
C_{14}		0.188	0.183	0.149	0.192
C_{21}	0.169		0.153		
C_{22}	0.088	0.114			
C_{23}		0.065	0.078		0.087
C_{24}				0.083	0.084
C_{31}	0.104			0.045	
C_{32}		0.055	0.065		
C_{33}	0.052		0.059		

Table 9. Interdependence Weight Matrix W_{43}

W_{43}	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}
A_1	0.469	0.637	0.605	0.497	0.513	0.361
A_2	0.426	0.265	0.301	0.390	0.266	0.486
A_3	0.105	0.099	0.094	0.113	0.221	0.153

	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}
A_1	0.617	0.478	0.522	0.635	0.528
A_2	0.283	0.366	0.359	0.264	0.268
A_3	0.100	0.156	0.119	0.101	0.204

Table 10. Normalized Supermatrix M_w

	G	P_1	P_2	P_3	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}
G	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P_1	0.591	0.000	0.315	0.361	0.000	0.000	0.000	0.000	0.000
P_2	0.268	0.300	0.000	0.139	0.000	0.000	0.000	0.000	0.000
P_3	0.141	0.200	0.185	0.000	0.000	0.000	0.000	0.000	0.000
C_{11}	0.000	0.249	0.000	0.000	0.000	0.151	0.124	0.186	0.138
C_{12}	0.000	0.143	0.000	0.000	0.105	0.000	0.068	0.116	0.089
C_{13}	0.000	0.056	0.000	0.000	0.000	0.084	0.000	0.000	0.000
C_{14}	0.000	0.052	0.000	0.000	0.138	0.095	0.066	0.000	0.057
C_{21}	0.000	0.000	0.231	0.000	0.069	0.000	0.070	0.000	0.000
C_{22}	0.000	0.000	0.124	0.000	0.062	0.043	0.063	0.078	0.077
C_{23}	0.000	0.000	0.083	0.000	0.070	0.054	0.000	0.000	0.049
C_{24}	0.000	0.000	0.062	0.000	0.024	0.032	0.041	0.047	0.042
C_{31}	0.000	0.000	0.000	0.302	0.033	0.000	0.027	0.040	0.000
C_{32}	0.000	0.000	0.000	0.137	0.000	0.023	0.024	0.000	0.030
C_{33}	0.000	0.000	0.000	0.062	0.000	0.017	0.017	0.033	0.019
A_1	0.000	0.000	0.000	0.000	0.235	0.318	0.302	0.248	0.257
A_2	0.000	0.000	0.000	0.000	0.213	0.132	0.151	0.195	0.133
A_3	0.000	0.000	0.000	0.000	0.052	0.049	0.047	0.056	0.110
	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	A_1	A_2	A_3
G	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C_{11}	0.000	0.170	0.160	0.124	0.178	0.000	0.000	0.000	0.000
C_{12}	0.133	0.123	0.000	0.108	0.122	0.213	0.000	0.000	0.000
C_{13}	0.064	0.000	0.129	0.000	0.062	0.106	0.000	0.000	0.000
C_{14}	0.094	0.000	0.094	0.092	0.074	0.096	0.000	0.000	0.000
C_{21}	0.000	0.085	0.000	0.076	0.000	0.000	0.000	0.000	0.000
C_{22}	0.000	0.044	0.057	0.000	0.000	0.000	0.000	0.000	0.000
C_{23}	0.067	0.000	0.032	0.039	0.000	0.044	0.000	0.000	0.000
C_{24}	0.040	0.000	0.000	0.000	0.041	0.042	0.000	0.000	0.000
C_{31}	0.046	0.052	0.000	0.000	0.022	0.000	0.000	0.000	0.000
C_{32}	0.030	0.000	0.027	0.033	0.000	0.000	0.000	0.000	0.000
C_{33}	0.026	0.026	0.000	0.029	0.000	0.000	0.000	0.000	0.000
A_1	0.181	0.309	0.239	0.261	0.317	0.264	1.000	0.000	0.000
A_2	0.243	0.141	0.183	0.180	0.132	0.134	0.000	1.000	0.000
A_3	0.076	0.050	0.078	0.060	0.051	0.102	0.000	0.000	1.000

4. Conclusion

The medical display monitors (MDMs) are commonly used in medical service centers, and the industry has been growing rapidly in the past decades. Generally speaking, MDMs require more advanced technology than LCD monitors. Therefore, the profit margin is higher than the standard LCD monitors. The color calibration device is a crucial component for the functional quality of MDM. In this study, we present a hybrid multiple criteria decision model for selecting the most suitable new color calibration device for a company interested in the MDM market to develop. The case company is a subsidiary of a well-established international LCD producer. Thus, the company's relations & corporate support, including local hospitals and large medical centers, are its main assets.

The presented ANP model was constructed using three evaluation processes: (1) Applying a fuzzy Kano model to identify the relevant factors for the studied problem; (2)

employing a modified gray relation analysis method to recognize the interdependency among perspectives, as well as criteria, and thus produce the ANP model; (3) Evaluating three alternatives and selecting the best alternative based on the ANP results, which are derived from the opinions of the high level management group in the case company. This model is innovative, as it utilizes modified fuzzy Kano model and gray relation analysis concept. Combining these two methods allows decision-makers to capture key factors and identify interrelationships. The conclusion based on the group suggests that the case company chooses to develop product A_1, due to its ease of mobility and long availability. Product A_1 will best fit the company's R&D capacity and market profitability.

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