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Identifying the critical factors of green supply chain management: Environmental benefits in Pakistan

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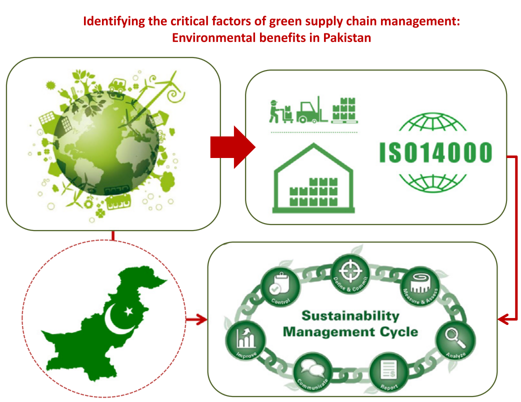
HIGHLIGHTS

- Developed a DEMATEL model based on ISO 14000 regarding GSCM.
- Provided empirical evidence on relationship between GSCM and performance practices.
- Analysis of GSCM practices in the industrial sector of Pakistan.
- Reduction the destructive effect of pollution on the environment.
- Guidelines to managers and decision makers about their approach towards GSCM.

GRAPHICAL ABSTRACT



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ABSTRACT

Pakistan is a developing country characterized by a growing industrialization, which is the major cause of environmental pollution in the country. To control the significant increase in pollution a green incentive has started, aiming to moderate the adverse effects of environmental pollution. Thus, Green Supply Chain Management (GSCM) plays an important role in influencing the total environment impact of any organizations. This study considers ten Pakistani industries that have implemented GSCM practices. The Decision-Making Trial and Evaluation Laboratory technique (DEMATEL) is used to find influential factors in selecting GSCM criteria. The results show that organizational involvement is the most important dimension useful to implement GSCM practices. In addition, commitment from senior managers, ISO 14000 certification of suppliers and recycle of waste heat are considered significant factors. The paper also signifies the casual relationship among the dimensions and the factors in the form of diagraphs. The main management implication of the paper is to help decision makers to focus on the critical dimensions/factors in order to implement the GSCM practices more effectively in Pakistan.

1. Introduction

Due to the increase in environmental pressures and desire for economic wellbeing, Green Supply Chain Management has emerged as an

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important strategy that can contribute to sustainability performance enhancement (Ruiz-Benitez et al., 2017). In fact, the concept of GSCM is to integrate environmental thinking into supply chain management (Srivastava, 2007; Cooper et al., 1997). In Pakistan GSCM is still in its developing stages since it not been a long time that industries are implementing these practices (Government of Pakistan, 2015). With the increase of the environmental constraints it becomes essential for a company to carry out the GSCM practices efficiently and to improve its environmental image (Sheu et al., 2005; Sheu et al., 2005; Hansmann and Kroger, 2001).

In fact, through advantage of GSCM practice, companies can select from a wide variety of suppliers and to eliminate the environmental impacts of supply chain activities Thus, new opportunities that help against the competition and also in including new values into the business must be explored (Hansmann and Kroger, 2001).

But, as stated by Grim (Grimm et al., 2014) in reality the implementation of GMSM practices has numerous difficulties. It would be relevant investigate effectively practices to address suppliers' environmental performance according to the specific need of each national and regional context. Unfortunately, research on this issue is relatively immature. For the above reasons, this research aims to investigate the industrial scenario in Pakistan. According to literature review and companies surveys three main dimensions: 1) *organizational involvement*; 2) *supplier selection*; and *eco-design* are identified that contribute towards the GSCM practices (Tseng et al., 2009). The dimensions are further divided into their respective factors: 1) *commitment from senior managers*; 2) *commitment from mid-level managers*; 3) *improvement by cross-functional corporations*; 4) ISO 14001 certification; 5) *environmental quality management*; 6) *cooperation with suppliers*, 7) *audit of suppliers*, 8) *ISO 14000 certification*; 9) *environmental friendly second-tier suppliers*, 10) *reduced material/energy consumption*, 11) *reuse/recycle of material*; and 12) *recycle of waste heat*.

The main goal of this study is to identify, using the DEMATEL (Decision Making Trial and Evaluation Laboratory) method, the critical dimensions and factors in GSCM developing an interrelationship between the dimensions of GSCM and also among their respective factors in order to promote environmental improvement actions within ten Pakistani companies. The direct and indirect affect among criteria, and computes the causal relationship and strength among GSCM factor is analyzed. The advantage of the DEMATEL method is the capability of revealing the relationship between these factors which influence other factors. Data were collected to identify to find key factor criteria to improve performance and provides a novel approach of decision-making information in GSCM implementation.

The rest of the study is organized as follows: Section 3 analyses literature review on this topic; in Section 5 the methodological approach is described; Section 7 describes the analysis and the case study; Section 2 discusses the main results obtained; and finally in Section 6 certain conclusions are drawn and potential issues and opportunities in the realm of GSCM are identified.

2. Literature review: approaches and critical factors of GSCM

Supply Chain Management (SCM) is considered as an important concept in managerial strategies (Chopra and Meindl, 2001). Li and Wang (2007) define supply chain management as the integration of internal organizational decisions with external factors. While, according to Gilbert (2001), Green Supply Chain Management (GSCM) implements all SCM practices taking in consideration their impact on the environment. Naini et al. (2011) clarify that the adoption of GSCM practices helps organizations to reduce the environmental risks and optimize material and energy consumption. However, several authors have recognized various critical factors of GSCM, briefly defined below (Mumtaz et al., 2018).

In 1996, Lamming and Hampson (1996) analyze the use of some good practices such as lifecycle management analysis (LCA), waste management and product stewardship etc.; they associated the use of these tools with SCM practices in order to establish an environmental friendly policy with suppliers and to assist in improvement. Unlike, Lamming and Hampson, Lippmann (Lippmann, 1999) suggests various activities and steps that an organization could adopt to enhance their environmental performance (such as written GSCM policies, supplier meetings, senior-level leadership, cross-functional cooperation, evaluation of suppliers and having supportive relations with both customers and suppliers). Similarly, Fai Pun (2006) identifies three groups of good practices: policy, product/process and performance evaluation. His results indicate that top management support is the most important factor contributing towards the achieving environmental friendly operations. While, Bowe et al. (2001) identify three kinds of green supply chain 1) *greening process*, that considers relationships with suppliers and recycling; 2) *product-based green supply* that includes treatment of the waste products; and 3) *advanced green supply* that includes implementing activities such as assessment of consumer performance, collaborative clean technology programs with suppliers, and risk sharing in the environmental standards.

Afterwards, in 2006, Hu and Hsu (2006) identify four critical dimensions in Taiwanese electronic industry, using a fuzzy analytic hierarchy approach: supplier management, product recycling, organizational involvement, and life cycle management. Another interesting study is proposed by Young and Kielkiewicz-Young (2001). Their results suggest that organizations must share sustainability related information, such as purchasing policies of the customers/suppliers, aims and objectives. In addition to this environmental standards such as ISO 14001 or EMAS must be recognized. They also propose that the suppliers' performance can be enhanced by carrying out periodic audits, and through cooperation with suppliers. In 2005, Zhu et al. (2005) assessed and defined the GSCM drivers and practices among several Chinese manufacturing organizations. Their result highlight the importance of international standards such as ISO 14001 certification. Furthermore, they conclude that environmental alertness in Chinese enterprises has improved due to external pressures such as competitive marketing environment. Zhu et al. also claim that support from top and mid-level managers was considered an important factor in implementing GSCM practices effectively. In 2008, Lee and Klassen (2008) conduct a survey considering small and medium sized organizations and comparing the effect of buyers' behavior on the environmental competences of suppliers. They conclude that factors such as “environmental championing,” “external means”, “GSCM” and “development of internal environmental management capabilities” can contribute to the environmental development. More recently, Toke et al. (2012) propose a study to identify the critical factors of GSCM in the Indian automotive industry. They divide GSCM practices into fifteen factors further divided into 113 subfactors. The aim of their study is to rank the crucial factors of GSCM. Their results suggest that support form top management is the most important factor for the success of GSCM. In 2013, Muduli et al. (2013) propose the use of interpretive structural modeling (ISM) to study various behavioral factors that effected GSCM in the mining industry of India. Their results support the outcome suggested by Toke et al. Their results also prove that top management support is the fundamental motivating factor for the success of GSCM. The results of Luthra et al. (2015) varied from Toke et al. (2012), Muduli et al. (2013), and Luthra et al. (2015) develop a set of factors called “critical success factors (CSF)” for successful execution of GSCM. They used ISM to rank these success factors. Their findings show that “Scarcity of Natural Resources” is the most vital CSF.

In summary, the literature analysis has been showed that GSCM is widely recognized. But, its implementation has faced various obstacles. In detail, the literature analysis has pointed out that an evaluation of the cause-effect interrelationships among critical factors of GSCM can play a critical role in influencing implementation of good practices. To address this need, as analyzed by some authors (Dou et al., 2015) several tools have been used to systemically to evaluate green supply chain management issues such as the Analytical Hierarchy Process (AHP), the interpretive structural modeling (ISM), the grey relational analysis. But, in this paper we are interested to capture the cause-effect relationships among factors. Thus, in order to evaluate the cause-effect interrelationships among the enablers, the DEMATEL is applied. DEMATEL method is used respect the other methodologies since the above methodologies are helpful for decision making purposes and they cannot effectively capture the cause-effect relationships among factors. Consequently, this paper aims to contribute to the existing GSCM literature by utilizing the DEMATEL method incorporating the principles of action research in a new light taking into account a developing country, Pakistan. Research like this on GSCM has previously not been conducted in Pakistan. Therefore, this research will give an idea about how the industrial sector of a developing country perceives GSCM practices.

3. Method

Fontela and Gabus (1976) of The Science and Human Affairs Program of Battelle Memorial Institute of Geneva were the first to develop DEMATEL (Decision Making Trial and Evaluation Laboratory) method. This method is used to solve complex interweaved problems (Lin et al., 2011). DEMATEL method does not use assumptions such as the variables being independent of each other. Furthermore, a structural modeling technique is used and diagraphs are constructed to define the relationships between various variables (Liou et al., 2007; Shieh et al., 2014); Tzeng et al., 2007; Gabus and Fontela, 1972; Yang et al., 2008).

The DEMATEL method can be represented by the following steps (Wu and Chang, 2015; Yang et al., 2013; Ho et al., 2011).

3.1. Step 1: Develop a pairwise matrix between factors

Calculation of an average matrix, using a scale 0, 1, 2, and 3, signifying a range from "no influence (0) to high influence (3)". Data is collected where the survey participants are asked, to what extent does factor i affects factor j, or to what extent are the factors related to each other. A notation x_{ij} in the matrix represents how much factor i influences factor j. For $i = j$ (the diagonal elements) there is no affect hence they are represented by "0". For each participant an "$m \times m$" non-negative matrix will be constructed, represented as $x^k = x_{ij}$ where k are the total number of respondents with $1 \le k \le n$, and m are the number of factors in the matrix. If there are "k" number of respondents the average matrix is calculated as follows:

$$\text{average matrix } (a) = \frac{1}{k}\sum_{k=1}^{n} x_{ij}^{k} \quad (1)$$

3.2. Step 2: Determine the initial influence matrix, through normalization of the direct-relation matrix

In this step the normalized initial direct-relation matrix is calculated. The normalized initial direct-relation matrix (N) is calculated by normalizing the average matrix. The matrix "N" is calculated by using the following equations:

$$N = s * (\text{average matrix}) \quad (2)$$

$$s = \left[\frac{1}{max_{1 \le i \le k}\sum_{j=1}^{n} x_{ij}}\right] \quad (3)$$

The sum of each row of a matrix represents the direct effects that factor exert on other factors. Where $max_{1 \le i \le k}\sum_{j=1}^{n} x_{ij}$ represents the factor with the highest influence on the remaining factors. "s" is identified as a scalar quantity which is multiplied to the average matrix to calculate N.

3.3. Step 3: Determine a total relation (influence) matrix

Calculation of the total influence matrix. The total influence matrix can be calculated using the following formula:

$$T = N(I-N)^{-1} \quad (4)$$

Subtract N from an Identity matrix I and take inverse of the answer obtained. Multiply N to the answer in order to calculate the total influence matrix.

Where "I" is an identity matrix and "N" is the normalized initial direct relation matrix.

After calculating the total identity matrix the sum of each row and column is defined.

r_i and c_i representing the sum of the respective row and column. After the sum of each row and column is calculated, compute $(r_i + c_i)$ and $(r_i - c_i)$. $(r_i + c_i)$ represents the importance of factor "i" in the system, higher values indicate greater importance. $(r_i - c_i)$ indicates the net effect that factor "i" contributes to the entire system, a positive value indicates a net cause whereas a negative value specifies that the factors is a net receiver. According to Lee et al. (2011), r_i is the sum of each row in matrix "T", and it represents the magnitude of direct or indirect influence over the remaining factors. Furthermore, c_i is the sum of columns in matrix "T" and it represents the magnitude of influence from other factors. Hence $r_i + c_i$ denotes the strength of association between the factors while $r_i - c_i$ indicates the strength of influence between the factors. Due to this $r_i + c_i$ is defined as the value indicating importance and $r_i - c_i$ as the net receiver.

3.4. Step 4: Determine the cause/effect relationships (prominence-causal diagram) among the factors and relative strengths

Computation of threshold value to plot the diagraph. Matrix "T" has a lot of information on how on factor affects another, by computing the threshold value, the factors with the negligible affects can be filtered out, this makes it easier to plot the diagraph. The threshold value can be calculated by computing the average of the elements in the matrix T. Diagraph is developed by plotting $(r_i + c_i)$ vs. $(r_i - c_i)$. The diagraph constructed in Fig. 1 represents the relationships between the dimensions of GSCM. $r_i + c_i$ is plotted on the x-axis while $r_i - c_i$ on the y-axis. The direction of the arrow heads implies the effect of one dimension on another. For instance, the arrow point form organizational towards supplier selection means that changes in organizational involvement will affect the supplier selection process. The y-axis which indicates the $r_i - c_i$ value implies whether the dimension is a causer or a receiver. A positive value suggests that a particular dimension acts as a net causer while a negative value implies that the dimension is a net receiver.

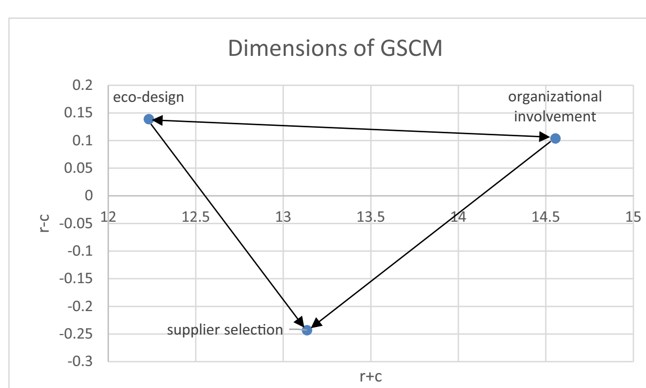

Fig. 1. diagraph of three dimensions of GSCM.

Researchers have confirmed the benefits of using DEMATEL method. According to Lin and Wu (2008), DEMATEL method helps in analyzing the casual relationships between various factors dividing them into cause and effect groups. It also helps in ranking factors based on superior influence. Furthermore, DEMATEL method helps in establishing the interrelationships between multiple factors within a research problem. In this study DEMATEL method helps to rank the dimensions/factors of GSCM. It also helps to find the interrelationships between these factors/dimensions represented visually in the form of diagraphs. According to Shahraki and Paghaleh (2011), diagraphs are more beneficial than "*directionless*" graphs because they can exhibit the relationships between sub-systems more clearly.

4. Case study: Pakistan scenario

In this research three dimensions have been identified that are shown in Table 1 to effectively implement the GSCM practices in Pakistani companies. Ten major process industries were identified. Then, the questionnaires were administered by face-to-face interview (detailed questionnaire is in Appendix 1). Data were collected from the supply chain department of each of the industry. In addition to this, it was made sure that these industries were already carrying out GSCM practices. Data collection started on 1st December 2016 and ended on 5th January 2017.

The dimensions of GSCM are identified from the help of existing literature. According to Zhu et al. (2008) internal factors lead towards the augmentation of GSCM. In addition to this GSCM practices have been divided into dimensions such as internal practices, suppliers and eco design in the current literature (Zhu and Sarkis, 2004; Zhu and Cote, 2002; Zsidisin and Hendrick, 1998). Based on the current literature GSCM parameters taken into consideration are: (1) organizational involvement, (2) supplier selection, and (3) eco-design. These dimensions helps companies and organizations to implement GSCM practices. The dimensions are further divided into twelve corresponding factors. The objective of the study was to identify the critical dimensions and corresponding factors so that organizations could implement GSCM practices effectively. The results are presented in the section below. Details of the calculations are mentioned in Appendix 2.

5. Results

The total direction matrices for the dimensions and factors are calculated in Section 7. From these matrices $(r_i + c_i)$ and $(r_i - c_i)$ values are calculated. These results are tabulated and the respective diagraphs are plotted. The $(r_i + c_i)$ values indicate the relative significance of a particular dimension or factor, whereas the $(r_i - c_i)$ values specify the net effect of a particular dimension or factor on the remaining dimensions/factors, a positive $(r_i - c_i)$ value indicates that a factor is a net cause where as a negative $(r_i - c_i)$ value specifies that it is a net receiver.

The results for the dimensions of GSCM are recorded in Table 2.

Table 1
Three dimensions and twelve respective factors.

Dimensions	Factors
Organizational involvement	Commitment from senior managers
	Commitment from mid-level managers
	Improvements by cross-functional corporations
	ISO 14001
	Environmental quality management
Supplier selection	Cooperation with suppliers
	Audit of suppliers
	ISO 14000
	Environment friendly second-tier suppliers
Eco-design	Reduced material/Energy consumption
	Reuse of waste material
	Recycle of waste heat

Table 2
Dimensions of GSCM.

Dimension	$r_i + c_i$	$r_i - c_i$
Organizational involvement	14.554	0.104
Supplier selection	13.135	−0.243
Eco-design	12.231	0.139

While, the diagraph of these results is shown in Fig. 1. The $(r_i + c_i)$ and $(r_i - c_i)$ values are also listed in the Table. The critical dimension is identified as the one with the largest $(r_i + c_i)$ and positive $(r_i - c_i)$ value. "Organizational Involvement" has the largest $(r_i + c_i)$ and a positive $(r_i - c_i)$ value, hence it is identified as the most critical dimension. "Eco-Design" has a positive $(r_i - c_i)$ value as well, a positive value of $(r_i - c_i)$ indicate that these dimensions will have an impact on the rest of the dimensions. Table 1 also indicates that "Supplier Selection" has a negative $(r_i - c_i)$ value. The negative value denotes that this dimension will be affected by those with a positive $(r_i - c_i)$ value. Furthermore the relationship between the dimensions is presented in the diagraphs plotted in Fig. 1. The directions of the arrows indicate how the dimensions are related to each other. For example, the direction of arrows between organizational involvement and eco design indicate that change in either is going to effect the other. For instance if the organizations behavior changes towards green supply, this change will also affect the supplier selection process. Form the results, we can determine that if an organization wants to implement GSCM practices they must focus of "Organizational Involvement."

"Organizational Involvement" is divided into five factors shown in Table 3 with their respective $(r_i + c_i)$ and $(r_i - c_i)$ values. From the table, "commitment from senior managers" can be identified as the critical factor. The corresponding diagraph is plotted in Fig. 2, it also represents the mutual relationship between the factors.

The results in Table 3 and Fig. 2 imply that commitment from senior managers and commitment from mid-level managers act as the net causes, i.e. when there is a change in these factors they modify the remaining factors as well. The diagraph in Fig. 2 postulates that commitment from senior and mid-level managers mutually affects each other, this means that a change in either one of them is going to affect the other. Furthermore the diagraph expresses that commitment from senior and mid-level managers are the cause of change in the remaining factors as well. The negative $(r_i - c_i)$ values of "improvements by cross-functional corporations, ISO 14001, and environmental management" explains this relationship. Direction of arrows in the diagraph (Fig. 2) represents the relationship among the factors. The results in the table and the diagraph determine that to improve organizational involvement, an organization must have committed senior managers.

"Supplier Selection" is divided into its corresponding four factors. These factors along with their $(r_i + c_i)$ and $(r_i - c_i)$ are represented in Table 4. The corresponding diagraph is plotted in Fig. 3.

Table 4 highlights that ISO 14000 certification has the maximum value of $(r_i + c_i)$ and a positive $(r_i - c_i)$, this means that the most important factor for supplier selection is the ISO 14000 certification. The positive $(r_i - c_i)$ values of ISO 14000, cooperation with suppliers, and environmental friendly suppliers indicate that these factors are the net causes i.e. changes in these factors will have an effect on "Audit of

Table 3
Factors of organizational involvement.

Organizational involvement	$r_i + c_i$	$r_i - c_i$
Commitment from senior managers	16.81	0.21
Commitment from mid-level managers	15.65	0.31
Improvements by cross-functional corporations	12.58	−0.08
ISO 14001	15.94	−0.16
Environmental quality management	16.67	−0.63

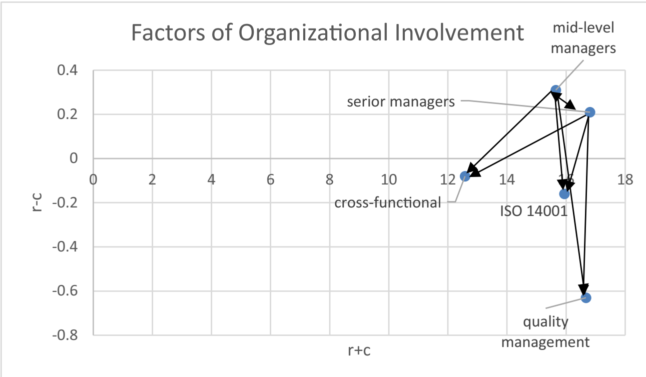

Fig. 2. diagraph of organizational involvement factors.

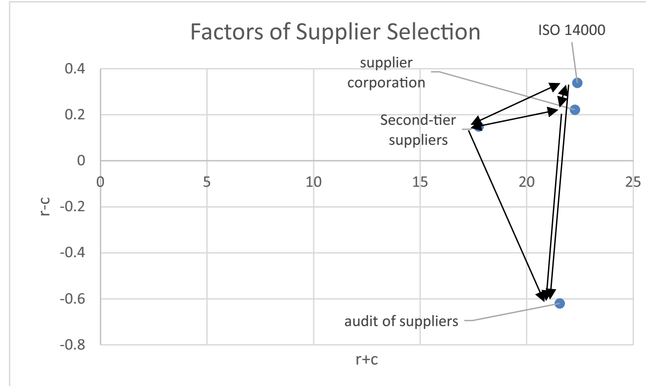

Fig. 3. diagraph of supplier selection factors.

suppliers” as well. The negative ($r_i - c_i$) value indicates that changes in audit of suppliers will not have any effect on the remaining three factors. The diagraph plotted in Fig. 3 represents the relationships between the factors. The diagraph shows that “ISO 14000 certification, cooperation with suppliers, and second-tier suppliers” mutually effect each other, this means that change in either of them will bring changes to the audit of suppliers as well. This relationship is presented by the direction of arrows in the diagraph. The results indicate that in order to choose green suppliers, an organization must focus on the ISO 14000 certification.

“Eco-Design” is divided into three corresponding factors. These factors along with their ($r_i + c_i$) and ($r_i - c_i$) are listed in Table 5.

The resultant diagraph is plotted in Fig. 4. From the results represented in Table 5 it is interpreted that “Recycle of waste heat” is the most vital factor within the eco-design dimension. It is considered the vital factor due to its largest ($r_i + c_i$) and positive ($r_i - c_i$) value. The positive ($r_i - c_i$) value indicates that changes in this factor will cause variations in the other factors. In addition to this “reuse/recycle of material” also has a positive ($r_i - c_i$) value, hence it is also a source of change. The positive ($r_i - c_i$) values of recycle of waste heat and reuse/recycle of material indicate that these factors will have an effect on reduced material/energy consumption, furthermore they will mutually effect each other as well. This means that changes in either of these factors will have an effect on the other. This relationship is graphically presented in the diagraph (Fig. 4). The direction of the arrows in the diagraph represents this relationship. The results prove that for an eco-design to promote GSCM focusing of the recycle of waste heat must be the top most priority of an organization.

The results of this study identifies the critical dimensions for the implementation of GSCM, as well as the respective critical factors.

6. Managerial implications

According to the findings, several implications of management are derived. *Organizational involvement* is the most critical dimension of GSCM. This means that an organization favoring green supply chain, and green process design will favor an eco-friendly supplier, and vice-versa.

Then, *supplier selection* is the second critical dimension. The results calculated from the collected data show that ISO 14000 certification is the most important factor since it provides guidelines and standards to organizations regarding conservation of environment.

The third and final dimension is *Eco-design*. The results determine recycle of waste heat as the most important factor, as it has the largest $r_i + c_i$ value. Due to the lack of heat conservation and heat recovery systems the emission of waste heat is a major problem in the industrial sector. Substantial amount of energy is wasted in the form of heated radiated into the atmosphere. Increasing heat radiations also has an adverse effect on the climate resulting in the increase of net climatic temperature. Therefore, heat management system must be incorporated into the design of industries, it will prove beneficial in both economic and environmental perspective.

The dimensions/factors of GSCM are ranked and the most important ones are chosen to help in better implementation of GSCM. As stated above, dimensions with larger $r_i + c_i$ value are considered critical. In addition to this the dimensions/factors are divided into net causers and net receivers. Changes in the net causers will have an effect on the net receivers. Positive $r_i - c_i$ values represent net causers while negative values represent net receivers. While, choosing the critical factors $r_i - c_i$ values must also be considered. A factor with the largest $r_i + c_i$ value with a positive $r_i - c_i$ value is considered the most important. For instance, organizational involvement has a $r_i + c_i$ value of 14.554 and a positive $r_i - c_i$ value. Furthermore eco-design has a $r_i + c_i$ value of 12.231 and a positive $r_i - c_i$ organizational involvement is considers as the critical dimension due to the larger $r_i + c_i$ value, irrespective of the difference between the magnitude. Eco-design will be ranked as the second important dimension. Therefore, while selecting the critical dimensions/factors both $r_i + c_i$ and $r_i - c_i$ values must be considered.

The results of this research helps management in implementing GSCM, but the limiting factors include the lack of quantitative assessment of organizational performance. The fear of losing market share or decline in economic performance can prevent organizations to implement these practices.

7. Conclusions

Green Supply Chain Management (GSCM) is a well-known concept in the modern world since the companies recognize the importance to combine environmental management practices form green supplier, green design, green production, etc.

Table 4
Factors of supplier selection.

Supplier selection	$r_i + c_i$	$r_i - c_i$
Cooperation with suppliers	22.258	0.222
Audit of suppliers	21.546	−0.620
ISO 14000 Certification	22.375	0.339
Environment friendly second-tier suppliers	17.741	0.149

Table 5
Factors of eco-design.

Eco-design	$r_i + c_i$	$r_i - c_i$
Reduced material/energy consumption	21.513	−0.471
Reuse/recycle of material	21.168	0.178
Recycle of waste heat	22.874	0.293

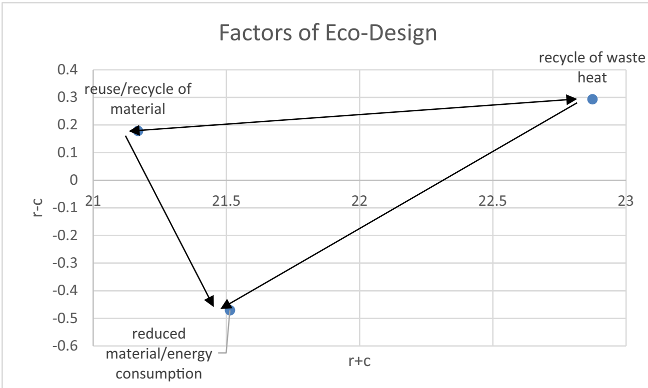

Fig. 4. Diagraph of eco-design factors.

The aim of the study was to identify the important dimensions and factors of GSCM practices in order to effectively implement it. For this purpose DEMATEL modeling method was used. GSCM practices are divided into three dimensions which are further divided into twelve factors. The results of this study show that organizational involvement is the most important dimension in GSCM. The study also identifies the factors that act as net causes. Two dimensions and seven factors are identified as the net causes, these include organizational involvement, eco-design, commitment form senior and mid-level managers, Cooperation with suppliers, ISO 14000 certification, environmental friendly second tier suppliers, recycle of waste heat and reuse/recycle of waste heat.

This research provides a guidelines to managers and decision makers about their approach towards GSCM. By focusing towards the factors identified in this research GSCM can be implemented more effectively. For further research a quantitative analysis of organization performance, after implementation of the critical factors will be carried out. Organization performance will include factors such as impact of GSCM practices on economic performance, the amount of environmental pollution (CO_2 emissions), and other external factors such as customer satisfaction and market impact. Furthermore, due to the novelty of GSCM adoption in Pakistan, the number of organizations implementing these practices are limited, hence a smaller sample size is used. This is a limitation of the study. Thus, future research will aim to investigate also a larger sample of companies.

Appendix 1 ***Dimensions of GSCM***

(0: no Influence, 1: Low Influence, 2: Medium Influence, 3: High Influence)

Evaluation for the influence relationship among the four dimensions of Green Supply Chain Management.

	Organizational involvement	Supplier selection	Eco-design
Organizational involvement			
Supplier selection			
Eco-design			

Factors of GSCM

(0: no Influence, 1: Low Influence, 2: Medium Influence, 3: High Influence)

Evaluation for the influence relationships among factors of GSCM.

Organizational involvement	Commitment from senior managers	Commitment from mid-level managers	Improvements by cross-functional corporations	ISO 14001 certification	Environmental quality management
Commitment from senior managers					
Commitment from mid-level managers					
Improvements by cross-functional corporations					
ISO 14001 certification					
Environmental quality management					
Supplier selection	Cooperation with suppliers	Environmental audit of suppliers	ISO 14000 certification	Environment friendly second-tier supplier	
Cooperation with suppliers					
Environmental audit of suppliers					
ISO 14000 certification					
Environment friendly second-tier supplier					

(0: no Influence, 1: Low Influence, 2: Medium Influence, 3: High Influence)

Eco-design	Reduced material/energy consumption	Reuse/recycle of material	Recycle of waste heat
Reduced material/energy consumption			
Reuse/recycle of material			
Recycle of waste heat			

Appendix 2

Dimensions:

$$X_1 = \begin{bmatrix} 0 & 3 & 3 \\ 3 & 0 & 1 \\ 3 & 1 & 0 \end{bmatrix} X_2 = \begin{bmatrix} 0 & 3 & 2 \\ 2 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix} X_3 = \begin{bmatrix} 0 & 3 & 3 \\ 3 & 0 & 2 \\ 3 & 1 & 0 \end{bmatrix} X_4 = \begin{bmatrix} 0 & 2 & 3 \\ 2 & 0 & 2 \\ 3 & 2 & 0 \end{bmatrix} X_5 = \begin{bmatrix} 0 & 3 & 2 \\ 3 & 0 & 1 \\ 3 & 2 & 0 \end{bmatrix}$$

$$X_6 = \begin{bmatrix} 0 & 3 & 2 \\ 3 & 0 & 2 \\ 1 & 1 & 0 \end{bmatrix} X_7 = \begin{bmatrix} 0 & 3 & 1 \\ 3 & 0 & 2 \\ 3 & 2 & 0 \end{bmatrix} X_8 = \begin{bmatrix} 0 & 2 & 3 \\ 2 & 0 & 1 \\ 2 & 2 & 0 \end{bmatrix} X_9 = \begin{bmatrix} 0 & 3 & 1 \\ 2 & 0 & 1 \\ 2 & 1 & 0 \end{bmatrix} X_{10} = \begin{bmatrix} 0 & 2 & 2 \\ 2 & 0 & 2 \\ 3 & 2 & 0 \end{bmatrix}$$

The matrices above show the interrelationship between the dimensions (Organizational Involvement, Supplier selection and Eco-Design).
The average matrix "a" is calculated by totaling the ten respondents above,

$$a = \begin{bmatrix} 0 & 2.7 & 2.2 \\ 2.5 & 0 & 1.5 \\ 2.3 & 1.5 & 0 \end{bmatrix}$$

The second step is to calculate the normalized initial direct-relation matrix "N",

$$N = \begin{bmatrix} 0 & 0.551 & 0.449 \\ 0.510 & 0 & 0.306 \\ 0.469 & 0.306 & 0 \end{bmatrix}$$

The third step is to calculate the total relation matrix "T",

$$T = \begin{bmatrix} 2.412 & 2.591 & 2.325 \\ 2.460 & 1.972 & 2.014 \\ 2.353 & 2.125 & 1.701 \end{bmatrix}$$

The final step is to calculate the threshold value, this is done by calculating the average of all the elements of matrix "T". The threshold value is "2.217".
Organizational Involvement:

$$X_1 = \begin{bmatrix} 0 & 3 & 2 & 3 & 3 \\ 2 & 0 & 2 & 2 & 2 \\ 2 & 2 & 0 & 1 & 2 \\ 3 & 2 & 1 & 0 & 3 \\ 2 & 1 & 1 & 3 & 0 \end{bmatrix} X_2 = \begin{bmatrix} 0 & 2 & 2 & 3 & 3 \\ 3 & 0 & 2 & 2 & 2 \\ 2 & 2 & 0 & 1 & 2 \\ 3 & 3 & 2 & 0 & 3 \\ 3 & 2 & 1 & 3 & 0 \end{bmatrix} X_3 = \begin{bmatrix} 0 & 3 & 3 & 2 & 3 \\ 3 & 0 & 2 & 2 & 2 \\ 2 & 1 & 0 & 2 & 2 \\ 2 & 2 & 2 & 0 & 2 \\ 3 & 2 & 2 & 2 & 0 \end{bmatrix} X_4 = \begin{bmatrix} 0 & 3 & 2 & 3 & 2 \\ 3 & 0 & 2 & 2 & 3 \\ 2 & 2 & 0 & 3 & 2 \\ 3 & 3 & 2 & 0 & 3 \\ 3 & 2 & 2 & 3 & 0 \end{bmatrix}$$

$$X_5 = \begin{bmatrix} 0 & 3 & 3 & 3 & 3 \\ 2 & 0 & 2 & 3 & 3 \\ 2 & 2 & 0 & 2 & 3 \\ 3 & 3 & 2 & 0 & 3 \\ 3 & 3 & 2 & 3 & 0 \end{bmatrix} X_6 = \begin{bmatrix} 0 & 3 & 2 & 3 & 3 \\ 3 & 0 & 3 & 3 & 2 \\ 2 & 2 & 0 & 2 & 2 \\ 3 & 2 & 1 & 0 & 3 \\ 2 & 2 & 1 & 3 & 0 \end{bmatrix} X_7 = \begin{bmatrix} 0 & 3 & 2 & 3 & 3 \\ 2 & 0 & 2 & 2 & 2 \\ 2 & 2 & 0 & 1 & 1 \\ 3 & 2 & 1 & 0 & 2 \\ 2 & 2 & 1 & 3 & 0 \end{bmatrix} X_8 = \begin{bmatrix} 0 & 3 & 2 & 3 & 3 \\ 3 & 0 & 2 & 3 & 2 \\ 2 & 2 & 0 & 2 & 2 \\ 3 & 2 & 1 & 0 & 2 \\ 3 & 2 & 1 & 3 & 0 \end{bmatrix}$$

$$X_9 = \begin{bmatrix} 0 & 3 & 3 & 2 & 3 \\ 2 & 0 & 2 & 3 & 3 \\ 2 & 2 & 0 & 2 & 2 \\ 3 & 2 & 1 & 0 & 3 \\ 3 & 2 & 2 & 2 & 0 \end{bmatrix} X_{10} = \begin{bmatrix} 0 & 2 & 2 & 2 & 3 \\ 2 & 0 & 3 & 3 & 3 \\ 2 & 2 & 0 & 1 & 2 \\ 2 & 3 & 1 & 0 & 3 \\ 3 & 2 & 1 & 2 & 0 \end{bmatrix}$$

The matrices above show the interrelationship between the factors of organizational involvement.
The average matrix "a",

$$a = \begin{bmatrix} 0 & 2.8 & 2.3 & 2.7 & 2.6 \\ 2.5 & 0 & 2.2 & 2.5 & 2.4 \\ 2.0 & 1.9 & 0 & 1.7 & 2.1 \\ 2.8 & 2.4 & 1.4 & 0 & 2.7 \\ 2.7 & 2.0 & 1.4 & 2.7 & 0 \end{bmatrix}$$

The normalized initial direct-relation matrix and the total relation matrix are as follows:

$$N = \begin{bmatrix} 0 & 0.2688 & 0.2208 & 0.2592 & 0.2496 \\ 0.240 & 0 & 0.2112 & 0.240 & 0.2304 \\ 0.192 & 0.1824 & 0 & 0.1632 & 0.2016 \\ 0.2688 & 0.2304 & 0.1344 & 0 & 0.2592 \\ 0.2592 & 0.192 & 0.1344 & 0.2592 & 0 \end{bmatrix}$$

$$T = \begin{bmatrix} 1.66 & 1.75 & 1.45 & 1.82 & 1.83 \\ 1.75 & 1.44 & 1.36 & 1.71 & 1.72 \\ 1.46 & 1.35 & 0.99 & 1.40 & 1.44 \\ 1.75 & 1.61 & 1.29 & 1.50 & 1.72 \\ 1.68 & 1.52 & 1.24 & 1.64 & 1.44 \end{bmatrix}$$

The threshold value for the above matrix is "1.541".
Supplier Selection:

$$X_1 = \begin{bmatrix} 0 & 3 & 3 & 2 \\ 3 & 0 & 3 & 2 \\ 3 & 3 & 0 & 1 \\ 2 & 2 & 1 & 0 \end{bmatrix} X_2 = \begin{bmatrix} 0 & 2 & 3 & 2 \\ 2 & 0 & 2 & 1 \\ 2 & 2 & 0 & 2 \\ 2 & 1 & 2 & 0 \end{bmatrix} X_3 = \begin{bmatrix} 0 & 3 & 2 & 2 \\ 3 & 0 & 2 & 2 \\ 2 & 2 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix} X_4 = \begin{bmatrix} 0 & 3 & 3 & 1 \\ 3 & 0 & 2 & 2 \\ 3 & 3 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix}$$

$$X_5 = \begin{bmatrix} 0 & 3 & 3 & 2 \\ 2 & 0 & 3 & 2 \\ 3 & 3 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix} X_6 = \begin{bmatrix} 0 & 3 & 3 & 2 \\ 2 & 0 & 3 & 2 \\ 3 & 3 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix} X_7 = \begin{bmatrix} 0 & 2 & 3 & 2 \\ 3 & 0 & 2 & 1 \\ 2 & 3 & 0 & 2 \\ 2 & 1 & 2 & 0 \end{bmatrix} X_8 = \begin{bmatrix} 0 & 2 & 2 & 2 \\ 2 & 0 & 3 & 2 \\ 3 & 3 & 0 & 2 \\ 1 & 2 & 2 & 0 \end{bmatrix}$$

$$X_9 = \begin{bmatrix} 0 & 3 & 2 & 2 \\ 2 & 0 & 2 & 1 \\ 3 & 3 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix} X_{10} = \begin{bmatrix} 0 & 3 & 3 & 2 \\ 3 & 0 & 3 & 1 \\ 3 & 3 & 0 & 2 \\ 2 & 1 & 2 & 0 \end{bmatrix}$$

The matrices above show the interrelationship between the factors of supplier selection.
The average matrix is:

$$a = \begin{bmatrix} 0 & 2.7 & 2.7 & 1.9 \\ 2.5 & 0 & 2.5 & 1.6 \\ 2.7 & 2.8 & 0 & 1.9 \\ 1.9 & 1.7 & 1.9 & 0 \end{bmatrix}$$

The normalized initial direct-relation matrix and the total direction matrix are given below:

$$N = \begin{bmatrix} 0 & 0.365 & 0.365 & 0.257 \\ 0.338 & 0 & 0.338 & 0.216 \\ 0.365 & 0.378 & 0 & 0.257 \\ 0.257 & 0.229 & 0.257 & 0 \end{bmatrix}$$

$$T = \begin{bmatrix} 2.755 & 3.063 & 3.022 & 2.400 \\ 2.818 & 2.603 & 2.818 & 2.224 \\ 3.051 & 3.099 & 2.784 & 2.423 \\ 2.394 & 2.408 & 2.394 & 1.749 \end{bmatrix}$$

The threshold value of the matrix above is "2.625".
Eco-Design:

$$X_1 = \begin{bmatrix} 0 & 2 & 3 \\ 2 & 0 & 1 \\ 3 & 1 & 0 \end{bmatrix} X_2 = \begin{bmatrix} 0 & 3 & 3 \\ 3 & 0 & 2 \\ 3 & 2 & 0 \end{bmatrix} X_3 = \begin{bmatrix} 0 & 2 & 3 \\ 2 & 0 & 3 \\ 3 & 3 & 0 \end{bmatrix} X_4 = \begin{bmatrix} 0 & 2 & 3 \\ 2 & 0 & 3 \\ 3 & 2 & 0 \end{bmatrix} X_5 = \begin{bmatrix} 0 & 1 & 2 \\ 2 & 0 & 2 \\ 3 & 2 & 0 \end{bmatrix}$$

$$X_6 = \begin{bmatrix} 0 & 2 & 2 \\ 2 & 0 & 3 \\ 2 & 3 & 0 \end{bmatrix} X_7 = \begin{bmatrix} 0 & 2 & 2 \\ 2 & 0 & 3 \\ 2 & 3 & 0 \end{bmatrix} X_8 = \begin{bmatrix} 0 & 2 & 2 \\ 2 & 0 & 2 \\ 3 & 3 & 0 \end{bmatrix} X_9 = \begin{bmatrix} 0 & 2 & 3 \\ 2 & 0 & 2 \\ 2 & 3 & 0 \end{bmatrix} X_{10} = \begin{bmatrix} 0 & 1 & 2 \\ 2 & 0 & 3 \\ 2 & 3 & 0 \end{bmatrix}$$

The matrices above show the interrelationship between the factors of eco-design.
The average matrix "a" is:

$$a = \begin{bmatrix} 0 & 1.9 & 2.5 \\ 2.1 & 0 & 2.4 \\ 2.6 & 2.5 & 0 \end{bmatrix}$$

The normalized initial direct-relation matrix and the total relation matrix are given below:

$$N = \begin{bmatrix} 0 & 0.373 & 0.490 \\ 0.412 & 0 & 0.471 \\ 0.509 & 0.490 & 0 \end{bmatrix}$$

$$T = \begin{bmatrix} 3.327 & 3.449 & 3.745 \\ 3.666 & 3.222 & 3.785 \\ 3.999 & 3.824 & 3.760 \end{bmatrix}$$

The threshold value for the matrix above is "3.642".

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