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Evaluation of the Most Effective Criteria in Green Supply Chain Management in Automotive Industries Using the Fuzzy DEMATEL Method

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ABSTRACT

Sustainability, green and environmentally issues are significant which has been discussed in recent years and a large number of firms implement green practices to improve their businesses. Automotive industries are considered one of the major contributors to environmental pollution and the area that requires implementation of more effective sustainability practices. So, it is important to pay attention to environmental requirements in supply chain process in automotive companies. In this article, we used the fuzzy DEMATEL method, to study the influence of the most important factors and to find out the ranking of critical factors in green supply chain management in automotive corporations and also a model with multi-criteria approach and 15 factors in green supply chain management was presented. Based on our research, we concluded that the top five important critical sub-factors of green supply chain management in automotive industries in Iran are as follows: Environmental policy, International, governmental and domestic environmental agreements and legislations, Green and cleaner production, Effective communication within companies and suppliers, and Green image.

KEY WORDS: green supply chain management, Sustainability, environmental management system, fuzzy DEMATEL

1. INTRODUCTION

Nowadays, Managers of companies are not only expected to reduce lead times, improve quality, decrease costs and increase flexibility, but also they are expected to become more environmentally responsible (Irajpour *et al.*, 2012a) and environmental performance is a concern for managers of every firms (Zhu and Sarkis, 2004). Recently, companies have begun to face increasing stakeholder concerns respecting the operational impact of the firm on the environment and society as individuals become more aware of the fact that each operational process has the potential for producing a negative impact on ecological and social systems (Setthasakko, 2010) and concerns about the sustainability and the protection of the natural environment have become increasingly significant issues amongst governments, environmentalists and society in many countries (Ribeiro and Guzman, 2010). Green supply chain management (GSCM) becomes a exciting topic and there is a worldwide trend for manufacturers to choose their green suppliers for constructing their green supply chain (Lee, 2008b) and with the increased environmental worries during the past decade, awareness is growing that issues of environmental pollution attending industrial development should be addressed together with supply chain management, so contributing to the initiative of Green supply chain management (Hu and Hsu, 2010) and many companies are now proactively implementing green practices (Wang et al., 2011). Also, all of the environmental management standards and green systems highlight the need for continuous improvement in trying to protect the environment and the nature (Chavan, 2005) and nowadays, many corporations have experienced increasing globalization and organizations struggle to improve their environmental image through green production (Zhu et al., 2008b) and green supply chain management has appeared as a significant new approach for industries to obtain earnings and market development by reducing environmental risks and damages (Hu and Hsu, 2010). In this study, we have used fuzzy DEMATEL method to study the influence of the most significant criteria in green supply chain management. This paper is organized as follows: Section 2 discusses the green supply chain management in automotive companies. Section 3 discusses the important factors of this research. Section 4 discusses the methodology. Section 5 analyzes the results and Section 6 discuses the study.

2. Green supply chain management (GSCM) in automotive corporations

Since the early days of the industrial revolution, the study and management of industrial pollution has been a critical issue for society and companies (Sarkis *et al.*, 2011) and the study of the automotive supply chain and environmental issues is important because its scope is international (Gonza´lez *et al.*, 2008). Automotive companies

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worldwide face increasing pressures in the environmental issues (lee, 2008b) and the automotive industries impacts on the natural and human environment along all stages of the product's life cycle (Koplin *et al*., 2009). So, automotive companies had to decrease environmental damages in recent decades with regard to increase of pressures in environmental issues (Geffen and Rothenberg, 2000) and successful green management requires effective coordination of production design, manufacturing, delivery, distribution and a green management supports inter-organizational innovation practices throughout the supply chain (Hong *et al.*, 2009).

3. The critical factors of Green supply chain management (GSCM) in automotive corporations

3.1 The important success factors

In this section we will explain the significant factors of green supply chain management. The choice of critical factors is based on some researches that for effective design and implementation of green supply chain management any automotive corporation must pay attention to them. Four main factors in this research are as follows: (1) Management approach, (2) External and social aspects, (3) Organizational change, and (4) Technical aspects. On this basis, 15 sub-factors were determined and classified in 4 main groups (table 1).

3.1.1 Management approach

For effective design and implementation of a green supply chain management, the management attitude is very essential. The sub-factors that come under management approach are as follows: Top management commitment and support (M_1), Environmental policy (M_2), and International, governmental and domestic environmental agreements and legislations (M_3).

Top management commitment and support: Many supply chain management in leading companies emphasize that the understanding of the top management of the value and support for their attempts made a significant difference to the success of their GSCM practices (Hu and Hsu, 2010). Also, management support is a critical element of implementation of innovations in an organization, especially environmental systems (Zhu *et al.*, 2008b) and without the total participation of top management, all quality attempts might fail (Padma *et al.*, 2008).

Environmental policy: Environmental policy is a statement of what a company implies to obtain from an environmental management systems. It ensures all environmental practices are consistent with the organization's strategies (Chavan, 2005). It is a statement of commitment from senior management about what environmental objectives will be obtained and it is a commitment of protecting the environment and improving environmental performance incessantly (Liyin *et al.*, 2006).

Table 1- The critical criteria and sub criteria

Criteria	Sub criteria	References
Management approach	Top management commitment and support (M_1)	Hu and Hsu (2010), Lee *et al.* (2009), Zhu *et al.* (2008a, b), Handfield *et al.* (2005), Chavan (2005), Evans and Johnson (2005), Arvidsson, (2004), Lim and Lee (2001),
	Environmental policy (M_2)	Hu and Hsu (2010), Holt and Ghobadian (2009), Sambasivan and Fei (2008), Chien and Shih (2007), Liyin *et al.* (2006), Humphreys *et al.* (2003),
	International, governmental and domestic environmental agreements and legislations (M_3)	Lee (2008a), Chien and Shih (2007), Zhu *et al.* (2005),
External and social aspects	Effective communication within companies and suppliers (E_1)	Hu and Hsu (2010), Hsu and Hu (2008), Lippmann (1999),
	Environmental auditing for suppliers (E_2)	Hu and Hsu (2010), Hsu and Hu (2008), Zhu *et al.* (2005),
	Green image (E_3)	Irajpour *et al.*, (2012a, b), Yeh and Chuang (2011), Che, *et al.* (2010), Lee *et al.* (2009), Juang *et al.* (2009),
Organizational change	Environmental education and training (O_1)	Hu and Hsu (2010), Zhu *et al.* (2008b), Lin and juang (2008), Hsu and Hu (2008),
	Manpower involvement (O_2)	Hu and Hsu (2010), Hsu and Hu (2008),
Technical aspects	Green purchasing (T_1)	Choudhary *et al.* (2011), Hu and Hsu (2010), Lee *et al.* (2009), Zhu *et al.* (2008b), Lee (2008a), Hsu and Hu (2008), Zhu *et al.* (2005),
	Green design (T_2)	Yeh and Chuang (2011), Hu and Hsu (2010), Zhu *et al.* (2010), Holt and Ghobadian (2009), Zhu *et al.* (2008a, b), Chien and Shih (2007), Zhu and Sarkis (2004), Humphreys *et al.* (2003), Handfield *et al.* (2002),
	Green and cleaner production (T_3)	Choudhary *et al.* (2011), Wan Mahmood *et al.* (2010), Zhu *et al.* (2010), Lee *et al.* (2009), Zhu *et al.* (2008a, b), Chien and Shih (2007),
	Green packaging (T_4)	Irajpour *et al.*, (2012a, b), Choudhary *et al.* (2011), Lee *et al.* (2009), Zhu *et al.* (2008a, b), Lin and juang, (2008), Zhu and Cote (2004), Handfield *et al.* (2002),
	Green labels (T_5)	Wan Mahmood *et al.* (2011), Blengini and Shields (2010),
	Reuse, recycle and recovery of material (T_6)	Yeh and Chuang (2011), Zhu *et al.* (2010), Zhu *et al.* (2008a, b), Lin and juang, (2008), Chien and Shih (2007), Humphreys *et al.* (2003), Handfield *et al.* (2002),
	Reduce energy consumption (T_7)	Irajpour *et al.*, (2012a, b), Che, *et al.* (2010), Holt and Ghobadian (2009), Lee *et al.* (2009), Juang *et al.* (2009), Daniel and Guide (2000)

International, governmental and domestic environmental agreements and legislations: The major drive for environmental awareness is increasing the role of government regulations (Chien and Shih, 2007). Domestic laws and corporations' environmental missions are the two main sources of pressure (Zhu and Sakis, 2006) and domestic environmental regulations alert corporations to accept relevant strategies and practices to improve their environmental performance. Furthermore, many companies and the government are also being influenced by international environmental agreements and standards such as the Kyoto agreement, the Climate Change Treaty, the Montreal Protocol (Chien and Shih, 2007) and the ISO 14001.

3.1.2 External and social aspects

The effective development and implementation of a green supply chain management is definitely influenced to a huge extent by external and social aspects that include: Effective communication within companies and suppliers (E_1), Environmental auditing for suppliers (E_2), and Green image (E_3).

Effective communication within companies and suppliers: Supplier–manufacturer relationships are mentioned important in developing a sustainable competitive advantage for the manufacturer (Chien and Shih, 2007) and in order to facilitate green supply chain management practices, it is necessary to establish an effective communication between companies and suppliers (Hu and Hsu, 2010).

***Environmental auditing for suppliers*:** Globalization permits working with a lot of different suppliers to get raw materials and preliminary products (Hsu and Hu, 2009) and green supply chain management involves the introduction and integration of environmental issues as well as concerns into supply chain management processes by auditing suppliers using environmental performance metrics (Hu and Hsu, 2010).

***Green image*:** It is essential for manufacturers to improve their green image through environmental tools such as the adoption of green supply chain management and firms should struggle to improve their environmental image through green production (Zhu *et al.*, 2008a). Companies should consider green image of suppliers (Yeh and Chuang, 2011) and to establish their environmental image, companies should re-examine the purpose of their business (Zhu *et al.*, 2005).

3.1.3 Organizational change

Design and implementation of green supply chain management requires significant changes in a corporation and the top management should ensure that the changes are obviously understood and supported by all employees in the company. The changes include: Environmental education and training (O_1), and Manpower involvement (O_2).

Environmental education and training: companies should recognize education and training needs and the training must include: environmental policy and green issues, relevant objectives and targets, job specific environmental impacts and benefits of improved performance (Sambasivan and Fei, 2008). Also, employees should be supplied with awareness and knowledge about the environmental effects from their operations and their activities (Hu and Hsu, 2010) and training and awareness guide to improvements in the environmental knowledge, skills and expertise of staff (Pe´rez *et al.*, 2007).

Manpower involvement: Human factors are key elements in successful implementation of green management practices (Hong *et al.*, 2009) and there is some manpower issues involved in the implementation of green supply chain management because the employees of various departments should take responsibility for individual impact and requirement of environmental regulations and standards (Hu and Hsu, 2010).

3.1.4 Technical aspects

The effective implementation of green supply chain management in manufacturing and service industries definitely depends on integrating it with technical aspects. These include: Green purchasing (T_1), Green design (T_2), Green and cleaner production (T_3), Green packaging (T_4), Green labels (T_5), Reuse, recycle and recovery of material (T_6), and Reduce energy consumption (T_7).

Green purchasing: By unifying the green principle into purchasing, corporations can provide design specifications to suppliers that include environmental requirements for green purchased items (Hu and Hsu, 2010) and environmental purchasing is a purchasing behavior in activities that include reduction, reuse, and recycling of materials and it is becoming an essential element of green supply chain management (Lee, 2008b).

Green design: Green product design has been recognized as a significant business practice in recent years (Hong *et al.*, 2009) and eco-design or design for environment is critical in green supply chain management practice to improve companies (Zhu *et al*., 2008a). So, the design of products (and related design of processes) is significant the most effective way to reduce environmental impacts is through prevention and better design (Zhu *et al*., 2005).

Green and cleaner production: These include: obtain new environment-friendly technology and require upgrade of technical equipment, manufacturing process control ability and Perform analysis significant impacts and provide response measures (Juang *et al*., 2009), test equipment (Hsu and Hu, 2009), monitoring and measuring equipment (Sambasivan and Fei, 2008), green technical capability and develop alternative materials, products, equipment and methods that alleviate life cycle shocks (Lin and Juang, 2008).

Green packaging: Packaging is one of the critical elements that can provide a competitive advantage in the market for many consumer products (Barber, 2010) and product package design (reusable package, high recovery package) complying with recycle requirements (Lin and Juang, 2008). Green packaging recognize the significance of behaving in an ecologically positive way. So, consumers' eco friendly behavior can be motivated by emphasizing the significance of environmental issues (Barber, 2010).

Green labels: Green labels include: ISO 14001 certification, energy star, green product and etc. Eco labeling provides information for consumers, and also encourages and support producers who are more aware and interested to the environment and manufacturing activities and green labels allow consumers to compare products based on scientifically sound, objective, and comparable environmental factors (Blengini and Shields, 2010).

Reuse, recycle and recovery of material: In green supply chain management, reuse, recycle and recovery of materials and products are essential. Corporations must decide to do the recovery, recycling or reuse of used products on their own, or to establish cooperation via local or more extended networks for the collection and recycling of similar products and also producers are required to train consumers about the recycling, recovery and reuse options available to them (Hu and Hsu, 2010).

Reduce energy consumption: Recently, energy management become our every day's care and a large number of numerous people care for the environment we live in (Kralj, 2008) and energy consumption has a critical impact on the environment (Chavan, 2005) and establishing an environmental management system or green supply chain management improves more efficient energy consumption and decreased amounts of waste **(**Bansal and Roth, 2000).

4. METHODOLOGY: THE FUZZY DEMATEL METHOD

Group decision-making is a key to draw inference from varying degrees of experience, ideas and motivations. However, decision-makers tend to give assessments according to their past experiences and knowledge, and their estimations are often expressed in equivocal linguistic terms (Gupta, 1991). DEMATEL (Decision Making Trial and Evaluation Laboratory) is one the multi criteria decision making instruments and has the ability to convert the qualitative designs to the quantitative analysis (Lee *et al*, 2010). The aim of DEMATEL is to change the relation between criterions, causal dimensions from a complex system to an understandable structural model of that system (Dalalah *et al*, 2011). With different dimensions of criteria for green supply chain management evaluation, each criterion may impact the other criteria that affect the decision-making. Therefore, understand the causal relationship among dimensions/criteria helps the decision-making process. The procedure of fuzzy DEMATEL method is as follows:

The initial step is to recognize the decision goal and our decision goal was to develop a comprehensive model for green supply chain management in automotive corporations. Then, we set up a group of managers and experts in environmental management systems. Then, it is essential to collect the relevant criteria in order to be able to create a comprehensive model. By brainstorming technique, the group finally recognized 15 criteria (see Table 1). Also, through the fuzzy linguistic scale (see Table 2), the relationships between each pair of criteria were measured and each individual assessment of experts can be achieved. Next, the averages of assessments of decision-makers are acquired by formula (1) and after it, we have initial direct-relation fuzzy matrix (see formula 2). Then, we calculated the normalized direct-relation fuzzy matrix that was earned by formula (5). To compute the total-relation fuzzy matrix $\tilde{T}$ we have to ensure the convergence of $\lim_{z\leq\to\infty}\tilde{p}^{(z)} = 0$ (Lin and Wu, 2004) and then, we calculated $\widetilde{D_\iota}$, $\widetilde{R_\iota}$ (see formula 13 and 14), $\widetilde{D_\iota} + \widetilde{R_\iota}$ and $\widetilde{D_\iota} - \widetilde{R_\iota}$, where $\widetilde{D_\iota}, \widetilde{R_\iota}$ are the sum of rows and the sum of columns of matrix $\tilde{T}$and for defuzzification we used the CFCS method (Opricovic and Tzeng, 2003; Lin and Wu, 2004; Lin and Wu, 2008).

Table2. The correspondence of linguistic terms and linguistic values

Linguistic terms	Linguistic values
No influence (NO)	(0,0,0.25)
Very low influence (VL)	(0,0.25,0.5)
Low influence (L)	(0.25,0.5,0.75)
High influence (H)	(0.5,0.75,1)
Very high influence (VH)	(0.75,1,1)

The formulas of fuzzy DEMATEL method are as follows (Gharakhani, 2012; Givarian *et al.*, 2012; Chang *et al.*, 2011; Lin and Wu, 2008; Lin and Wu, 2004):

$\tilde{E} = \left(\frac{\tilde{E}^1 + \tilde{E}^2 + \cdots + \tilde{E}^3}{m}\right)$ (1) $m = number\ of\ experts$ and we have m fuzzy matrices $\tilde{E}^{(1)}, \tilde{E}^{(2)}, \dots, \tilde{E}^{(m)}$.

$$\tilde{E} = \begin{bmatrix} 0 & \tilde{E}_{12} & \cdots & \tilde{E}_{1n} \\ \tilde{E}_{21} & 0 & \cdots & \tilde{E}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{E}_{n1} & \tilde{E}_{n2} & \cdots & 0 \end{bmatrix} \quad (2)$$

$\tilde{E}$ is the initial direct relation fuzzy matrix and $\tilde{E}_{ij} = (q_{ij}, k_{ij}, l_{ij})$, are triangular fuzzy numbers and n = number of criteria.

$$\tilde{a}_{ij} = \sum_{j=1}^{n} \tilde{E}_{ij} = \left(\sum_{j=1}^{n} q_{ij}, \sum_{j=1}^{n} k_{ij}, \sum_{j=1}^{n} l_{ij}\right) \quad (3) \qquad \text{and} \qquad s = \max_{1\le i\le n}\left(\sum_{j=1}^{n} \tilde{E}_{ij}\right) \quad (4)$$

$$\tilde{P} = \begin{bmatrix} \tilde{p}_{11} & \tilde{p}_{12} & \cdots & \tilde{p}_{1n} \\ \tilde{p}_{21} & \tilde{p}_{22} & \cdots & \tilde{p}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{p}_{n1} & \tilde{p}_{n2} & \cdots & \tilde{p}_{nn} \end{bmatrix} = \tilde{P}_{ij} = \frac{\tilde{E}_{ij}}{s} = \left(\frac{q_{ij}}{s}, \frac{k_{ij}}{s}, \frac{l_{ij}}{s}\right) \quad (5-1)$$

$\tilde{P}$ is the normalized direct-relation fuzzy matrix.

$$P_q = \begin{bmatrix} 0 & \acute{q}_{12} & \cdots & \acute{q}_{1n} \\ \acute{q}_{21} & 0 & \cdots & \acute{q}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \acute{q}_{n1} & \acute{q}_{n2} & \cdots & 0 \end{bmatrix}, P_k = \begin{bmatrix} 0 & \acute{k}_{12} & \cdots & \acute{k}_{1n} \\ \acute{k}_{21} & 0 & \cdots & \acute{k}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \acute{k}_{n1} & \acute{k}_{n2} & \cdots & 0 \end{bmatrix}, P_l = \begin{bmatrix} 0 & \acute{l}_{12} & \cdots & \acute{l}_{1n} \\ \acute{l}_{21} & 0 & \cdots & \acute{l}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \acute{l}_{n1} & \acute{l}_{n2} & \cdots & 0 \end{bmatrix} \text{ and } \tilde{P}_{ij} = (\acute{q}_{ij}, \acute{k}_{ij}, \acute{l}_{ij}) \quad (5-2)$$

$$\tilde{P}^z = \begin{bmatrix} \tilde{p}^z{}_{11} & \tilde{p}^z{}_{12} & \cdots & \tilde{p}^z{}_{1n} \\ \tilde{p}^z{}_{21} & \tilde{p}^z{}_{22} & \cdots & \tilde{p}^z{}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{p}^z{}_{n1} & \tilde{p}^z{}_{n2} & \cdots & \tilde{p}^z{}_{nn} \end{bmatrix} \text{ where } \tilde{p}^z{}_{ij} = \left(q_{ij}^{(z)}, k_{ij}^{(z)}, l_{ij}^{(z)}\right) \text{ and } z = 1, \ldots, m. \quad (6)$$

$$\tilde{T} = \lim_{z\to\infty}\left(\tilde{P} + \tilde{P}^2 + \ldots + \tilde{P}^z\right) \quad (7)$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \tilde{t}_{nn} \end{bmatrix}, \text{ Where } \tilde{t}_{ij} = \left(q''_{ij}, k''_{ij}, l''_{ij}\right) \quad (8)$$

$$[q''_{ij}] = P_q \times \left(I - P_q\right)^{-1}, [k''_{ij}] = P_k \times (I - P_k)^{-1}, [l''_{ij}] = P_l \times (I - P_l)^{-1} \quad (9)$$

$$\text{Matrix}[q''_{ij}] = \lim_{z\to\infty}\left(P_q + P_q{}^2 + \cdots + P_q^z\right) = \lim_{z\to\infty} P_q\left(P_q + P_q{}^2 + \cdots + P_q^z\right) = P_q \times \left(I - P_q\right)^{-1} \quad (10)$$

$$\text{Matrix}[k''_{ij}] = \lim_{z\to\infty}\left(P_k + P_k{}^2 + \cdots + P_k^z\right) = \lim_{z\to\infty} P_k\left(P_k + P_k{}^2 + \cdots + P_k^z\right) = P_k \times (I - P_k)^{-1} \quad (11)$$

$$\text{Matrix}[l''_{ij}] = \lim_{z\to\infty}\left(P_l + P_l{}^2 + \cdots + P_l^z\right) = \lim_{z\to\infty} P_l\left(P_l + P_l{}^2 + \cdots + P_l^z\right) = P_l \times (I - P_l)^{-1} \quad (12)$$

$$D = \left[\sum_{j=1}^{n} \tilde{t}_{ij}\right]_{n\times 1} \quad (13) \qquad R = \left[\sum_{i=1}^{n} \tilde{t}_{ij}\right]_{1\times n} \quad (14)$$

5. RESULTS

In this study we have used a scientific and comprehensive framework for understanding the casual relationship among evaluation criteria and the fuzzy DEMATEL technique is as a useful and applicable method to understand the relationship between criteria for effective development and implementation of a green supply chain. In our study we described how fuzzy DEMATEL can be a useful managerial tool to evaluate green supply chain management and relationships between criteria to each other and also can be significant for every firms and we used fuzzy DEMATEL technique to compensate the weakness of traditional DEMATEL approach and this technique providing knowledge into the relationships between the green supply chain management.

In table 3, the amounts of $(\widetilde{D}_\iota + \widetilde{R}_\iota)^{def}$ shows how significant the criterion is and the amounts of $(\widetilde{D}_\iota - \widetilde{R}_\iota)^{def}$ separates the criteria into cause and effect groups and if the value $(\widetilde{D}_\iota - \widetilde{R}_\iota)^{def}$ is positive, the criterion is a part of the cause group and also, If the value $(\widetilde{D}_\iota - \widetilde{R}_\iota)^{def}$ is negative, the criterion is a part of the effect group (Lin and Wu, 2004).

Table 3: The amounts of $\widetilde{D}_\iota, \widetilde{R}_\iota, \widetilde{D}_\iota + \widetilde{R}_\iota, \widetilde{D_\iota - \widetilde{R}_\iota}, (\widetilde{D}_\iota + \widetilde{R}_\iota)^{def}$ *and* $(\widetilde{D}_\iota - \widetilde{R}_\iota)^{def}$

Sub-criteria		$\widetilde{R_\iota}$	$\widetilde{D_\iota} + \widetilde{R_\iota}$		(	(
M_1	(2.84 ,4.92 , 10.69)	(2.25 ,4.60 ,10.17)	(5.35 ,9.52 ,20.86)	(0.34 ,0.31 ,0.52)	11.91	0.39
M_2	(2.20 ,4.21 ,9.63)	(4.77 ,6.88 ,12.71)	(6.96 ,11.09 ,22.34)	(-2.57 ,-2.67 ,-3.08)	13.46	-2.77
M_3	(2.44 ,4.51 ,9.99)	(4.42 ,6.45 ,12.28)	(6.86 ,10.96 ,22.27)	(-1.98 ,-1.95 ,-2.28)	13.36	-2.07
E_1	(2.55 ,4.58 ,10.05)	(3.16 ,5.12 ,10.83)	(5.71 ,9.70 ,20.88)	(-0.61 ,-0.54 ,-0.78)	12.10	-0.64
E_2	(1.51 ,3.57 ,8.43)	(3.04 ,5.05 ,10.53)	(4.56 ,8.62 ,19.16)	(-1.53 ,-1.48 ,-1.39)	10.78	-1.63
E_3	(3.22 ,5.31 ,11.12)	(2.39 ,4.34 ,9.73)	(5.61 ,9.65 ,20.85)	(0.84 ,0.96 ,1.39)	12.04	1.06
O_1	(2.32 ,4.38 ,9.97)	(2.37 ,4.51 ,9.88)	(4.69 ,8.89 ,19.85)	(-0.05 ,-0.13 ,0.09)	11.14	-0.03
O_2	(2.76 ,4.81 ,10.45)	(1.84 ,3.92 ,9.30)	(4.61 ,8.73 ,19.74)	(0.92 ,0.89 ,1.15)	11.03	0.99
T_1	(2.86 ,4.93 ,10.47)	(1.54 ,3.59 ,8.87)	(4.40 ,8.51 ,19.34)	(1.33 ,1.34 ,1.60)	10.75	1.42
T_2	(2.14 ,4.17 ,9.59)	(3.03 ,5.14 ,10.91)	(5.17 ,9.31 ,20.50)	(-0.90 ,-0.97 ,-1.33)	11.66	-1.07
T_3	(2.84 ,4.91 ,10.63)	(3.69 ,5.71 ,11.42)	(6.52 ,10.62 ,22.05)	(-0.85 ,-0.80 ,-0.79)	13.06	-0.82
T_4	(2.46 ,4.52 ,9.78)	(2.12 ,4.11 ,9.17)	(4.58 ,8.63 ,18.95)	(0.34 ,0.42 ,0.61)	10.72	0.46
T_5	(3.46 ,5.51 ,11.18)	(1.38 ,3.44 ,8.86)	(4.84 ,8.95 ,20.04)	(2.09 ,2.07 ,2.32)	11.28	2.16
T_6	(3.59 ,5.64 ,11.16)	(1.38 ,3.43 ,8.63)	(4.97 ,9.07 ,19.80)	(2.21 ,2.21 ,2.53)	11.28	2.31
T_7	(2.53 ,4.57 ,9.83)	(2.10 ,4.24 ,9.87)	(4.62 ,8.80 ,19.70)	(0.43 ,0.33 ,-0.05)	11.04	0.24

As the table 3 shown, the evaluation criteria were visually separated to the cause group, including $M_1, E_3, O_2, T_1\ T_4\ T_5, T_6$ and T_7 and the effect group, including $M_2, M_3, E_1, E_2, O_1, T_2$ and T_3. Also, the criteria of Reuse, recycle and recovery of material (T_6), Green labels (T_5), and Green purchasing (T_1), with the largest positive values of $(\widetilde{D_\iota} - \widetilde{R_\iota})^{def}$, these three have the best effect on the other criteria. The criterion of Environmental policy (M_2), with the largest $(\widetilde{D_\iota} + \widetilde{R_\iota})^{def}$, is the most significant factor for green supply chain management. Also, the Environmental policy (M_2), with the most negative Value of $(\widetilde{D_\iota} - \widetilde{R_\iota})^{def}$, is the most easily improved of the effect group criteria. The ranking of sub-criteria are reported in Table 4.

Table 4: The ranking of sub-criteria

Sub-criteria	M_2	M_3	T_3	E_1	E_3	M_1	T_2	T_5	T_6	O_1	T_7	O_2	E_2	T_1	T_4
$(\widetilde{D_\iota} + \widetilde{R_\iota})^{def}$	13.46	13.36	13.06	12.10	12.04	11.91	11.66	11.28	11.28	11.14	11.04	11.03	10.78	10.75	10.72
Ranking	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

So, we can see that the top five sub-criteria are as follows: Environmental policy (13.46), International, governmental and domestic environmental agreements and legislations (13.36), Green and cleaner production (13.06), Effective communication within companies and suppliers (12.10), and Green image (12.04).

6. DISCUSSION

Environmental laws, green production and eco products have become significant issues to manufacturers like automotive industries and green supply chain management practices have become progressively significant for manufacturers and in this increasingly competitive market, companies are required to implement green management practices. Significance of environmental protection has attracted attention of the governments, customers and companies and recently, firms pay more attention on environment and environmental issues have become a key factor of performance in the marketplace. In this study, we used the fuzzy DEMATEL method, to study the influence of the most important factors and to find out the ranking of critical sub-factors in green supply chain management in automotive corporations. The implications and usefulness of the technique are clear and managers are able to recognize what criteria of green supply chain management within their organization need more attention and which ones may be given less priority and this method has the ability to clearly express the causal relations between criteria. We also can use this method to assistance plan the direction of every organization by determining how one criteria of green supply chain, influence other ones and if every firm wishes to improve existing green supply chain, this method can provide clear relationships on which criteria of green supply chain should be emphasized to insure greater success of programs. So, we have seen this approach flexible and applicable for application in a broad variety of managerial and decision environments and our study emphasizes that the fuzzy DEMATEL method can be a useful to many researches which must deal with complex criteria problems that need to use group decision making in the fuzzy environment. This research struggles to explore and analyze the critical factors of green supply chain management in automotive corporations in Iran. The main part of this study was to recognize the critical factors of green supply chain management in automotive corporations and this identification permits managers to a better understanding of green supply chain management practices and follow academic researchers to develop and testing theories of green issues. Additionally, the critical factors of green supply chain management in this study can guide other researchers to recognize those areas of green supply chain management that require acceptance and improvements. Based on our research, we concluded that the top five important critical sub-factors of green supply chain management in automotive industries in Iran are as follows: Environmental policy, International, governmental and domestic environmental agreements and legislations, Green and cleaner production, Effective communication within companies and suppliers, and Green image. The literature review that conducted by different authors helped ensure the content validity and the this study is align with research of Irajpour *et al.,* (2012a, b), Wang *et al.,* (2011), Choudhary and Seth (2011), Wan Mahmood *et al.,* (2011), Bai *et al.,* (2010), Hu and Hsu (2010), Holt and Ghobadian (2009), Lee (2008b), Simpson *et al.,* (2007), Zhu *et al.,* (2007), Zhu *et al.,* (2005), Zhu and Sarkis (2004).

Also, the scope of this research is limited to the Iranian automotive industries and its components and we had some limitations in our research and as the main contribution of this study are to identify the critical factors of green supply chain management in automotive corporations, the reorganization of the critical factors of green supply chain management is very critical. Same the researches of (Gharakhani, 2012; Fu *et al.*, 2010), an important limitation in our research was the evaluation struggle that required with the fuzzy DEMATEL technique. Also, the evaluation of the importance of the sub-criteria in these types of studies is based on the interrelationship and level of influence of criteria on each other. This influence may only be observational and not necessarily be a significance characteristic of the factor. For example, even a criterion that does not have a strong causal relationship to other criterion may be critical to a firm due to a strategic and this information is not necessarily captured by this methodology.

Researchers can also find this method valuable for other study and this study provides an essential step into further research on greening the supply chain and also, other researchers can develop and use our model, for other green supply chain management researches and our observations may be completed over time with the same case study. This research suggests further researches in order to extend the scope of this study. For example: other criteria can be added to green supply chain or such research can be done in environmental protection, green design, green policy, green purchasing, green sales and marketing, green products, green technology, and green chemistry.

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