Selection of Sustainable Warehouse Location in Supply Chain Using the Grey Approach

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Abstract

Supply chain sustainability has recently gained an increasing attention in the supply chain context both from the practitioners' perspective and as a research area. There have been many incentives for more sustainable warehousing in supply chains. Sustainable Warehousing includes activities such as, for example, terminal and warehouse location, proper storing and disposing of hazardous materials, donation of excess or obsolete inventory to local communities, and training to safely operate forklifts. A sustainable warehousing company would not only have to consider the economic factors, such as rent and operations costs, but also balance the social and environmental effects that occur within the warehouse compound as well as its surrounding vicinity. Sustainable warehouse location selection decision has a crucial role in the supply chain management process. In this study cost, labor, transportation, environment and geographical location are taken as decision criteria. Grey approach is used under the sustainability basis for the warehouse location selection problem. This method is appropriate for solving the group decision-making problem in an uncertain and inconsistent environment. Warehouse location alternatives for the supply chain of the medical companies are evaluated in this study.

Keywords: Sustainable supply chain, sustainable warehousing, grey approach

1. INTRODUCTION

The term sustainability, which increasingly refers to an integration of social, environmental, and economic responsibilities, has begun to appear in the literature of business disciplines such as management and operations. In addition, companies are beginning to rapidly adopt the term sustainability (Carter and Rogers, 2008). Sustainability today demands that supply chains must be explicitly extended to include by-products of the supply chain (Linton et al., 2007).

The need of seriously exploring the concept of sustainable supply chains within a collaborative perspective is seen as a goal to improve companies' revenue growth and costumer's recognition (Kleindorfer, et al., 2005). A focus on supply chains is therefore a step towards the adoption of a growth on sustainability.

The location of a warehouse is generally one of the most important and strategic decision in the optimization of supply chain (Frazelle, 2002). It is a long-term decision and can be influenced by different quantitative and qualitative criteria, but not all of the criteria have the same effect on the decision process. In this study costs, labor, transportation, environment and geographical location criteria are used. Due to the prejudice of the decision makers, conventional approaches can be less effective in dealing with a proper assessment. Therefore, a multi-criteria based decision making procedure is used.

This paper describes the Grey approach and its application for evaluating warehouse locations in supply chain based on sustainability criteria. This method is appropriate for solving the group decision-making problem in an uncertain and inconsistent environment. The work is structured in the following manner. In Section 2, a literature review of the sustainable supply chain is given. In Section 3 definition of sustainable warehousing is given. In Section 4, the grey approach is defined. An evaluation of warehouse location selection, the proposed methodology and results are fully shown in Section 5. Finally, conclusions and considerations are reported in Section 6.

2. Sustainable Supply Chain

A focus on supply chains is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery to the customer (Linton et al, 2007). Extending the supply chain to include issues such as remanufacturing, recycling and refurbishing adds an additional level of complexity to existing supply chain design in addition to a new set of potential strategic and operational issues, which in turn can increase costs, at least in the short term (Corbett and Klassen, 2006). Sustainable supply chains have not yet been clearly defined. A popular definition states that sustainable supply chains require coordination of the social, environmental and economic dimensions. Linton et al. (2007) transfer the concept of sustainability to supply chains and state that: a sustainable supply chain is a supply chain integrating issues and flows that extend beyond the core of supply chain management such as product design, manufacturing by-products, product management during use, product life extension, product end-of-life and recovery processes at end-of-life.

Companies that implement ecological and social factors relating to the supply chain gain financial benefits through reduced costs and operational efficiencies, also sustainable supply chain practices can be a source of differentiation and competitive advantage.

3. Sustainable Warehousing

One of the key components within the sustainable supply chain is sustainable warehousing. Sustainable warehousing includes activities such as terminal and warehouse location, proper storing and disposing of hazardous materials, donation of excess or obsolete inventory to local communities, and training to safely operate forklifts (Carter and Jennings, 2000).

In real life, most warehousing and transportation companies have little regard for the environmental impacts of their actions and do not understand the social consequences of their business activities. A sustainable warehousing company would not only have to consider the economic factors like rent and operations costs, but also balance with the social and environmental effects that occur within the warehouse compound as well as its surrounding vicinity (Tan et al, 2010). Among supply chain studies, many papers on warehouse/facility location problem have been published (Vlachopoulou et al. 2001; Sharma and Berry, 2007; Sharma and Sharma, 2000). But, in most of them, environmental issues are not studied due to the policy of these companies.

Different warehouse location selection studies are analyzed to select the suitable criteria, and also environment criterion is added in view of the sustainability. These criteria are:

Cost: Costs are one of the factors highly affected by the facility location. Cost criterion is evaluated by taking into account of labor costs, transportation costs, handling costs and land cost.

Labor: This criterion defines the state of qualified labor at a location and the degree of the availability of such labor.

Transportation: Ease of transportation, traffic density and distance from the alternative warehouses to main warehouse are considered by the decision makers.

Environment: Carbon minimization and other environmental policies are considered for the decision process.

Geographical location: This criterion defines the land availability that changes according to the structure of the alternative regions.

4. The Grey Approach

In this section, the Grey approach will be described. In this method, there are m possible warehouse alternatives given as $W = \{W_1, W_2, \dots, W_m\}$. $A = \{A_1, A_2, \dots, A_n\}$ is the set of n independent criteria. $\otimes w\ \{\otimes w_1, \otimes w_2, \dots, \otimes w_n\}$ is the vector of criteria weights. In this study, criteria weights and ratings of the warehouses are taken as linguistic variables. These values are given in Table 1 and Table 2. In Table 1, linguistic criteria weights whereas in Table 2 criteria rating values $\otimes G$ in Grey numbers are given. A Grey number is shown as $\otimes G = [\underline{G}, \overline{G}]$. The detailed procedure is given below (Li et al., 2007; Baskaran et al., 2012):

Step 1: Criteria weight identification

A group of decision makers (DM) identifies the criteria weights. If there is K number of decision maker, then the criteria weight is calculated as

$$\otimes w_j = \frac{1}{K}\left[\otimes w_j^1 + \otimes w_j^2 + \cdots + \otimes w_j^K\right] \tag{1}$$

where $\otimes w_j^K$ $(j = 1, 2, \ldots, n)$ is the criteria weight of the Kth DM.

Step 2: Criteria rating value in linguistic variables

Criteria rating values in linguistic variables are calculated using

$$\otimes G_{ij} = \frac{1}{K}\left[\otimes G_{ij}^1 + \otimes G_{ij}^2 + \cdots + \otimes G_{ij}^K\right] \tag{2}$$

where $\otimes G_{ij}^K$ $(i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n)$ is the criteria rating value of the Kth DM.

Table 1: Scale of attribute weights

Scale	W
Very low (VL)	[0.0, 0.1]
Low (VL)	[0.1, 0.3]
Medium low (ML)	[0.3, 0.4]
Medium (M)	[0.4, 0.5]
Medium high (MH)	[0.5, 0.6]
High (H)	[0.6, 0.9]
Very high (VH)	[0.9, 1.0]

Table 2: Scale of attribute ratings

Scale	W
Very poor (VP)	[0, 1]
Poor (P)	[1, 3]
Medium poor (MP)	[3, 4]
Fair (F)	[4, 5]
Medium good (MG)	[5, 6]
Good (G)	[6, 9]
Very good (VG)	[9, 10]

Step 3: Establish the Grey decision matrix

$\otimes Gij$ are linguistic variables based on the grey number. Grey decision matrix is:

$$\begin{bmatrix} \otimes G11 & \otimes G12 & \cdots & \otimes G1n \\ \otimes G21 & \otimes G22 & & \otimes G2n \\ \vdots & & \ddots & \vdots \\ \otimes Gm1 & \otimes Gm2 & \cdots & \otimes Gmn \end{bmatrix} \tag{3}$$

Step 4: Normalize the Grey decision matrix

In the normalization process, the ranges of the Grey numbers are limited to [0, 1]. Normalization depends on either minimization (cost) or maximization (benefit) of the criteria. Maximization criteria $\otimes G_{ij}^*$ is given as

$$\otimes G_{ij}^* = \left[\frac{\underline{Gij}}{G_j^{max}}, \frac{\overline{Gij}}{G_j^{max}}\right], G_j^{max} = max_{1\leq i\leq m\{\overline{Gij}\}} \tag{4}$$

Minimization criteria $\otimes G_{ij}^*$ is given as below

$$\otimes G_{ij}^* = \left[\frac{G_j^{min}}{\overline{Gij}}, \frac{G_j^{min}}{\underline{Gij}}\right], G_j^{min} = min_{1\leq i\leq m\{\underline{Gij}\}} \tag{5}$$

Step 5: Establish the weighted normalized Grey decision matrix

The weighted normalized Grey decision matrix is the product of normalized Grey decision matrix and criteria weights $(\otimes Vij = \otimes G_{ij}^* * \otimes w_j)$.

Step 6: Set ideal warehouse alternative as referential warehouse alternative

From m possible warehouse alternative set ($S = \{S_1, S_2, \ldots, S_m\}$) the ideal referential warehouse alternative ($S^{max} = \{G_1^{max}, G_2^{max}, \ldots, G_n^{max}\}$) by using

$$S^{max} = \left\{\left[\begin{matrix} max \\ 1 \le i \le m \end{matrix}\underline{Vi1}, \begin{matrix} max \\ 1 \le i \le m \end{matrix}\overline{Vi1}\right], \ldots, \left[\begin{matrix} max \\ \le i \le m \end{matrix}\underline{Vin}, \begin{matrix} max \\ 1 \le i \le m \end{matrix}\overline{Vin}\right]\right\} \qquad (6)$$

Step 7: Calculate the Grey possibilities

Compare warehouse alternatives set $S = \{S_1, S_2, \ldots, S_m\}$ with ideal referential warehouse alternative S^{max};

$$P\{S_i \le S^{max}\} = \frac{1}{n}\sum_{j=1}^{n}\{\otimes Vij \le \otimes G_{ij}^{max}\} \qquad (7)$$

Step 8: Prioritize warehouses

Rank the order of warehouse alternatives based on the comparison given in Eq. (7). If S_i value is smaller, the ranking order of S_i is better. Otherwise, the ranking order is worse.

5. Application

In this study, the Grey approach is used for the warehouse location selection problem of a pharmaceutical company in Turkey. The company has six different warehouse location alternatives (S); each of them is evaluated by four decision makers (DM) according to the criteria of cost (C_1), labor (C_2), transportation (C_3), environment (C_4) and geographic location (C_5). The calculation procedure is given below:

Step 1

By using Eq. (1), criteria weights are calculated.

Step 2

Criteria ratings values for six warehouse alternatives are calculated by using Eq. (2).

Step 3

Using Eq. (3), establish the grey decision matrix.

Step 4

Establish the grey normalized decision table.

Step 5

Establish the grey weighted normalized decision table.

Step 6

Make the ideal warehouse S^{max} a referential alternative, using Eq. (6).

S^{max} = {[0.333, 0.950], [0.353, 0.650], [0.482, 0.925], [0.416, 0.725], [0.513, 0.825]}

Step 7

Calculate the grey possibility degrees, using Eq. (7). Grey possibility degree results are given below:

$P\{S_1 \leq S^{max}\}$ = 0.862 $P\{S_3 \leq S^{max}\}$ = 0.729 $P\{S_5 \leq S^{max}\}$ = 0.686

$P\{S_2 \leq S^{max}\}$ = 0.963 $P\{S_4 \leq S^{max}\}$ = 0.716 $P\{S_6 \leq S^{max}\}$ = 0.735

Step 8

Rank the order of six warehouses, according to the results given in Step 7.

$S_5 > S_4 > S_3 > S_6 > S_1 > S_2$

From the results, it’s seen that S_5 is the most suitable location alternative for the company.

6. CONCLUSION

A warehouse location selection is a multi-criteria decision-making problem including both quantitative and qualitative criteria. In this paper, a multi-criteria decision making approach for sustainable warehouse location selection is given. The main criteria for the selection of sustainable warehouse location were identified. After the main criteria were determined, the hierarchy of the sustainable warehouse location selection was structured. The proposed method is applied a pharmaceutical company, and decision makers from the company are asked to evaluate alternatives and criteria. By using Grey approach, alternative 5 can be selected by the company.

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