Analysis of green supply chain management initiatives: A study of critical implementation barriers

EHSAN POURJAVAD
Industrial Systems Engineering
University of Regina
3737 Wascana Parkway, Regina, SK, S4S 0A2
CANADA
Epourjavad@uregina.ca Tel:1-639-571-1415

AYDIN M. TORKABADI
Industrial Systems Engineering
University of Regina
3737 Wascana Parkway, Regina, SK, S4S 0A2
CANADA
torkabam@uregina.ca

RENE V. MAYORGA (corresponding author)
Industrial Systems Engineering
University of Regina
3737 Wascana Parkway, Regina, SK, S4S 0A2
CANADA
Rene.Mayorga@uregina.ca

Abstract: Environmental issues are key factors that determine the success of organizations in the green economy era. Green Supply Chain Management (GSCM) is a leading philosophy to improve the ecological efficiency and control the negative environmental impact. This Paper identifies the pressures that reportedly jeopardize the GSCM strategies. To evaluate the impact of the identified pressures, a framework is proposed to quantitatively analyze the factors. A Fuzzy Analytical Hierarchy Process (AHP) is used in the framework to incorporate the expert knowledge in evaluating the barriers of GSCM implementation. To examine the proposed approach of this study a real supply chain from pipe manufacturing industry is studied. The results confirm the practicality of the proposed framework and indicate the importance of the identified barriers.

Keywords: Green Supply Chain Management, Sustainability, Environmental Pressures, Analytical Hierarchy Process, Fuzzy, Multi-Criteria Decision Making

1 Introduction

To ensure the success of businesses in today’s competitive market, adapting strategies to cope with the changing market issues is critical [1]. The rising demand for environmental protection and green manufacturing is a major issue. Green Supply Chain Management (GSCM) is a modern philosophy in the theory of organizations with the goal to create a competitive economical and market advantage by improving the ecological efficiency and minimizing the negative environmental impact [2]. The environmental research is receiving greater attention due to the growing green regulations, green institutions pressure, competition to create a green business image, customer preferences, media, and etc.

GSCM benefits the organization by focusing on waste elimination, environmental efficiency improvement, and cost reduction. Improving the market share, developing new markets, and increasing the profit is reported as achievements of GSCM implementation [3].

Moreover, the fast depletion of natural resources, growing concerns about the distribution of wealth, and corporate social responsibility, emphasize the significance of research in environmental issues. Hence, adopting GSCM practices is recognized as an important factor for the successful industry. In fact, there are pressures to adopt GSCM practices in industries.

Still, evaluating the pressures that threaten the implementation of GSCM is a challenge for industries that are seeking to improve their environmentally friendly image [4], [5], [6]. Although several factors that pressure the industries have been identified; simultaneously responding to all the factors is not possible for industries with limited resources.

Therefore, there is a demand for a detailed analysis to find the most critical pressure factors that influence the GSCM implementation. In this regard, there are several studies; for example, Muduli et al. [7] studied the impact of behavioral variables in the mining industry that challenges the implementation of GSCM. They recognized the key issues by applying Interpretive Structural Modeling (ISM). Fonseca et al. [8] also studied the mining industry and summarized the key issues that sustainability initiatives face by using a constructive critique of the GRI approach. Gomes et al. [9] studied the mining industry in Brazil with the goal to improve the business performance through sustainability practices.

Analytical Network Process (ANP) has been successfully applied in accordance to GSCM components to create a strategic decision-making framework [10]. The method was also applied for selection problems to assess the important activities of business functions [11].

Multi-objective optimization models are applied to examine the trade-off between total cost and the environmental impact [12]. The approach is applied for facilitating the decision making process. Integration of Memetic algorithm and a Taguchi method is used to deal with a multi-objective optimization problem in GSCM [13]. The cost and environmental impact were considered as the criteria in the research.

The Fuzzy DEMATEL was applied to evaluate factors such as green procurement, green design and product recovery in green supply chain context [14]. The study investigated the improvement of economic and environmental performance by implementing GSCM.

The AHP technique was applied to rank the GSCM adaptation barriers based on expert knowledge [15]. The study examined the approach by studying a case from the mining industry. Integration of fuzzy AHP and the Bee algorithm is implemented to assess the suppliers based on green issues [16].

The gap in the research remains due to the scarcity of studies that analyze the impact of indirect pressures on GSCM. There is no evidence of research that evaluates and prioritizes the indirect GSCM adaptation pressures.

In response, this Paper study is critical due to its focus on analyzing and prioritizing the GSCM adaption initiatives in pipe industries. The purpose of this Paper work is to inspire and support the industry practitioners to identify and implement strategies to cope with the most critical pressures that impact the GSCM adaptation efforts. The approach of this Paper contributes to filling the research gap.

Bearing in mind those pressures on GSCM adaption can be categorized and classified under several criteria; this Paper defines a multi-criteria decision making (MCDM) problem, and provides an appropriate solution approach. The Analytical Hierarchy Process is a common approach to solve MCDM problems [17]. Moreover, this approach provides a systematic framework and structure for solving MCDM problems [18]. One of the biggest advantages of AHP is its capability to incorporate both qualitative and quantitative variables. However, it still needs crisp values for the process of pair-wise comparisons. This issue comes as a shortage of decision-making experts that express their preferences linguistically. Due to the uncertainty involved with the linguistic expressions and human judgments [19], [20], there is a quest in current literature to implement suitable methods to deal with this ambiguity. The approach by Chang [21] involves the concept of fuzzy set theory in AHP; due to this reason which is called Fuzzy AHP.

In this paper, an integrated framework is proposed for evaluating the GSCM pressures to support and help supply chain managers. To resolve the conventional AHP shortcomings, in this paper a Fuzzy AHP is proposed.

2. Fuzzy AHP

The Analytical Hierarchy Process (AHP) is praised for its practicality in solving complex decision-making problems [22]. Saaty [23] (1980) first presented the AHP method that has been widely applied in various decision-making problems [24], [25]. The fundamental assumption of the AHP method is the condition of the functional independence between same level factors. The upper hierarchical structure, therefore, can have no dependency and similarly all the lower layers are independent of other factors in the same level.

One of the best advantages of the AHP is its capability to deal with both qualitative and quantitative factors. However, the AHP needs crisp values for pair-wise comparisons. The issue is disadvantageous as the expert knowledge is mostly translatable through linguistic expressions [19]. To deal with the uncertainty involved in linguistic expressions, chang [26] introduced a fuzzy AHP technique. Chang's method applies triangular fuzzy numbers to create a comparison scale that accounts for human uncertainty in decision making. The method greatly resolves the shortage of conventional AHP in dealing with uncertainty. The Fuzzy AHP method is recognized as a suitable technique for decision-making problems. By integrating the concept of fuzzy set theory and hierarchical structure analysis; the AHP facilitates the quantification of expert expressions. Several methods have been proposed for Fuzzy AHP by researchers [27].

This Paper applies to GSCM the approach by Chang [21], 26]; also called extent analysis since the steps of this approach are easier than the other fuzzy AHP approaches.

The steps of Chang [21, 26] extent analysis approach are as follows:
let X = {x1,x2, . . . ,xn} be an object set; and U = {u1,u2, . . . ,um} be a goal set. According to the method of Chang [21] extent analysis, each objective is taken and extent analysis for each goal, g_i, is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^{1}, M_{gi}^{2}, \ldots\ldots M_{gi}^{m},\ i = 1,2,\ldots\ldots,n \quad (1)$$

where all the M_{gi}^{j} (j = 1,2,…..,m) are TFNs.

The detailed steps of Chang's extent analysis can be given as follows:

Step 1: The value of fuzzy synthetic extent with respect to the ith object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} * \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad (2)$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (3)$$

And to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$, perform the fuzzy addition operation of M_{gi}^{j} (j = 1,2,…..,m) values such that:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_i, \sum_{j=1}^{m} m_i, \sum_{j=1}^{m} u_i\right) \quad (4)$$

and then compute the inverse of the vector in Eq. (11) such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{m} u_i}, \frac{1}{\sum_{j=1}^{m} m_i}, \frac{1}{\sum_{j=1}^{m} l_i}\right) \quad (5)$$

Step 2: The degree of possibility of $M_2 = (l_2,m_2,u_2) \geq (l_1,m_1,u_1)$ is defined as:

$$V(M_2 \geq M_1) = \sup\left[\min(\mu_{M1}(x), \mu_{M2}(y))\right] \quad (6)$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = \mathrm{hgt}\,(M_1 \cap M_2)$$
$$= \mu_{M2}(d) = \begin{cases} 1, & if\, m_2 \geq m_1 \\ 0, & if\, l_1 \geq m_2 \\ \frac{u_2 - l_1}{(m_2 - m_1) - (u_2 - l_1)}, & otherwise \end{cases} \quad (7)$$

Where d is the ordinate of the highest intersection point D between μ_{M1} and μ_{M2} (see

Fig. 1). To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i ($i = 1,2,. . . ,k$) can be defined by:

$$V(M \geq M_1, M_2, \ldots M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \ldots (M \geq M_k)] = \min V(M \geq M_i), i=1,2,\ldots,k. \quad (8)$$

Assume that:

$$d'(A_i) = \min (S_i \geq S_k) \quad (9)$$

For k = 1,2,. . . ,n; k ≠ i. Then the weight vector is given by:

$$W' = \left(d'(A_1),\ d'(A_2), \ldots \ldots \ldots d'(A_n)\right)^T \quad (10)$$

Where A_i $(i = 1,2,. . . ,n)$ are n elements.

Step 4: Via normalization, the normalized weight vectors are:

$$W = \left(d(A_1),\ d(A_2), \ldots \ldots \ldots d(A_n)\right)^T \quad (11)$$

Where W is a non-fuzzy number.

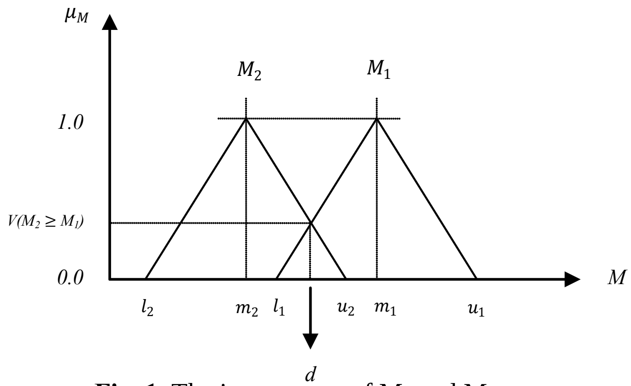

Fig. 1. The intersection of M_1 and M_2

3 Proposed approach

This Paper develops a solution approach based on the Fuzzy AHP method to rank the GSCM pressures. The approach is exemplified for a real case industrial company called Kooshan Etesal Co., A pipe and fitting manufacturer located in the center of Iran. The purpose of the case study is to demonstrate the capability of the proposed approach to prioritize the factors and to provide an example for industry practitioners on how to implement the approach. The steps of this approach are as follow:

3.1 Criteria and alternatives identification

One of the most important aspects of using MCDM techniques is choosing appropriate criteria to compare and evaluate alternatives. Results of these techniques are strictly dependant on criteria. The first step of the proposed model is finding appropriate criteria to evaluate the project complexity. Regarding this point that main aim of this Paper is evaluating and prioritizing GSCM pressures; nine pressures are taken into account as alternatives. These pressures are divided into 3 categories, Regulations, Social, and Commercial and Operational. These categories are defined as criteria for this model. In fact, nine pressures are evaluated based on these three categories. It should be noted, that case study managers determine the dimensions and alternatives. Table 1 shows the dimensions and pressures of this study.

Table 1. Model dimensions and alternatives

Dimensions	Pressures
Regulations (D1)	Environmental regulations of foreign countries (P1) Internal environmental regulations (P2) High penalty for environmental pollutions (P3)
Social (D2)	Pressures from Non-governmental organizations (NGOs) (P4) Customer demand for green product (P5) Firm's competitiveness (P6)
Commercial and operational (D3)	Scarcity of raw material (P7) Social responsibility (P8) Financial incentives of energy savings (P9)

3.2 Structuring the model

Modelling the problem in a hierarchical structure is one of the major issues in AHP approach. For this purpose, the objective of the model should be defined and the dimensions to achieve the goal should be laid out in a horizontal position. The higher dimension elements then are decomposed into sub-dimensions that create another horizontal layer and called attribute-enablers. Once the hierarchical layers are defined the relationship between the dimensions and pressures should be defined. Via brainstorming process, the problem structure and relationships are defined in this study (Fig.2)

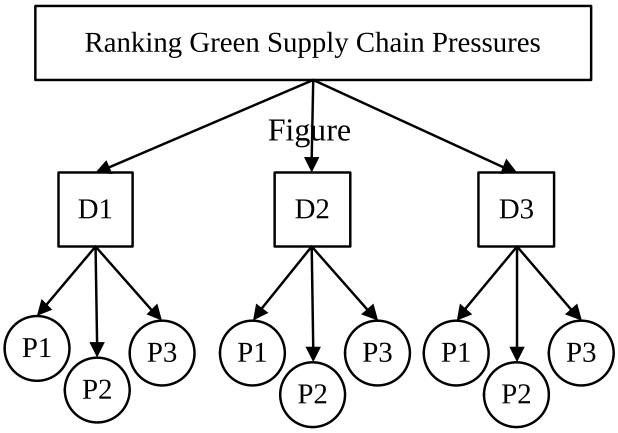

Fig.2. Hierarchy of GSC pressures

Table 2.Linguistic scales for importance

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Absolutely equal	(1, 1, 1)	(1, 1, 1)
Equally Important (EI)	(1/2, 1, 3/2)	(2/3, 1, 2)
slightly more Important (WMI)	(1, 3/2, 2)	(1/2, 2/3, 1)
moderately more Important (SMI)	(3/2, 2, 5/2)	(2/5,1/2, 2/3)
strongly more Important (VSMI)	(2, 5/2, 3)	(1/3, 2/5, 1/2)
extremely more Important (AMI)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

3.3 Building pair-wise comparison matrices between components/attributes

Determining the weight that represents the importance of dimensions and factors is the second step in the proposed approach. Assigning the weights is based on pair-wise comparisons. Section 2 illustrates the technique to execute the comparisons. This technique to compare the dimensions is based on the Fuzzy AHP. It applies triangular fuzzy numbers (TFNs) (Table 2). The linguistic expression of two SCM experts and supply chain managers is the source of judgments.

3.4. Calculating the consistency ratio (CR) of comparison matrix

This approach examines the agreement of every judgment to assure the consistency of comparisons. The quality of the process is assured by this step. The index introduced by Saaty [23] is used to measure the consistency. The index is presented in a matrix called fuzzy consistency matrix and should be converted to a crisp matrix for the AHP method [11]. The technique used by Chang [26] is considered the basis for this step of the present approach due to its simplicity and effectiveness.

To illustrate the uncertainty involved with expert judgment this approach defines α as preference and λ as the risk tolerance of the expert. ãij = (lij, mij , uij) demonstrates a triangular fuzzy number. Defuzzification of this TFN is demonstrated below: [21]

$$(a_{ij}^{\alpha})^{\lambda} = \left[\lambda \,.\, l_{ij}^{\alpha} + (1-\lambda)u_{ij}^{\alpha}\right], 0 \le \lambda \le 1, \quad 0 \le \alpha \le 1, \qquad (12)$$

$l_{ij}^{\alpha} = (m_{ij} - l_{ij}) \times \alpha + l_{ij}$ shows the left-end value of α-cut for a_{ij} and $u_{ij}^{\alpha} = u_{ij} - (u_{ij} - m_{ij}) \times \alpha$ shows the right-end value of α-cut for a_{ij}. α determines the level of fluctuation (or firmness), and takes values from 0 to 1, where bigger values show higher stability and lowe values show higher fluctuation. So, uncertainty is lowest when α = 1. Also, λ shows the level of expert optimism and takes values from 0 to 1. When λ is 0, the expert is highly optimistic, and when α is 1, the expert is pessimistic. [21]

The crisp pair-wise comparison matrix is built by transforming triangular TFNs to crisp numbers.

$$\left[(A^{\alpha})^{\lambda}\right] = \left[(a_{ij})^{\lambda}\right] = \begin{bmatrix} 1 & (a_{12}^{\alpha})^{\lambda} & \cdots & \cdots & (a_{1n}^{\alpha})^{\lambda} \\ (a_{21}^{\alpha})^{\lambda} & 1 & \cdots & \cdots & (a_{2n}^{\alpha})^{\lambda} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ (a_{n1}^{\alpha})^{\lambda} & (a_{n2}^{\alpha})^{\lambda} & \cdots & \cdots & 1 \end{bmatrix} \qquad (13)$$

Based on Chen (2015) The consistency index (CI) for a comparison matrix now can be calculated via the following formula:

$$CI=\frac{\lambda_{max} - n}{n-1} \quad (14)$$

where λ_{max} indices the biggest eigenvalue of the matrix and n indices the dimension of the matrix. The consistency of a given evaluation matrix and consistency of a random matrix is measured by consistency ratio (CR) [23].

$$CR=\frac{CI}{RI} \quad (15)$$

RI, as demonstrated in Table 3, is a random index that relies on the size of matrix n. for CR values that are equal or less than 0.1, the value can be accepted.

Table 3. Random index (RI) of random matrices

N	3	4	5	6	7	8	9
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45

3.5 C alculation of the global pressures' weights

To calculate the global weights, it is necessary to consider the interdependent weights for criteria and the local weights calculated by the Fuzzy AHP. By multiplying the local weights of pressures with the interdependent weights of the belonging criteria, the global pressures' weights are produced. The pressures are ranked based on the final global weights. The Table 4 shows the computed values.

Table 4. Global weights of pressures

Dimensions	Local weight	Pressures	Local weight	Global weight
D1	0.31	P1	0.41	0.127
		P2	0.21	0.065
		P3	0.38	0.118
D2	0.39	P4	0.18	0.070
		P5	0.52	0.203
		P6	0.30	0.117
D3	0.30	P7	0.47	0.141
		P8	0.22	0.066
		P9	0.31	0.093

4 Conclusions

This paper has presented a Fuzzy AHP approach to evaluate GSCM pressures. Three dimensions are identified to classify the pressures. To examine the effectiveness of proposed approach a real case from a pipe industry is studied. The social dimension obtained the highest rank among pressures for the studied case. That result shows that the highest level of significance in GSCM adoption belongs to social pressures. The other two dimensions pressures for GSCM were recognized to have the same level of importance. These equally important dimensions are regulations, and commercial/ operational. A more detailed analysis revealed the significance of factors within every individual dimension. Among social pressures, the most important factor is the customer demand for green products. This result confirms that the recent consumption trend and a tendency toward green products are vivid in the studied industry. The result also shows the importance of social awareness and the level of impact that this factor has on GSCM. The customer-oriented approach of the studied industry contributes to the high significance of the customer demand factor. Next, among the regulation factors, the environmental regulations of foreign countries factor is ranked the highest. The results show that international trade and requirements by international trade regulatory laws are contributing significantly to GSCM implementation. This suggests that the impact of domestic environmental regulations is highly significant for the industry in the international contest as well as in the domestic market. Finally, among the commercial and operational factors, the scarcity of raw materials is recognized as the most important factor.

The consistency of the obtained results with the concerns raised by the experts of industry proves the practicality of the proposed approach. Highlighting the most significant issues can balance the efforts of organizations to focus on what matters the most. Planning and implementing green strategies is possible via conducting this approach.

Acknowledgment
This paper research has been supported by a grant (No: 155147-2013) from the Natural Sciences and Engineering Research Council of Canada (NSERC).

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