INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY ADVANCED RESEARCH TRENDS
ISSN : 2349-7408
VOLUME II, ISSUE I, FEBRUARY 2015

A MATHEMATICAL MODEL FOR SUSTAINABLE ENVIRONMENT THROUGH GREEN ENERGY

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ABSTRACT

Sustainable Development is the kind of development which fulfills the current generation's requirements, without reducing the next generation's ability to meet theirs. Due to increasing social awareness and emphasis on environmental issues, sustainable development is becoming more important. Therefore, organizations are required to consider environmental issues if they are to have a place in the global markets. Considering manufacturing a product, from processing raw materials to customer delivery, focusing on the supply chain in the sustainable development environment will better adapt organizations to sustainable development. Based on previous studies on green supplier selection, there is no comprehensive mathematical model capable of explaining environmental issues, price and other decisive factors in selecting a supplier. Thus, this study has tried to fill this void by presenting a model for optimizing the allocation of a manufacturer's demands to different suppliers, considering the three main sustainability criteria including economic, social and environmental. Firstly, appropriate scales, consistent with sustainable development, were selected. They were then quantified using the Linker's Scale. The presented model is the first multi-objective mathematical programming model focusing on four objectives including quality, price, service level and environmental performance; certain constraints included meeting all the demands, capacity of suppliers etc. In this paper, the Global Criteria Method (GCM) was used to convert the mentioned four-objective model into an analyzable model. Using this model along with information about the performance of each supplier, a manufacturer is able to specify the optimum portion for each supplier in satisfying its demands.

Key Words: sustainable development, green supplier selection, mathematical programming model, Multi criteria decision making

1. INTRODUCTION:

1.1 Green Energy:

The word green in our society today has become a household term. Today the term green is used all across the globe as a reference to living in a way that is environmentally friendly. When it comes to green power or ***green energy***, the same connotation impl*i*es. It is the term that is used when

describing energy sources or sources of power that are known to be non-polluting energy sources that are fundamentally environmentally friendly. It is also an environmentally friendly means of locating and finding power that will remedy the effects of pollutants on our environment, as well as prevent future global warming. When ***green energy*** is used, the primary objective is to reduce air pollution, and minimize or eradicate completely any impacts to the environment. Thus, the primary benefits are as follows:

(i)The reduction of impacts to the environment based on the methods of energy or power that is used

(ii).The reduction of emissions that are harmful to the environment based on the methods of energy or power that we use. Most often**, *green energy*** is considered when it comes to issues such as cogeneration, heating, and electricity. It can be purchased by consumers or businesses as a means of supporting environmentally friendly living by reducing impacts to the environment that occur when conventional methods of generating electricity are used. By doing so, consumers and business assist in increasing the energy dependence of their country Owing to an increase in social awareness and the number of governmental laws supporting environment, organizations ought to consider environmental issues if they are about to enter global markets. Organizations are not only supposed to obey the environmental laws to sell their product, but they are also required to plan some micro strategies to decrease environmentally disruptive influence of their products. Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat.

1.2. **Sustainable energy:**

Sustainable energy is the form of energy obtained from non-exhaustible resources, such that the provision of this form of energy serves the needs of the present without compromising the ability of future generations to meet their needs**.**

Technologies that promote sustainable energy include renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave

power, geothermal energy,bio energy, tidal power and also technologies designed to improve energy efficiency. Costs have fallen dramatically in recent years, and continue to fall. Most of these technologies are either economically competitive or close to being so. Increasingly, effective government policies support investor confidence and these markets are expanding. Considerable progress is being made in the energy transition from fossil fuels to ecologically sustainable systems, to the point where many studies support100% renewable energy.

Implementation of sustainable development policy is one of the most complicated tasks and challenges faced by the global community. The efforts to move the concept of sustainable development from a theoretical level to a decision-making level and to link the economic development to environment are followed by a number of problems. To gain sustainable development, integrating all social, economic and environmental criteria is the biggest challenge [1]. Due to increasing the attention of beneficiary organizations, U.N., NGOs, governments, competitors in market, customers and the employee to environmental issues, environment management is becoming more important to organizations [2]. Therefore, organizations, which play the role of a purchaser in supply chain management, should assess their suppliers on environmental criteria, along with quality, price and service level. Consequently, each organization requires a system of green supplier selection capable of determining the portion of each supplier. The term sustainable development was describing both development and environment. In this paper, for the first time a multi-objective programming model for green supplier selection is presented, in which environmental issues are completely considered. There is no mathematical model capable of considering all criteria for supplier selection such as environmental, price, quality and service level. Therefore, we will fill this void by presenting a mathematical programming model in this paper.

2. Concept, Method and Model:

2.1. Sustainable development:

The concept of sustainable development was first raised in a conference of The United Nations in Stockholm in 1972. The term sustainable development was describing both development and environment. Fifteen years later, it was well

publicized in a report of World Commission on Environment and Development called our shared future.

2.2. Global Criteria Method (GCM):

GCM is the widely used method for multi-objective decision making. In this paper this method was applied to convert the multi-objective model into a linear programming model. Furthermore, AHP method was used to calculate the coefficients of the objective function in GCM.

2.3. Elements of green supplier selection model:

An environmental objective function was added to the proposed model by Ghodsypour and O'Brien [14]. Thus, our model is a multi-objective model considering 4 objectives of price, quality, service level and environmental issues. In this model the purchaser is supposed to have n alternatives to choose a supplier. All suppliers have limited capacities. Consequently, 4 objective functions and 3 constrains are considered.

The parameters of the proposed model are defined as follow:
D: The amount of the annual demand
N: The number of suppliers
Xi: The percent of the whole demand devoted to the supplier i
Pi: The purchase cost proposed by the supplier i
Ci: The annual capacity of the supplier i
Si: The percent of items delivered on time by the supplier i
qi: The percent of intact items provided by supplier i
qa: The minimum acceptable percent of intact items entered factory
The relation below is true when the demand is non phase
(X_i and q_i do not change).

$0 \le X_i \le 1 \qquad i = 1,2,\ldots n$

Our model includes four objective functions to optimize the four criteria for green supplier selection: quality, price, service level and environmental performance of suppliers. Considering the model proposed by Ghodsypour and O'Brien [14], the price, quality and service level functions are expressed as follows:

$$Min(Z_1) = \sum_{i=1}^{n} P_i X_i D$$

$$Max(Z_2) = \sum_{i=1}^{n} q_i X_i D$$

$$Max(Z_3) = \sum_{i=1}^{n} S_i X_i D$$

Nowadays environmental performance is the other criterion which is highly emphasized by organizations. In the following part the procedure that resulted in the environmental performance function is discussed.

2.4. Environmental performance function

The function of each environmental criterion is represented by f_i as follows:

$$f_i = \alpha_{i1} x_1 + \alpha_{i2} x_2 + \ldots + \alpha_{in} x_n \quad i = 1, 2, \ldots, m$$

Where *n* stands for the number of suppliers and, m stands for the number of environmental criteria. A questionnaire, which is based on the format proposed by Humphreys et al [15], ought to be carried out to determine the number of criteria (appendix 1).

α_{ij}, which represents the performance of supplier i in criterion i, is determined by means of a nine-point Likert scale(appendix 2).

After m environmental sub-criteria are determined, environmental performance function can be expressed as $Z_4 = \beta_i f_i$, in which β_i represents the impact of each criterion and can be concluded from the paired comparison between the criteria using AHP method.

Therefore, if we apply the proposed process, we will achieve to function that should be E_is can be obtained from combining the β's and C_{ij}s and it means the comparative score of the suppliers due to their environmental performances. All in all the Z_4 defined as follow:

$$\max Z_4 = \sum_{n} E_i .DX_i$$

2.5. Constraints:

This model considers the constraints upon the organization and suppliers, including the minimum acceptable quality, supplying the whole demand and limited capacity of suppliers.

2.6. Mathematical Model:

$$Min \quad (Z_1) = \sum_{i=1}^{n} P_i X_i D$$

$$Max \quad (Z_2) = \sum_{i=1}^{n} q_i X_i D$$

$$Max \quad (Z_3) = \sum_{i=1}^{n} S_i X_i D$$

$$Max \quad (Z_4) = \sum_{i=1}^{n} E_i X_i D$$

$$ST :$$

$$\sum_{i=1}^{n} q_i X_i \geq q_a$$

$$X_i D \leq C_i \qquad i = 1, 2, \ldots, n$$

$$X_i \leq Y_i \qquad i = 1, 2, \ldots, n$$

$$\Lambda_i \geq \varepsilon Y_i \qquad i = 1, 2, \ldots, n$$

$$\sum_{i=1}^{n} X_i = 1$$

$$X_i \geq 0 , Y_i = 0 ,1, \qquad i = 1, 2, \ldots, n$$

GMC is used to solve this multi-objective model. After the above model is converted into a linear programming model, it can be solved by Lingo and then the portion of each supplier is determined.

Conclusions

Nowadays protecting the environment and sustainable development are increasingly considered by international organizations, people and industrial companies. Moreover, suppliers play a crucial role in supply chains of industrial organizations. Considering the mentioned issues, a need for an accurate model for supplier selection is felt. This void was filled by presenting a model in this study which is the first mathematical programming model with the real world constraints in the field of green supplier selection. Thus, this model can be used by different companies to fulfill their demands by devoting appropriate portions to candidate suppliers.

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