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GREEN SUPPLIER SELECTION IN EDIBLE OIL PRODUCTION BY A HYBRID MODEL USING DELPHI METHOD AND GREEN DATA ENVELOPMENT ANALYSIS (GDEA)

Narges Banaeian[1], Izabela Ewa Nielsen[2], Hossein Mobli[1], Mahmoud Omid[1]

[1] *Department of Mechanics of Agricultural Machinery, University of Tehran, Iran*
[2] *Department of Mechanical and Manufacturing Engineering, Aalborg University, Denmark*

Corresponding author:
Narges Banaeian
University of Tehran
Department of Mechanics of Agricultural Machinery
Karaj, Iran
phone: (+98936) 229-9431
e-mail: nrgsbanaei@ut.ac.ir

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Abstract
An organization's environmental performance is affected by its suppliers' environmental performance, and selecting green suppliers is a strategic decision in order to be more competitive in today's global market. By developing green movement across the globe, organizations are under pressure to reduce the emissions across their supply chain. Formerly the food production systems was oriented and optimized to satisfy economic demands and the nutritional needs of a rapidly growing world population. The food production industry requires large inputs of resources and causes several negative environmental effects. In recent years, environment factors rapidly emerging as an important issue for decision makers in food industries.
This study identifies best supplier in holistic perspective for edible oil production, and proposes a hybrid model using Delphi method and Green Data Envelopment Analysis (GDEA). Delphi method identifies the main criteria influenced in supplier selection process based on opinion of company purchase experts. GDEA evaluates the overall performances of suppliers and choose green supplier. Proposed hybrid model applied to a well-known company who produce edible oil (palm, soybean and olive oil) to evaluate green suppliers (among 13 main potential suppliers). Delphi questionnaire included 17 factors which were from financial, services, qualitative and environmental factors. The factors with the highest Delphi score (raw material price, quality, delivery and carbon footprint) entered in DEA model and high efficiency suppliers selected. Results showed that the most efficient raw oil suppliers of company are: S4 among soybean oil suppliers, P1 among palm oil suppliers and O3 among olive oil suppliers. Also palm oil not only has fewer price and carbon footprint but also the highest mean efficiency.

Keywords
GDEA, Delphi method, Green supplier selection, Edible oil, carbon footprint.

Introduction

The contemporary supply management is to maintain long term partnership with suppliers, and use fewer but reliable suppliers. Supplier selection is the process by which suppliers are reviewed, evaluated, and chosen to become a part of the organization's supply chain [1]. The Supplier Selection Problem consists of analyzing and measuring the performance of a set of suppliers in order to rank and select them for improving the competitiveness of the whole supply system [2]. A good supplier selection makes a significant difference to an organization's future to reduce operational and environmental costs and improve the quality of its end products. Green supplier selection (GSS) is interfering environmental issues in conventional supplier selection process [3].

There have been a lot of factors in today's global market in which that influence companies to search

for a competitive advantage. In recent years, environmental factors rapidly emerging as an important issue for decision makers. Organizations are now demanding that their suppliers reduce their carbon footprints while doing so themselves. Carbon foot printing is an accurate technique to deal with subjectivity in environmental factors. It provides a precise and accurate measure to judge a supplier's eco-efficiency. The term 'carbon footprint' is commonly used to describe the carbon dioxide (CO2) and other Greenhouse Gas (GHG) emissions for which an individual or organization is responsible [4].

The food production systems are oriented and optimized to satisfy economic demands and the nutritional needs of a rapidly growing world population. Comparing to other industries, food and agricultural products have some unique characteristics related to public health. Food companies are closely monitored by their customers who want to be confident that the food being purchased is safe. Also food industry requires large inputs of resources and causes several negative environmental effects. There are several GSS studies in various industries (automotive, manufacturing and etc.) [3] but from this point of view, food industry is neglected. Despite of high potential of environmental issues in food industry, has not been given much attention.

In green supply chain literature, various techniques are used to evaluate and to select green suppliers. Some of the main techniques include Analytical Hierarchy Process (AHP) [2, 5–7]; Analytic Network Process (ANP) [8-10]; Data Envelopment Analysis (DEA) [4, 11]. Other techniques blend two or more systems to create a hybrid methodology. There have been a lot of hybrid methods employed in the last 10 years at the literature in terms of supplier evaluation and selection methods [3, 12].

As the most important responsibility of purchasing management, the problem of vendor evaluation and selection has always received a great deal of attention from practitioners and researchers. This management decision is a challenge due to the complexity and various criteria involved. In this paper Delphi method used to identify the main criteria influenced in supplier selection process based on opinion of company purchase experts. This study identifies financial, qualitative, service and environmental issues of different supplier for edible oil production, and determined the most important criteria for supplier selection and finally proposes a DEA model based on important criteria to evaluate the overall performances of suppliers with respect to selected criteria.

Methodology

The constructed method is based on following steps:

- Definition of criteria and determination the most effective criteria for GSS (Delphi);
- Data collection and estimation (Inventory data and carbon footprint calculation);
- Ranking and GSS among potential suppliers based on effective criteria (GDEA).

Delphi method

Delphi is a method of popular survey technique that brings consensus of opinions among a set of experts or panelists (informed individuals) by maintaining the unanimity among them [13]. Each Delphi panelist was asked to answer two main questions:

First round- According to criteria collection, describe sub-criteria which are important for your supplier selection.

Second round- Score each sub-criteria between 1 (not important) to 9 (very important).

Delphi score is proposed by Listone and Turoff [14] as illustrated in Eq. 1:

$$\begin{aligned}&\text{Delphi Score}\\&= [(\text{Lowest Score}+\text{Highest Score}+4)\\&\times\text{Average Score})]/6.\end{aligned} \tag{1}$$

Carbon footprint

There is essential to estimate some life cycle inventory data using expert opinions and literatures due to the lack of reliable data and missing values. Conversion of all inventories to carbon dioxide (CO_2) performed by the "emission factors (GHG coefficient) from across the sector tool" section at the GHG protocol website or literature [15–17].

Carbon footprinting is also undertaken to reduce emissions over time, to identify and quantify the key emissions sources, to report the foot print accurately to a third party, to fulfill requests from business/retail customers or investors, to ascertain level of emissions needed to offset, and to become 'carbon neutral'. Carbon footprinting in productions essentially involves the following activities [4]:

- Calculating direct emissions and emissions from electricity – e.g. Onsite fuel usage, onsite electricity usage, transports which individuals use;
- Calculating basic carbon footprints, converting the fuel, electricity and transport consumption figures into CO_2 equivalents by using the standard emission factors. The end result is a carbon footprint in $KgCO_2$.

DEA

DEA first introduced by Charnes, Cooper, and Rhodes (CCR) [18]. The original CCR model was applicable only to technologies characterized by constant returns to scale (CRS) globally. In what turned out to be a major breakthrough, Banker, Charnes, and Cooper (BCC) [19] extended the CCR model to accommodate technologies that exhibit variable returns to scale (VRS).

Banker, Charnes [19] divided the overall efficiency into technical and scale efficiencies. Technical efficiency is defined as the Decision Making Unit's (DMU's) ability to achieve maximum output from given inputs.

Efficiency = Weighted sum of outputs / Weighted sum of inputs.

Using standard notations, the efficiency can be written as:

$$efficiency = \frac{u_1 y_1^{j*} + u_2 y_2^{j*} + ... + u_N y_N^{j*}}{v_1 x_1^{j*} + v_2 x_2^{j*} + ... + v_M x_M^{j*}}, \qquad (2)$$

where $u_1, u_2, ...$ are the weight given to output n ($n = 1, 2, ..., N$); $y_1^{j*}, y_2^{j*}, ..., y_N^{j*}$ are the amount of output n ($n = 1, 2, ..., N$) of DMU j^*; $v_1, v_2, ...$ are the weight given to input m ($m = 1, 2, ..., M$); $x_1^{j*}, x_2^{j*}, ..., x_M^{j*}$ are the amount of input m ($m = 1, 2, ..., M$) to DMUj^*; and j^* is the DMU under consideration. The efficiency is usually constrained to be between zero and one.

A unit can be made efficient either by reducing the input levels and getting the same output (input orientation) or by increasing the output level with the same input level (output orientation). The input oriented analysis is becoming more common in DEA applications because profitability depends on the efficiency of the operations.

In this study the data analysis was carried out with the help of the Excel 2010 spreadsheet, SPSS 16.0 software and DEA-Solver professional Release 6. The DEA-solver software was used to calculate variable returns to scale (BCC-input oriented model) with radial distances to the efficient frontier and to rank DMUs using the benchmark method.

Results-A case study

The proposed methodology is applied to rank potential suppliers of a well-known food processing company in Iran. This company in the section of vegetable edible oil production produces three types of edible oil, frying oil and olive oil. Vegetable oil, a well-balanced healthy edible oil is now an important energy source for mankind. After preliminary evaluation, company selected 13 potential raw oil suppliers including: six soybean oil suppliers, four olive oil suppliers and three palm oil suppliers.

Supplier selection process is based on criteria. The Expert team is applied to weighting criteria for determination of the most effective ones. In order to obtain a rational framework, the model was developed through an expert team (6 people) described in Table 1. However experts had a variety of titles, but were responsible for purchase issues and environmental activities within raw oils suppliers of company. The most relevant criteria in green supplier selection studies selected (financial, services, qualitative and environmental criteria) [3, 12]. Results of first round in Delphi questionnaire included 17 sub criteria which were from four relevant criteria (four main groups). In second round of Delphi questionnaire the factors with the highest Delphi score from each main groups determined. According to Table 2, raw material price, quality, delivery and carbon footprint selected to enter in DEA model.

In this study system boundary for life cycle inventory is defined from cultivation and harvesting vegetables to extract and transport raw oil and finally deliver to company for ultimate refinery and packaging. Functional unit of this study is one liter of oil and carbon footprint expressed in $kgCO_2$ per liter of oil.

Apart from the standard carbon footprinting process in each place, following main steps used for footprint estimation of edible oil production [20]:

1. Planting, cultivation & harvesting (including chemical fertilizers, biocides, Diesel for traction, machinery, electricity and etc.);
2. Milling & oil extraction (Electricity, diesel, soda, chemicals and etc.);
3. Transportation (Diesel for maritime freight).

Table 1
Summary of expert team.

Expert occupation	Experience	Total expert
Purchase manager	professional and academic	1
Purchase staff	professional and academic	4
Research and development staff	professional and academic	1

Table 2
Delphi score and investigating the effective criteria.

Criteria	Sub criteria	Delphi score
Financial	A1- Capital and financial power of supplier company	22.5
	A2- Proposed raw material price	24
	A3- Transportation cost to the geographical location	21
Delivery & service	B1- Communication System	17.8
	B2- On time delivery	27
	B3- After sales service	22
	B4- Production capacity	19.3
Qualitative	C1- Quality	30.9
	C2- Operational control	19.2
	C3- Expert labor, technical capabilities and facilities	24.6
	C4- Business experience and Position among competitors	26.2
Environmental management system	D1- Environmental emissions (carbon footprint)	17.4
	D2- Environmental planning	14.8
	D3- Environmental friendly material	11.3
	D4- Environmental friendly technology	10.8

The agricultural phase (step 1) includes the following steps: soil cultivation, sowing or planting tree, weed control, fertilization, pest and pathogen control, harvest and drying of the grains. Data for cultivation, taken from the Ecoinvent database [21], are comparable with average data for European cultivations [22]. Highest amount of greenhouse gas emissions is related to step 1 (about 90%) since high environmental impacts of chemical fertilizers. Energy consumption for milling and oil extracting phase and CO_2 equivalent coefficient are derived from suppliers databank and literature review [23]. Also missing values are supplied by expert opinions. CO_2 equivalent coefficient for maritime transportation [24] and distance of supplier to company are calculated in third step [25].

Data used for DEA (constant return to scale-input oriented model) analysis presented in Table 4. Carbon footprint and price proposed by suppliers are inputs and delivery and quality performance are outputs. Because of differences in type of edible oils, price and carbon footprint of suppliers are divided by its average amount of price and carbon footprint. Soybean, palm and olive oil suppliers (DMUs) displayed by "S", "P" and "O" respectively in Table 3. Also expert team ranked delivery and quality of each suppliers by likert scale 1–9 (from extreme weak to extreme good) [4]. Details of inputs and outputs for each DMU (suppliers' characters) and final efficiency results of DEA analysis are shown in Table 3. Supplier No. 4 (S4) was the best with highest efficiency among other suppliers.

Table 3
Suppliers' characters and efficiencies.

No.	DMU	(I) Price	(I) Carbon footprint	(O) Delivery	(O) Quality	Efficiency
1	S1	0.988	0.976	8	9	0.999
2	S2	1.011	0.977	5	6	0.665
3	S3	0.996	1.129	6	7	0.764
4	S4	0.980	0.975	8	9	1
5	P1	0.987	1.001	8	9	0.992
6	P2	1.012	0.999	6	5	0.732
7	P3	1	0.999	5	8	0.871
8	O1	1.001	0.997	6	6	0.733
9	O2	1.007	1.007	7	6	0.853
10	O3	0.995	1.007	8	8	0.984
11	O4	0.995	1.007	7	6	0.861
12	S5	1.013	0.96	6	6	0.758
13	S6	1.009	0.97	2	4	0.444

*S: Soybean oil supplier, P: Palm oil supplier, O: Olive oil supplier

Table 4
Mean efficiency of oil types.

Edible oil type	Average Price ($/L)	Average carbon footprint ($kgCO_2/L$)	Mean efficiency	The most efficient supplier
Soybean	0.373	589.260	0.772	S4
Palm	0.270	328.694	0.865	P1
Olive	5.333	489.376	0.858	O3

Due to intensive operations on farms, average carbon footprint in soybean oil was higher than palm and olive oil which are cultivated on orchards. According to Table 4 mean efficiency of raw oils are 0.772, 0.865 and 0.858 respectively for soybean, palm and olive. Although olive oil was the most expensive oil, but result showed an acceptable mean efficiency.

Since about 1900, palm oil has been increasingly incorporated in to food by the global commercial food industry. Palm oil contains more saturated fats than other vegetable oils. Therefore, palm oil can withstand the high heat of deep frying and is resistant to oxidation compared to highly unsaturated vegetable oils [26]. Table 4 showed that palm oil not only has less average price and carbon footprint but also the highest mean efficiency.

The most efficient suppliers of company are: S4 among soybean oil suppliers, P1 among palm oil suppliers and O3 among olive oil suppliers. So decision maker can establish long and stronger relation in future with these efficient suppliers.

Conclusion

In food industry, environmental issues are getting more and more attention. In order to extend the product life cycle and to pursue enterprise perpetuity, firms need to emphasize environmental and green protection, now as a critical part of social responsibility. Thus, today there is an urgent requirement to control emissions in order to arrest global warming, carbon footprint is a good tool to interfere in supplier selection.

In this paper, a Delphi GDEA model is constructed for GSS. In order to demonstrate effectiveness of the approach, an application to a well-known company that produces edible oil is presented to evaluate green suppliers of raw oil (palm, soybean and olive oil).

This study identifies financial, qualitative, service and environmental criteria as the main issues in GSS. 17 sub criteria defined and the most important sub criteria determined by Delphi for supplier selection. Finally a DEA model proposed to evaluate

the overall performances of suppliers with respect to selected sub criteria. The methodology was successful in selecting the most suitable raw oil suppliers in each type of oil.

The strength of the proposed model is that despite the vagueness of expert team opinions in the evaluation process, the model is easy to apply. Delphi let the decision maker to determine the sub criteria which are more important and suitable for their case. GDEA approach is based on encouraging the suppliers to reduce their carbon footprints in order to survive the competition and become green. The approach considered in this paper provides a sustainable and flexible framework for future research in terms of green supplier selection. Collaborating with green supplier will lead to more financial benefits, suitable services and quality. Also companies that consider and control carbon footprint in supply chain will award green labels and environmental certificates.

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