Journal of Scientific & Industrial Research
Vol. 76, January 2017, pp. 28-31

Performance Evaluation of Medical Device Manufacturers Using a Hybrid Fuzzy MCDM

Yen-Chun Lee[1]*, Pei-Han Chung[2] and Joseph Z Shyu[2]

*[1]Department of Business Administration and Graduate School Service and Business Management, Chihlee University of Technology, Taiwan
[2]Institute of Management of Technology, National Chiao Tung University, Taiwan

Received 05 February 2016; revised 10 August 2016; accepted 22 November 2016

Fuzzy multi-criteria decision making (fuzzy MCDM) methods have developed rapidly and have evolved to accommodate various types of applications. This study aimed to explore a performance evaluation model based on a hybrid fuzzy MCDM approach for Taiwan's medical device manufacturers. The hybrid fuzzy MCDM approach was composed of the fuzzy analytic hierarchy process (fuzzy AHP) method and the technique for order performance by similarity to ideal solution (fuzzy TOPSIS) method, to facilitate industrial practitioners on performance evaluation in a fuzzy environment. The proposed performance evaluation model can also enable government policy makers to better understand the complete evaluation process and provide a more effective decision support tool.

Keywords: Performance Evaluation, Fuzzy MCDM, Fuzzy AHP, Fuzzy TOPSIS, Medical Device Manufacturer

Introduction

In today's competitive environment, an increasing number of firms and public organizations have applied performance measurement to improve their functioning1. In the private sector, performance measurement was used to improve competitive advantage2. Performance evaluation is therefore essential to determine the success of a firm's strategy, to make necessary adjustments and to learn from past experiences3. Using the empirical setting of medical device manufacturing industry, Macher and Nickerson examined organization and performance, knowledge development and knowledge transfer4. Ghadimi and Heavey narrowed the gap in sustainability evaluation of suppliers specifically operating in medical device industry toward sustainable manufacturing5. In addition, several studies have investigated various methods of performance evaluation and identified different performance indicators6,7. However, there is few research works using a hybrid fuzzy multi-criteria decision making (fuzzy MCDM) method to evaluate the relative performance of medical device manufacturers. Hence, using real cases of Taiwan's medical device manufacturers, this study aimed to provide industrial practitioners with a performance evaluation model based on a hybrid fuzzy MCDM approach. The fuzzy analytic hierarchy process (fuzzy AHP) was used to determine the preference weights of evaluation. The fuzzy technique for order of preference by similarity to ideal solution (fuzzy TOPSIS) was then deployed to rate the performance of alternatives and to identify the gaps of alternatives for achieving the aspired levels.

Taiwan's medical device manufacturing industry

Taiwan's medical device market was worth about US$4.3 billion in terms of sales value in 2013, growing by a CAGR of 7.9% between 2008 and 20138. Because of the limited size of Taiwan's market, domestic medical device makers rely on exports for most (over 60%) of their sales. The top three export items in 2013 were blood glucose meters and strips, mobility aids (including electric wheelchairs and scooters) and contact lenses. At present, there are more than 700 medical device companies in Taiwan, most of which produce mid- and low-level medical devices, with 90% of them involved in manufacturing for multinationals. To improve Taiwan's competitive advantage in global markets, this study attempted to assist government policy makers or industrial practitioners in evaluating their relative performance. This study invited 10 experts to evaluate the performance of four

*Author for Correspondence
E-mail: focuslee2@gmail.com

representative companies via the proposed hybrid fuzzy MCDM approach.

Fuzzy MCDM methods

Fuzzy numbers and linguistic variables

The merit of using a fuzzy approach is to assign the relative importance of criteria using fuzzy numbers instead of precise numbers9. Linguistic variables are variables whose values are given in linguistic terms. Linguistic terms have been found intuitively easy to use in expressing the subjectiveness and/or qualitative imprecision of a decision maker's assessments10. Several theoretical definitions of fuzzy numbers and linguistic variables can be reviewed from literature11,12. The study adopted nine-point linguistic scales for fuzzy AHP calculation ranging from 1 to 9, and six-point linguistic scales for fuzzy TOPSIS calculation ranging from 0 to 10.

Fuzzy AHP

AHP is one of the MCDM methods based on an additive weighting process, in which the priority weights of multiple criteria are calculated through their relative importance13. Fuzzy AHP may further reflect human thinking style by converting experts' crisp values to fuzzy numbers in the paired comparison matrices14. This study used this method to calculate the priority weights of criteria. The fuzzy AHP procedure consists of the following steps12: (1) Establish a hierarchical structure; (2) Determine linguistic variables and construct fuzzy paired comparison matrices; (3) Undertake defuzzification; and (4) Calculate overall criteria weights.

Fuzzy TOPSIS

TOPSIS is also one of the MCDM methods for identifying an alternative which is closest to the positive ideal solution (PIS) and farthest to the negative ideal solution (NIS) in a multi-dimensional computing space12. Several research works have extended TOPSIS method to the fuzzy environment, namely fuzzy TOPSIS, for solving group decision-making problems12,15. This study used this method to evaluate the alternative performance of Taiwan's medical device manufacturers and rank their priority accordingly. The fuzzy TOPSIS procedure consists of the following steps: (1) Determine linguistic variables and construct a fuzzy decision matrix; (2) Normalize the fuzzy decision matrix; (3) Establish the weighted fuzzy normalized decision matrix; (4) Determine the FPIS and FNIS reference points; (5) Calculate the distance of each alternative from FPIS and FNIS; and (6) Estimate the performance and rank the alternatives.

Performance evaluation of Taiwan's medical device manufacturers

This study first conducted focus group research method to determine the six evaluation criteria: innovation competence, manufacturing excellence, operations and logistics management, human resource management, quality of service, and financial management. The whole hierarchy of evaluating the performance of four representative medical device manufacturers can be visualized from Fig. 1. After the construction of the hierarchy, the priority weights of six criteria were computed using the fuzzy AHP method. The relative weights for each criterion are: innovation competence (0.195), manufacturing excellence (0.213), operations and logistics management (0.262), human resource management (0.104), quality of service (0.137), and financial management (0.089). From the fuzzy AHP results, we can understand the first two important criteria for the evaluation of medical device manufacturers are operations and logistics management, and manufacturing excellence. Moreover, the less important criterion is financial management. Next, the fuzzy TOPSIS method was deployed to evaluate the performance of medical device manufacturers and rank their priority accordingly. We used the technique of average value to integrate the fuzzy judgment values of different evaluators regarding the same evaluation criteria. Table 1 shows the weighted normalized fuzzy decision matrix. After defining the FPIS and FNIS reference points, the distances (and) of each alternative from the FPIS and FNIS were calculated, and the closeness coefficients ( ) of four alternatives were then determined. Moreover, we can

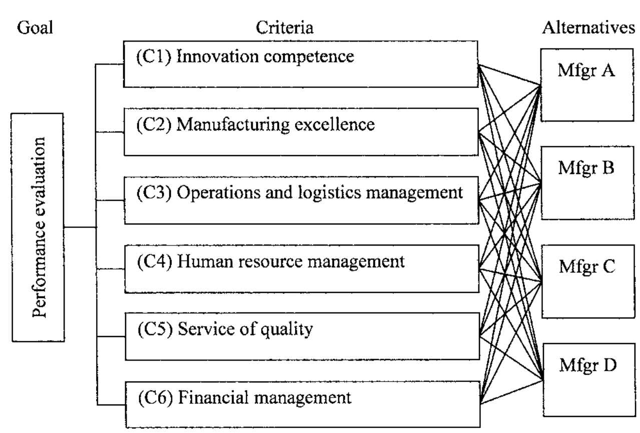

Fig.1 — Hierarchical model of performance evaluation

Table 1—The weighted normalized fuzzy decision matrix

	Mfgr A	Mfgr B	Mfgr C	Mfgr D
C1	(0.05, 0.09, 0.13)	(0.14, 0.18, 0.20)	(0.10, 0.14, 0.18)	(0.04, 0.08, 0.11)
C2	(0.06, 0.11, 0.16)	(0.13, 0.18, 0.21)	(0.09, 0.14, 0.18)	(0.05, 0.09, 0.14)
C3	(0.07, 0.13, 0.18)	(0.17, 0.23, 0.26)	(0.12, 0.17, 0.22)	(0.05, 0.10, 0.15)
C4	(0.04, 0.06, 0.08)	(0.05, 0.07, 0.09)	(0.06, 0.08, 0.10)	(0.02, 0.04, 0.06)
C5	(0.04, 0.07, 0.09)	(0.09, 0.12, 0.14)	(0.07, 0.09, 0.12)	(0.02, 0.05, 0.07)
C6	(0.03, 0.05, 0.06)	(0.06, 0.08, 0.09)	(0.03, 0.05, 0.07)	(0.02, 0.03, 0.05)

Table 2—The closeness coefficients for the four alternative manufacturers

	d_i^-	d_i^+	CC_i^- (satisfaction degree)	CC_i^+ (gap degree)	Rank
Mfgr A	0.367	0.524	0.412	0.588	3
Mfgr B	0.667	0.222	0.750	0.250	1
Mfgr C	0.527	0.361	0.593	0.407	2
Mfgr D	0.267	0.638	0.295	0.705	4

define as satisfaction degree in ith alternative and as gap degree in ith alternative. Hence, we can know which and how gaps should be improved for achieving aspiration levels. Table 2 shows the satisfaction degrees and gap degrees of each manufacturer. From the results of Table 2, the satisfaction degree values of the four manufacturers are 0.412, 0.750, 0.593, and 0.295 levels respectively; i.e., 0.588, 0.250, 0.407, and 0.705 levels should be improved, respectively.

Implications and Conclusions

A performance evaluation model for Taiwan's medical device manufacturers was constructed by the proposed hybrid fuzzy MCDM approach. In the performance evaluation, we first conducted focus group research method to determine the six criteria? innovation competence, manufacturing excellence, operations and logistics management, human resource management, quality of service, and financial management. We then used the fuzzy AHP method to obtain the overall priority weights as well as to identify the first two important criteria? operations and logistics management, and manufacturing excellence. Operations and logistics management, by virtue of its huge collective budget, provides a major opportunity for Taiwan's medical device manufacturing firms to improve its profitability. It is the most important element for these small and medium-sized manufacturers to compete in global markets. Manufacturing excellence, regarding a combination of productivity, disciplined process control, process capability and equipment reliability, and on-time delivery of better quality products, is also considered to be an important element in a firm's endeavor to improve firm performance. Finally, using real cases, we deployed the fuzzy TOPSIS method to evaluate the performance of four representative firms and rank their priority. The satisfaction degree of manufacturer B and manufacturer C is bigger than others. We therefore we considered that both manufacturer B and manufacturer C are similarities to aspired level. The proposed model not only facilitates industrial practitioners on performance evaluation in a fuzzy environment, but also enables government policy makers to better understand the complete evaluation process and provide a more effective decision support tool. Future works may involve theoretical verification for the influential relationships among these factors.

References

1 Koufteros X, Verghese A J & Lucianetti L, The effect of performance measurement systems on firm performance: A cross-sectional and a longitudinal study, *J Oper Manag*, **32** (2014) 313-336.

2 Chan F T, Nayak A, Raj R, Chong A Y L & Manoj T, An innovative supply chain performance measurement system incorporating research and development (R&D) and marketing policy, *Comput Ind Eng*, **69** (2014) 64-70.

3 Meybodi M Z, Alignment of strategic benchmarking performance measures: a lean manufacturing perspective, *J Compet Stud*, **21** (2013) 14.

4 Macher J & Nickerson J A, Strategic problem solving: A knowledge-based examination in medical device manufacturing, *Acad Manage Proc*, (2015) 10967.

5 Ghadimi P & Heavey C, Sustainable supplier selection in medical device industry: Toward sustainable manufacturing, *Procedia CIRP*, **15** (2014) 165-170.

6 Taticchi P, Garengo P, Nudurupati S S, Tonelli F & Pasqualino R, A review of decision-support tools and performance measurement and sustainable supply chain management, *Int J Prod Res*, **53** (2015) 6473-6494.

7 Vilanova M R N, Magalhães Filho P & Balestieri J A P, Performance measurement and indicators for water supply management: Review and international cases, *Renewable Sustainable Energy Rev*, **43** (2015) 1-12.

8 Taiwan Biotechnology Industry White Papers 2005-2014, Ministry of Economic Affairs, Taiwan, (2014), 8-25.

9 Azadeha A, Ghaderia S F, Mirjalilib M, *et al*, Optimization of human resources and industrial banks with ambiguous

inputs using intelligent fuzzy mathematical programming approach, *J Sci Ind Res India*, **74** (2015) 545-554.

10 Kiron K & Kannan K, Prioritizing the factors affecting innovation capability of steel manufacturing smes using fuzzy logic, *J Sci Ind Res India*, **74** (2015) 665-669.

11 Bairagi B, Dey B, Sarkar B, *et al*, Selection of robotic systems in fuzzy multi criteria decision-making environment, *Int J Comput Sys Engr*, **2** (2015) 32-42.

12 Lee Y C & Chou C J, Technology evaluation and selection of 3DIC integration using a three-stage fuzzy MCDM, Sustainability, **8** (2016) 1-15.

13 Saaty T L & Ergu D, When is a decision-making method trustworthy? Criteria for evaluating multi-criteria decision-making methods, *Int J Inf Tech Decis*, **14** (2015) 1171-1187.

14 Lin G T R & Lee Y C, Evaluation and decision making in Taiwan semiconductor industry through silicon via technology, *J Sci Ind Res India*, **73** (2014) 456-460.

15 Kannan D, de Sousa Jabbour A B L & Jabbour C J C, Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company, *Eur J Oper Res*, **233** (2014) 432-447.