Using Integrated FMEA-DEA Approach to Classify Purchasing Items Based on Kraljic's Model

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Abstract

Effective purchasing management has played an important role in the success of supply chain management. For organizations that maintain thousands of purchasing items, it is unrealistic to provide equal consideration to each item. Managers are required to classify these items in order to appropriately control each class according to its importance rating. In this paper, failure mode and effect analysis (FMEA) and Data envelopment analysis (DEA) techniques are used to classify purchasing items. In the first phase, weights of evaluation criteria are determined by FMEA techniques with fuzzy RPN numbers. Then, considering supply risk and profit impact based on Kraljic's model, purchasing items are classified using DEA technique. Finally, in order to show the application aspects, a numerical example has been conducted by using the proposed approach.

Keywords: Purchasing items, classification, Kraljic's model, FMEA, TOPSIS.

1. Introduction

Organizations usually have to deal with a large number of products and a variety of suppliers. Obviously, not all buyer-supplier relationships are to be managed in the same way. Effective purchasing and supply management requires the selection of strategies that are appropriate for the prevailing circumstances. Research findings indicate that successful supply chain management requires the effective and efficient management [1]. This places purchasing managers for the task of developing and executing a set of differentiated supplier strategies. The need for differentiated supplier strategies implies that some sort of classification is necessary [2]. Therefore, in advance a portfolio model for supplier relationships appears to be a useful tool. Olsen and Ellram (1997) posited that there is an acknowledged need for development of purchasing portfolio models in the pursuit of differentiated purchasing strategies [3]. For a long time, the ABC-analysis was the only tool for differentiating between important and less important purchases. The ABC-analysis however, does not provide strategic recommendations for the categories. Due to this lack of guidelines, the ABC-analysis cannot be considered as a full portfolio technique. It is merely a classification tool. It was until 1983 that Kraljic introduced a complete purchasing portfolio approach. Despite subsequent developments by [4, 5], a weakness with Kraljic's model is that it is in essence qualitative in nature, relaying on the subjective judgment of managers to assess a supplier's position on the matrix. It would be more effective if a means could be devised to quantify the criteria used for placement within the matrix. Therefore, in this paper FMEA and DEA techniques are used to classifying purchasing items (PIs). Also, both quantitative and qualitative criteria were used together for this purpose.

2. Literature Review

2.1. Kraljic's matrix

For the first time Kraljic (1983) developed a conceptual model in order to determine the purchasing strategies for an organization [6]. This simple model is a two dimensional figure which on the first side profit impact has been allocated and the other side supply risk has been allotted. Several large companies such as Shell, Alcatel, Philips, and Siemens have applied his model. The main purpose of Kraljic's approach is to identify strategic items. Other purposes of Kraljic method are identification and separation of purchasing items. Kraljic offers a systematic logic for diagnosis of the differences between the PIs. Regarding to the PIs supply risk and its profit impact, this method divides PIs into four groups of strategic, bottleneck, leverage and routine. Fig.1 shows this logic.

The first category relates to the routine items. The routine items are non-critical items which are produced in standard configuration. The best method of control of these items is to keep the level of the inventory in optimal level and one does not need to think other attributes. The second groups are leverage items. The leverage items are the materials which purchaser has big maneuver to bargain and it is easy to find the best price by calling for tenders. The bottleneck items are the one which their supply involves various risks and problems. In this situation the guaranty of the contract, supplier control, and all plan in order to keep enough inventory is suggested. Finally, the strategic items are the group of materials which there are strategic/long-term relationship between buyer and supplier in order to have safe business.

Insert Figure 1 about here.

Insert Figure 2 about here.

Currently, Kraljic's matrix is widely used by purchasing professionals. Especially in Western Europe the Kraljic approach has received large-scale recognition and has attained an increasing degree of adoption. Lamming and Harrison (2001) stated that Kraljic's matrix remains the foundation for purchasing strategies of many organizations across sectors [7]. In a survey of Dutch companies Boodie (1997) found that 44% of the responding purchasing managers used the Kraljic matrix for formulating purchasing strategies [8]. No less than 80% of industrial companies that operate on a mass production basis use it. Several years later, Bos et al. (2005) reported in a similar study that portfolio usage was increased to 61% [9]. In the course of time the Kraljic approach has entered many textbooks on purchasing and supply management. Gradually Kraljic has gained acceptance in other countries, notably in the USA, Canada and Northern Europe.

2.2. FMEA

FMEA is a tool that widely used in the automotive, aerospace, and electronics industries to identify, prioritize, and eliminate known potential failures, problems, and errors from systems under design before the product is released [10]. Several industrial FMEA standards such as the Society of Automotive Engineers, US Military of Defense, and Automotive Industry Action Group employ the Risk Priority Number (RPN) to measure risk and severity of failures. An improved FMEA methodology, which utilizes the fuzzy rules base and grey relation theory to model the entire system, was presented by Pillay and Wang [11]. Xu et al. (2002) proposed a fuzzy logic-based FMEA technique and a prototype assessment expert system [12]. Yeh and Hsieh (2007) proposed a new risk assessment system based on fuzzy theory to deal with RPN, which is often subjective and described qualitatively in natural language [13]. A great deal of literature works [14-18] have been carried out in fuzzy RPN methods.

2.3. DEA

Data envelopment analysis (DEA) is a linear programming methodology that evaluates the efficiency of a number of units. These units are called decision making units (DMUs) such as schools, hospitals, or sales outlets [19]. The DEA is designed to measure relative efficiency in such situations where there are one or multiple inputs and one or multiple outputs. The DEA model must be run n times, once for each unit, to get the relative efficiency of all DMUs. DEA successfully divides them into two categories; efficient DMUs and inefficient DMUs. DEA was initially proposed by Charnes et al. (CCR model) [19] and was improved by other scholars. The formulation is represented by Eq. (1):

$$\max \sum_{r=1}^{s} u_r y_{ro} \qquad (1)$$

s.t.

$$\sum_{i=1}^{m} v_i x_{io} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \quad j = 1,2,\dots,n$$

$$u_{o\ free}$$

$$v_i \geq 0 \quad i = 1,2,\dots,m$$

$$u_r \geq 0 \quad i = 1,2,\dots,s$$

Where x_{ij} and y_{rj} (all nonnegative) are the inputs and outputs of the DMU_j, v_i and u_r are the input and output weights (also referred to as multipliers). x_{io} and y_{ro} are the inputs and outputs of DMU_o.

3. Methodology

The provided method works in this way that initially some criteria which have been noticed by the researchers in risk and profit area based on Kraljic's model, offered to the decision-makers. Risk criteria are such as cost, quality, delivery, after sale services, capacity and potential future collaboration; and Profitability criteria such as revenue, net profit, quantity sale, and management opinion. Indeed, both qualitative and quantitative criteria considered. Quantitative values that are related to the profit impact, the data were existed in accounting and planning department was used. Management opinion, asa profit impact criterion, is qualitative evaluated based on the importance of PIs in final product. Afterwards, it was asked from decision-makers to fill the questionnaire which was provided to determine the mentioned risk criteria. The questionnaire has been designed due to FMEA approach and for measuring the risk of each criteria, FRPN (Fuzzy RPN) was used. The logic of this method is that the decision-makers due to their experience from supply PIs have expressed Occurrence (O), Severity (S) and Detection (D) fault for each criterion and PIs. Besides, the interval has defined from very low (VL) to very high (VH). Triangular fuzzy number (TFN) was used for information analysis.

The linguistic scale shown as fig.2.Multiplying the O, S and D values of decision-makers opinions, and then making defuzzy, RPN numbers obtained for each criterion of each PI. Table1.shows the value for PI1. Using geometric mean, final values of RPN were obtained. Final supply risk values (obtained from the geometric mean) can be seen in Table2. In order to classify PIs into high and low supply risk, results obtained in previous stage (see Table2) are analyzed by DEA model.Virtual input andrisk criteria are considered as an input and output of DEA model, respectively. Results are shown in Table 4. Thus, considering supply risk PIs are classified into high risk (efficiency value equal to one) and low risk (efficiency value less than one). On the other hand, evaluation of PIs according to profit impact is quantitative. Evaluation value for these criteria is given in Table3. Using DEA model, PIs are classified into high profit impact (efficiency value equal to one) and low profit impact (efficiency value less than one). Final classification of PIs isshown in Table 4.As we can see, combining obtained efficiency values based on Kraljic's model, PIs are classified into strategic, leverage, bottleneck and routine items.

Insert Tables 1 about here

Insert Tables 2 about here

Insert Tables 3 about here

Insert Tables 4 about here

4. Discussion and conclusions

Aircraft Manufacturing Industrial Company (HESA) identified tenpurchasing itemswhich needs supplier for the sake of supply. This company hasnot had a documental plan for supplier selection yet. In selections which have been made so far, the nature of the product has not been regarded. It was suggested to this company to categorize the purchasing itemsbefore selecting the supplier and ordering allocation in order to do this action with a wide view. The foundation of this suggestion was the logic provided by Kraljic. Also for measuring the risk and the profit, FMEA and DEA tools was selected. According to the proposed method, purchasing items were categorized into four categories; Strategic, Leverage, Bottleneck, and Routine purchasing items. Each of the four categories requires a distinctive approach, in proportion to the strategic implications. Routine items require efficient processing, product standardization, order volume and inventory optimization.

Leverage items allow the buying company to exploit its full purchasing power, for instance by tough negotiating, target pricing and product substitution. Bottleneck items on the other hand cause a lot of problems and risks. Volume insurance, vendor control, security of inventories and backup plans are recommended. For the strategic items consider company buying strength against the strengths of the supply market.As shown in Table 4, PI2 and PI4 are strategic items and somehow are the most important PIs. On the other side, PI8 and PI10 are routine items and are highly sensitive to supply these items are not recommended. PI1, PI7 and PI9 are bottleneck items and PI3, PI4 and PI6 are also leverage items. These two categories are in a lower priority than strategic items and would be supplied more sensitive than routine items. The results of applying the proposed model in Aircraft Manufacturing Industrial Company (HESA) indicate the validity and effectiveness of this model. Also it should be noted that efficiency of the proposed model is not limited to this industry.

The proposed model can classify purchasing items and select relevant suppliers according to the nature of each purchasing item Appropriate and long-term relationships with suppliers, bargaining power and replacement are important issues that can be response with the proposed model.

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Fig. 1.Kraljic's matrix (Kraljic, 1983)

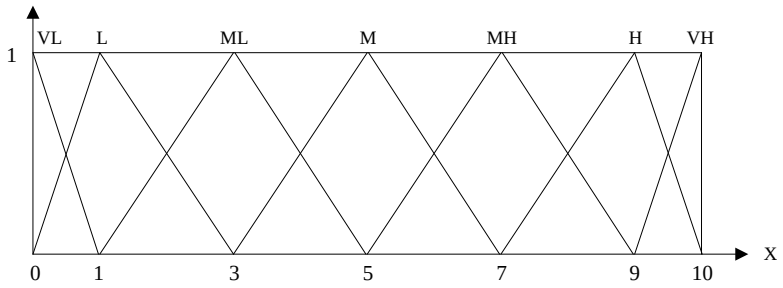

Fig. 2.A linguistic scale (Amin and Razmi, 2009).

Table1. The FRPNs for PIs 1 (for example)

Risk factors	Occurrence	Severity	Detection	FRPN
Cost	VH	ML	MH	**415.00**
Quality	M	MH	ML	**150.00**
Delivery	MH	ML	VL	**115.67**
After sale services	ML	ML	H	**230.00**
Capacity	M	VH	M	**370.00**
Potential future collaboration	VL	H	L	**212.67**

Table2. The FRPNs and weights of Supply Risk criteria

Supply Risk	PI 1	PI 2	PI 3	PI 4	PI 5	PI 6	PI 7	PI 8	PI 9	PI 10
Cost	500.6	474.5	425.0	353.2	258.2	453.0	493.2	221.5	446.4	375.0
Quality	330.9	266.1	176.1	128.6	402.1	364.9	504.2	181.4	193.1	380.5
Delivery	289.5	196.3	215.8	139.0	329.3	129.1	320.8	196.4	448.8	144.7
After sale services	426.2	158.7	96.8	288.0	292.3	166.5	406.5	150.9	395.7	350.1
Capacity	499.1	386.3	68.4	182.5	542.0	70.0	431.0	364.8	227.6	122.4
Potential future collaboration	328.5	455.2	111.0	194.5	132.8	98.57	405.4	132.9	264.8	173.2

Table3. The weights of Profit Impact Criteria

Profit Impact	PI 1	PI 2	PI 3	PI 4	PI 5	PI 6	PI 7	PI 8	PI 9	PI 10
Revenue	618	820	82	350	755	750	120	420	650	780
Profit	313	650	980	917	550	60	211	665	175	480
Quantity Sale	36	72	135	187	26	121	145	52	25	52
Management opinion	0.32	0.85	0.09	0.78	0.89	0.31	0.58	0.25	0.45	0.78

Table4.classify purchasing items based on Kraljic's model

DEA Results	PI 1	PI 2	PI 3	PI 4	PI 5	PI 6	PI 7	PI 8	PI 9	PI 10
Supply Risk	1.00	1.00	0.85	0.71	1.00	0.91	1.00	0.69	1.00	0.85
Profit Impact	0.75	1.00	1.00	1.00	1.00	1.00	0.78	0.81	0.79	0.95
Classification	Bottleneck	Strategic	Leverage	Leverage	Strategic	Leverage	Bottleneck	Routine	Bottleneck	Routine