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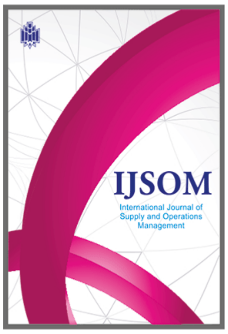

Development of Data Envelopment Analysis for the Performance Evaluation of Green Supply Chain with Undesirable Outputs

Amir Amini[a*], Alireza Alinezhad [b], Sadegh Salmanian [b]

[a] *Alghadir institute of higher education, Tabriz, Iran*
[b] *Faculty of Industrial and Mechanical Engineering, Qazvin branch, Islamic Azad University, Qazvin, Iran*

Abstract

In the conventional and common structure of Data Envelopment Analysis (DEA), Decision-Making Units (DMUs) generally operate as a black box that ignores the inner structures. It is assumed that DMUs' operation is a function of selective inputs and outputs. A fundamental problem is the use of DEA in multistep or multilevel processes such as supply chain, lack of attention to processes' internal communications in a way that the recent studies on DEA in the context of serial processes have focused on closed systems that the outputs of one level become the inputs of the next level and none of the inputs enter the mediator process. The present study aimed to examine the general dimensions of an open multilevel process. Here, some of the data such as inputs and outputs are supposed to leave the system while other outputs turn into the inputs of the next level. The new inputs can enter the next level as well. We expand this mode for network structures. The overall performance of such a structure is considered as a weighted average of sectors' performance or distinct steps. Therefore, the suggested model in this study, not only provides the possibility to evaluate the performance of the entire network, but creates the performance analysis for each of the sub-processes. On the other hand considering the data with undesirable structure leads to more correct performance estimation. In the real world, all productive processes do not comprise desirable factors. Therefore, presenting a structure that is capable of taking into account the undesirable structure is of crucial importance. In this study, a new model in the DEA by network structure is offered that can analyze the performance considering undesirable factors.

Keywords: Network Data Envelopment Analysis; Green supply chain; Undesirable output.

Corresponding author email address: mr62.amini@gmail.com

1. Introduction

Data Envelopment Analysis (DEA) is a tool to measure the relative efficiency of decision-making units (DMU) with several inputs and outputs. As reported in a study by Cooper et al. (2004), DMUs can contribute in various contexts such as hospitals, universities, businesses, transport, etc. In the classic DEA, DMUs are considered as a black box in which the inner structures are ignored and DMUs' performance is regarded as a function of final inputs and outputs. In most of the cases, DMUs can have inner network structure. Fare and Grosskopf (2000), Castly et al. (2004), Toon and Tesotesotoei (2009), all have offered new methods for performance evaluation based on DEA method. About the last case, the overall performance can be stated as a weighted average of effectiveness regarding sections and this indicates the importance of each section. The present study has concentrated on efficiency extraction that has analyzed it as a convex combination of radial sizes for different sections as well as sub-processes of DMU. The model of interest in this study has a feature through which the weight of each stage is variant. These DMUs not only have input and output, but the intermediate values have been considered for them as well. Accordingly, each stage can have its input and output of interest. Recently, several studies have been conducted on DMUs that consider the processes of each stage. For example, Seiford and Zhu (1996) consider profitability and supply ability regarding U.S. banks as a two-stage process. In their study, profitability has been considered in the first stage as the input, using workforce and assets. Also, profit and productivity are measures as output. In the second stage, the ability to launch, profit and productivity have been considered as input; also, income and return are regarded as output. Kao and Hwang (2008) described a process that at the first stage considers 24 insurance firms that use cooperation and insurance costs to create insurance premium and at the second stage, considers profit commitment and investment. Among the other examples it can be pointed to the effect of IT on the performance of bank branches (Chen & Zhu, 2004) and the performance of U.S. Sports Network (Sexston & Lewis, 2003). Some of the studies have used conventional approach of DEA among which we can refer to Siford and Kho (1999), (Sexston & Lewis, 2003), and Chen and Zhu (2004). Finally, this approach points to potential problems between two stages that are caused by intermediate values. If there is a need to decrease inputs (intermediates) to meet functional status, such an approach leads to a reduction in the output of the first stages and consequently, decreased functional status of the first stage. New approaches have been extended for modeling the intermediate values between the two stages in DMU. Kao and Hwang (2008) have offered a radial model in standard DEA by analyzing the overall performance of two stages. Although the presented approaches can be generalized for DMUs by network structure, this generalization needs to share multistage processes and unique features to create the input for the next level. In other words, except the first level, all other cases do not have their independent input (or output) and this is true when the systems are closed, but where the systems are open (this structure practically exists, especially in industries), the offered model will create a significant advantage over other methods that have been proposed. Also, the offered model in this study, in addition to the aforementioned advantages over the studies models, will consider the undesirable data in a way through which can have more accurate performance evaluation.

2. Literature Review

Most of the previous studies on DEA basic models such as CCR (Charnes et al., 1987), BCC (Banker et al., 1984) and FDH and others have been conducted to evaluate performance based on DEA. Pina and Torres (2001) measured transport efficiency of public and private sectors based on BCC. Also, they performed regression analysis to determine the logical reasons of performance. With more extension of performance measurement, new models were offered regarding DEA by Anderson and Peterson (1993), Cooper et al. (2000) and others. Golani (2001) and Baross et al. (2009) focused on the performance of air transport industry and have measured airline network performance. Itoh (2002) used a window approach to evaluate the performance change of international ports. Hwang et al. (2010) evaluated the performance of Asian ports using DEA. Boam (2004) implemented his model to estimate the performance of urban transport systems. Sheet et al. (2007) performed a comparison between the network models of Fare and Grossopf (2000) and target program model (Atanasopolos, 1995) based on performance analysis of different bus transport routs. In this study, despite desirable inputs (the number of vehicles, the path, staff, fuel, etc.), there were several undesirable outputs such as the rate of accidents and pollution that had been considered in measuring efficiency and performance. Haklos and Tezermes (2013) investigated the relationship between the level of economic efficiency of Eco members and the level of environmental sustainability and compatibility of these countries between 2001 and 2010 based on two-stage DEA. The results indicated that the high level of economic efficiency of these countries, does not guarantee the regarding environmental efficiency. Maghbouli et al. (2014) evaluated the performance of 39 airlines. In this study, the performance of airlines was investigated based on DEA, considering undesirable outputs. Azadi et al. (2014) investigated functionalization in green supply chain by focusing on public transport system in the framework of two-stage DEA. In all implemented model in the above mentioned studies based on DEA, it is not possible to introduce a model that is able to evaluate performance in network structure, considering the effect of undesirable effects that have the capability to extend to VRS structure and also consider the effect of intermediate values as well as all subsections in their own structure. Therefore, in this study, a model will be presented that will consider all the mentioned features as a proposed model.

3. Green Supply Chain Management

Intensifying the global competition in an environment which is continuously changing has doubled the importance of appropriate responses of organizations and companies insists on their flexibility regarding the uncertain external environment. The present organizations are trying to obtain an appropriate place in national and global contexts and for that, they need to make use of a suitable pattern such as green supply chain management in order to meet competitive advantage and customers' expectations. Customers in today's organizations are along the organizations' members regarding production and services, procedures and processes, knowledge expansion and competitive proficiency. Effective green supply chain management is considered as the main elements of survival. Also, the use of IT in green supply chain management has increased the potential for value making in the chain. Generally, green supply chain management focuses on increasing companies' adaptability and flexibility and has the capability to make quick and effective response to market changes.

Today’s world is faced with issues such as global warming, pollutions, increased greenhouse gases that can potentially lead to human extinction. Therefore, the environmental related strategies were quickly considered as an important organizational innovation. On one hand, the organization should have concentrated on profitability and competitive advantages and on the other hand, finding appropriate methods to destroy or minimize the amount of wastes (energy, emissions, chemicals, hazardous solid wastes). Accordingly, the idea of green supply chain management was proposed and drew public attention.

In fact, this is a new management model for environmental protection. Green supply chain management, regarding the life span of product, includes all stages of raw materials, design and product development, product sales and transportation, product use and recycling products. Using green supply chain management, the company can decrease the negative environmental effects and obtain optimal use of resources and energy. Green supply chain management uniforms supply chain management considering the environmental necessities in all stages of product design, choice, process and environmental considerations. So far, the world has done too much regarding studies and developing environmental products and these proceedings have limited the use of dangerous materials. Green supply chain management functions as a pioneer approach for companies such as Dell, Sony, IBM, etc. This phenomenon points to this fact that companies have understood this issue that environmental awareness can function as a source for their competitive advantages. Green supply chain management is able to increase cooperation among business partners and co-leaders and help to improve environmental performance and reduce wastes.

Due to the economic, social and environmental challenges that threat organizations, customer-oriented approach and focusing on their demands and designing various strategies want to satisfy customers have led to the lack of competitive advantages in organizations. If in last two decades, customer-orientation was considered as the competitive advantage element, today due to the created challenges through customer-orientation, organizations have moved away from this point and concentration. Customer has always been looking for the best, cheapest and fast delivering product. This view led to environmental pollution and those processes that have not been consistent with the environment. In this regard, organizations find their survival in taking responsibility in three areas of economic, social, and environmental contexts. The green view in the organization and the development of organizational structures as the green guarantee has been an alternative for organizational units such as quality assurance. Studies state that today, environmental management with its emphasis on environmental protection has turned into one of the most important issues of customers, stakeholders, governments, staff and rivals. Also, global pressures have necessitated the organization to produce products and services consistent with the environment. It is often believed that green supply chain means abandoning the use of toxic chemicals. This imagination is totally wrong, since the chain has moved far away and considers all units of an organization. Indeed, green supply chain is the result of economic goals and environmental goals association. Therefore, the evaluation of green supply chains in pioneer organizations is highly important. One of the techniques that can be used to evaluate green supply chain is DEA.

Ashish et al. (2014) developed a framework in the context of traditional versus green supply chain management to select the green suppliers and further investigate how to overcome the barriers in green supply chain. According to Ruimin et al. (2012), every business activity in supply chain process consists of various objective risk factors and issues. The occurrence of the different risks disturbs various operations and processes of GSC, and declines the overall performance of the industries (Qianlei, 2012). Thereby, in order to effectively manage (GSC), the background of the risks in GSC is important to discuss. Therefore, to help industries, it is recommended to evaluate the risks for an effective understanding and implementation of GSC business practices. Kannan et al. (2014) proposed the fuzzy multi-attribute group decision making approach based on (GSCM) practices from the high risk supply chain perspectives. GSCM helps organizations and their business to improve competitive advantages and profits in the high-risk supply chain environment. Cosimato and Troisi (2015) investigated the role of emergent green technologies in making logistics organizations finally green and competitive through SEM technique.

The adoption of (GSCM) initiatives will lead to better economic performance through enhanced environmental performance such as less waste, enhanced energy efficiency and an improved recyclability of the end product (Mor et al., 2015). At the same time, new green initiatives might require organizations to redesign and improve various aspects of their exiting processes in order to adopt these innovations successfully. It is essential for the organization to identify those areas at both the individual organization and supply chain levels that are least prepared to handle the green innovation successfully (Nazam et al., 2015).

4. Multistage Data Envelopment Analysis

In these units, each decision-making section is comprised of two stages. First of all, a number of inputs enter the first stage and then, a number of outputs go out. These outputs enter the second stage. Therefore, the first stage's input is for the second stage. The outputs of the first stage and the inputs of the second stage have intermediate elements. Then, the final outputs go out of the second stage. Consider a decision-making unit (DMU) according to Figure (1). Each DMU consists of x_{ij} (input) and D (output) for the first stage. These outputs are the inputs of the second stage that are identified as the intermediate element. Then, "s" that has been indicated by $y_{rj}(r = 1, \dots, s)$, leaves the second stage. Figure (1) shows the schematic structure the two-stage units.

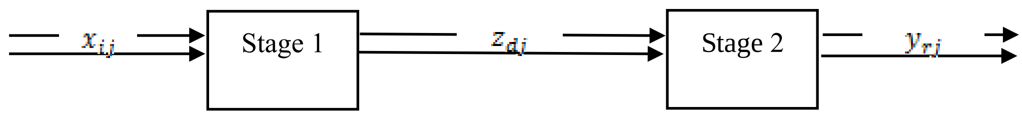

Figure1. A simple two-stage structure.
Source :(Fare and Grossopf. 2000)

Kao and Hwang's Method (2008)

In this method, the multiplication of the two stages is considered as the overall performance. The performance of first and second stages for DMUj consists of:

$$\theta_j^1 = \frac{\sum_{d=1}^{D} \eta^1{}_d \; z_{dj}}{\sum_{i=1}^{m} \; v_j x_{ij}} \tag{1}$$

$$\theta_j^2 = \frac{\sum_{r=1}^{s} \; u_r y_{rj}}{\sum_{d=1}^{D} \; \eta_d^2 z_{dj}}$$

$\eta_d^1 (d = 1, \dots, m)$ and $v_i (i = 1, \dots, m)$ are the input and output weights of the first stage, respectively.

$U_r (r = 1, \dots, s)$ and $\eta_d^2 (d = 1, \dots, D)$ are the inputs and output weights of the second stage.

In this model, it is assumed that $\eta_d^1 = \eta_d^2 = \eta_d$. In other words, all the output values of the first stage are consumed in the second stage. Based on this description, Kao and Hoang's model is as follows:

$$\theta_o^* = max \left(\frac{\sum_{d=1}^{D} \; \eta_d z_{do}}{\sum_{i=1}^{m} \; v_i x_{io}} \times \frac{\sum_{r=1}^{s} \; u_r y_{ro}}{\sum_{i=1}^{m} \; \eta_d z_{do}} = \frac{\sum_{r=1}^{s} \; u_r y_{ro}}{\sum_{i=1}^{m} \; v_i x_{io}} \right)$$

$$s.t.$$

$$\frac{\sum_{d=1}^{D} \; \eta_d z_{dj}}{\sum_{i=1}^{m} \; v_i x_{ij}} \leq 1 \qquad ,i = 1, \dots, m \tag{2}$$

$$\frac{\sum_{r=1}^{s} \; u_r y_{rj}}{\sum_{i=1}^{m} \; \eta_d z_{dj}} \leq 1 \qquad ,r = 1, \dots, s$$

$$\eta_d, v_i, u_r \geq 0 \qquad ,d = 1, \dots, D$$

The above model goes as follows after linearization process:

$$\theta_o^* \max \sum_{r=1}^{s} u_r y_{ro}$$

$$s.t.$$

$$\sum_{i=1}^{m} v_i x_{io} = 1 \qquad ,i = 1, \dots, m \tag{3}$$

$$\sum_{i=1}^{d} \eta_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad ,j = 1, \dots, n$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{d=1}^{D} \eta_d z_{dj} \leq 0 \qquad ,r = 1, \dots, s$$

$$\eta_d, v_i, u_r \geq 0 \qquad ,d = 1, \dots, D$$

Chen et al.'s Method (2009)

In this method, the total harmonic of two stages' performance presents as the overall performance. This model is as follows:

$$\theta_o^* = max \left(w_1 \frac{\sum_{d=1}^{D} \eta_d z_{do}}{\sum_{i=1}^{m} v_i x_{io}} + w_2 \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} \eta_d z_{do}} \right)$$

$$s.t.$$

$$\frac{\sum_{d=1}^{D} \eta_d z_{dj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad ,i = 1, \dots, m \tag{4}$$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} \eta_d z_{dj}} \leq 1 \qquad ,r = 1, \dots, s$$

$$\eta_d, V_i, u_r \geq 0 \qquad ,j = 1, \dots, n \qquad ,d = 1, \dots, D$$

W1 and w2 are the weights of the first and second stages, such that: w1 + w2 = 1. These weights indicate the relative importance of each stage which is equal to the inputs or resources ratio of each stage to total inputs or resources ratio of DMU (inputs of the first and second stage). Therefore:

$$w_1 = \frac{\sum_{i=1}^{m} v_i x_{io}}{\sum_{j=1}^{m} v_j x_{io} + \sum_{d=1}^{D} \eta_d z_{do}} \tag{5}$$

$$w_2 = \frac{\sum_{i=1}^{m} \eta_d z_{do}}{\sum_{i=1}^{m} v_i x_{io} + \sum_{d=1}^{D} \eta_d z_{do}}$$

By substituting w1 and w2 in the previous model and implementing linearization stages, the model would be resulted as follows. In this model, all outputs of the first stage is consumed in the second stage and this is assumed as well: $\eta_d^1 = \eta_d^2 = \eta_d$

$$\theta_o^* = max \sum_{d=1}^{D} \eta_d z_{do} + \sum_{r=1}^{s} u_r y_{ro}$$

$s.t.$

$$\sum_{i=1}^{m} v_i x_{io} + \sum_{d=1}^{D} \eta_d z_{do} = 1 \qquad ,j = 1, \dots, n$$

$$\sum_{i=1}^{d} \eta_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad ,i = 1, \dots, m \tag{6}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{d=1}^{D} \eta_d z_{dj} \leq 0 \qquad ,r = 1, \dots, s$$

$$\eta_d, v_i, u_r \geq 0 \qquad ,d = 1, \dots, D$$

Hwang and Chen indicated that if we show the performance of Chen's model and Kao's model with θ_o^{*c} and θ_o^{*k}, respectively, it will be proved as: $\theta_o^{*c} \geq \theta_o^{*k}$

Chen and colleagues estimated the overall performance with the data from Kao and Hwang's study using total harmonic method and by using Spearman correlation coefficient indicated that the obtained performance values from two different methods of Kao and Cheng do not have any significant difference. Therefore, total harmonic method is valid.

Also, Liang and Kho showed that assuming output as stable, these two methods are consistent. In this study, it has been stated that Kao and Hwang's method has advantage over Chen's method in a way that can present performance analysis while Chen's method lacks this capability. The advantage of Chen's model over Kao's model is that Kao's model cannot be used assuming performance as variable, because in this condition, the model would be nonlinear. On the other hand, this is not true in the case of Chen's model. According to the presented concepts, each of the proposed models has advantages and disadvantages that are usable depending on the condition of interest. The models are from basic and source models in two or multistage structures. But in this study, a model will be proposed that despite presenting estimation in span structure to variable ratio, has the capability of analyzing each stage and since is presented as envelopment form, can easily estimate the limitation of undesirable condition, without linearization.

5. The proposed model

Consider the *n* decision counter unit ($j = 1, \dots, n$).Each unit consisted of *p* step decision-making.

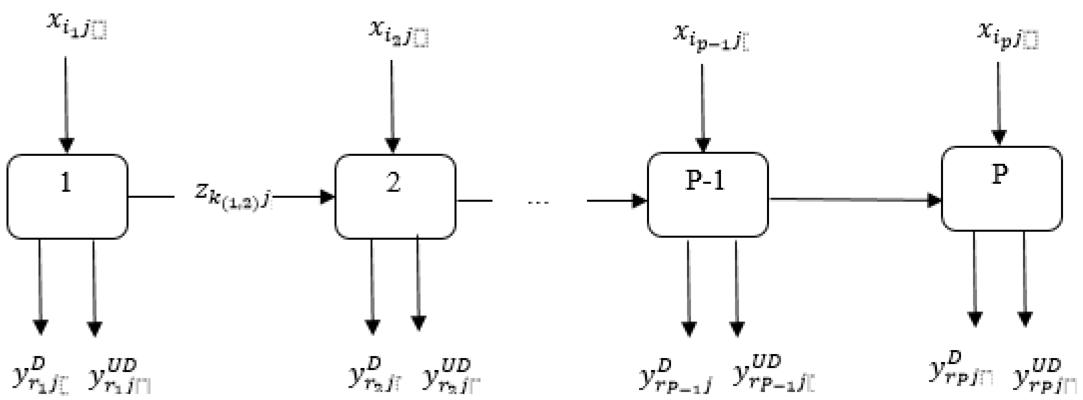

Figure 2. Network structure with undesirable outputs

$x_{i_p j}$ is the input (i) P, from DMU.

$y^D_{r_P j}$ is the output (r) value of P which belongs to DMU that leaves the system. The outputs are available as desirable and undesirable.
UD stands for *Undesirable* and D stands for *Desirable*.

$z_{k_p j}$ indicates the value of intermediate k of p level from DMUj. The intermediate values do not leave the network and will be a part of input for the next stage.

$\theta^R_{O,\dots,}\theta^1_O$: target function values of stages 1 to P for DMUo (decision-making unit under evaluation).

$w^p_O w^1_O$:relative weights related to stages as:

$+w^2_O+\ldots+w^p_O = 1w^1_O$

According to the assumptions, the proposed model based on Relation (7) is as follows:

$$max \sum_{p=1}^{p} w^p_o \theta^p_o$$

ST.

$$\sum_{j=1}^{n} \lambda^p_j x_{i_p j} \leq \left(1-\theta^p_o\right) x_{i_p o} \qquad , \qquad i_p = 1, \dots \ , I_p$$

$$\sum_{j=1}^{n} \lambda_j^p y_{r_p j} \geq \left(1+\theta_o^p\right) y_{r_p o} \quad , \quad r_p^D = 1, \dots, R_p^D \quad (7)$$

$$\sum_{j=1}^{n} \lambda_j^p y_{r_p j} \leq \left(1-\theta_o^p\right) y_{r_p o} \quad , \quad r_p^{UD} = 1, \dots, R_p^{UD}$$

$$\sum_{j=1}^{n} \lambda_j^p z_{k_p j} \geq \left(1+\theta_o^p\right) z_{k_p o} \quad , \quad k_p = 1, \dots, K_p$$

$$\sum_{j=1}^{n} \lambda_j^{p+1} z_{k_p j} \geq \left(1-\theta_o^{p+1}\right) z_{k_p o} \quad , \quad k_p = 1, \dots, K_p$$

$$\lambda_j^p \geq 0 \ , \quad j = 1, \dots, n \quad , p = 1, \dots, P$$

Target function is the maximum of harmonized total of target functions of sub-processes. If the target function is obtained as zero, then the unit is efficient and it is larger than zero, the unit is not efficient. The first limitation: linear combination from the inputs of level *P*, is smaller and equal to the input of the unit of interest in the same stage. The second limitation: the linear combination of desirable outputs in level *P* is larger and equal to the output from the unit of interest in the same stage. The third limitation: the linear combination of undesirable outputs in level *P* is smaller and equal to the output from the unit of interest. The forth limitation: the linear combination of intermediate size that leaves level *P* and is larger and equal to the output from the unit of interest. The fifth limitation: the intermediate size that enters the level *P+1* as a part of input and is smaller and equal to the intermediate size from the unit of interest. Various methods have been proposed while dealing with undesirable elements. But in this study, in dealing with undesirable outputs, it is treated as input. On the other hand, in the case of undesirable inputs, it is treated as output. Since the model is as envelopment, the entrance of undesirable elements to the model is easier and is possible without linearization takes place. Also, it is possible to generalize this model into a variable scale through adding a limitation. Moreover, the intermediate elements are not passive in this model and there is no trace of surplus and shortage variables.

6. Numerical Example

In this section, the structure of a green supply chain management has been evaluated. This supply chain is formed by four stages of supply, producer, distributor, and customer. The inputs of the first stage or supplier consist of purchase costs, transportation costs, labor costs, confidentiality costs. Also, the outputs of the first stage consist of the level of facilities, the flexibility of suppliers, the capacities of suppliers, services and PPM. Also, in order to evaluate the performance of green supply chain, each chain is considered as a DMU. The overall structure of this chain has been depicted in Figure (2).This figure shows the implemented inputs and outputs in each stage.

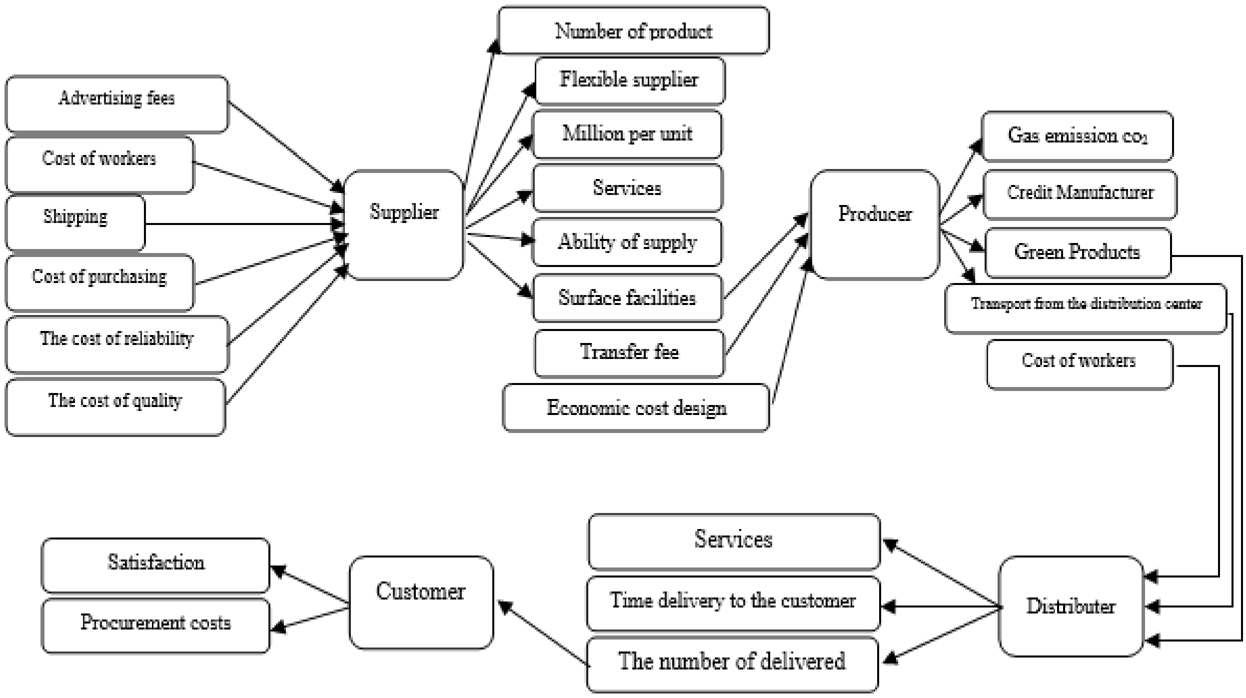

Figure 3. Structure of green supply chain network (Mirhedayatian et al., 2013)

PPM is an index to evaluate suppliers and is considered as an undesirable output in DEA. The intermediate size is the number of units from supplier to producer. The inputs consist of transportation costs from supplier to producer. The economic design cost and emission of CO_2 (undesirable output) and the credence of producer consist of intermediate sizes, number of produced green products and transportation costs of producer to the distributor. In the distributor section, the input is labor costs and output consists of services and desirable delivery to the customer. The intermediate sizes are the number of delivered products to the customer. The evaluation factors are shown in Table (1).

Table 1. The evaluation factors

Factors	**Definition**	**stage**	**Factors**	**Definition**	**stage**
$x_{1,j}$	Transfer fee	Producer	$x_{1,j}$	cost of purchasing	Supplier
$x_{2,j}$	Economic cost design		$x_{2,j}$	Shipping	
$y^{UD}_{1,j}$	Gas emission co_2		$x_{3,j}$	Cost of workers	
$y^{D}_{2,j}$	Credit Manufacturer		$x_{4,j}$	The cost of quality	
$x_{1,j}$	Cost of workers	Distributer	$x_{5,j}$	Advertising fees	

Table 1. Continued

Factors	Definition	stage	Factors	Definition	stage
$y^{D}_{1,j}$	Services		$x_{6,j}$	The cost of reliability	
$y^{D}_{2,j}$	Time delivery to the customer		$y^{D}_{1,j}$	number of product Transfer	
$x_{1,j}$	Procurement costs	Customer	$y^{D}_{2,j}$	Flexible supplier	
$y^{D}_{1,j}$	Satisfaction		$y^{D}_{3,j}$	Ability of supply	
$z^{1}_{1(1,1)j}$	Surface facilities	Intermediate size	$y^{D}_{4,j}$	Services	
$z^{1}_{1(1,2)j}$	Green Products		$y^{UD}_{1,j}$	PPM	
$z^{1}_{1(1,3)j}$	transport from the distribution center				
$z^{1}_{1(1,4)j}$	The number of delivered				

In customer section the input is the number of transported products and the output is customers' satisfaction and provisions' costs. The weights of each stage of supplier, producer, distributor and customer are 0.3, 0.4, 0.2 and 0.1, respectively. These weights are determined by the decision-maker. In order to evaluate the green supply chain performance, 10 Iranian active companies in foodstuffs were evaluated in GSCM conditions.

Each supply chain is considered as a DMU and phase outputs have been changed into finite numbers using $\frac{a+4m+b}{6}$. The data of each stage have been stated in Tables 2 to 6.

Table 2. First stage (supplier), Weight= 0.3

DMU	cost of purchasing	Shipping	Cost of workers	The cost of quality	Advertising fees	The cost of reliability	number of product Transfer	Flexible supplier	Ability of supply	Services	PPM
	$x_{1_1 j}$	$x_{2_1 j}$	$x_{4_1 j}$	$x_{4_1 j}$	$x_{5_1 j}$	$x_{6_1 j}$	$y^{D}_{1_1 j}$	$y^{D}_{2_1 j}$	$y^{D}_{3_1 j}$	$y^{D}_{4_1 j}$	$y^{UD}_{1_1 j}$
DMU_1	290	220	85	75	104	60	3	2	1250	4	39
DMU_2	300	345	95	110	125	65	2	2	1295	2	34
DMU_3	288	350	110	85	110	72	3	3	1320	3	46
DMU_4	320	330	80	65	105	78	2	3	1295	3	32
DMU_5	290	275	92	93	135	90	4	2	1320	2	53
DMU_6	340	210	103	115	142	88	3	4	1349	4	62
DMU_7	325	370	100	125	159	92	4	2	1329	2	39
DMU_8	330	250	87	150	130	95	2	4	1276	3	45
DMU_9	349	320	75	145	115	105	4	4	1293	4	72
DMU_{10}	295	335	92	80	100	70	3	3	1302	2	42

Table 3. Second stage (manufacturer), Weight= 0.4

DMU	Transfer fee	Economic cost design	Gas emission co_2	Credit Manufacturer
	$x_{1_2 j}$	$x_{2_2 j}$	$y^{UD}_{1_2 j}$	$y^{D}_{2_2 j}$
DMU_1	139	394	155	3
DMU_2	125	454	167	2
DMU_3	155	329	153	3
DMU_4	132	442	180	3
DMU_5	149	526	167	2
DMU_6	176	349	156	3
DMU_7	125	527	178	3
DMU_8	192	397	167	2
DMU_9	156	309	153	3
DMU_{10}	145	403	174	3

Table 4. Stage 4 (customer), Weight= 0.1

DMU	Procurement costs $x_{1_4 j}$	Satisfaction $y^{D}_{1_4 j}$
DMU1	102	4
DMU2	112	2
DMU3	130	3
DMU4	100	4
DMU5	139	4
DMU6	149	3
DMU7	147	4
DMU8	125	2
DMU9	130	3
DMU10	104	2

Table 5. Data related to intermediate amounts

DMU	$z^{1}_{1_{(1,2)}j}$	$z^{1}_{1_{(2,3)}j}$	$z^{1}_{1_{(2,3)}j}$	$z^{1}_{1_{(3,4)}j}$
DMU1	236	490	127	9790
DMU2	279	523	147	9721
DMU3	247	539	247	10372
DMU4	289	597	184	10333
DMU5	275	479	194	9742
DMU6	298	623	204	11036
DMU7	320	589	215	11553
DMU8	327	532	167	10846
DMU9	297	508	201	10432
DMU10	217	632	156	10467

As stated, if the value of function is obtained as zero, the unit is efficient and if is larger than zero, it is not efficient. Also, using this model it can be found out that this inefficiency is related to which sub-process. Table (7) shows the obtained results from Lingo Software. The results indicate that none of the supply chains were efficient, because the amount of target function of all supply chains were something other than zero.

Table 6. The results of model solution

DMU	The objective function	supplier	manufacturer	distributor	customer
DMU_1	0.0099	0000	0000	0000	0.0099
DMU_2	0.0482	0000	0000	0.022	0.382
DMU_3	0.039	0.001	0000	0.065	0.26
DMU_4	0.0024	0000	0000	0.012	0000
DMU_5	0.0185	0000	0000	0.011	0.16
DMU_6	0.0724	0000	0.033	0.129	0.33
DMU_7	0.025	0000	0000	0.033	0.19
DMU_8	0.042	0000	0000	0000	0.428
DMU_9	0.044	0000	0000	0.086	0.268
DMU_{10}	0.035	0000	0000	0000	0.350

7. Conclusion and Suggestions

Green supply chain leads to the fast delivery of product and services, decreased delay, decreased costs and increase quality. In order to evaluate effective performance of green supply chain, it is necessary to evaluate effective and complex internal structures. Various methods exist in this context among which, it can be referred to DEA. In this study, a model was proposed to evaluate the effectiveness of multi-stage units with the presence of undesirable elements. Using this example, when the supply chain is inefficient, it can be identified that this inefficiency related to which sub-process of supply chain. Also, it helps the manager to improve the performance of supply chain by creating change in inputs or outputs of inefficient sub-unit. Also, more studies can be conducted on other DEA structures such as parallel structure and using phase data or uncontrollable data instead of finite data.

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