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DEVELOPMENT OF DECISION SUPPORT SYSTEM FOR SELECTING QUALITY MANAGEMENT SYSTEMS AND MANAGEMENT TOOLS

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ABSTRACT

The purpose of this study is to develop a decision support system for the selection of QMS and management tools. The combination of ANP and TOPSIS are used for multi-criteria decision making technique in selecting QMS techniques. ANP determines the relative weights of multiple evaluation criteria while the modified TOPSIS approach was used to rank the alternatives. For the management tools selection, the matrix diagram of the tools benefits and process step is employed. The paper illustrates how the proposed approach was applied to a problem.

***Keywords**: Decision Support System, MCDM, Quality Management Systems (QMS) And Management Tools.*

1. INTRODUCTION

The food industry is an industry that is important to the economic development of Thailand significantly. In 2011, the food industry was an industry with the highest production values as shown in Figure 1, but there are still critical issues in the industry development relating to the enforcement of production standards as well as the Non-Tariff Barriers in terms of standard of products and production processes, the difficulty in the selection of quality system standards and tools used for quality management (Deslandres and Pierreval, 1997) (Fotopoulos, Psomas and Vouzas,2010), the decision criteria used in the selection of quality system standards and tools used for quality management (Holleran, Bredahl and Zaibet,1999) (Jin, Zhou and Ye,2008) (Arpanutud, Keeratipibul, Charoensupaya et al, 2009) (Thawesaengskulthai, 2007), and the problems of human decision making. Thus, it requires the development of decision support systems on the basis of the model to assist in making decision and make decision more effective.

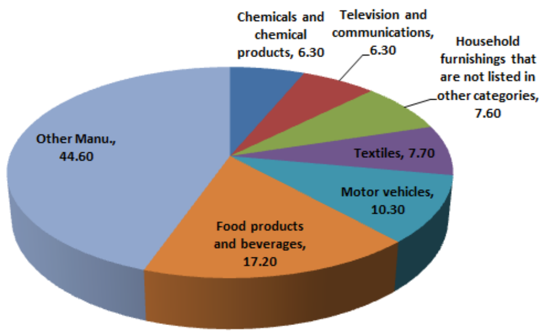

Figure 1. Gross Domestic Product originating from MANUFACTURING at Current Market Prices 2011

Building the decision support systems for the selection of quality management systems and quality management tools in the food industry requires the approach called MCDM to assist in deciding to choose the best option that meets the goals set in which it is considered the complex problem. There is a variety of decision criteria same as the problems of this research.

Another popular method for solving MCDM problems is the TOPSIS (technique for order performance by similarity to idea solution) which was first developed by Hwang and Yoon. The TOPSIS bases upon the concept that the optimal alternative should have the shortest distance from the positive idea solution (PIS) and the farthest distance from the negative idea solution (NIS). Although the concept of TOPSIS is rational and understandable, and the computation involved is uncomplicated, the inherent difficulty of assigning reliable subjective preferences to the criteria is worth of note.

The ANP is a comprehensive decision-making technique that captures the outcome of dependence and feedback within and between clusters of elements (Saaty 1996). ANP involves a combination of two parts, where the first comprises a control hierarchy or network of criteria and sub-criteria that controls the interactions, and the second part comprises a network of influences among the elements and clusters.

Whereas AHP represents a framework based on a unidirectional hierarchical relationship, ANP permits more complex interrelationships among decision levels and attributes. Not only do the importances of the criteria determine the importance of the alternatives as in a hierarchy, but the importance of the alternatives may also influence the importance of the criteria (Saaty 1996).

Matrix evaluations (Peniwati, 2007) referred to methods for presenting information to facilitate the evaluation of alternatives. It provided nothing more than simple structures to assist a facilitator and improve understanding of the problem. It did not limit the number of criteria or factors considered in the analysis. It may describe factors and sub-factors involved in a problem with their ranking scores, or it may provide the relative overall positions of alternatives in a multidimensional space.

This paper has modeled the selection of quality management systems and management tools in the food industry as an MCDM problem and proposed a four-phase. For the selection of quality system standards, we have applied the technique of analytic network process (ANP) and modified TOPSIS. The ANP method was used in obtaining the relative weights of criteria but not the entire evaluation process to reduce the large number of pairwise comparison. As for the performance corresponding to each alternative, the modified TOPSIS approach using a new defined weighted Euclidean distance was conducted to rank quality management systems. For the selection of tools used for quality management, we have applied the Matrix Evaluation method in creating the decision support systems since the Matrix Evaluation is capable of outlining the scope of the problem and can be easily used. The method presented here did not account for deriving the evaluation criteria for quality management systems and management tools selection. However, the proposed model may provide organizations a way to devise and refine adequate criteria and alleviate the risk of selecting sub-optimal solutions.

The rest of this paper is structured as follows: In the next section, we briefly introduce the original ANP and TOPSIS method. Section 3 the procedure is presented and an overview of the techniques used in our model is given. In Section 4, we present our results and discuss an empirical study. In Section 5, we conclude the results reported in this paper.

2. THEORETICAL BACKGROUND

2.1. The ANP method

The ANP, also introduced by Saaty, is a generalization of the AHP (Saaty 1996). Whereas AHP represents a framework with a uni-directional hierarchical AHP relationship, ANP allows for complex interrelationships among decision levels and attributes. The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate, direct or indirect (Meade and Sarkis 1999). For instance, not only does the importance of the criteria deter-mine the importance of the alternatives, as in a hierarchy,but also the importance of the alternatives may have impact on the importance of the criteria (Saaty 1996). Therefore, a hierarchical structure with a linear top-to-bottom form is not suitable for a complex system.

AHP is a comprehensive framework that is designed to cope with the intuitive, the rational, and the irrational when we make multi-objective, multi-criterion, and multi-actor decisions, with or without certainty for any number of alternatives. The basic assumptions of AHP are that it can be used in functional independence of an upper part or cluster of the hierarchy from all its lower parts and the criteria or items in each level (Meade and Sarkis 1999). Many decision-making problems cannot be structured hierarchically because they involve the interaction and dependence of higher level elements on lower level elements (Saaty and Takizawa 1986; Saaty 1996). Structuring a problem involving functional dependence allows for feedback among clusters. This is a network system. Saaty (1996) suggested the use of AHP to solve the problem of independence on alter-natives or criteria, and the use of ANP to solve the problem of dependence among alternatives or criteria.

The major difference between AHP and ANP is that ANP is capable of handling interrelationships between the decision levels and attributes by obtaining the composite weights through the development of a “supermatrix” (Shyur 2006). The supermatrix is actually a partitioned matrix, where each matrix segment represents a relationship between two components or clusters in a system (Saaty 1996). In addition to this, final weights can be calculated using matrix operations, especially where the numbers of criteria in the model are relatively few. Matrix operations are used in order to convey with ease the workings of the methodology used and how dependencies are worked out. Supermatrix is without doubt the better choice when the number of elements increases (Yüksel and Da˘ gdeviren 2007). Matrix operations of Saaty and Takizawa (1986) were used in this study as they are easy-to-understand in the calculation of the weights of criteria by ANP.

The process of ANP involves three sub steps and shown as follows (Shyur 2006):

Step1: Without assuming the interdependence among criteria, the decision makers are asked to evaluate all proposed criteria pairwise. They responded questions such as: “which criteria should be emphasized more in personnel, and how much more?” The responses were presented numerically and scaled on the basis of Saaty’s 1–9 scale. Each pair of criteria is judged only once. A reciprocal value will be automatically assigned to the reverse comparison. Once the pairwise comparisons are completed, the local weight vector w_1 is computed as the unique solution to

$$A w_1 = \lambda_{max} w_1 \quad (1)$$

where λ_{max} is the largest eigenvalue of pairwise comparison matrix A. The obtained vector is further normalized by dividing each value by its column total to represent the normalized local weight vector w_2.

Step 2: Next to resolve the effects of the interdependence that exists between the evaluation criteria. The decision makers examine the impact of all the criteria on each other by using pairwise comparisons as well. Questions such as: “which criterion will influence criterion 1 more: criterion 2 or criterion 3? And how much more?” are answered. Various pairwise comparison matrices are formed for each of the criterion. These pairwise comparison matrices are needed to identify the relative impacts of criteria interdependent relationships. The normalized principal eigenvectors for these matrices are calculated and shown as column component in interdependence weight matrix of criteria B, where zeros are assigned to the eigenvector weights of the criteria from which a given criterion is given.

Step 3: Now we can obtain the interdependence weights of the criteria by synthesizing the results from previous two steps as follows:

$$w_c = B w_2^T \quad (2)$$

There are many studies in the literature using ANP to solve decision making problems. Meade and Sarkis (1998, 1999) used ANP in two of their studies. In the first study, alternative projects for agile manufacturing are evaluated via ANP and logistics and supply chain management analysis is per-formed in the second. Also in two separate studies performed by Lee and Kim (2000, 2001), ANP is used in the interdependent information system project selection process. Besides, Karsak et al.

(2002) and Partovi and Corredoira (2002) used ANP in quality function deployment process, while Meade and Presley (2002) used ANP to evaluate alternative research-development projects. Mohanty et al. (2005), Agarwal et al. (2006) and Ravi et al. (2005) employed ANP in R&D project selection problem, modeling the metrics of lean, agile and leagile supply chain, analyzing alternatives in reverse logistics for end-of-life computers, respectively. ANP is used by Yüksel and Da˘gdeviren (2007) for SWOT analysis and by Da˘gdeviren et al. (2008) to determine faulty behavior risks in work systems.

2.2. The TOPSIS method

The TOPSIS was first developed by Hwang and Yoon (1981). According to this technique, the best alternative would be the one that is nearest to the positive ideal solution and farthest from the negative ideal solution (Ertugrul and Karakasoglu 2007). The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria (Wang and Elhag 2006). In short, the positive ideal solution is composed of all best values attainable of criteria, whereas the negative ideal solution consists of all worst values attainable of criteria (Wang 2007).

The TOPSIS method consists of the following steps (Shyur and Shih 2006):

Step 1: Establish a decision matrix for the ranking. The structure of the matrix can be expressed as follows:

$$D = \begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} F_1 & F_2 & \cdots & F_j & \cdots & F_n \\ f_{11} & f_{12} & \cdots & f_{1j} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2j} & \cdots & f_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{i1} & f_{i2} & \cdots & f_{ij} & \cdots & f_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mj} & \cdots & f_{mn} \end{bmatrix} \quad (3)$$

Where A_i denotes the alternatives i, i =1,2,...,m; F_j represents jth attribute or criterion, j =1,2,...,n, related to ith alternative; and f_{ij} is a crisp value indicating the performance rating of each alternative A_i with respect to each criterion F_j.

Step 2: Calculate the normalized decision matrixR(=[r_{ij}]). The normalized value r_{ij} is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{i=1}^{m} f_{ij}^2}}, i=1,\ldots,m \quad j=1,\ldots,n \quad (4)$$

Step 3: Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized value v_{ij} is calculated as:

$$v_{ij} = w_j r_{ij}, \; i=1,\ldots,m \quad j=1,\ldots,n \quad (5)$$

where w_{ij} represents the weight of the j th attribute or criterion.

Step 4: Determine the positive-ideal and negative-ideal solutions.

$$V^+ = \{v_1^+, v_2^+ \ldots, v_n^+\}$$
$$= \{(\max_i v_{ij} | j \in J), (\min_i v_{ij} | j \in J')\},$$
$$V^- = \{v_1^-, v_2^- \ldots, v_n^-\}$$
$$= \{(\min_i v_{ij} | j \in J), (\max_i v_{ij} | j \in J')\},$$

(6)

where J is associated with the benefit criteria, and J' is associated with the cost criteria.

Step 5: Calculate the separation measures, using the m-dimensional Euclidean distance. The separation of each alternative from the positive-ideal solution (D_i^+) is given as

$$D_i^+ = \left\{ \sum_{j=1}^{n} (v_{ij} - v_j^+)^2 \right\}^{1/2}, \quad i=1,\ldots m, \quad (7)$$

Similarly, the separation of each alternative from the negative-ideal solution (D_i^-) is as follows:

$$D_i^- = \left\{ \sum_{j=1}^{n} (v_{ij} - v_j^-)^2 \right\}^{1/2}, \quad i=1,\ldots m, \quad (8)$$

Step 6: Calculate the relative closeness to the idea solution and rank the performance order. The relative close-ness of the alternative A_i with respect to V+ can be expressed as

$$C_i = D_i^- / \left(D_i^+ + D_i^-\right), \quad i = 1, \ldots, m \qquad (9)$$

where the C_i index value lies between 0 and 1. The larger the index value means the better the performance of the alternatives.

In the aggregation process, a set of alternative candidate is to be compared with respect to predefined criteria (Shyur 2006):

The performance rating of each candidate for each criterion is assigned and formed as a decision matrix. In addition, the normalization formula as shown in Eq.4 is used to transform the various scales into a comparable scale. The normalized decision matrix is weighted by multiplying each column of the matrix by its associated criteria weight in the above process. Then the overall performance of an alternative candidate is then determined by its Euclidean distance to V^+ and V^- (Shyur 2006). However, Shipley et al. (1991) points out that this distance is interrelated with the criteria weights and should be incorporated in the distance measurement (Shyur 2006). This is because all alternatives are compared with V^+ and V^-, rather than directly among themselves. Deng et al. (2000) presents the weighted Euclidean distances to instead of creating a weighted decision matrix. In this process, Shyur (2006) defined the positive-ideal solution (R^+) and the negative-ideal solution (R^-), which are not depended on the weighted decision matrix, as

$$R^+ = \{r_1^+, r_2^+ \ldots, r_n^+\} = \{(\min_i r_{ij} | j \in J), (\min_i r_{ij} | j \in J')\},$$

$$R^- = \{r_1^-, r_2^- \ldots, r_n^-\} = \{(\min_i r_{ij} | j \in J), (\min_i r_{ij} | j \in J')\},$$

(10)

The weighted Euclidean distances, between A_i and R^+, and A_i and R^-, are calculated, respectively, as

$$D_i^+ = \left\{ \sum_{j=1}^{n} w_j (r_{ij} - r_j^+)^2 \right\}^{1/2}, \quad i = 1, \ldots m,$$

$$D_i^- = \left\{ \sum_{j=1}^{n} w_j (r_{ij} - r_j^-)^2 \right\}^{1/2}, \quad i = 1, \ldots m,$$

(11)

where the value of w_j (j =1 to n) is the element of vector w_c which is calculated by Eq.2. Then closeness coefficient can obtained for each alternative based on Eq.9. Finally, a set of alternative candidate can be preference ranked according to the descending order of closeness coefficient.

There are some studies in the literature which consider the TOPSIS. Deng et al. (2000) used the TOPSIS method in the comparison inter-company with objective weights. Shyur (2006) developed a decision making model for COTS evaluation with TOPSIS. In addition to these studies Shyur and Shih (2006), for strategic vendor selection; Tsou (2007), Multi-objective inventory planning; Onüt and Soner (2007) in the transshipment site selection; Olcer (2008) for optimization problems in ship desig and shipping, used TOPSIS method.

3. RESEARCH METHOD

The evaluation procedure of this study consists of several steps as shown in Figure. 2. The first step is to identify the multiple criteria that are considered in the decision making process for the decision makers to make an objective and unbiased decision. Create metric model for the selection of management tools from academic texts and various research studies. Then a relationship between criteria that shows the degree of interdependence relationship is determined by group expert discussion in general. After constructing the relationship of a criteria network structure, the criteria weights can be calculated by applying ANP. Then, we conduct a modified TOPSIS approach to achieve the final ranking results. The detailed descriptions of each step are elaborated in each of the following subsection. Finally, we develop the decision support systems, and select a quality management system and management tools in the form of Microsoft Excel.

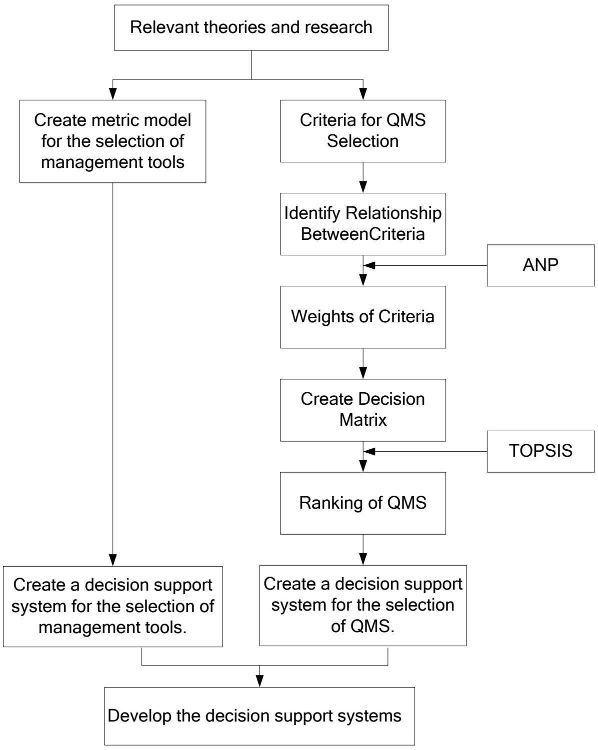

Figure 2. Research methodology

4. RESULT AND DISCUSSION

To illustrate the proposed determination process for selecting quality management systems (QMS), the study presents an application that is based on practical experience and that has been implemented at a food industry. During the first stage, reviewing the literatures and interviewing quality experts who work in the case study. Experts were subjected to questioning by NGT to determine the evaluation criteria for selecting quality management systems. Next, the screening criteria were created to conduct a QMS initiative looking for suitable and narrow the field, where screening criteria are the minimum requirements about QMS. During the second stage, two rounds of NGT were used to make sure the multidirectional relationship among evaluation criteria and sub-criteria. The decision problem faced by the experts involved prioritizing potential alternative for selecting QMS. The phase composes of a series of complex review and decision but short of an explicit approach. In this study, the proposed method was applied to solve this problem and the computational procedure is summarized as follows:

Step 1: The experts were asked to assess all proposed criteria and sub-criteria in a pairwise fashion while assuming no interdependence existed. The normalized eigenvector was calculated as unique solution (1) and resembles w_{21}, which represents the related local priority of the criteria and w_{32} which represents the related importance of sub-criteria in terms of their upper level criteria.
Step 2: Additionally the dependence among the selection criteria and sub-criteria was considered and analyzed. The experts separately examined the impact of all the criteria via pairwise comparison. The normalized eigenvectors for these matrices are calculated and presented as w_{22} and w_{33}, where zeros are assigned to the eigenvector weights of the criteria and sub-criteria on which a given criteria is based.
Step 3: The relative importance of the criteria considering interdependence now can be obtained by synthesizing the results from Steps 1 and 2.
Step 4: In this step of the decision framework, evaluators were asked to build the decision matrix by comparing candidates under each of the sub-criteria separately. The experts were asked to provide a set of crisp values within the range 1 to 10 to represent the performance of each alternative in terms of each sub-criterion. After the decision matrix was determined using formula (3), the matrix was normalized using formula (4) to (5).
Step 5: The final ranking procedure starts at the determination of the ideal and negative-ideal solutions. The ideal and negative-ideal solutions are defined by formula (9).

5. CONCLUSION

Selecting quality management systems and management tools in the food industry is difficult and subjective which and involves a multi-criteria decision-making (MCDM). The quality management systems and management tools selection problem should be solved on the basis of an objective decision-making process rather than the personal judgments of the decision-makers. In this study, we proposed a comprehensive model for the quality management systems and management tools selection problem

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using ANP and modified TOPSIS methods and matrix diagram. The ANP method was used to obtain dependence weights of the criteria considered in the selection process and the modified TOPSIS method was adopted in ranking of the alternatives.

Although the application of the model proposed in this study is specific to a company, it can also be used with slight modifications in other industries. To increase the efficiency and ease-of-use of the proposed model, simple software such as MS Excel can be used. Pairwise comparisons related to the criteria used in quality management systems selection and the dependence among these criteria is carried out once at the beginning of the decision-making process; so, decision-makers can skip these steps in the future use of the model. Evaluation of the alternatives on the basis of the criteria only will be sufficient for the future applications of the model and implementation of this evaluation via simple software will speed up the process. Besides, some criteria could have a qualitative structure or have an uncertain structure which cannot be measured precisely. In such cases, fuzzy numbers can be used to obtain the evaluation matrix and the proposed model can be enlarged by using fuzzy numbers.

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