Distribution Evaluation Based on Data Envelopment Analysis

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***Abstract*— Companies have found that the optimal Supply Chain Management (SCM) increases successfulness by acquiring direct and indirect benefits in the supply chain. Therefore, SCM has attracted managers and researchers attention nowadays. Distributors, as a part of a supply chain and a link between the producer and the customers, can help producers to develop new products and processes. In this paper, an integrated Kano-DEA method has introduced for distribution evaluation. This combination has used to determine the importance weights of evaluation criteria. Then, distributors have been evaluated using Data Envelopment Analysis (DEA) technique. Finally, in order to show the application aspects, a numerical example is presented.**

***Keywords*—** *Supply Chain Management (SCM), Distribution evaluation, Distributor selection, Kano model, Data Envelopment Analysis (DEA).*

1. Introduction

Supply chain management (SCM) has received more attentions from both academicians and practitioners in the past decade. Many articles and books have been published for the methods and opinions about the application of SCM. Distributor's selection is an important issue in SCM, particularly in the current competitive environment. Distributor selection involves evaluation and choice (Cavusgil *et al.* 1995). The evaluation task typically consists of identifying the attributes, criteria or factors relevant to the decision and then measuring or rating eligible distributors on each factor (Patton, 1996).

It should be noted that distributor selection has not been studied deeply and the theoretical methods developed by academics have not been fully applied in industry. To date, little work has been done in selection of distributor, particularly in empirical studies. Only conceptual, descriptive and simulation results focused primarily on firm resources and general marketing/selling factors were discussed (Cavusgil *et al.* 1995; Yeoh and Calantone, 1995). Fonsson and Zineldin (2003) proposed a conceptual model including behavioral dimensions of supplier–dealer relationships and presented hypotheses about how to achieve satisfactory inter-organizational relationships. Their results showed that good reputation and close relationship are key variables for the achievement of high satisfaction in a ‘‘high-trust and commitment relationship”. Sharma *et al.* (2004) proposed a composite Distributor Performance Index (DPI) to evaluate distributors' performance. Based on a case study, Wang and Kess (2006) found that task-related and partner-related dimensions in partner selection of international joint ventures were useful in distributor relationship. A distributor relationship is a product-tied relationship, and product innovation can be used as an approach for performance improvement in distributor relationship. Lin and Chen (2008) derived four key constructs from marketing, supply chain, and logistics literature to investigate their influences on the distributor selection. Based on the evolutionary trends in distribution research, Sheresheva and Kolesnik (2010) came up with the idea to investigate distribution networks processes using mathematical tools of probability theory. They considered a distribution network in a stochastic way, where a focal agent optimizes the distribution chain at each decision-making node by switching between possible partners. Chen and Wu (2010) presented a systematic procedure to evaluate an automobile manufacturer–distributor partnership. The proposed process provided an effective means to develop a three-stage hierarchic/network model of the partnership, including partnership selection, partnership establishment, and partnership maintenance. Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) were applied to partnership evaluation based on as many as 20 system variables. Zou *et al.* (2011) introduced a method based on Rough set theory, which has been recognized as a powerful tool in dealing with qualitative data, and modified for preferred distributor selection. Cummings and Holmberg (2012) presented a new conceptual comprehensive partner selection framework that includes dynamic partner selection considerations. Developed and tested with input from over two hundred alliance managers, the comprehensive partner selection framework included new perspectives and an analysis of four critical alliance partner selection criteria, or critical success factors (CSFs) including task-related, learning-related, partnering-related, and risk-related. They embed these four sets of criteria within a comprehensive partner selection framework and provide guidelines, examples and a specific methodology designed to help managers address the complexities involved in developing their own, unique partner selection criteria and processes. Ghorbani *et al.* (2012) provided a new method to categorize and select distributors. The fuzzy Adaptive Resonance Theory (ART) algorithm was utilized to categorize distributors according to their similarity.

DEA is a non-parametric linear programming technique for evaluating the relative efficiencies of production units that operate in similar operating environments. DEA has been extensively applied in different industries since its introduction by Charnes *et al.* (1978). For a comprehensive treatment of DEA technologies refer to the textbook by Cooper *et al.* (2007). The capability of dealing with multi-input/multi-output settings without requiring explicit specifications of the relationships between the inputs and outputs provides DEA an edge over other performance benchmarking tools. In order to get familiar with applicability of DEA in SCM, authors refer to Xu *et al.* (2009), Chen (2011) and Toloo and Nalchigar. Xu *et al.* (2009) studied the supply chain performance evaluation of a furniture manufacture industry in the southwest of China. They identified the main uncertainty factors affecting evaluation process, and then they modeled and analysed them using rough data envelopment analysis (RDEA) models. Chen (2011) proposed a structured methodology for supplier selection and evaluation based on the supply chain integration architecture. Potential suppliers were screened through DEA. TOPSIS, a Multi Attribute Decision Making (MADA) method was adapted to rank potential suppliers. Toloo and Nalchigar (2011) proposed a new integrated DEA model which is able to identify most efficient supplier in presence of both cardinal and ordinal data. Utilizing this model, an innovative method for prioritizing suppliers by considering multiple criteria was proposed.

In this paper, an integrated Kano-DEA method has introduced to evaluate distributors. This combination has used for determination of the important weights of evaluation criteria. Then, distributors have been evaluated using DEA technique. Finally, in order to show the application, a numerical example has been conducted by using the proposed approach.

2. The proposed approach

2.1 Determination of quality attribute of the criteria

The Kano's model was first developed by Noriaki Kano and his colleagues in 1984 (Kano *et al.* 1984) to categorize the attributes of a product or service, based on how well they are able to satisfy customers' needs (Shahin, 2004). In practice, five types of attributes are identified:

I. Must-be attributes: These are attributes that often are unnoticed by customers and sufficiency of them will not result more satisfaction, but insufficiency of these elements will result dissatisfaction.

II. One-dimensional attributes: These are attributes that sufficiency of them will result satisfaction and insufficiency of them will result dissatisfaction. These attributes are also termed "more is better" or "faster is better".

III. Attractive attributes: These are attributes that sufficiency of them will cause customers to feel excitement and their absence will not dissatisfy customers.

IV. Indifferent attributes: These are attributes that sufficiency or insufficiency of them will not affect customer satisfaction.

V. Reverse attributes: These are attributes that if they are provided, customer will be dissatisfied and vice versa.

Kano (1984) used functional (positive) and dysfunctional (negative) questionnaires and 5 by 5 evaluation table to determine different attributes. This is achieved by asking two questions:

1. If the product/service provided to you, work well, how do you feel?
2. If the product/service provided to you, does not work well, how do you feel?

In this paper, Kano questionnaire is utilized to determine quality attributes of criteria. Therefore, functional (positive) and dysfunctional (negative) questions are asked from experts for each criterion (See Table 2).

Table 1. Kano evaluation Table

Customer requirements → ↓		Dysfunctional form of the question				
		1) I like it that way	2) It must be that way	3) I am neutral	4) I can live with it that way	5) I dislike it that way
Functional form of the question	1) I like it that way	Q	A	A	A	O
	2) It must be that way	R	I	I	I	M
	3) I am neutral	R	I	I	I	M
	4) I can live with it that way	R	I	I	I	M
	5) I dislike it that way	R	R	R	R	Q

Table 2. Single answer for Kano questionnaire

Kano questionnaire	Like	Must-be	Natural	Live-with	Dislike
Functional	✓				
Dysfunctional				✓	

Using Table 1, nature of each criterion is determined by combining results of functional (positive) and dysfunctional (negative) questions.

2.2 Evaluation potential distributors

2.2.1 Defining the evaluation grades and acquiring evaluation data

To characterize the relative importance of each distributor with respect to each criterion, we define for each criterion a set of assessment grades $G_j = \{P_{j1}, \dots, P_{jN}\}$ $(j = 1, \dots, C)$, where $P_{j1}, \dots, P_{jN}$ represent the importance from the most to the least important and *N* is the number of assessment grades for criterion *j*. We assess each distributor against each defined criteria in five levels such as very high, high, medium, low and very low by asking from corresponding experts.

G={Very High, High, Medium, Low, Very Low} = {VH, H, M, L, VL}.

Having defined the sets of evaluation grades, the distributors that needed to be prioritized were assessed one by one against the selected criteria.

2.2.2 Transition of qualitative weights to quantitative weights

Assume that criterion j will be assessed by X experts $(j = 1, \dots, C)$ and X_{rjn} are the number of experts who asses item r to grade P_{jn} under the criterion j. It is evident that $\sum_{n=1}^{N} X_{rjn} = X$. Table 3 shows the number of experts who select their desired grade for each item with respect to every criterion.

Table 3. Supplier selection decision making matrix

Alternatives	Criteria C_1		…	C_j		…	C_C	
	P_{11}	… P_{1N}	…	P_{j1}	… P_{jN}	…	P_{C1}	… P_{CN}
A_1	x_{111}	… x_{11N}	…	x_{1j1}	… x_{1jN}	…	x_{1C1}	… x_{1CN}
⋮	⋮	⋮		⋮	⋮		⋮	⋮
A_r	x_{r11}	… x_{r1N}	…	x_{rj1}	… x_{rjN}	…	x_{rC1}	… x_{rCN}
⋮	⋮	⋮		⋮	⋮		⋮	⋮
A_R	x_{R11}	… x_{R1N}	…	x_{Rj1}	… x_{RjN}	…	x_{RC1}	… x_{RCN}

Let $w(P_{jn})$ be the weight of grade P_{jn} $(n = 1, 2, \dots, N)$. The local weight of each item with respect to every criterion can be defined as

$$W_{rj} - \sum_{n=1}^{N} W(P_{jn}) X_{rjn} \qquad r - 1, \dots, R, \quad j - 1, \dots, C \quad (1)$$

To determine the local weight of each item *i* with respect to every criterion, each item is considered as a DMU, $W(P_{jn})$ as a decision variable and also the weight assigned to the output X_{ijn}, and the following DEA model:

$$W_{ij}^{*} = max \sum_{n=1}^{N} W(P_{jn}) X_{ijn} \qquad (2)$$

s.t.

$$\sum_{n=1}^{N} W(P_{jn}) X_{ijn} \leq 1, \qquad r = 1, \dots, R, \quad j = 1, \dots, C$$

$$W(P_{j1}) \geq 2W(P_{j2}) \geq \cdots \geq NW(P_{jN}) \geq 0,$$

Where $W(P_{j1}), \dots, W(P_{jN})$ are the decision variable and following equation $W(P_{j1}) \geq 2W(P_{j2}) \geq \cdots \geq NW(P_{jN}) \geq 0$ is the strong ordering condition imposed on grades, which is similar to the strong ordering condition on different ranking places in voting systems proposed by Wang *et al.* (2008).

3. Numerical Example

In this study, a numerical example is presented to show performance of the proposed approach. In this example, a Company with 10 distributors is considered. The proposed approach is applied in two phases. At first, the weights of evaluation criteria are determined and in the second step, distributors are evaluated and ranked. The proposed approach is shown in Fig. 1.

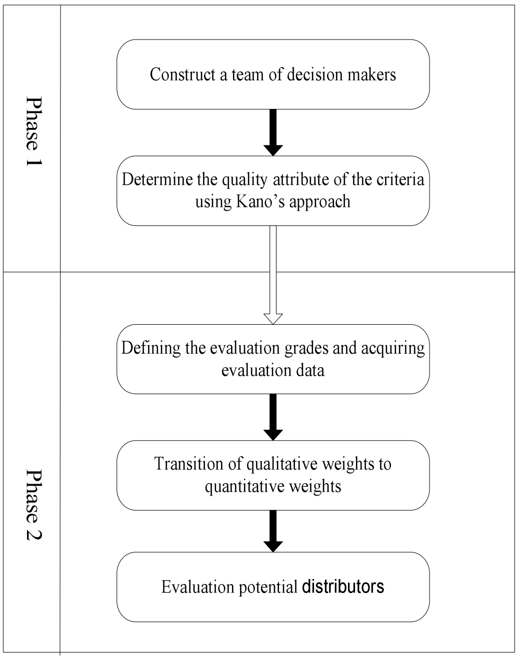

Figure 1. Proposed method

The computational procedure is summarized in the following steps:

Step 1: The decision making team is consisted of 10 decision makers (DMs). The DMs have identified the following six criteria to evaluate 10 distributors such as marketing capabilities (C1), logistic capabilities (C2), relationship intensity (C3), brand (C4), infrastructure (C5) and turnover (C6).

Step 2: The Kano questionnaire is then distributed between DMs to determine the quality attributes of the determined criteria. Table 4 shows the frequency of quality attributes for each evaluation criteria.

Step 3: In this step, important weight of each criterion is determined using Eq. 2. As a novel innovation, we consider $P_{jn,}\ n = 1, \ldots, 5$ as quality attribute (e.g., must-be, one-dimensional, attractive, indifferent and reverse) in phase 1. This consideration is based on assessment rule that introduced by CQM (1993). This rule shows the important effects of each attributes such as $M > O > A > I$. Important weight of each criterion has been illustrated in Table 4.

Table 4. Frequency of quality attributes and resultant weights

Criteria	Quality attributes				Weights
	Must-be	One-dimensional	Attractive	Indifferent	
C1	7	1	2		1.000
C2	5	3	1	1	0.867
C3	2	5	3		0.674
C4	3	3	4		0.714
C5	6	1	2	1	0.908
C6	1	1	5	3	0.480

Step 4: In this step, potential distributors are evaluated with respect to each criterion. Assessment grades are very high, high, medium, low and very low. Evaluation profile of distributors with respect to mentioned criteria are shown in Table 5 and Table 6, respectively.

Step 5: Multiplying importance weights of criteria with local weights of distributors, evaluation score of each distributor is calculated. Table 7 shows the evaluation scores and final ranking of distributors.

Table 5. Evaluation profile of suppliers for screening phase

Distributors	Criteria														
	Marketing					capabilities					Logistic capabilities				
	VH	H	M	L	VL	VH	H	M	L	VL	VH	H	M	L	VL
Distributor 1	1	4	5						7	3	1	2	7		
Distributor 2		2	6	2		3	5	1	1				1	4	5
Distributor 3				8	2	5	1	4			3	2	5		
Distributor 4	3	5	2			7	1	1	1				2	4	4
Distributor 5	2	2	6				3	1	6		5	3	2		
Distributor 6			1	9		4	3	3			3	3	4		
Distributor 7	7	2	1				3	5	2		6	2	2		
Distributor 8			5	5				9	1				5	5	
Distributor 9	8	2					2	1	3	4		6	3	1	
Distributor 10	5	3	2					7	2	1			4	6	

Table 6. Evaluation profile of suppliers for ranking phase

Distributors	Criteria														
	Brand					Infrastructure					Turnover				
	VH	H	M	L	VL	VH	H	M	L	VL	VH	H	M	L	VL
Distributor 1	3	2	5			7	1	2				4	6		
Distributor 2	8	1	1			5	3	1	1			3	2	5	
Distributor 3		4	3	2	1	2	2	6				5	3	2	
Distributor 4				8	2			4	2	4	6	2	2		
Distributor 5	3	5	1				6	2	1	1	3	5	1	1	
Distributor 6	9	1				1	1	5	3			1	9		
Distributor 7	5	3	2			2	2	4	2			2	4	4	
Distributor 8		5	2	3					10			6	3	1	
Distributor 9				9	1		4	3	3			3	6	1	
Distributor 10				3	7	7	3				7	1	2		

Table 7. Evaluation scores and final ranking

Distributors	Criteria							
	C1	C2	C3	C4	C5	C6	Final Score	Rank
Distributor 1	0.5185	0.2907	0.5652	0.5965	0.9608	0.4898	2.6848	6
Distributor 2	0.3889	0.7526	0.3043	0.9298	0.8333	0.4184	2.8682	3
Distributor 3	0.2667	0.8454	0.7391	0.3895	0.5882	0.4898	2.5450	8
Distributor 4	0.6852	1.0000	0.3217	0.2526	0.3098	0.9388	2.6812	7
Distributor 5	0.5556	0.4124	0.9348	0.6140	0.4843	0.7143	2.7638	5
Distributor 6	0.2870	0.8041	0.7609	1.0000	0.4608	0.4286	2.8352	4
Distributor 7	0.9259	0.4536	1.0000	0.7544	0.5686	0.4082	3.2438	1
Distributor 8	0.3241	0.4021	0.3804	0.4123	0.2941	0.5204	1.7402	10
Distributor 9	1.0000	0.3567	0.5543	0.2579	0.4412	0.4184	2.4682	9
Distributor 10	0.7963	0.3753	0.3696	0.2263	1.0000	1.0000	2.9201	2

4. Discussion and Conclusions

As shown in Table 4, criteria 1, 2 and 5 are must-be, criteria 4 and 6 are attractive and criteria 3 is one-dimensional. It should be mentioned that having the best performance in criteria is necessary but not sufficient. Although distributor 10 is the best in two criteria, it is placed behind distributor 7, which is the best in only one criterion. On the other hand, distributor 2 is the best in none of criteria, but has been placed as third in final ranking.

The proposed approach is simple to understand and easy to use. In the first phase, we determine the important weights of evaluation criteria using Kano model. In the second phase, qualitative evaluations of suppliers are transformed in to the quantitative evaluation using the DEA approach. To illustrate the applicability of our approach, a case study is conducted at the end of the paper.

A practical extension to the proposed approach is to consider allocation of products for each distributor using mathematical modeling. Considering fuzzy evaluation of suppliers is another possible direction for further research that can perform a fully fuzzy decision process. Furthermore, other MCDM and MODM techniques could be applied and comparison with the proposed method could be carried out.

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