Resources, Conservation and Recycling 107 (2016) 185–194

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

Investigation of the influential strength of factors on adoption of green supply chain management practices: An Indian mining scenario

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ARTICLE INFO

Article history:
Received 2 June 2014
Received in revised form 22 February 2015
Accepted 4 May 2015

Keywords:
GSCM
Mining industries
DEMATEL
Causal relationships

ABSTRACT

Rapid industrial development that leads to economic growth and massive employment generation needs intense support from mining industries which act as a downstream supply chain partner for an industry. The counter side of intensive and unregulated mining activities is the massive waste generation and environmental degradation. Waste produced by mining industries is acquired by their upstream supply chain partners. So, there is a growing pressure on mining companies to enhance their ecological performance. In this regard, green supply chain management (GSCM), emerged as an environmental strategy that not only improves the environmental performance of individual organizations, but also that of the entire supply chain which has also been accepted by industries. However, an exception is observed in the case of the mining industries in India. This can be attributed to the poor understanding of the involved factors. Hence, an attempt is made here to identify the drivers of GSCM and extract the causal relationship among them through the use of decision making trial and evaluation laboratory (DEMATEL). Further, the strength of influence of these drivers on each other as also on the entire system is investigated to prioritize the drivers according to their influential strength. The results of the study, explore 'top management commitment' and 'competitiveness' as the two most important drivers whereas 'employee pressure' is the least important driver.

1. Introduction

Pressure has been surmounting on companies to employ processes and produce products that are eco-friendly following increased public concern for the environment globally. It is understood that organizations acquire waste from their suppliers and so the environment is affected by the burden of their downstream supply chain partners (Arimura et al., 2011). Moreover, organizations from all sections of the industry are increasingly being asked by their stakeholders to mention the sources of their raw materials, and take action over and above this recognition and disclosure, to influence the supply chain to improve business and ecological performance (Guerin, 2010). Hence the environmental performance of mining companies draws attention for being at the downstream of a supply chain. Negative environmental and social impacts in the extractive industries manifest themselves in extremes, including ecological degradation, industrial accidents, impact on the livelihood of local communities, health and safety issues, and human rights violations (Mutti et al., 2012). The counter side to this is the proven employment and wealth generating capability of this sector. As per the Central statistical organization's estimation the present value of mineral production in India is US$ 41,790 million, which accounts for 2.5% of national GDP. The government realizes that the advantages that come with permitting mining projects, including employment and revenue generation, also create problems regarding natural resource depletion and potential environmental damage (Newbold, 2006). In an attempt to mitigate the adverse effects on the environment, countries are increasingly turning to the implementation of legal policies for the protection of the natural environment (Elvan, 2013).

In response to these environmental policies mining companies in India are increasingly focusing on developing and deploying

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http://dx.doi.org/10.1016/j.resconrec.2015.05.022

processes that will enable them to reduce their contribution to environmental pollution without compromising economical benefits. GSCM is one such idea that takes environmental elements into consideration when managing the supply chain, enabling industries to enhance their economical as well as ecological performance and so is seen by many as a promising organizing concept (Govindan et al., 2015a,c; Shi et al., 2012; Mudgal et al., 2009; Alzaman, 2014; Jabbour et al., 2014). Through access and collaboration with environmental management programs of the upstream and downstream supply chain partners GSCM practices help organizations reduce material usage, achieve green product recycling and become energy efficient (Rostamzadeh et al., 2015; Shaharudin et al., 2015; Wu et al., 2012). It may be due to a reactive practice or a proactive practice, that today many companies are interested in adopting GSCM practices. But, the transition of traditional supply chain to a green supply chain is not an easy task for organizations, due to the existence of many barriers. No doubt these barriers hinder GSCM effectiveness despite this, there being certain other variables in the system that initiate and enhance GSCM effectiveness. So, identification and thorough investigation of the effectiveness of these drivers need to be understood before GSCM adoption. Through the utilization of DEMATEL, this study recognizes the position of each variable in the system along with their strengths of influence on the system as well as on other factors. This information on the system variables will help the decision makers to identify the major influential factors to be focused on to achieve overall improvements in the system. The DEMATEL method works satisfactorily with limited data (Chang et al., 2011), which is the additional benefit of using this technique, as it is very difficult to obtain expert opinion from busy individuals. Knowledge of the drivers and their driving potential will help organizations formulate strategies to reduce the inhibiting impact of barriers and enhance GSCM effectiveness in their organizations.

In this context, this research aims to identify the potential drivers of GSCM, investigate the causal relationships among them and evaluate the strength of influence of these drivers in mining industries. The next section provides a review of literature on GSCM. Next, a brief description of the problem is introduced in Section 3. The research methodology is introduced in Section 4. Section 5 illustrates the application of the proposed model with a case study. Discussions, managerial implications and conclusions are provided in Sections 6–8 respectively.

2. Literature review

This section provides an overview of green supply chain management and GSCM in the Indian context. Further, a review of literature on GSCM in mining industries and GSCM drivers are provided in this section.

2.1. Green supply chain management

GSCM, a cross-organizational supply chain greening activity that needs integration of internal and external resources of the organizations (Wu et al., 2012) has been growing in recent years with increasing interest from both academia and industry (Govindan et al., 2014a,b). The concept of GSCM emerged from the realization that isolated implementations of environmental practices by companies are not as effective as collective actions that make the entire supply chain greener (Ageron et al., 2012; Kannan et al., 2014). GSCM cuts across varied boundaries of the supply chain management (Min and Kim, 2012) and consider emphasizing environmental issues in upstream and downstream business enterprises in a supply chain (Shipeng and Linna, 2011; Govindan et al., 2014a,b). For example, it is not possible to implement GSCM successfully without addressing the environmental issues in purchasing, product design and development, production, transportation, packaging, storage, disposal and end of product life cycle management activities (Min and Kim, 2012; Kannan et al., 2014). GSCM utilizes upstream supply chain partners' processes, technologies and their ability to integrate environmental concerns to enhance the competitive advantage of any firm (Tseng et al., 2014). Empirical studies demonstrate the existence of a positive relationship between GSCM practices and improved organizational performance in various sectors including electrical and electronics (Chien and Shih, 2007; Shang et al., 2010), automobile (Zhu et al., 2007b), manufacturing (Darnall et al., 2008; Zhu et al., 2007a; Eltayeb et al., 2011; Green et al., 2012) and nuclear power generation (Sheu, 2008).

2.1.1. GSCM in Indian context

Due to the relative scarcity of resources, increased internal pressures and the potential pressure to produce 'green products' for trade, both the Indian government and industries have started to promote various environmental management principles in manufacturing enterprises (Gandhi et al., 2006; Xu et al., 2013). In fact, India is the first country to constitualise environmental actions based on human right approaches (Ghose, 2003b; Muduli and Barve, 2013a). But, a thorough scanning of past literature revealed that, except automobile, manufacturing and chemical industries the GSCM adoption rate was not encouraged in the case of Indian industries. The major reasons include weaker enforcement practices by local and the central government of India (Barve and Muduli, 2013), inadequate consumer awareness (Mathiyazhagan et al., 2014), unwillingness of consumers in India to pay premium prices for greener products and process (Ishaswini and Datta, 2011; Mitra and Datta, 2014), lack of managerial awareness regarding the benefits of GSCM (Govindan et al., 2014a,b), restrictive company policies to product/process stewardship (Mudgal et al., 2010; Mathiyazhagan et al., 2014) and lack of commitment from top management (Luthra et al., 2011; Mudgal et al., 2010; Mathiyazhagan et al., 2014; Govindan et al., 2014a,b). Recent data reveals that India ranks the 3rd amongst the countries emitting green house gas. It had set a 20% emission reduction target (Mitra and Datta, 2014). In this regard, research on GSCM issues in Indian industries specifically in the mining sector which has a higher environmental impact on comparison with others (Jenkins and Yakovleva, 2006) is essential.

2.2. GSCM in the context of mining industries

Environmental complexities of mining industries have drawn the attention of researchers. So, several studies were conducted on GSCM issues including investigation of challenges to cleaner production implementation in American mines (Hilson, 2000), analysis of barriers of environmental management system in mines in Greece (Nikolaou and Evangelinos, 2010), development of eco-efficiency framework for Australian mines (Berkel, 2007), investigation of benefits and challenges of implementation of environmental management programs in Tanzanian mining industries (Mutagwaba, 2006), exploration of key mega trends and potential challenges of environmental sustainability in mining industries of Australia (Mudd, 2010) and Catalonia (Vintró et al., 2014).

In an Indian mining context, studies on GSCM issues are limited. For instance, Ghose (2003a) explored the techno-economic and socio-cultural challenges of cleaner production in the context of small-scale mining industries. In another study, Ghose (2003b) investigated environmental management strategies of small scale mining industries. Other studies available on GSCM issues in an Indian mining context are quantification of the barriers to GSCM implementation using graph theoretic and matrix approach

(Muduli et al., 2013a), analysis of behavioral factors of GSCM adoption using interpretive structural modeling (Muduli et al., 2013b) and green vendor evaluation and selection using AHP and Taguchi loss functions (Sivakumar et al., 2014). In recent years, Indian mining and mineral industries play a big role in the Indian economy (Muduli et al., 2013a,b). They also face a lot of pressure from government regulations and from foreign customers who are instigating them to shift to green practices (Sivakumar et al., 2014).

2.3. GSCM drivers

The growing importance of GSCM due to diminishing raw material resources, overflowing waste sites and increasing pollution levels (Mathiyazhagan and Haq, 2013), have motivated various researchers to discover the factors influencing GSCM implementation. Walker et al. (2008) identified the factors that drive or inhibit GSCM implementation in organizations through a review of past literature. They categorized such drivers as internal and external. Organisational factors were referred to as internal drivers and regulations, customers, competitors, society and suppliers came under the “external drivers” ambit. Latter, Holt and Ghobadian (2009) investigated the nature and extent of GSCM practices in the manufacturing sector of the UK. Their work also explored the factors that compel organizations to implement GSCM practices.

Mudgal et al. (2009) explored fifteen drivers for GSCM implementation in Indian manufacturing industries. The study employed ISM methodology to understand the interrelationship between these drivers. The study identified ‘societal concern for protection of the natural environment’, ‘government policies and regulations’ and ‘eco-literacy amongst supply chain partners’ as the most important drivers. In another study, Diabat and Govindan (2011), explored eleven drivers of GSCM adoption through the review of literature and consultation with experts from industry on a manufacturing company in India. Interpretive structural modeling (ISM) methodology was used in this study for the analysis of the hierarchical relationship existing between the drivers. ‘Government regulations and legislation’ and ‘reverse logistics’ were found the most significant drivers.

Latter, Mathiyazhagan and Haq (2013) identified twenty five factors that pressuring companies to implement GSCM. Identification of these influential pressures of GSCM was based on a review of previous literature. They further analyzed the interdependencies between these drivers through an ISM approach. Their study indicates that ‘central governmental environmental regulations’ and ‘regional environmental regulation’ occupy the bottom of the hierarchical structure and are the two most significant drivers. Xu et al. (2013) compared the degree of influence various drivers have on the rate of GSCM adoption in four industrial sectors in India. The study considered twenty six drivers and indicated that all the four sectors: chemical, electrical and electronics, automobile and textiles, differ in their perception regarding GSCM drivers. Competitors’ pressure, government regulations and pressure from foreign customer were found to be the most dominant drivers for automobile industries, chemical industries and textile industries respectively. The study also reveals that electrical and electronics sectors in India face less pressure compared to the other three sectors discussed earlier.

In a recent study, Mohanty and Prakash (2013) conducted a survey on micro, small and medium enterprises in India. They analyzed the data collected from 114 respondents through structural equation modelling (SEM). Their study established ‘government regulations’, ‘pressure from customers’, ‘competitors’ pressure’ and ‘pressure of neighboring communities’ as external drivers of GSCM while ‘support from top managers’, ‘educational level of employees’ and ‘frequent environmental training’ was founded to be internal drivers of GSCM.

2.4. Research gap

The literature review reveals that India is far behind developed countries in the analysis of GSCM issues (Mitra and Datta, 2014). Even studies on influential factors of GSCM in China are much higher compared to India (Xu et al., 2013). Most of the studies conducted in Indian industries, mainly analyze the GSCM issues either in the context of automobile or manufacturing industries and largely ignore the mining industries. Further, few studies which explored GSCM issues in mining did not discuss GSCM drivers much. It is evident from the past literature that depending upon the customer preference and government regulations, industries from different countries and sectors have differences in perception regarding the influences of various drivers on GSCM adoption (Zhu and Sarkis, 2006; Xu et al., 2013). Hence the scarcity of research on the drivers of GSCM adoption in mining industries can be considered a research gap. Further, it can be seen that there is scarce research on the exploration of the causal relationship between these drivers. Diabat and Govindan (2011) and Mathiyazhagan and Haq (2013) used ISM methodology to examine the driving and the dependence relationship existing between the drivers. Examination of the contextual relationship among the drivers with the help of the ISM in their study was based on experts’ judgment. In the ISM based analysis used, in the study, equal importance was given to the degree of influence imparted to or received from other elements of a particular element (Muduli and Barve, 2013b). However the results of the assessed weights would be higher than or lower than the real situation (Yang and Tzeng, 2011; Muduli and Barve, 2013b). This research tries to bridge these gaps by exploring potential drivers of GSCM and analyzing them using the DEMATEL methodology in an Indian mining context.

3. Problem description

India is emerging as one of the biggest manufacturing economies with a global ranking of ten (Mathiyazhagan and Haq, 2013). To support this industrial growth, intense mining activities are carried out. These extractive activities in India are further intensified by the heavy demand for coal from power sector aided by a huge demand for metals from China. As a result of the indiscriminate and unplanned mining over the years, the environment has been degraded significantly (Muduli et al., 2013a). Studies show contribution to global green house emission by ‘Odisha’ one of the states in India to be one percent (Wysham, 2003). Another study by the Blacksmith Institute of USA ranks Sukinda as the world’s fourth most polluted region in 2007 (Das, 2009). In addition to this, eight mining disasters since 1973 have occurred in India causing several casualties. According to a report published by the Centre for Science and Environment (CSE) mining of major minerals in India produced 1.84 billion tonnes of waste in 2006. The above statistics indicate that an immediate response is needed from the Indian mining industries to improve their environmental performance. GSCM whose concepts are parallel with that cleaner production and environmental management (Zhu et al., 2010), demonstrated improved environmental performance in mining industries (Suppen et al., 2006; Newbold, 2006). Hence, extractive industries from developed countries are increasingly showing interest in GSCM adoption. However, at the present scenario demonstrates, GSCM is at a preliminary stage in India. Therefore, mining companies need higher motivation for the adoption of GSCM. In that sense, this study identified twenty drivers (shown in the Table 1) through a review of pertinent literature. Next, a questionnaire based survey on the mining industry was conducted providing 144 valid responses out of 500 requests. Hence, an overall response rate of 28.8% was obtained. This response rate is higher than the that obtained by Xu et al.

Table 1
GSCM drivers.

Sl. no.	Variable	Description	Contributors
1	Societal concern for environmental protection	This factor addresses to the various activities of NGOs and various social organizations that drives organizations to adopt GSCM	Azapagic (2004), Jenkins and Yakovleva (2006), Ghose and Roy (2007), and Mudgal et al. (2009)
2	Regulatory requirements	It refers to the pressure exerted by the government, both in national as well as regional level on companies for adoption of green processes and technology	Hart (1997), Ghose (2003), Ghose and Roy (2007), Walker et al. (2008), Mudgal et al. (2009), Diabat and Govindan (2011) and Wu et al. (2012)
3	Economic benefits	Financial benefits obtained in terms of cost savings due to GSCM adoption	Hilson and Nayee (2002), Azapagic (2004) and Berkel (2007)
4	Profitable business opportunities	This factor refers to the opportunities to get access to international markets	Hansmann and Claudia (2001), Chiou et al. (2011), Mathiyazhagan and Haq (2013) and Mathiyazhagan et al. (2013)
5	Protecting a business from risks of environmental, health and safety factors	It refers to prevention of losses due to the reduction of environmental accidents through GSCM practices	Mathiyazhagan and Haq (2013), Mathiyazhagan et al. (2013)
6	Top managerial realization	Awareness of Top management regarding necessity of GSCM	Hilson and Nayee (2002); Zadek (2004), Berkel (2007), Testa and Iraldo (2010)
7	Investors pressure	Pressure exerted by the shareholders for adoption of GSCM	Azapagic (2004), Jenkins and Yakovleva (2006), Ghose and Roy (2007) and Nikolaou and Evangelinos (2010)
8	Eco literacy among supply chain partners	Increased interest of the upstream supply chain partners in the environmental performance of their suppliers.	Azapagic (2004), Chen et al. (2006), Mudgal et al. (2009) and Nikolaou and Evangelinos (2010)
9	Competitiveness	This factor refers to the tendency of industries to follow the strategy of the competitors	Ferguson and Toktay (2006), Chen et al. (2006), Mudgal et al. (2009), Nikolaou and Evangelinos (2010) and Mathiyazhagan et al. (2013)
10	Availability of energy saving and cleaner process	Development of new energy saving and clean technologies that significantly reduce the environmental burden of the organization	Mudgal et al. (2009), Mathiyazhagan and Haq (2013) and Mathiyazhagan et al. (2013).
11	Employee pressure	The activities of the employees that pressurize decision makers to take actions that will minimize accidents, improve working conditions, etc.	Henriques and Sadorsky (1999), Buysse and Verbeke (2003), Azapagic (2004), González-Benito and González-Benito (2006) and Mathiyazhagan et al. (2013)
12	Corporate social responsibility	The voluntary actions taken by firms to portray their social responsible image are falling under this category	Jenkins and Yakovleva (2006), Mathiyazhagan and Haq (2013) and Mutti et al. (2012)
13	Support and encouragements from government	Various steps taken by the governments to encourage GSCM adoption, including the introduction of awarding schemes, subsidy schemes, etc.	Darnall (2003), Darnall and Edwards (2006), Wu et al. (2012) and Mathiyazhagan et al. (2013)
14	Pressure from labor unions	This driver refers to various moves of labor unions regarding workplace safety, and other employee health related issues	Azapagic (2004)
15	Shortage of landfill areas	Huge amounts of waste generated over the years have led to a scarcity of landfill areas. Hence it is regarded as one of the drivers of GSCM	Mathiyazhagan and Haq (2013) and Xu et al. (2013)
16	Media pressure	The negative media campaign on the environmental performance of any company attracts government and public attention. This not only harms the company reputation, but also accelerates government actions against the company. Hence can be regarded as one of the drivers of GSCM	Mathiyazhagan and Haq (2013), Mathiyazhagan et al. (2013) and González-Benito and González-Benito (2006)
17	Pressure from local community	Local residents are gradually getting aware of the health problems arising due to pollution. Hence, they put pressure on mining industries to minimize their emissions	Azapagic (2004) and Jenkins and Yakovleva (2006)
18	Ease in getting finance from financial institutions	Financial institutions are increasingly considering improved environmental performance as one of the major criteria for sanction of loan or financial aids	Hilson and Nayee (2002), Azapagic (2004), Jenkins and Yakovleva (2006 and Mathiyazhagan et al. (2013)
19	Increasing scarcity of superior grades of ores.	Extraction of inferior ore grades requires higher energy consumption and involves higher emission rate. Hence the focus is to increase the rate of extraction of superior grades of ore	Mathiyazhagan and Haq (2013) and Chikkatur et al., 2009.
20	Support and initiatives from various organizations	Several associations in various organizational sectors have been formed these days that provide methods of measurement of environmental performance of the member organizations and also have provisions of rewards and encouragements for the best performers. This acts as a stimulus for the organizations to enhance their environmental performance	Nikolaou and Evangelinos (2010)

Table 2
Mean and standard deviation values of GSCM drivers.

Sl. No.	Variable	Mean	Standard deviation
D_1	Societal concern for environmental protection	4.19	1.124
D_2	Regulatory requirements	4.11	.997
D_3	Economic benefits	4.09	.960
D_4	Profitable business opportunities	4.07	1.126
D_5	Protecting a business from risks of environmental, health and safety factors	4.05	.999
D_6	Top managerial realization	4.05	.926
D_7	Investors pressure	4.01	.908
D_8	Eco literacy among supply chain partners	4.00	1.134
D_9	Competitiveness	3.97	1.013
D_{10}	Availability of energy saving and cleaner process	3.95	.880
D_{11}	Employee pressure	3.76	1.136
D_{12}	Corporate social responsibility	3.63	.736
D_{13}	Support and encouragements from government	3.54	.960
D_{14}	Pressure from labor unions	3.36	.921
D_{15}	Shortage of landfill areas	3.30	.893
D_{16}	Media pressure	3.28	.913
D_{17}	Pressure from local community	3.28	.971
D_{18}	Ease in getting finance from financial institutions	3.22	.935
D_{19}	Increasing scarcity of superior grades of ores	3.17	.931
D_{20}	Support and initiatives from various organizations	2.90	.808

(2013) (24.3%) in a similar research and so is considered reasonable. Of the 144 valid responses, 13.89% are from the manganese ore sector, 45.14% of the iron ore sector and the remaining 40.97% is from the coal sector. Zone wise 40.97% of the respondents are from the eastern part of India, 28.47% of the southern part, 22.92% belong to the central & the western part of India while the remaining 7.64% are from north India. Similarly, based on the number of years of experience, 36.8% of the respondents have less than 5 years of experience, 40.3% have experience between 5 and 10 years while 22.9% have more than 10 years of experience. In terms of production capacity 52.8% of respondents belong to large scale industries, while 47.2% belong to small scale industries. Based on the designation 34.03% of the respondents were at the executive level, whereas the rest are at various managerial levels (41.67% in assistant manager level, 17.36% in deputy manager level and 6.94% in senior managerial positions). Mean values of the drivers were calculated and the drivers were ranked according to the descending values of their mean as shown in the Table 2.

4. Solution methodology

DEMATEL has been proposed in this study as the solution methodology. DEMATEL was developed by the Battle memorial institute of Geneva between 1972 and 1976 under the belief, that improvements in understanding of the specific problematic cluster of intertwined problems could be brought through the use of appropriate scientific methods leading to the identification of workable solutions by a hierarchical structure (Hsu et al., 2011, 2013). It has been proved as a potent and comprehensive technique in generating a structure from a set of complex and interdependent criteria, analyzing the dependence and feedback relationship between the criteria. This method is based on directed graphs or digraphs instead of directionless graphs as the former has proved its superiority over the latter by demonstrating directed relationships of elements of a system (Muduli and Barve, 2013b). Further use of the digraph enables DEMATEL to portray the structural relationships existing among system elements where a numeral represents the strength of the relationship (Wu and Lee, 2007).

Literature demonstrates the successful use of DEMATEL in the areas of selection strategy of knowledge management (Wu, 2008), assessment of safety measurement in avaiation industry (Liou et al., 2007), evaluation of core success factors of service quality in health care sector (Shieh et al., 2010), assessment of core competences of integrated circuit (IC) design service company (Lin et al., 2011), evaluation of the dimensions of restaurant space design (Horng et al., 2013), analysis of green supply chain management practices (Lin, 2013) and supplier selection (Hsu et al., 2013).

The process of development of DEMATEL based model is summarized as follows:

Step 1 Generation of direct-relation matrix

The perception of individual experts regarding the degree of influence of each variable on other variables is collected through the questionnaire. The pair wise comparison values between factor 'i' and 'j', for nth respondent were expressed using a comparison scale with four influential levels ranging between 0 and 4, the numerals used indicating the strength of a relationship. Pair-wise comparison data obtained from each expert is used to develop a 'direct relation matrix' using Eq. (1).

$$D_n = \left[X_{ij}^n\right], \tag{1}$$

where $1 \le n \le R$; R = number of respondents. 'D_n' is the direct relation matrix for nth respondent.

Step 2 Development of average direct relation matrix

An 'average direct-relation matrix' is generated from a set of direct-relation matrices where each aspect of the average direct relation matrix 'A' is the average value of the same aspect in different direct relation matrices of the respondents. Eqs. (2) and (3) are used for construction of the 'average direct-relation matrix' from the direct-relation matrices developed in step 1.

$$a_{ij} = \frac{1}{R}\Sigma_{n=1}^{R} X_{ij}^{n} \tag{2}$$

$$A = \left[a_{ij}\right] \tag{3}$$

Step 3 *Development of direct influence matrix*

To construct an 'initial direct-influence matrix', the 'average direct-relation matrix' developed in step 2 is normalized using Eqs. (4) and (5).

$$D = c\mathrm{A},\ c > 0 \tag{4}$$

$$\text{where} c = \frac{1}{\max \Sigma_{j=1}^{k}} \text{for} 1 \le i \le k \tag{5}$$

Step 4 Construction of total relation matrix

The direct-influence matrix 'D' developed in step 3, is used to calculate the total relation matrix 'T' using formula $T = D(I - D)^{-1}$, where 'I' is the identity matrix.

Step 5 Construction of cause and effect diagram

The sum of the ith row r_i of the matrix 'T' is calculated to evaluate total influences both direct and indirect exerted by the ith factor on other factors. Next, the sum of jth column 'c_j' of the matrix 'T' is calculated to assess the total influence, direct and indirect, received

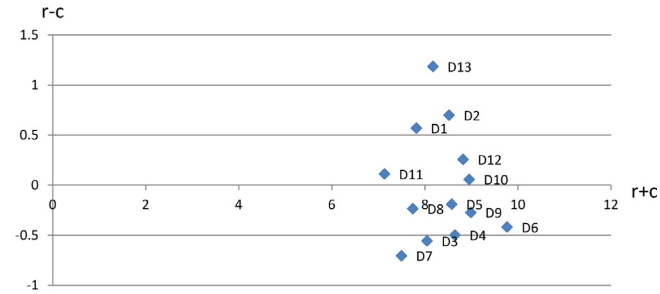

Fig. 1. Cause and effect diagram.

by jth factor from other factors. When $j = i$, the expression $(r_{i+}c_j)$ represents the degree of influence of the variable 'i' on the system, the difference $(r_i - c_j)$ indicates the net effect variable 'i' contributes to the system (Shieh et al., 2010). The cause and effect diagram is obtained through mapping the data set of $(r + c_j, r_i - c_j)$ for all $i = j$.

5. Case illustration

Thirteen drivers are selected for further analysis with higher values of mean as it is impractical to address all the factors simultaneously with limited resources. The selection of thirteen variables, is based on the recommendation of the experts. The experts chosen for the study are from two mining industries engaged in the extraction of iron ore. In addition to iron ore they also extract manganese ore. These industries are in the private sector and have ISO 14001 certification. The experts are of the rank of project manager and environmental engineer and have a working experience more than 10 years. After the selection of thirteen key drivers, a second questionnaire was prepared to collect expert opinion. The experts, mentioned above, were asked to rate the importance of each of the drivers regarding the other drivers in a scale ranging between 0 and 4. In our questionnaire '0' corresponds to no influence, 1 corresponds to very low influence, 2 corresponds to low influence, 3 corresponds to high influence and 4 corresponds to very high influence. The responses obtained from the experts were analyzed employing the DEMATEL methodology.

Initially, four direct-relation matrices were developed using responses from four experts employing the Eq. (1) mentioned in Section 4. These direct relation-matrices are then used to construct average direct-relation matrix 'M'. The average direct-relation matrix developed in this study is shown in the Table 3.

Initial direct-influence 'D' generated through the normalization of average direct-relation matrix 'M' using Eqs. (4) and (5) is shown in Table 4.

Next, total relation matrix 'T' is derived from the direct-influence matrix 'D' as shown in Table 5.

The degree of influence of each driver on each other, as well as on the system was calculated using step 4 mentioned in Section 4 and shown in Table 6. The '$r_i + c_j$' and '$r_i - c_j$' values for all $i = j$ shown in Table 6 was used to construct the cause and effect diagram, shown in Fig. 1.

6. Discussion

In decision problems, often complex criteria are encountered which either influence, or are influenced by several other criteria. The former group of criteria are called cause group and the latter the effect group. Improvement in one or two criteria necessarily does not bring improvements in the overall system due to the existence of dependence and feedback relationship among the criteria. To make an effective decision, cause group criteria are to be identified and improved first which in turn improves the effect group criteria. Keeping the above in mind, DEMATEL methodology was used in this study to explore the interactions among multiple attributes, which filled the gap left by traditional models that set strategies by only considering direct effects or single directions of criteria (Horng et al., 2013).

Final results that indicate influence levels of each variable in the system as well as on each other are presented in Table 6. On the basis of the '$r_i - c_j$' values, the factors are divided into two groups as cause and effect groups. The variables (D_1) societal concern for environmental protection, (D_2) regulatory requirements, (D_{10}) availability of energy saving and cleaner process, (D_{11}) employee pressure, (D_{12}) corporate social responsibility, (D_{13}) support and encouragements from government fall under the cause group for having positive '$r_i - c_j$' values. The variables having negative '$r_i - c_j$' values are categorized as effect group variables, which include variables (D_3) economic benefits, (D_4) profitable business opportunities, (D_5) protecting business from risks of environmental, health and safety factors, (D_6) top managerial realization, (D_7) investors pressure, (D_8) eco literacy among supply chain partners and (D_9) competitiveness. The results of cause and effect analysis show that top management realization belongs to effect group drivers though it is the most important driver. This result is in line with the findings of Mudgal et al. (2009) which shows that top management commitment is driven by external factors like government policies and regulations.

Through the analysis of the '$r_i + c_j$' values it is found that the driver D_6 (Top management realization) is the most important driver. The result is supported by the argument that top management realization about GSCM benefits is essential to extract their commitment and support for GSCM implementation. Without top management support and commitment, it would be difficult to arrange resources required for GSCM implementation. Moreover, top management takes the responsibility of preparing the environmental policy of an e organization and developing the GSCM implementation plan. After the confirmation of top management realization as the most important driver, '$r_i + c_j$' values of other drivers are inspected to assess their priorities. The drivers, according to their degree importance were identified as $D_6 > D_9 > D_{10} > D_{12} > D_4 > D_5 > D_2 > D_{13} > D_3 > D_1 > D_8 > D_7 > D_{11}$. The result shows that competitiveness as the second most important driver, which is not surprising as the imitating competitors strategy fully or partially are more often given priority instead of focusing on innovations in the case of Indian mining companies. The results of the priority weight analysis of the drivers show that the driver 'employee pressure' (D_{11}) has less influence on GSCM adoption. The fact is that, a majority of the employees in Indian mining industries is neither adequately trained nor have higher educational qualifications due to poor investment capability and inferior working conditions of the industries (Das, 2009; Barve and Muduli, 2013). These untrained and less educated employees have poor environmental awareness and exert lower pressure on the mining industries to adopt GSCM.

The results also indicate that two of the drivers from cause group, (D_1) 'societal concern for environmental protection' and (D_2) 'regulatory requirements' are ranked as the 10th and 7th important drivers, respectively. There are basically two reasons for lower influence of 'societal concern for environmental protection' on GSCM adoption by the mining industries in India. First, in India very few NGOs are present to show special interest in the environmental issues of mining industries. Second, mechanization of activities which may help improvement in GSCM performance in mining are objected to by local residents due to the fear of loss of employment opportunities (Ghose, 2003a; Barve and Muduli, 2013). Similarly, the reason behind the lower ranking of 'regulatory requirement' can be justified by the argument that, regulatory enforcement of the mining industry in India is inadequate due to a shortage of

Table 3
Average direct relation matrix.

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}	D_{13}
D_1	0	2.75	1.5	1.5	1.75	3	3	2.5	1.75	2.25	2.25	2.75	2.25
D_2	2.25	0	2.25	2.25	2	3.75	2.5	3.25	2.75	2.5	2.75	1.75	2.25
D_3	0.5	1.25	0	2	1.25	2.75	2.75	2	3.75	2.5	1.75	2	1.75
D_4	1	1.75	2.75	0	1.75	3.25	2	1.5	3.5	3	1.5	2.25	2
D_5	2.25	2.25	2.25	2.5	0	2.5	2	2.25	2.75	2.5	2	2	2
D_6	2.5	2.25	3	3.5	3.25	0	1.75	2	3	2.5	1.5	3.25	2
D_7	1.25	1.75	1.75	2	2.25	2.5	0	1.5	2	1.75	1.5	2	1.5
D_8	2	2	2	2.25	3	2.75	2	0	1.75	2	1.5	1.5	1.5
D_9	1.75	2	2.75	3	2.5	3.25	2.5	2.25	0	2.25	2	2.75	1.5
D_{10}	2.25	2.75	2.5	3.25	2.75	2.25	2.5	2.25	2.25	0	2	2.75	2
D_{11}	1.75	2.5	1.75	1.5	2.25	2.5	1.75	1.75	2	1.75	0	2.25	1.5
D_{12}	3	2	2.5	3	3	2	2	2.5	2.25	3	2.25	0	2.25
D_{13}	3	2.25	2.75	2.75	2.75	3.25	2	2.25	2.25	3	1.75	2.5	0

Table 4
Direct influence matrix.

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}	D_{13}
D_1	0	0.08148	0.0444	0.0444	0.05185	0.08889	0.0889	0.074	0.0519	0.0667	0.0667	0.08148	0.0667
D_2	0.0667	0	0.0667	0.0667	0.05926	0.11111	0.0741	0.096	0.0815	0.0741	0.0815	0.05185	0.0667
D_3	0.0148	0.03704	0	0.0593	0.03704	0.08148	0.0815	0.059	0.1111	0.0741	0.0519	0.05926	0.0519
D_4	0.0296	0.05185	0.0815	0	0.05185	0.0963	0.0593	0.044	0.1037	0.0889	0.0444	0.06667	0.0593
D_5	0.0667	0.06667	0.0667	0.0741	0	0.07407	0.0593	0.067	0.0815	0.0741	0.0593	0.05926	0.0593
D_6	0.0741	0.06667	0.0889	0.1037	0.0963	0	0.0519	0.059	0.0889	0.0741	0.0444	0.0963	0.0593
D_7	0.037	0.05185	0.0519	0.0593	0.06667	0.07407	0	0.044	0.0593	0.0519	0.0444	0.05926	0.0444
D_8	0.0593	0.05926	0.0593	0.0667	0.08889	0.08148	0.0593	0	0.0519	0.0593	0.0444	0.04444	0.0444
D_9	0.0519	0.05926	0.0815	0.0889	0.07407	0.0963	0.0741	0.067	0	0.0667	0.0593	0.08148	0.0444
D_{10}	0.0667	0.08148	0.0741	0.0963	0.08148	0.06667	0.0741	0.067	0.0667	0	0.0593	0.08148	0.0593
D_{11}	0.0519	0.07407	0.0519	0.0444	0.06667	0.07407	0.0519	0.052	0.0593	0.0519	0	0.06667	0.0444
D_{12}	0.0889	0.05926	0.0741	0.0889	0.08889	0.05926	0.0593	0.074	0.0667	0.0889	0.0667	0	0.0667
D_{13}	0.0889	0.06667	0.0815	0.0815	0.08148	0.0963	0.0593	0.067	0.0667	0.0889	0.0519	0.07407	0

Table 5
Total relation matrix.

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}	D_{13}
D_1	0.2308	0.32338	0.3146	0.3326	0.32814	0.4034	0.3409	0.322	0.3408	0.3433	0.2847	0.34639	0.2837
D_2	0.3143	0.27203	0.3618	0.3811	0.36186	0.45516	0.3535	0.365	0.397	0.3773	0.3188	0.34779	0.3048
D_3	0.2201	0.2561	0.2447	0.3168	0.28536	0.36257	0.3067	0.28	0.3638	0.3199	0.2464	0.29886	0.2455
D_4	0.2519	0.28897	0.3422	0.2842	0.31972	0.40096	0.308	0.287	0.3815	0.356	0.2579	0.3273	0.2704
D_5	0.2913	0.30981	0.335	0.3588	0.27718	0.39127	0.3155	0.315	0.3687	0.3504	0.2778	0.32724	0.2769
D_6	0.3239	0.33752	0.3864	0.4185	0.39675	0.35904	0.3391	0.337	0.4104	0.3841	0.2905	0.39071	0.303
D_7	0.2218	0.24931	0.2706	0.2914	0.28751	0.32951	0.2096	0.247	0.2941	0.2776	0.2222	0.2757	0.2218
D_8	0.2606	0.27721	0.2996	0.3218	0.33011	0.36354	0.2878	0.225	0.3124	0.3077	0.241	0.28534	0.2407
D_9	0.2865	0.31205	0.3591	0.3836	0.3572	0.42223	0.338	0.324	0.306	0.3552	0.2859	0.35722	0.2725
D_{10}	0.3081	0.34075	0.3616	0.3993	0.37273	0.40876	0.3477	0.333	0.3782	0.3029	0.2946	0.36606	0.2938
D_{11}	0.2481	0.2829	0.2845	0.2932	0.30241	0.34701	0.2731	0.268	0.309	0.2923	0.1923	0.29652	0.2339
D_{12}	0.3298	0.32416	0.3633	0.3948	0.38146	0.40454	0.3372	0.342	0.3797	0.3868	0.3028	0.29328	0.3021
D_{13}	0.338	0.33873	0.3796	0.3992	0.38479	0.44737	0.3458	0.344	0.3902	0.3965	0.297	0.37217	0.2473

Table 6
Total effects and net effects for each influential factors.

	r_i	c_j	$r_{i}+c_j$	r_i-c_j
D_1	4.194286	3.6252	7.819447	0.569124
D_2	4.61069	3.91292	8.523607	0.697773
D_3	3.746687	4.3028	8.049494	-0.55612
D_4	4.076397	4.5754	8.651796	-0.499
D_5	4.194489	4.38522	8.579705	-0.19073
D_6	4.677203	5.09539	9.772592	-0.41819
D_7	3.397856	4.1028	7.500642	-0.70493
D_8	3.753446	3.989	7.742159	-0.23527
D_9	4.359118	4.632	8.991089	-0.27285
D_{10}	4.507711	4.4501	8.957826	0.057595
D_{11}	3.62311	3.5121	7.13522	0.110999
D_{12}	4.541689	4.28458	8.826271	0.257108
D_{13}	4.680679	3.4962	8.176872	1.184486

manpower in government agencies like the central pollution control board (Ministry of Mines, 2010) and its corresponding delay in decision making (Sharma et al., 2009), the presence of corruption and weak political support (Ghose, 2003b; Muduli et al., 2013a).

7. Managerial implications

Use of DEMATEL in this study makes it easier to capture the complexity of the decision problem by categorizing the complex criteria into cause and effect groups, thereby facilitating the making of profound decisions. The managerial implications that emerge out of this study as discussed below.

- All the factors are categorized into two cause and effect groups. This will help the decision makers to identify the group of factors (cause group) which need to be controlled and attended to (Lin et al., 2011). The fact is that variables included in the cause group are difficult to move while those included in effect group are easily moved (Wu and Lee, 2007). Further, prioritization of the drivers will help the decision makers in recognizing the drivers needing improvement on a priority basis, which in turn improves other drivers as well as the entire system.

- It can be observed from Fig. 1 (cause and effect diagram), that factor D_{13} (support and encouragement from the government) is a significant driver though it is ranked the 8th important driver. Further, it has the highest 'R_i' value which is an indication of the highest degree of influence imparted by it on other variables as well as on the system (Muduli and Barve, 2013b). Hence top managements should work to get adequate support from the government.
- It can be observed that 'D_{10}' availability of energy saving and cleaner process is the third most important variable. It is a cause group variable and also has the higher driving power due to its higher value of 'r_i'. Hence, managements need to identify the available cleaner and greener technologies for their organizations. It can be inferred from this result, that there is a growing requirement for top management to emphasize innovation, which leads to the development of new, greener and economic process.
- Factor Corporate social responsibility 'D_{12}' is a cause group driver and is the fourth most important. The factor also exhibits a high driving power (high r_i, value), hence managements should focus on this as improvement here will lead to improvement in several other factors.
- Causal diagram shown in Fig 1. confirms that regulatory requirement (D_2) is a cause group criteria. Further analysis of the 'r_i' values indicates that it has a strong influence on other factors. Therefore, managers should aim at formulating strategies that emphasize fulfilling regulative requirements for enhanced environmental performance as it brings improvements in the GSCM performance (Zhu et al., 2007a,b).
- 'Employee pressure' (D_{11}) is the least important driver having the least value of '$r_i + c_j$'. However, it should not be ignored as it belongs to the cause group Managements through giving proper attention to employee voices can build trust between them and employees. This will lead to employee commitment towards GSCM implementation. Higher commitment from an employee will result in improved GSCM effectiveness as employees execute the actual program.

8. Conclusion

An increasing awareness of environmental protection in India and the world, has led to an overwhelming response to a green trend in conservation of natural resources and protection of the environment, thereby exerting pressure on industries operating not only in India but also across the globe (Kumar et al., 2012; Xu et al., 2013). Consequently, several environmental management techniques were developed and adopted by organizations from different industrial sectors across the globe. GSCM is one such strategy that is gaining popularity due to its ability of improving environmental performance of the entire supply chain). Improvement in the environmental performance of an organization depends to a large extent on the environmental performance of its suppliers as they inherit the waste in their downstream supply chain. Earlier studies provided evidence of improvement in organizational performance through improved environmental supply (Carter et al., 2000; Walker et al., 2008). Hence, it is essential to focus on the improvement of environmental performance of mining industries which lie at the extreme end of the downstream supply chain.

Though there is a growing realization of GSCM's importance, and though its benefits are well understood, it has not been widely accepted by Indian mining industries yet. The reason may be a poor understanding of various influential factors of GSCM and their interdependence. These influential factors can be categorized as barriers and drivers. Barriers offer resistance to GSCM implementation and were studied by Muduli et al. (2013a) in a mining context. But, drivers that encourage GSCM adoption were not studied exclusively in an Indian mining context. These drivers are industry specific, and differ according to their strength of influence on each other as well as on the entire system. Hence, mining industries need a clear understanding of these drivers before GSCM implementation to ensure maximum benefits. DEMATEL methodology was proposed in this research to assess the direct and indirect influences of GSCM drivers. DEMATEL technique assists in the decision-making process to evaluate the causal relationship as well as the influence/strength of the drivers of the target system and presents the direct and indirect effects of drivers through a visual diagram (Chuang et al., 2013; Wu et al., 2012).

This study involved a questionnaire based survey on Indian mining industries. The survey instrument contained twenty items (drivers) identified with the help of literature and expert opinion. Thirteen drivers were chosen for further analysis based on their mean values, as it is impractical to think of a simultaneous improvement of all factors. The DEMATEL method used in this study analyzed these thirteen drivers. The result obtained through the analysis was categorized into two parts. First, the degree of influence of each driver (priority weight) on the system was evaluated and used as a basis for ranking them. Secondly, the drivers were classified as the net dispatcher (cause group) variable or net receiver (effect group) variables. The cause group drivers not only have higher driving power of the entire system, but also a strong influence on the effect group drivers or, in other words, the improvement in drivers of the former group will lead to improvement in the drivers of the latter group. Hence, the study recommends that, extractive industries interested in GSCM adoption should higher attention to the factors categorized as cause group drivers (societal concern for environmental protection, regulatory requirements, availability of energy saving and cleaner process, employee pressure, corporate social responsibility, support and encouragements from government). However, the variable 'top management realization', categorized as the effect group driver cannot be ignored. This variable was found the most influential driver, according to the priority weight analysis. Hence, the top management should maximize their level of involvement in GSCM activities to get better performance. The study also finds employee pressure as the least important driver. However, as this is a cause group driver, it should not be ignored.

9. Limitations and scope of the future work

Analysis of GSCM drivers with DEMATEL method is performed using the judgment of four experts chosen from the case company. However, for constructing a generalized model, future studies should include a higher sample size. Factors that influence GSCM adoption like the size of the industry, the type of mineral extracted from the industry and geographical location can also be considered. Moreover, experts generally prefer natural language expressions over sharp numerical values in their assessments (Tseng et al., 2014; Muduli and Barve, 2013b). So, fuzzy/grey DEMATEL capable of providing the freedom to experts to express their judgments through natural languages can also be used in future studies (Xia et al., 2015; Patil and Kant, 2014; Govindan et al., 2015b).

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