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Research Article

A Multicriteria Framework to Evaluate Supplier's Greenness

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Environmental protection is becoming more and more important for enterprises because of stronger public awareness, competitors and communities, and government regulations. For this purpose, some programs have become more popular for raising environmental awareness including total quality environmental management and green supply chain management. Reducing the environmental pollution from upstream to downstream during procuring raw materials, producing, distribution, selling products, and products depreciation is the most important goal of Green Supply Chain Management (GSCM). The main contribution of this study is introducing the main factors in green supply chain management that are very important in environmental attributes by providing an evaluation framework to select the most eligible green suppliers by examining the influential and important criteria and subcriteria among ten elements of two main GSCM practices, namely, green logistics and environmental protection. First, these factors are divided into two groups, that is, green logistics and environmental protection, and then by applying DEMATEL technique, the complex causal relationship between all factors dependencies and feedbacks among them is examined. Finally, by drawing the impact relationship map the most important and influential factors are determined for improving green supply chain environmental aspects.

1. Introduction

The emergence of Green Supply Chain Management (GSCM) is one of the most significant environmental developments in the past decade, offering the opportunity for companies to align their supply chains in accordance with environmental and sustainability goals. More attention, recently, has been paid to these environmental problems while the supply chain operation combined with sustainable consideration has increasingly been a major issue [1–4]. The most important challenge for enterprises has been integration of social, environment, and economic performances to obtain sustainable improvement [5]; in other words, if firms want to survive in the global market, they cannot disregard environmental issues. While traditional supplier selection focused on price, quality, and delivery on time [6] or focused only on the requirements of single organizations and ignored considering the whole supply chain [7], green supplier selection processes have to be focused on improving environmental factors in whole supply chain through organizational performance and activities, consumption, logistics, customer service, and financial performance concurrently [4, 8]. Today, buyers are willing to purchase products and services from suppliers that manage to provide them with high quality, low cost, and short lead time with environmental responsibility at the same time due to increased environmental attentiveness. By the way, one of the most obvious gaps by considering previous studies is lack of direct consideration to environmental protection and its aspects in proposed evaluation models in this area. In the green foundation, the first target that is extremely egregious is environment conversation. On the other hand, another powerful category named green logistics that has a direct relation to improving green supply chain management [9], so combination of the two main clusters, green logistics and environmental protection, can play an important role in improving GSCM.

In addition, previous studies have worked just on quantitative models that have been applied for selecting green suppliers such as analytic hierarchy process technique [10, 11], fuzzy comprehensive evaluation [12], comprehensive grade model [13], and grey widespread evaluation [14] with no consideration to the complex causal relationship between criteria of the system along with dependencies and feedbacks among criteria and alternatives simultaneously [15]. Therefore, interactions between main features of green supplier selection could not be considered and any evaluation would not be accurate and reliable. Therefore, this study proposes the causal evaluation model which consists of two main green categories and applies the DEMATEL technique to evaluate the model and examine the relationship and interaction between the GSCM factors including their direct and indirect effects on each other. Finally, dimensions are divided into cause and effect groups. By improving aspects in cause group, improvements in the whole GSCM will come to pass.

In next part, we present some related background regarding green supply chain and its significant related features and methods.

2. Literature Review

2.1. Green Supply Chain Management. Green supply Chain Management (GSCM) is a multiple business network and collaborative relationship for better environment; it is not a business chain with business-to-business or one-to- one relationship [16]. Successful integration coordination and management across members is required in the supply chain including manufacturers, raw material supplier's recyclers, distributors, and users [17]. Three green supply chain management general characteristics are known as strategy, environment, and logistics. The environmental and green purchasing which was assumed to be a subset of green supply chain management accounted for the environmental and green issues whilst disregarded the social conditions [18]. Reference [19], however, gave its complete definition; according to the report, sustainability of supply chain management is regarded as the material management, capital flow information, and company's cooperation along the supply chain, while goals are taken from all the dimensions of sustainable development, including social, economic, and environmental, into account which met the stakeholder and customer requirements. In the supply chain sustainability, social and environmental criteria are required to be fulfilled by the members to retain the supply chain, while anticipating the maintenance of competitiveness by meeting the customer requirements and criteria for related economy. The definition, however, includes the green supply chain management and social responsibility of supply chain management [20, 21].

For the companies transferring to "greenness" in their supply chain, motivations should be different. Although some of the motivations are unclear, according to [22], some of the organizations do this due to the fact that it is the right thing for the environment. Although some are more radical for the change of the environment, others may not [22]. Researchers have reported that reduction in the cost and profitability are some of the major business motivations to become "green" in the supply chain [23, 24].

2.2. Significance of Green Supplier Selection. Reference [22] has shown that in the corporate value chain, every element engages in minimizing the firms' environmental impact from the onset till the end of supply chain management; however, this differed compared to the traditional supply chain management. To be precise, green supply chain needs not only the companies to be alert throughout the entire process while considering the traditional supply chain management including timeliness of delivery, material cost flexibility, and other factors, but also it should be mindful of procurement of materials and reduced production, marketing, and other environmental negative impacts (e.g., harmful substances, packaging recycling). As a result of this, the green supply selection is important [25]. Organizational assessment is the most common GSCM practice involved in the performance of the suppliers' environment, which requires suppliers to undertake measures that ensure product environmental quality, evaluating the wastage in the cost of their system of operation [26]. Environmental high level of performance achieved by a firm may be broken down due to poor level of environmental management via its support. Next section discusses the method and proposes an evaluation framework by regarding green supplier selection.

3. Material and Method

This study proposes a causal model based on the DEMATEL methodologies to support green supply chain management strategic decisions and green supplier selection. Firstly, two main criteria, namely, green logistics and environmental protection, are identified and subcriteria that are related to them are defined. In the next step, vectors indicate direct relationships and loops indicate interdependencies inside the two clusters. According to previous studies, five elements for each cluster due to improving green supply chain management have been identified [4, 27–29].

3.1. Proposed Causal Model for Green Supplier Selection. The general view of the proposed green supplier causal model is exposed in Figure 1. Green supplier selection problem is a sort of complex multiple criteria decision making problem including both quantitative and qualitative factors, which may be inconsistent and uncertain. Due to the nature of supplier selection, multicriteria decision making (MCDM) methods are required to handle and solve the problem effectively [30]. The techniques of MCDM are comprehensibly derived to manage this kind of problems [31, 32].

3.2. Criteria for Green Supplier Evaluation. According to the review of previous researches, two main clusters for improving green supply chain management have been identified: green logistics (GL) and environmental protection (EP).

3.2.1. Green Logistics (GL). GL is the management activities to pursue customer satisfaction and social development goals, connecting the main body of green supply and demand and overcoming space and time obstacles to achieve efficient and rapid movement of goods and services. It inhibited the

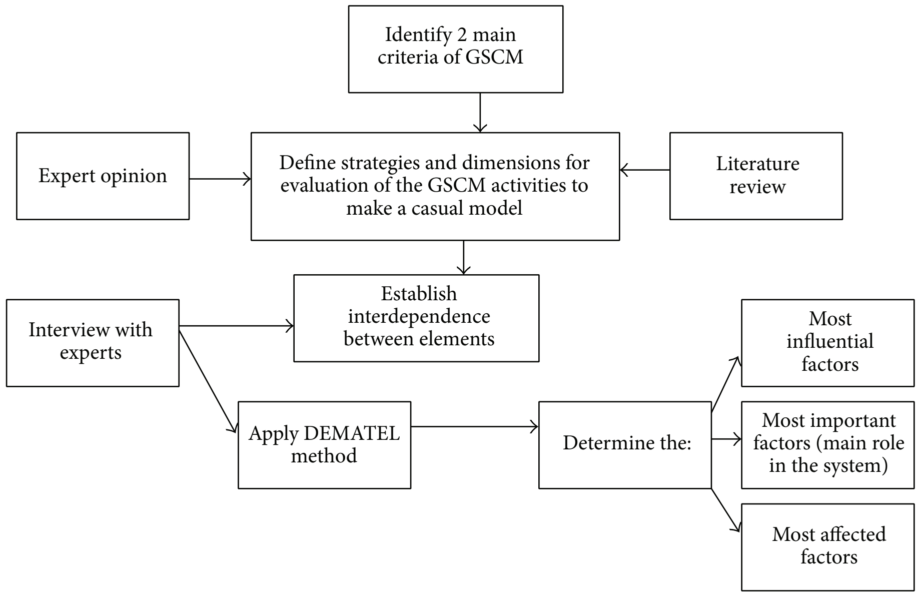

Figure 1: Causal evaluation model methodology.

damage to environmental to achieve the purification of the logistics environment and the best use of logistics resources. GL is a multilevel concept which includes both the green logistics business activities and social activities for green logistics management, standard and control [33].

The main elements of green logistics dimension include *procurement, production, distribution, packaging*, and *reverse logistics* [6, 27, 34, 35].

3.2.2. Environmental Protection. Protection of the environment is a major area of green supply chain which compares the system of environmental protection like controlling all kinds of pollutions, design products according to green image, ISO 14001, and so forth. Major indicators are engaged in the recovery of resources conservation and resource utilization and resource type, environmental governance, environmental pollution, and reinvented ability. Moreover, it is made up of packaging materials, transport, emissions, garbage, and emissions [36–38]. In the US, Air pollution Control Act and Water Pollution Control Act 1955 and 1948 were introduced by the Environmental Protection Agency (EPA). Environmental protection dimensions consist of green design of products, ISO 14001, Eco-labeling, life cycle, and pollution control [28, 29].

3.2.3. Green Logistics Dimensions

(i) *Production*. The anticipation is that 80% of environmental impact related products are determined in the design phase; therefore, combining early environmental considerations in the developmental cycle for the product design is the best active means of decreasing their impact [39]. However, the major elements of the stage design include selection of materials and design products [39]. Production has great effects on the green supply chain via the production process and design. Suppliers should aim at enhancing the raw material and packaging type for use in green environmental protection and green supply chain advancement. Moreover, supplier's production capabilities can be divided into many areas which include manufacturing quality equipment, highly developed equipment, and the number of workers with qualified experience, and the technical levels is comprised of three components: the ability to design green products and services and services, the level of technical security, and higher technological degrees [37]. The use of hazardous or restricted raw material through the entire manufacturing protocol, one important issue that should be addressed during the process is waste reduction [40–42]. In this function, total quality environmental management, closed-loop manufacturing, source reduction, and demanufacturing have some value added contribution, although some also influenced other functional areas [35].

(ii) *Procurement*. The initial stage in the chain of environmental friendliness is supplier procurement and selection. Reduction in purchase or procurement and using materials that are reusable, or have been recycled, have a significant role to play in green supply chain [9].

(iii) *Distribution*. Distribution is one of the protocols that show effects on the green supply chain. Different items including delivery services, customer distance and transporter capacity, fuel type used, and shipping frequency or transport [9] influence the green distribution performance. Moreover, the forward and reverse logistic network is influenced by many decisions of transportation and also transportation type and shipping, location of distribution channel, just-in-time (JIT) strategy, and system control. The distribution and transportation network process are not only essential attributes of operation with major effects on the green supply chain, but also they are most closely attached to the features and requirements of the custom. Therefore, involvement of customers in the distribution design system and growth is likely to give an active network distribution. For instance, joining decision location to those vendors and customs will enhance JIT system [4].

(iv) *Reverse Logistics.* A major GSCM trend is the strategic recognition of reverse logistics. From the environmental perspective, reverse logistics means focusing primarily on the return of reusable and recyclable products and material into the forward supply chain.Effective design of RL network is the key in economic benefit provision required to start and sustain the initiatives of GSCM on a larger scale [9, 43]. According to [44], reverse logistics was primarily motivated by economic condition, but not concerns on ecosystem protection [45, 46] have stated that reverse logistics is capable of bringing profitability only, reducing wastage and advert. Reverse logistics may be seen as the opposite of traditional or forward logistics [47]. According to [48, 49], reverse Logistics is a process where manufacturers initially accept shipping products from a point of consumption for possible recycling and remanufacturing. The basis of reverse logistics is illustrated by [47] as works around RL include the flow material management towards recycling and remanufacturing, which minimizes the cost of developing new products [49]. Reverse logistics is widely applied in automobile companies including General Motors and BMW [50]. Studies on logistics are thought of as part of the process of reverse logistics [51], which identified some stages in the channel of reverse logistics which include separation, collection, transitional process, densification, integration, and delivery.

(v) *Packaging.* Characteristics of packaging, for example, material size and shape, have effects on distribution as a result of their effect on the product transport characteristics. Reorganized loading patterns and good packages can minimize material usage and raise utilization of space in warehouses and in trucks as well as reduction in the level of handling. For systems where returnable packaging is encouraged, stronger customer supplier relationship with active channel for reverse logistics is required [9]. An active program for green packaging is decisive to the general environmental program success [52].

3.2.4. Environmental Protection Dimensions

(i) *Green Design*. Green design means product design or services with consideration to some environmental awareness which is a subset of green supply chain management. If companies desire good image, they should design their products to be in line with the requirements of environmentally friendliness, and also as a result of limitations in resources and modern society environmental degradation [36, 37]. Green design is highly associated with environmental conditions as product safety, risk management, waste reduction and pollution avoidance, and resource protection to prevent being damaged. Moreover, analysis of lifecycle is needed in green design conception. Resource related and environmental related products are assessed by LCA through the protocol of production. Alternatively, green design has been adopted with the objective of lowering product impact on the environment throughout the entire life cycle of product such as raw material choice, production, marketing, development disposal, and use of products meaning "the systematic incorporation of environmental factors into the design of products and development" [28]. Many researchers have argued the green design; in 1998, Barros et al., which are related to the product reuse with the Dutch government's support, suggested a two-level model location. The activity of purchasing in reverse logistic system and design in 1998 was assessed [44]. Applied logarithms were created by [53] for product recovery design system. The study demonstrated that "core algorithm" and allocation "algorithms" are two system schedules that can assist in waste reduction. Measurement designs by Green include tracking materials and product reverse flow from raw material retrieval from the environment to product disposal to the environment [54].

(ii) *ISO 14001.* International organization for Standardization (ISO) is the world's international standard publisher. ISO is a national standard institute network of 161 countries, with its secretariat in Geneva, Switzerland, which runs the system. It is a nongovernmental organization that acts as a mediator between private and public sectors. Vendors who possess ISO 14000 certification are preferred in the purchase and procurement decisions; hence risk of the environment is lowered [4]. ISO 14000 is a recognized standard for the management of environment. Environmental management can interact between environment and modern human society. A good of researches have stressed the need for ISO 14000 in green supply chain management improvement [55].

(iii) *Pollution Control.* Major indicators are engaged in the recovery of resources conservation and resource utilization and resource type, environmental governance, environmental pollution, and reinvented ability. Moreover, it is made up of packaging materials, transport, emissions, and garbage [36, 37]. In the US, Air pollution Control Act and Water Pollution Control Act 1955 and 1948 were introduced by the Environmental Protection Agency (EPA). According to [56], the rules and standards for greenhouse gas prevention effects have been violated routinely. In the US discharge of greenhouse gas has risen by 14% from

1990 to 2008 (EPA 2008). Transport and generation of electricity are the major gas emitters. The total greenhouse discharge of gas worldwide from human activities increased by 26% from 1990 to 2005 [57].

(iv) *Eco-Labeling*. Eco-labeling is an approach that voluntarily to the certification of environmental performance. It is practices all over the world. A product that fulfils certain criteria effectiveness or standard is identified by "eco-label." It is awarded by a third-party organization for services or product that is ready to fulfill certain environmental criteria. Different organizations such as nonprofit and profit organizations, government have built eco-label program. There are differences in the issues addressed by eco-labelled programs; for example, energy star focuses on the use of energy during the operation of equipment, whereas others address environmental life cycle problems and ergonomic and worker and issues of safety and health. The decision to use eco-labels by purchasers to help in purchase decisions should review carefully the criteria to ensure that program reflects on their specific problems. The meaning of environmentally preferable purchase (EPP) is that items are identified and purchased with eco-labelled services and products; for example, "Green" from USA, "Blue Angel" from Germany, Ecomark from Japan, and Environmental Choice from Canada are known eco-labeled services or product certifications [28]. Eco-labeling is included in environmental attributes considered by consumer's recyclability, upgradability, low acoustic levels, energy efficiency, ease of serviceability, and limitation of hazardous material content [58].

(v) *Life Cycle*. Life cycle analysis is a major subconcept in green design analysis of life cycle introduced for environment and resource related product measurement of the production process [43]. The measurements include steps in the raw material production, extraction, distribution and remanufacturing, and recycling and disposal. According to [59] report that the analysis of lifecycle "examines and qualifies the energy and material used, wasted and assesses the impact of product on the environment." Regulation by government is also a measure that organizations use for the analysis of life cycle. Life cycle analysis framework has been discussed by [54]. The stage of life cycle product will essentially influence the supply chain greening. For instance, from the initial stages, the design seriously affected the product and environmental issues design, playing pivotal roles at this stage for the decline and maturity product life cycle stages, and process improvement, with an active system of reverse logistics, while the organizational environmental practices will be affected. In the analysis of multiproduct, the decision of environmental management becomes highly complicated. However in the company's product portfolio variable environmental strategies and life cycle product development foci will depend on product maturity life cycle [4].

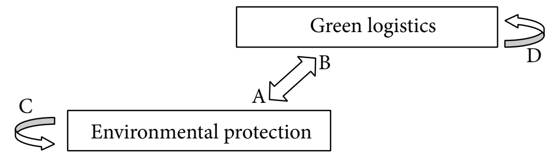

Figure 2: The causal evaluation model.

4. Causal Model for Improving Green Supply Chain

Based on criteria identification phase, direct and indirect effects and interactions between all elements are detected and causal model for green supplier selection is provided in Figure 2. To ensure the validity of the model, in this phase, five researchers from University Putra Malaysia (UPM), who work on SCM, are consulted.

In Figure 2, arrows (A and B) indicate the interactions between two elements and loops (C and D) show interdependencies between elements inside the clusters. As an instance, when the factors of a cluster "green logistics" depend on factors of "environmental protection" cluster, this relation is represented by an arrow from component of "green logistics" to element of "environmental protection."

In addition, Figure 3 demonstrates detailed causal evaluation model consisting of all elements and main criteria.

5. Application and Testing of the Model

For testing the model, as same as our previous research attempt [60], "case study with expert interview technique" is applied for this research. The objects were 10 professional experts who are working in supply chain departments of Iran Khodro Co. Each interview has been done individually by each expert and took time between minimum 30 minutes to maximum 45 minutes for each of them. First, the evaluation model along with all components and interactions between criteria was described for each of them. Next step in interview is determining relations between concepts according to loops and arrows. In this step, consolation committee with experts determines the relations among influential factors in causal evaluation model. Each expert performs pairwise comparisons between factors and gives the score from 0 to 4 according to their experiences and believes that factor i affects factor j. For this purpose, a group of engineers are selected from Iran Khodro supply chain department SAPCO (Supplying Automotive Parts, Co.), the most important supplier and the main subset for Khorasan Iran Khodro Company. In fact, to apply DEMATEL technique, using expert's opinion among and within the elements to paired comparison analysis is required.

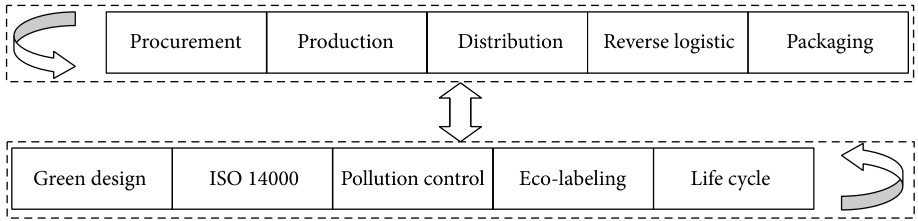

Figure 3: Detailed causal evaluation model.

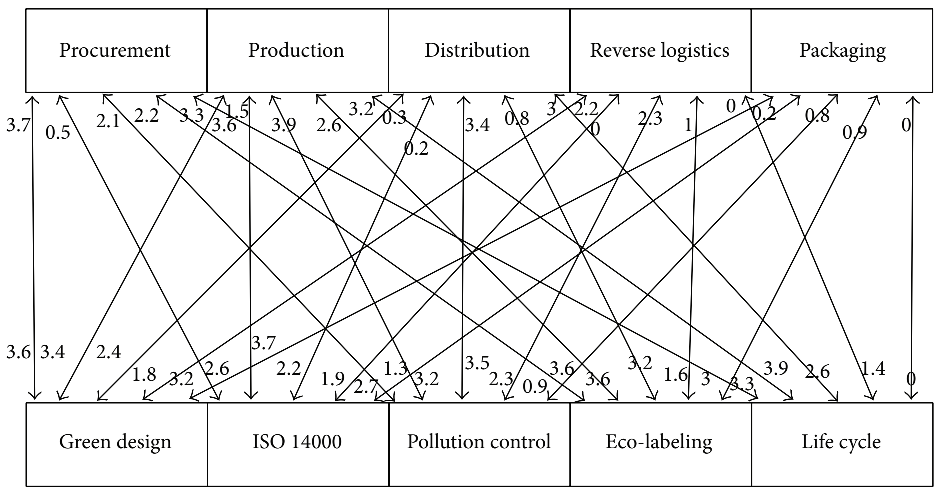

Figure 4: Graphical initial direct impact relation between EP and GL.

6. Case Analysis Method

Green supplier selection problem is a sort of complex multiple criteria decision making problem including both quantitative and qualitative factors, which may be inconsistent and uncertain. Due to the nature of supplier selection, MCDM methods are required to handle and solve the problem effectively [60]. Multiple criteria decision making (MCDM) using the decision making trial and evaluation laboratory (DEMATEL) was proposed in this case analysis. The method of DEMATEL was chosen to assess the interdependence level existence of green supply chain management, for selected practice indicators [61, 62]. In DEMATEL structure, each factor or part may exert an effect and obtain from other higher or lower level factors. The entire factors establish worth and importance of factors instead of considering only specific factors [62, 63].

6.1. The Procedures of the DEMATEL Technique. There are 5 main steps for applying DEMATEL, [64]. The procedures of the DEMATEL method can be expressed as follows.

Step 1 (*finding the direct-relation (average) matrix*). At first we have four scales that determine the values of relationships between different factors according to the experts' opinion:

0 = no influence;

1 = low influence;

2 = high influence;

3 = very high influence.

There are H experts and n factor (criteria) to be considered. Each expert answers the certain questions to illustrate the degree of a criterion i effect criterion j due to her or his beliefs. For now a_{ij} denotes pairwise comparisons between any two criteria and it is assigned integer score ranging from 0, 1, 2, 3, and 4. The scores are given by each expert and $X^1 X^2 \cdots X^H$ are the answers of each of them that make the $n \times n$ nonnegative matrix $X^k = [x_{ij}^k]_{n\times n}$, with $1 < k < H$. A high score indicates a belief that greater improvement in i is required to improve j. Then it is possible to calculate the $n \times n$ average matrix A on account of all experts' opinions by averaging the H their scores as follows:

$$[a_{ij}]_{n\times n} = \frac{1}{H}\sum_{k=1}^{H}[x_{ij}^k]_{n\times n}. \quad (1)$$

The average matrix $[a_{ij}]_{n\times n}$ is also called the initial direct-influenced matrix which indicates the initial direct effects each criterion exerts on and receives from other criteria. Moreover in this step, obtaining the causal effect between each pair of criteria in a system by drawing an influence map will be possible. Also consider the following.

If $a_{ij} \leq 1$ (independence is identified among all criteria; otherwise, nonindependence will be identified).

Table 1: Total-relation matrix of environmental protection and green logistics.

	Environmental protection and green logistics					
	Procurement	Production	Distribution	Reverse logistics	Packaging	R
Green design	0.679	0.787	0.59	0.408	0.521	2.985
ISO 14001	0.578	0.751	0.539	0.387	0.463	2.718
Pollution control	0.429	0.639	0.557	0.371	0.317	2.313
Eco-labeling	0.691	0.818	0.653	0.41	0.52	3.092
Life cycle	0.564	0.692	0.51	0.328	0.288	2.382
C	2.941	3.687	2.849	1.904	2.109	

Table 2: Total-relation matrix of green logistics and environmental protection.

	Green logistics and environmental protection					
	Green design	ISO 14001	Pollution control	Eco-labeling	Life cycle	R
Production	0.42	0.065	0.365	0.282	0.338	1.47
Procurement	0.454	0.144	0.571	0.345	0.36	1.874
Distribution	0.062	0.024	0.341	0.095	0.046	0.568
Reverse logistics	0.237	0.014	0.281	0.134	0.062	0.728
Packaging	0.024	0.018	0.098	0.079	0.011	0.23
C	1.197	0.265	1.656	0.935	0.817	

Table 3: Ranking dimensions: environmental protection on green logistics.

	Ranking of affected factors	Ranking of influential factors
1	Production	Eco-labeling
2	Procurement	Green design
3	Distribution	ISO 14001
4	Packaging	Life cycle
5	Reverse logistics	Pollution control

Table 4: Ranking dimensions based on I relation.

	Ranking of affected factors	Ranking of influential factors
1	Pollution control	Procurement
2	Green design	Production
3	Eco-labeling	Reverse logistics
4	Life cycle	Distribution
5	ISO 14001	Packaging

The structural relations between the criteria of a system are converted to intelligible and logical map of the system.

Step 2 (*normalizing the initial direct-relation matrix*). By normalizing the average matrix A, normalized initial direct relation matrix D is obtained in the following formulation:

$$S = \max\left\{\max \sum_{j=1}^{n} a_{ij}, \max \sum_{i=1}^{n} a_{ij}\right\},$$
$$D = \frac{A}{S}. \tag{2}$$

Consequently total direct effects that criterion i exerts on the other criteria are obtained by sum of each row i of matrix A; the sum of each column j represents most direct effects on others by total direct effects of the criterion. Likewise, since the sum of each column j of matrix A represents the total direct effects received from other criteria by criterion i; $\max \sum_{i=1}^{n} a_{ij}$ represents the total direct effects that the criterion j receives, the most direct effects, from other criteria and the positive numerical s takes the smaller of the two as the upper bound, and the matrix D is obtained by dividing each element of A by the scalar s. Each element d_{ij} of matrix D is between zero and less than 1: $0 < d_{ij} < 1$.

Step 3 (*calculating the total-relation matrix*). A continuous reduction of the indirect effects of problems beside the powers of matrix D, like to an engrossing Markov chain matrix, guarantees convergent solutions to the matrix inversion.

Note that

$$D^2, D^3, \ldots, D^{\infty},$$
$$\lim_{m\to\infty} D^m = [0]_{n\times n}, \tag{3}$$

$[0]_{n\times n}$ is a $n \times n$ null matrix.

The total relation matrix $T_{n\times n}$ is achieved as follows:

$$\begin{aligned}\sum_{m=1}^{\infty} D_i &= D + D^2 + D^3 \cdots D^m \\ &= D\left(I + D + D^2 + \cdots + D^{m-1}\right) \\ &= D(I-D)^{-1}(I-D)\left(I + D + D^2 + \cdots + D^{m-1}\right) \\ &= D(1-D)^{-1}\left(I - D^m\right) = D(I-D)^{-1},\end{aligned} \tag{4}$$

where I is identity matrix and T is total relation matrix ($[T]_{n\times n}$).

Table 5: Total-relation matrix for elements of environmental protection.

	Environmental protection							
	EP1	EP2	EP3	EP4	EP5	R	$R+C$	$R-C$
Green design (EP1)	0.677	0.75	0.923	0	0	2.35	5.46	−0.76
ISO 14001 (EP2)	0.815	0.5	0.85	0.218	0.154	2.537	5.063	0.011
Pollution control (EP3)	0.514	0.443	0.358	0.189	0.133	1.637	4.946	−1.672
Eco-labeling (EP4)	0.54	0.401	0.568	0.172	0.121	1.802	2.553	1.051
Life cycle (EP5)	0.564	0.432	0.61	0.172	0.121	1.899	2.428	1.37
C	3.11	2.526	3.309	0.751	0.529			

Table 6: Total-relation matrix for elements of green logistics.

	Green logistics							
	LG1	LG2	LG3	LG4	LG5	R	$R+C$	$R-C$
Procurement (GL1)	0.523	0.491	0.924	0.924	0.734	3.596	6.977	0.215
Production (G2)	0.671	0.471	0.916	0.914	0.74	3.712	6.606	0.818
Distribution (GL3)	0.816	0.747	0.892	0.888	0.949	4.292	8.914	−0.33
Reverse logistics (GL4)	0.645	0.557	0.847	0.844	0.688	3.581	8.191	−1.029
Packaging (GL5)	0.726	0.628	1.043	1.04	0.667	4.104	7.882	0.326
C	3.381	2.894	4.622	4.61	3.778			

7. Case Analysis Result and Discussion

In this phase, at first in part one, both direct and indirect influences will be achieved by applying DEMATEL technique according to the arcs (A and B). After that in part two, direct and indirect influences and also interdependencies will be found out inside clusters based on loops (C and D).

Part One. Direct and Indirect Influences between Elements of Two Clusters.

Step 1. At first, a committee was formed including the ten experts from supply chain department in an automotive company which is named Iran Khodro.

Step 2 (*finding the initial direct-relation (average) matrix*). Figure 4 illustrates the values of relationships between elements that are determined by pairwise comparisons between any two criteria according to the experts' opinions and they are assigned integer score ranging from 0, 1, 2, 3, and 4. Figure 4, shows network relation among the elements of two clusters. The values in Figure 4 are calculated according to (1).

Step 3. Normalized initial direct relation: direct-relation (average) matrix D is obtained by normalizing the initial matrix A according to (2).

Step 4. Calculate the total-relationships matrix T for causal relation by achieving the $D(I-D)^{-1}$ according to (4). Tables 1 and 2 indicate the total-relation matrix T.

According to Table 1, eco-labeling has the highest degree of dispatching impacts (R) on aspects of green logistics as 3.092. After eco-labeling, green design has major impact on green logistics cluster with 2.985. Indeed, production, procurement, distribution packaging, and reverse logistics get the most impact from eco-labeling and green design, respectively.

According to Table 2, in this interaction first, production and then procurement have the highest degree of dispatching impacts (R) on aspects environmental protection factors as 1.874 and 1.47, respectively. In contrast, pollution control receives the maximum effects from factors of green logistics as 1.656, both direct and indirect.

8. Ranking Dimensions Based on Impact of Environmental Protection on Green Logistics

In this step all factors are prioritized according to their power in sending impact or receiving effect to other factors. According to Table 3, the maximum total effects both direct and indirect which are received from factors of environmental protection are related to production. As a result, to improve the green logistics cluster based on this relation, eco-labeling and green design have to be considered more than other factors in environmental protection group.

9. Ranking Dimensions Based on Impact of Green Logistics on Environmental Protection

Table 4 indicates the priority of all factors according to their power in sending impact or receiving effect from other factors based on Impact of GL on EP. According to prioritizing the factors, to develop the environmental protection cluster based on this relation, production and then procurement

Table 7: Ranking dimensions of environmental protection.

	Ranking of important factors	Ranking of affected factors	Ranking of influential factors
1	Green design	Pollution control	ISO 14001
2	ISO 14001	Green design	Green design
3	Pollution control	ISO 14001	Life cycle
4	Eco-labeling	Eco-labeling	Eco-labeling
5	Life cycle	Life cycle	Pollution control

Table 8: Ranking dimensions of green logistics.

	Ranking of important factors	Ranking of affected factors	Ranking of influential factors
1	Distribution	Distribution	Production
2	Reverse logistics	Reverse logistics	Distribution
3	Packaging	Packaging	Packaging
4	Procurement	Production	Reverse logistics
5	Production	Procurement	Procurement

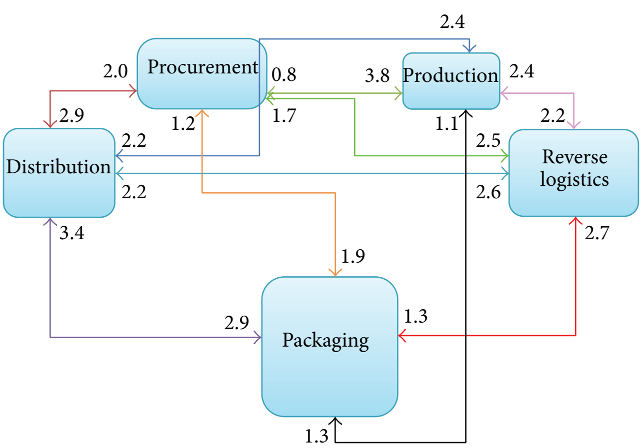

Figure 5: Graphical initial direct impact relation inside environmental protection.

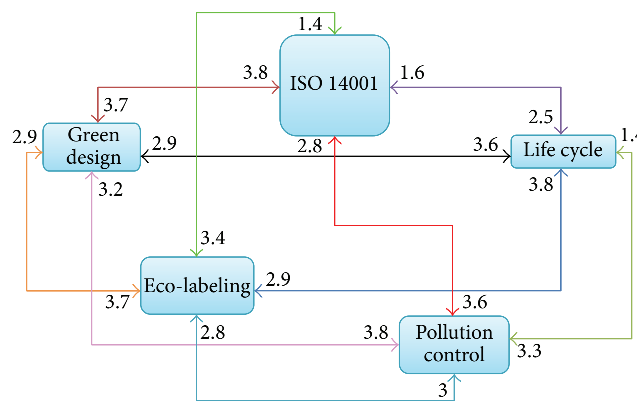

Figure 6: Graphical initial direct impact relation inside green logistics.

have to be considered more than other factors in green logistics group.

Part Two. Direct and Indirect Influences between Elements Inside of Two Clusters. In this part all steps are same as part one, but calculations are based on loops. Figures 5 and 6 show network relations inside the elements of two clusters. The values in Figures 4 and 5, are calculated according to (1).

Normalized initial direct relation matrix D is obtained by normalizing the initial matrix A according to (2).

Total-Relation Matrix for Environmental Protection. The total-relationships matrix T for causal relation by achieving the $D(I-D)^{-1}$ according to (4). Tables 5 and 6 indicate the total-relation matrix T.

Table 5 demonstrates the total-relationships matrix for aspects of environmental protection cluster. To the degree that Table 5, both direct and indirect impacts among dimensions of environmental protection are emerged.

According to the result of Table 5, the maximum degree of influential impact R (2.537) and maximum degree of receiving impact C (3.309) are related to ISO 14001 and pollution control, respectively. It means that ISO 14001 has the highest impacts on other aspects and pollution control is the most influenced factor in this category. In addition, by considering $(R + C)$ scores, the highest value belongs to green design with 5.46. Hence, green design plays a central role between dimensions and it catches the most important position in the group. Nevertheless, the $(R - C)$ value of green design is negative (−0.76), fairly below zero and it is an effect factor.

Based on the result of Table 6, the maximum values of R (4.292) and C (4.622) are related to distribution. It means that distribution has the greatest impacts on other factors and also it is influenced by other factors mostly at the same time. Similarly, by considering the amount of $(R + C)$, the highest value belongs to distribution. In spite of the considerable degree of importance of the role that distribution has in

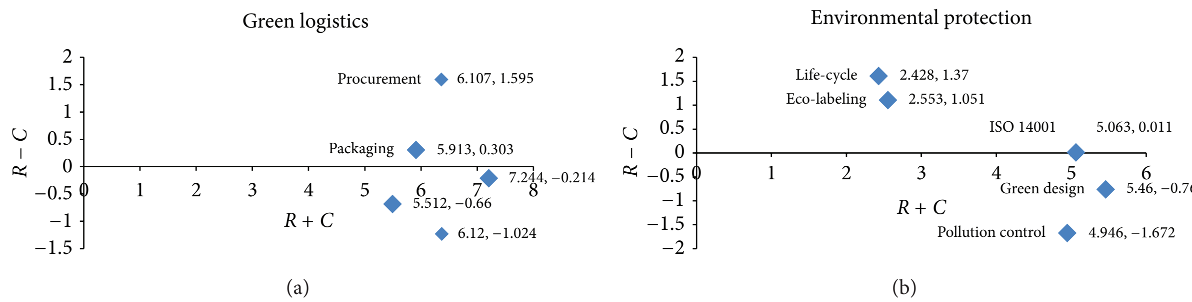

Figure 7: Impact relationship diagram.

the system, it receives more impacts from the whole green logistics group.

Ranking Dimensions of Environmental Protection and Green Logistics. The priority of factor importance, factor influenced, and factor influencing are illustrated in Tables 7 and 8, respectively. According to Table 7, green design plays the most important role in EP cluster, but ISO 14001 has the highest impact on other 4 dimension in EP cluster. On the other hand, pollution control receives the most impact from other factors inside the EP cluster.

By considering Table 8, distribution plays the most important role in GL cluster, but it is the most affected factor in GL cluster. Production is the most powerful factor inside the GL cluster as well.

Impact-Relation Map of Environmental Protection and Green Logistics. The impact relationship diagram is provided by mapping a data series of $(R+C, R-C)$ in Figure 7. The causal diagram represents the importance of each of environmental protection and green logistic factors based results that are indicated in Tables 5 and 6. Elements that are located in the positive part of the graph belong to the cause group and the others that are posited in the negative part of the chart belong to the effect group. It would be necessary to focus on the cause group dimensions which will be discussed in conclusion. According to the causal diagram in Figure 7, life cycle, eco-labeling, and ISO 14001, production, packaging, and procurement should be paid more attention to develop the system.

10. Conclusion

This study proposes the multilevel causal framework to improve green supply chain by applying the DEMATEL method to analyze and prioritize two essential green image groups and their elements in automotive industries. The results of this research enable enterprises to find out which suppliers are suitable by considering the environmental practices in proposed multilevel causal model. Finally, all concepts inside the clusters are divided into cause and effect groups by applying DEMATEL method. By considering Tables 5 and 6, in EP cluster cause group consists of "life cycle," "eco-labeling," and "ISO 14001" and effect group includes "pollution control" and "green design" while in the GL cluster cause group contains "production," "packaging," and "procurement" and effect group includes "distribution" and "reverse logistics." To develop the whole system, enterprises and suppliers have to concentrate on the cause group because elements in cause group have considerable impacts on the system, especially on elements in effect group. By improving the cause group, the whole system will be developed automatically. In spite of the considerable degree of importance of the role that green design plays in the system, it gets more impacts through the environmental protection system; it suggests that although green design is just slightly influenced by other system aspects, it has significant influence on the other factors and plays the central role in environmental protection cluster at the same time. As a result it could not be the most powerful factor in this category. Therefore, the proposed model can be applied for two purposes: first, it would help enterprisers to find out which factors are more effective and important to select the best possible green supplier with regard to both direct and indirect relations between elements. On the other hand, if a company is a supplier for other companies and wants to implement environmental practices in its own manufacturing system, it can apply the model for the whole the system.

In fact, the case study of this research finds criteria that influence green supplier selection. The current study finds that both eco-labeling and procurement have a considerable impact on the other criteria, so by improving these 2 criteria, other criteria will be improved automatically. This study suggests further researches to extend the scope of this study or add green image group to proposed causal model for improving green supply chain practices more acquire.

Conflict of Interests

The authors declare that this research work has no possible conflict of interests.

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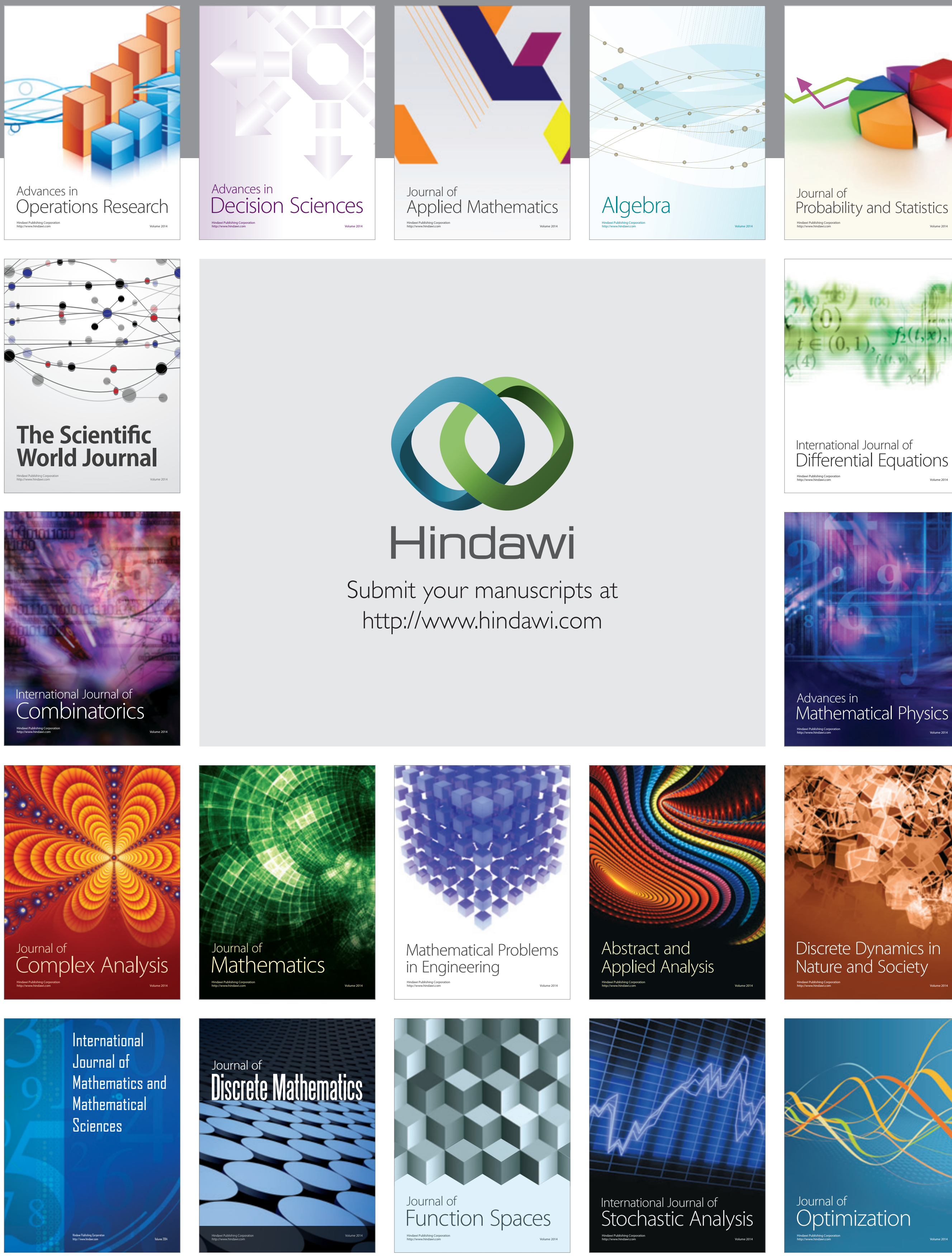
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