Sustainable development practices in mining sector: a GSCM approach

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Abstract: Public interest on environment and ecology has grown manifolds due to rapid climate changes, environmental health hazards and energy crisis. This has drawn the attention of mass media, societies and governments to intensify pressure on organisations for transforming their process into eco-friendly process. Subsequently, organisations have been looking for developing models, algorithms, technologies, information and communication system that can contribute best to their sustainable development (SD) policies by integrating their economical, social and environmental objectives. This paper aims at developing a sustainable development framework for Indian mining industries through GSCM approach. A hierarchical model of the drivers affecting the implementation of green supply chain management in Indian mining industries has been developed using an interpretive structural modelling (ISM) framework. The various drivers of green supply chain management (GSCM) are identified based on the review of GSCM literature and expert consultations.

Keywords: sustainable development; SD; green supply chain management; GSCM; interpretive structural modelling; ISM; mining industries.

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1 Introduction

Minerals are the basic raw materials which contribute to the growth of both industrialised and industrialising countries. Mining industries have proved to be an important source for employment and wealth creation. Yet, indiscriminate and unplanned mining activities over the years have significantly contributed to environmental degradation (Muduli et al., 2012). Mining operations rely on the extraction, transportation and use of non-renewable natural resources, which lead to a variety of environmental impacts, including depletion of non-renewable resources, disturbance of the landscape and above-average threats for health and safety of workers and citizens (Azapagic, 2004). Mining and allied industries are confronted with the challenge of having to control a wide range of potentially serious environmental problems such as acid mine drainage (AMD), chronic soil erosion, tailings contamination, and heavy metals overloading. Many mines face additional complications in the form of toxic chemical additives such as mercury, cyanide, and surfactants, which are often used in mineral concentration processes (Hilson and Nayee, 2002). Mining disasters with several casualties occurred in the past have raised the perception in the public opinion of mining being a high risk activity for environment, workers and public health: Pressure groups, including some non-governmental organisations, are drawing international attention to environmental incidents and in several sites local communities protest against and impede or even shut down mines (Botta et al., 2009).

Hilson (2003) has listed 27 potential environmental impacts of interactions between ecosystems and complex material cycles of mining activities. To bring sustainability in mining sector these complex material cycles are to be managed in such a way that maximise the value to society while minimising negative impacts, be they economic, social or environmental (Norgate and Haque, 2010). Thus, the mining sector has increasingly given importance to the concepts of ‘environmental management’ (Hilson and Nayee, 2002; Suppen et al., 2006), ‘sustainable development’ (Hilson and Murck, 2000; Berkel, 2007) and ‘corporate social responsibility’ (Jenkins and Yakovleva, 2006) over the last two decades (Norgate and Haque, 2010).

The main objectives of this paper are:

1 to develop a sustainable development framework for the mining sector through GSCM approach
2 to identify the drivers of GSCM in mining industries
3 to establish the interrelationship between these drivers of GSCM in mining sector.

2 Sustainable development

Rapid population growth and increase in living standard has resulted in huge increase in demand for various kinds of products and services. Due to this growth and development, pollution and resource exploitation has exceeded the carrying capacity of the earth. History has witnessed the fall of many ancient societies including the Babylonian Empire due to exploitation of earth’s resources beyond its capacity and environmental degradation (Mebratu, 1998). Hence, there is demand from every segment of society that development and growth should be carried out in a judicious manner so as to accommodate the needs of existing population without sacrificing those of the future generations. In general, to prepare a sustainable developmental framework that will enable companies to eliminate or minimise waste and emissions from their industrial activities and from consumer end-of-life process, to cut the use of virgin raw materials, to improve water and air quality and potentially save money (Borland, 2009).

Many conceptualisations of sustainable development exists however the most well-adopted and most often quoted definition is that of the Brundtland Commission [World Commission on Environment and Development, (1987), p.8]: "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (Carter and Rogers, 2008). This implies future generations have rights over resources and current generation has a duty to include future generations' needs in its decision-making. However, Brundtland Commission's definition is so far reaching, organisations often find it difficult to determine their individual roles within this broader, macro-economic perspective (Shrivastava, 1995; Carter and Rogers, 2008). To make it simpler and more encompassing organisational definitions of sustainable development in the engineering literature have explicitly incorporated the social, environmental, and economic dimensions of the macro-viewpoint by defining organisational sustainability as, "a wise balance among economic development, environmental stewardship, and social equity" (Sikdar, 2003; Carter and Rogers, 2008). The three dimensions of sustainable development identified from literature are discussed below.

2.1 Economic dimensions

Financial aspects of the organisations are addressed by this component. Many organisations view economic dimension as the most important dimension for sustainable development and it is considered as the basic motivation behind any organisation. It is argued that, without economic success, no supply chain will exist in long run.

2.2 Environmental dimensions

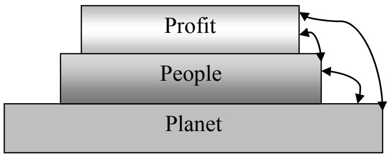
The most important issue in today's world, environmental hazards, is addressed by environmental dimension of sustainable development. Environmental deterioration takes place as a result of the adverse impacts of various industrial process and services on air, water, land, biodiversity. This dimension of sustainable development focuses on various initiatives for environmental protection or minimisation of environmental damage caused by industrial and technological advancements.

2.3 Social dimensions

Various social needs of employees including equity, healthcare facility, education, workplace safety, employee retention, labour rights, human rights, and wages and working conditions at outsourced operations etc., are addressed by the social dimension of sustainable development. In order to boost employee morale and increase their productivity organisations have to pay attention to these needs. Social dimension of sustainability has to be dealt carefully in order to achieve success.

Many authors have attempted to show the interrelationship between these three components of sustainable development and its effect in achieving sustainability. Triple bottom line (Elkington, 1998), nested model (Gidding et al., 2002) and triple bottom line with four facets (Carter and Rogers, 2008) are some of the examples. Most of the conceptualisations are based on triple bottom line concept. When the triple bottom line is adopted, invariably, it is the economic dimension that dominates and the social and environmental dimensions become token afterthoughts or measured against the economic dimension (McDonough and Braungart, 2002; Borland, 2009). In fact, in proposing a hierarchy of dimensions, to be addressed for sustainable development, the author sees that the most important dimension is the planet, which supports all human activities and the various human activities are transformed into financial benefits. This hierarchy emphasises the underlying importance of the planet in sustaining and maintaining all life on earth and in providing the richness and diversity of financial and socio-cultural benefits that we enjoy (Capra, 1997; Hart and Milstein, 1999; Borland, 2009).

Figure 1 Hierarchy of dimensions of sustainable development



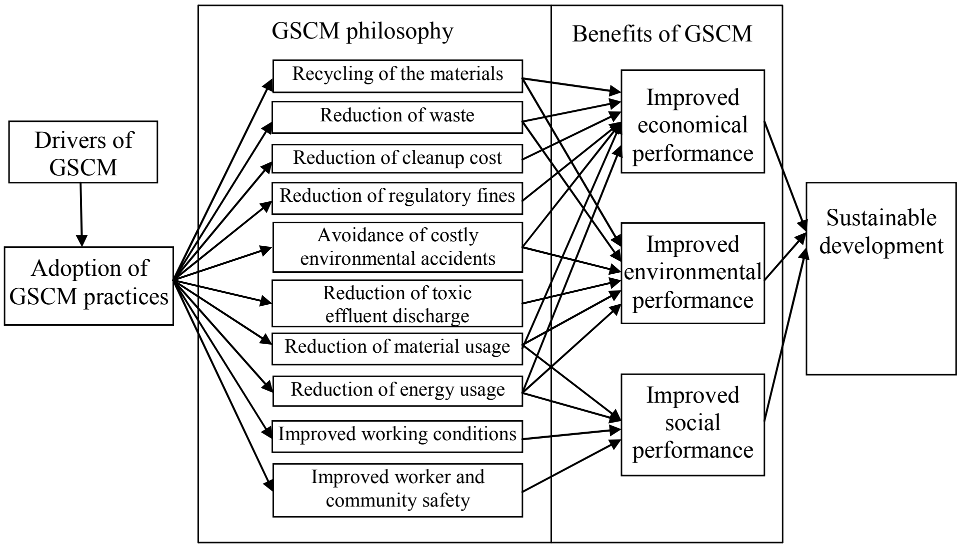
3 Green supply chain management

The voluntary pursuit of any activity that encompasses the concern for energy efficiency, environment, water conservation, use of recyclable products and renewable energy is defined as 'green' (Mudgal et al., 2010). To portray environmental friendliness image of various business process the word 'green' is widely used in conjunction with these process including green design, green purchasing, green packaging and green supply chain management (GSCM) to list a few. To counter environmental deterioration, GSCM integrates environmental management principles with supply chain activities in order to either improve the environment or to preserve it so no further depletion is allowed (Muduli et al., 2012). Green supply chain concept covers all phases of a product's life cycle, from the extraction of raw materials through the design, production, and distribution phases, to the use of the product by consumers and its disposal at the end of the product's life cycle (Walker et al., 2008; Diabat and Govindan, 2011). It aims at identifying and eliminating or reducing the potential harmful effects of each and every stages of supply chain along with minimisation of utilisation of resources and energy.

4 GSCM approach for SD

Industrial sectors are trying to explore the SD principles for their business process that will contribute best to the SD practices without compromising with their business goals. Similarly mining industries are also trying to develop SD policies for their operations which are much more complicated for them as they rely mostly on extraction of non-renewable resources. Hilson and Murck (2000) point out that in order to contribute to sustainable development mining industries must reduce their environmental impacts through effective environmental management programs. SD focuses on stretching of environmental management efforts and operations throughout the entire supply chain instead of focusing on local optimisation of environmental factors, which is in accordance with the philosophy of GSCM. The green supply chain not only emphasises the customer's demand as the central criteria but also simultaneously emphasises the recycling of the materials and energy among the enterprises in the supply chain, and emphasises the unification of the economic objective, social objective and environmental objective thus leading to sustainable development. Integrating various green supply chain activities into its operations, a mining operation can put itself in a better position to anticipate problems with waste, avoid unnecessary cleanup costs and regulatory fines, avoid costly environmental accidents, reduce its discharges of toxic effluent, avoid tailings pond spills and leaks, can minimise usage of raw materials (Hilson and Nayee, 2002) as well as can attract financial groups, thus earning economic benefits. Additionally, improved ecological efficiency through GSCM practices can accelerate sustained competitive advantage resulting in improved long term profitability (Paulraj, 2009).

Figure 2 Framework for sustainable development



From the angle of relatively inadequate resources, per capita energy and the great pressure of resources and energy, GSCM emphasises on minimisation of resource and energy utilisation. Additionally the industry can be able to meet challenges regarding worker and community safety, poor working conditions and associated accidents coupled with various occupational health hazards, which are the causes of poor quality of work force, shortage of work force and reduced productivity by following GSCM practices. Thus, generating its socially responsible image and improves its reputation and relation with courts, regulatory agencies, enforcement groups, municipalities, lending institutions, and financial groups which view activity that responds to EMS conformance requirements as an indication of diligence.

5 Identification of drivers for greening the mining supply chains

To address negative environmental impacts of their supply chain and gain competitive advantage almost every sector has been chosen GSCM practices as an important new innovation that helps organisations to develop ‘win-win’ strategies for achieving profit and market share objectives by lowering their environmental risks and impacts while raising their ecological efficiency (van Hoek, 1999), and the mining industry is no exception. Integration of environmental concerns into mining supply chains is still in its nascent stage. In this paper, eleven important variables categorised as ‘drivers’ that initiate environmental concerns in the mining supply chains, are selected through literature survey and discussions with experts. The identified drivers are discussed in details as follows.

5.1 Managerial realisation

Adoption of any change in organisational policy or decisions is initiated by the top management, which are responsible for allocating resources and setting guidelines. Managers are beginning to recognise, that greater social and environmental responsibility can improve firm performance (Porter and van der Linde, 1995; Zadek, 2004). It has been observed that mining companies demonstrating their awareness of legislative requirements, and having goals, targets, and action plans in accordance with compliance, have less chance for infraction (Hilson and Nayee, 2002), have better materials efficiency, effective resource utilisation capability and reduced energy consumption and greenhouse gas emission tendency (Berkel, 2007). There is also evidence that courts, regulatory agencies, enforcement groups, municipalities, lending institutions, and financial groups view activity that responds to EMS conformance requirements as an indication of diligence (Plaut, 1998). The realisation of these commercial benefits as ‘side-effects’ of environmental improvement represent the most important motivating driver for managers to extend their support and commitment towards the greening efforts (Testa and Iraldo, 2010) which are critical factors in successful implementation of GSCM practices (Zhu et al., 2008).

5.2 Societal concern for protection of natural environment

Public opinion of the sector as a whole is poor (Jenkins and Yakovleva, 2006), which puts an ever-greater emphasis on minimising the environmental and social costs associated with mineral development, even few groups dare to publicly oppose the topic of natural conservation and environmental protection (Huang, 2005). A number of NGOs are taking special interest in the mining and minerals sector (Azapagic, 2004). These pressure groups have consistently targeted the sector at local and international levels, challenging the industry’s legitimacy (Jenkins and Yakovleva, 2006). Their main concern is in securing environmentally and socially responsible approach to mining and associated activities (Azapagic, 2004; Ghose and Roy, 2007).

5.3 Investors pressure

The mining and minerals sector is mainly financed by commercial banks with additional funding provided by international institutions such as the World Bank, International Finance Corporation and the regional development banks. Commercial banks expect companies to reduce financial risks wherever possible and are increasingly becoming interested in ethical and socially responsible investment, screening companies on their environmental and social performance (Azapagic, 2004; Jenkins and Yakovleva, 2006). The banking sector in Greece has developed a variety of new financial products for both environmentally friendly companies (e.g., better lending criteria) and for companies that implement environmental management practices (e.g., cleaner technology funds) (Nikolaou and Evangelinos, 2010). In India, the Public Investment Board requires an environmental clearance from the Department of Environment (DOE), Ministry of Environment and Forests, Government of India, for sanction for funding for all major projects (Ghose and Roy, 2007)

5.4 Government and regulations

Regulations are the most frequently cited external drivers for environmental action, impacting firms at the local, state, national and international levels (Porter and van der Linde, 1995; Hart, 1997; Mudgal et al., 2010). The feature of the regulatory pressure was the exact requirements of environmental protection, which helped companies overcome the organisation's inertia using the proactive environmental management system (EMS) (Darnall, 2003; Wu et al., 2012). The policy promoted improvements that would allow small-scale mining to be carried out in a scientific, efficient, and eco-friendly manner. In particular, the policy provided that each region of the country should integrate mining and environmental planning (Chaulya, 2004). It is mandatory to draft an environmental management plan (EMP) before commencing mining projects in India (Ghose and Roy, 2007). The most promising development in India has been the increased constitualisation of environmental actions based on human rights approaches. Recently, the Supreme Court of India ruled that every person has a fundamental right to the enjoyment of pollution-free water and air (Ghose, 2003).

5.5 Economic interests

Implementing cleaner production methods and innovation cost savings can be achieved due to lower closure and post-closure costs (Azapagic, 2004). GSCM practices also results in reduction of process waste and enhancement of co-product values (Berkel, 2007). The second major benefit is that a mining EMS makes practical business sense, and despite potentially being costly in the beginning, usually pays for itself over the long term through reduced operating costs and improved efficiency (Bhat, 1999; Hilson and Nayee, 2002). In short, by integrating these and related tools into its EMS, a mining operation puts itself in a better position to anticipate problems with waste, avoid unnecessary cleanup costs and regulatory fines, reduce its discharges of toxic effluent, avoid tailings pond spills and leaks, and minimise usage of raw materials and keys to preventing costly environmental accidents (Hilson and Nayee, 2002). New technological initiatives of mining companies, within 'environmental imperative', can represent a potential new profit opportunity and a determining factor for companies' stock market value (Nikolaou and Evangelinos, 2010).

5.6 Competitiveness

In today's world, the competition among company is very high. To make customer impressed, the company needs to make themselves standing out from others. Being environmental friendly is one way to differentiate them from the competitors. A proactive environmental strategy can help a firm to gain competitive advantage through the development of supply chain management capabilities (Ferguson and Toktay, 2006). Companies that pioneer in green innovation enjoy the 'first mover advantage', which allow them to ask for a higher price for green products and, at the same time, improve their corporate images, develop new markets and gain competitive advantages (Chen et al., 2006; Mudgal et al., 2010). In addition, organisations can generate more business opportunities than their competitors if they can address environmental issues (e.g., by implementing a proper EMS) successfully (Hansmann and Claudia, 2001; Chiou et al., 2011). Nikolaou and Evangelinos (2010), points out that EMS may assist Mining companies to gain competitive advantages not only over environmentally friendly companies but also over other companies of the industry that do not implement corresponding practices.

5.7 Employee pressure

Previous studies indicate that environmental pro-activeness is strongly associated with higher employee pressure (Henriques and Sadorsky, 1999; Buysse and Verbeke, 2003; González-Benito and González-Benito, 2006). In addition to fair remuneration packages, employees are likely to be interested in good, safe and healthy working conditions, opportunities for training and career development and other sustainability aspects, including company's environmental, social and ethical performance (Azapagic, 2004). Studies pointed out that low investment capacity and poor working conditions of Indian mining industries leads to scarcity in skilled manpower (Das, 2009). A long-term accident statistics shows that the industry poses above-average risks to employees (Azapagic, 2004). Employee unions always put pressure for safety in work place and good housekeeping practices. Good housekeeping practices generally cost very little but help in improving workers' morale and workplace safety and are a basic measure of improving environmental performance in any firm.

5.8 Eco-literacy amongst supply chain partners

Although mining industries are at the bottom of the supply chain still it has a number of suppliers including providers of energy, chemicals and other materials. The industry also relies to a large extent on contractors and consultants for various parts of its operations, such as drilling, transport, permitting and mine closure. The contractors and suppliers generally are interested in economic viability of the company and whether their contracts will be paid in accordance with terms (Azapagic, 2004). Besides, the consultants involved in permitting and Environmental Impact assessments may also have an interest in environmental and social aspects of company's activities (Azapagic, 2004). Further, environmental consciousness of the consumers which are at the upstream side of supply chain is a major force driving companies to be engaged in environmental activities (Chen et al., 2006; Mudgal et al., 2010). In order to accept foreign products, the majority of western countries require companies to gain accredited environmental status from a global organisation like the International Organization of Standardization (ISO) (Nikolaou and Evangelinos, 2010).

5.9 Availability of clean technology

Technological innovation has generally been accepted as one important basis for substantive, sustained, long-term improvements in both economic and environmental performance (Ashford, 1993; Mudgal et al., 2010). These technologies extract and use natural resources more efficiently, generate products with fewer harmful components, minimise pollutant releases to air, water and soil during manufacturing and product use, and produce more durable products that can be recovered or recycled to the greatest possible extent (OECD, 1995). The development and installation of clean technologies provide one mechanism for achieving improved environmental performance at the operations level (Mudgal et al., 2010).

5.10 Support and initiatives from various organisations

Today, there are several associations in different sectors or institutions that provide general methods to measure the environmental performance of their members and reward companies with better environmental or sustainable performance, with an aim to stimulate their members to begin some type of environmental management practice and to assist their members at least to maintain or to improve environmental performance (Nikolaou and Evangelinos, 2010). Holt et al. (2001) indicated that the government support has improved companies' environmental performance (Wu et al., 2012). Grants and technical supports provided by government could reduce a company's expenses and technical uncertainties, as well as help that company implement GSCM practices (Darnall, 2003; Darnall and Edwards, 2006). Government of Odisha has instituted two awards, 'Prakruti Mitra' for the institutions, showing excellence in environmental conservation and 'Prakruti Bandhu' for individuals, for their excellence in environmental conservation and awareness.

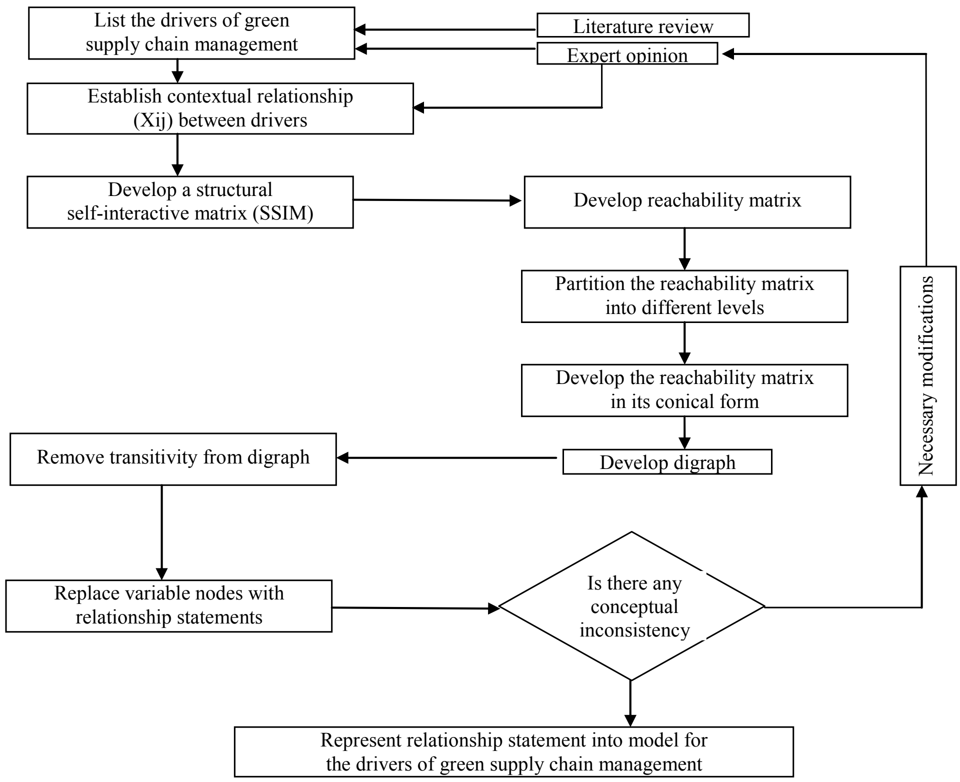
5.11 Sustainable development practices

Sustainability and corporate social responsibility are becoming ever more common as agenda items in boardrooms across the globe. Corporate social responsibility calls for sustainable development, which is a framework for companies and their management to transform their responsibility for environmental, economic and social behaviour into business practices (Mudgal et al., 2010). For the mining industry, sustainable development agenda is the increasing need for individual companies to justify their existence and document their performance through the disclosure of social and environmental information (Peck and Sinding, 2003; Jenkins and Yakovleva, 2006). To survive in long run mining companies are gradually inclining towards sustainable development practice. Regardless of whether a mining company operates at home or abroad, they are looking towards sustainable development practices in order to have access to resources, financial support and increased market share (Peck and Sinding, 2003; Salmi, 2008).

6 Interpretive structural modelling

Presence of large number of elements make the analysis of complex systems very difficult as the interrelationships (direct or indirect) that exist among these elements make the structure of the system unclear. This necessitates the development of a methodology which aids in identifying a structure within a system. To fill this gap ISM was developed in the period 1971–73 by John N. Warfield at the Battlle Memorial Institute. It was first described in Battle Monograph Number 4, titled Structuring Complex Systems. ISM is interpretive as the relation between the variables are decided based on the judgment of the selected group of experts, and it is structural as an overall structure can be extracted from the complex set of variables based upon their relationship (Mudgal et al., 2010). ISM is intended for use when desired to utilise systematic and logical thinking to approach a complex issue under consideration. It can act as a tool for imposing order and direction on the complexity of relationships among the variables. ISM is primarily intended as not only a group learning process, but can also used individually (Barve et al., 2007).

Figure 3 Flow diagram for ISM construction



Transitivity and reachability are two basic concepts in ISM methodology (Raj et al., 2008). Transitivity implies that if an element *k* relates to an element *j* and the element *j* to element *i*, then the element *k* relates to element *i*. Transitivity helps in maintaining the conceptual consistency. The reachability concept is the building block of ISM methodology. Different identified elements are compared on a pair-wise basis with respect to their interrelation. This information is represented in the form of binary matrix. If an element *i* reaches another element *j*, then entry in the cell (*i*, *j*) of the reachability matrix is 1 and if element *i* does not reach *j*, then entry in the cell (*i*, *j*) of the reachability matrix is 0.

ISM is a powerful technique, which can be applied in various fields. Several examples of the use of ISM have appeared in the literature. Contribution of ISM methodology in different areas is shown in Table 1.

Table 1 Applications of ISM

Sl. no.	*Author*	*Year*	*Contributors areas in which ISM has been applied*
1	Saxena et al.	(1992)	Energy conservation in Indian cement industry
2	Sharma et al.	(1995)	Waste management in India
3	Mandal and Deshmukh	(1994)	Vendor selection
4	Singh et al.	(2003)	Knowledge management (KM) in manufacturing industries
5	Jharkharia and Shankar	(2004)	IT-enabled supply
6	Ravi et al.	(2005)	Productivity improvement
7	Bolanos et al.	(2005)	Improving decision-making process among
8	Faisal et al.	(2006)	Risk mitigation in agility
9	Faisal et al.	(2007)	Supply chain agility
10	Barve et al.	(2007)	Third party logistics
11	Kannan et al.	(2009)	Selection of reverse logistics provider
12	Mudgal et al.	(2010)	Green supply chain management
13	Luthra et al.	(2011)	Green supply chain management

Steps for constructing ISM based model are as follows:

6.1 Structural self-interaction matrix (SSIM)

In this research, experts from the industry and academia were consulted in identifying the nature of contextual relationship among the variables of GSCM practices in Indian mining industries. In order to analyse the relationship among the GSCM drivers, a contextual relationship of 'leads to' type is chosen. For example, economic interests leads to competitiveness. In a similar manner, the contextual relationships between the variables are developed. Keeping in mind the contextual relationship for each variable, the existence of a relation between any two variables (*i* and *j*) and the associated direction of the relation are questioned. Four symbols are used to denote the direction of relationship between the variables (*i* and *j*):

V variable *i* will help to alleviate variable *j*

A variable *j* will be alleviated by variable *i*

X variable *i* and *j* will help to alleviate each other

O variable *i* and *j* are unrelated.

Based on the contextual relationships, the SSIM is developed for the 11 variables identified as drivers of the GSCM practices in Indian mining industries shown in Table 2.

Table 2 Structural self-interaction matrix

Sl. no.	*Factors*	*Sustainable development practices*	*Support and initiatives from various organisations*	*Availability of clean technology*	*Eco-literacy amongst supply chain partners*	*Employee pressure*	*Competitiveness*	*Economic interests*	*Government regulations*	*Investors pressure*	*Societal concern for environmental protection*	*Managerial realisation*
1	Managerial realisation	V	A	V	A	A	V	V	A	A	A	X
2	Societal concern for environmental protection	V	V	V	V	V	V	V	X	V	X	
3	Investors pressure	V	O	V	O	O	V	V	A	X		
4	Government regulations	V	V	V	V	V	V	V	X			
5	Economic interests	V	A	A	A	A	V	X				
6	Competitiveness	V	A	A	A	A	X					
7	Employee pressure	V	O	V	O	X						
8	Eco-literacy amongst supply chain partners	V	O	V	X							
9	Availability of clean technology	V	A	X								
10	Support and initiatives from various organisations	V	X									
11	Sustainable development practices	X										

Table 3 Reachability matrix

Sl. no.	*Factors*	*Sustainable development practices*	*Support and initiatives from various organisations*	*Availability of clean technology*	*Eco-literacy amongst supply chain partners*	*Employee pressure*	*Competitiveness*	*Economic interests*	*Government regulations*	*Investors pressure*	*Societal concern for environmental protection*	*Managerial realisation*	*Driving power*
1	Managerial realisation	1	0	1	0	0	1	1	0	0	0	1	5
2	Societal concern for environmental protection	1	1	1	1	1	1	1	1	1	1	1	11
3	Investors pressure	1	0	1	0	0	1	1	0	1	0	1	6
4	Government regulations	1	1	1	1	1	1	1	1	1	1	1	11
5	Economic interests	1	0	0	0	0	1	1	0	0	0	0	3
6	Competitiveness	1	0	0	0	0	1	0	0	0	0	0	2
7	Employee pressure	1	0	1	0	1	1	1	0	0	0	1	6
8	Eco-literacy amongst supply chain partners	1	0	1	1	0	1	1	0	0	0	1	6
9	Availability of clean technology	1	0	1	0	0	1	1	0	0	0	0	4
10	Support and initiatives from various organisations	1	1	1	0	0	1	1	0	0	0	1	6
11	Sustainable development practices	1	0	0	0	0	0	0	0	0	0	0	1
	Dependence power	11	3	8	3	3	10	9	2	3	2	7	

6.2 Reachability matrix

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X and O by 1 and 0 as per the case. The rules for the substitution of 1 s and 0 s are as follows:

- if the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0
- if the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1
- if the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 1
- if the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 0.

Following these rules, initial reachability matrix for the GSCM drivers is identified and the final reachability matrix is obtained by incorporating the transitivities, this is shown in Table 3. In this table, the driving power and dependence of each variable are also shown. The driving power of a particular variable is the total number of variables (including itself), which it may help to achieve while the dependence is the total number of variables, which may help to achieve it.

6.3 Level partitions

The reachability and antecedent set for each variable are obtained from final reachability matrix. The reachability set for a particular variable consists of the variable itself and the other variables, which it may help to achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all variables. The variable for which the reachability and the intersection sets are the same, is assigned as the top-level variable in the ISM hierarchy as it would not help to achieve any other variable above their own level. After the identification of the top-level element, it is discarded from the list of remaining variables. From Table 4, it is seen that the sustainable development practices (variable 11) is found at level I. Thus, it would be positioned at the top of the ISM hierarchy. This iteration is repeated till the levels of each variable are found out. The identified levels aids in building the digraph and the final model of ISM (Table 5).

6.4 Formation of ISM-based model

The structural model is generated from the final reachability matrix and the digraph is drawn. Removing the transitivity as described in the ISM methodology, the digraph is finally converted into the ISM as shown in Figure 4. It is observed from this figure that government regulations (variable 4) and societal concern for environmental protection (variable 2) are very significant drivers of GSCM practices in Indian mining industries as it forms the base of ISM hierarchy. Sustainable development practices (variable 11) is the driver that has appeared at the top of the hierarchy, indicating that it is the least significant of all the variables. In order to bring improvement in the top level variable in the hierarchy we have to address the other variables which are below it in the hierarchy.

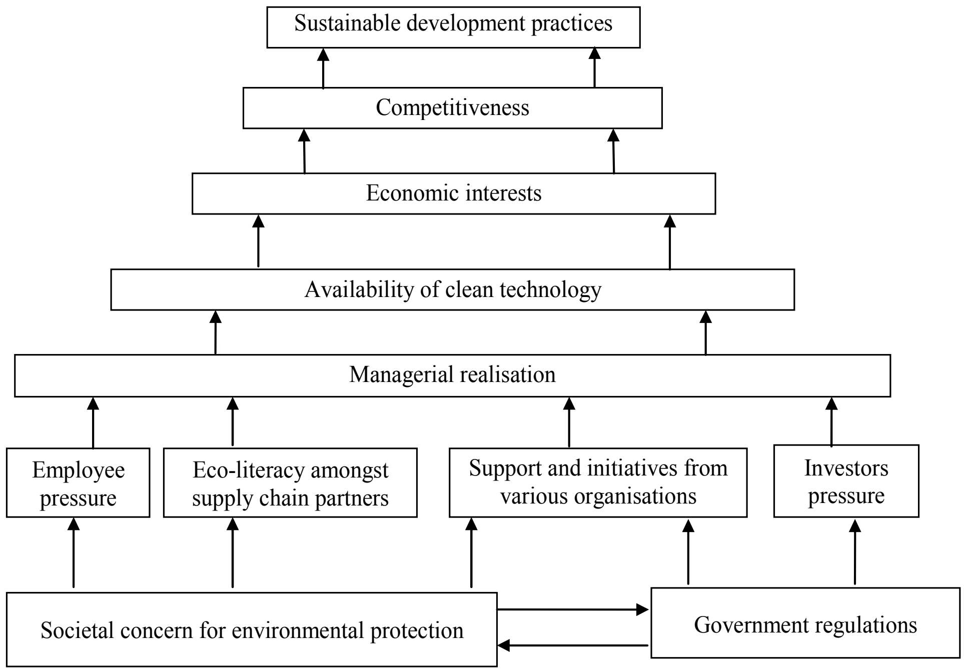
Table 4 Iteration I

Sl. no.	*Factors*	*Reachability set*	*Antecedent set*	*Intersection*	*Level*
1	Managerial realisation	1, 5, 6, 9, 11	1, 2, 3, 4, 7, 8, 10	1	
2	Societal concern for environmental protection	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	2, 4	2, 4	
3	Investors pressure	1, 3, 5, 6, 9, 11	2, 3, 4	3	
4	Government regulations	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	2, 4	2, 4	
5	Economic interests	5, 6, 11	1, 2, 3, 4, 5, 7, 8, 9, 10	5	
6	Competitiveness	6, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	6	
7	Employee pressure	1, 5, 6, 7, 9, 11	2, 4, 7	7	
8	Eco-literacy amongst supply chain partners	1, 5, 6, 8, 9, 11	2, 4, 8	8	
9	Availability of clean technology	5, 6, 9, 11	1, 2, 3, 4, 7, 8, 9, 10	9	
10	Support and initiatives from various organisations	1, 5, 6, 9, 10, 11	2, 4, 10	10	
11	Sustainable development practices	11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	11	I

Table 5 Iteration II–VII

Sl. no.	*Factors*	*Reachability set*	*Antecedent set*	*Intersection*	*Level*
1	Managerial realisation	1	1, 2, 3, 4, 7, 8, 10	1	V
2	Societal concern for environmental protection	2, 4	2, 4	2, 4	VII
3	Investors pressure	3	2, 3, 4	3	VI
4	Government regulations	2, 4	2, 4	2, 4	VII
5	Economic interests	5	1, 2, 3, 4, 5, 7, 8, 9, 10	5	III
6	Competitiveness	6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	6	II
7	Employee pressure	7	2, 4, 7	7	VI
8	Eco-literacy amongst supply chain partners	8	2, 4, 8	8	VI
9	Availability of clean technology	9	1, 2, 3, 4, 7, 8, 9, 10	9	IV
10	Support and initiatives from various organisations	10	2, 4, 10	10	VI
11	Sustainable development practices	11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	11	I

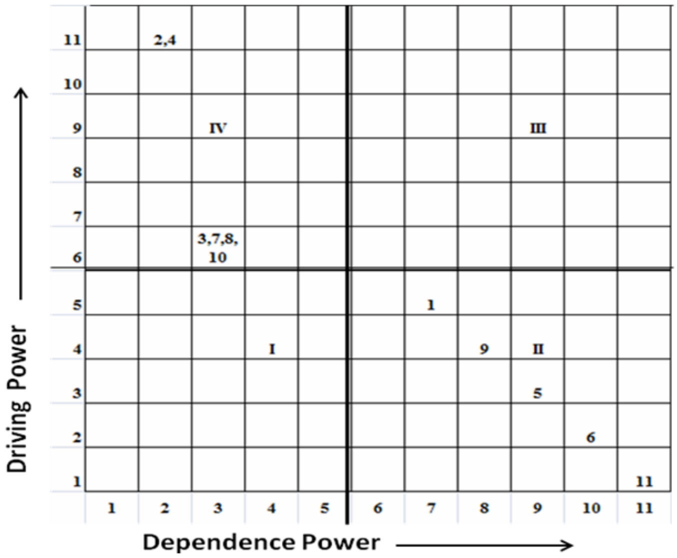
Figure 4 ISM-based model for drivers of GSCM



7 MICMAC analysis

The objective of the MICMAC analysis is to analyse the driving power (DP) and the dependence of the variables (Mandal and Deshmukh, 1994; Barve et al., 2007). In this analysis, the GSCM drivers described earlier are classified into four clusters (Figure 5). The first cluster consists of the 'autonomous variables' that have weak DP and weak dependence. These variables are relatively disconnected from the system, with which they have only few links, which may not be strong. The 'dependent variables' constitute the second cluster which has weak DP, but strong dependence. Third cluster has the 'linkage variables' that have strong DP and strong dependence. These variables are unstable due to the fact that any change occurring to them will have an effect on others and also a feedback on themselves. Fourth cluster includes the 'independent variables' having strong DP but weak dependence. The DP and dependence of each of these variables are shown in Table 3. In this table, an entry of '1' added along the columns and rows indicates the dependence and DP, respectively. Subsequently, the driver power-dependence diagram is constructed and is shown in Figure 5. For example, it is observed from Table 3, that driver 4 (government regulations) and driver 2 (societal concern for environmental protection) have driving power 11 and dependence of 2, therefore, in Figure 5, both of the drivers are positioned at a place corresponding to driver power of 11 and dependency of 2.

Figure 5 Driving-dependence power diagram



8 Managerial implication

Main objective of present research is to analyse the effectiveness of various factors which initiate as well as accelerate GSCM implementation thus leading to sustainable development in mining industries. Following are some managerial insights that emerge from the present research.

- The hierarchical model developed using ISM approach is used to analyse the interactions among different drivers of GSCM. This will help the decision makers to identify the hierarchy of actions to be taken for addressing these drivers for successful transformation of traditional supply chain management practices into GSCM practices.
- Identified interrelationships among the drivers can help the managers to rationale the resource and time constraint.
- Figure 5 (driver power-dependence diagram) shows none of the drivers are present in 'cluster I' which indicates absence of autonomous drivers in the system. So it can be inferred that all the considered drivers play a significant role in the initiation of GSCM. The managers and practitioners thus have to pay attention to all the identified drivers instead of focusing on one or two of them.
- Drivers 'managerial realisation', 'economic interest', 'competitiveness' and 'availability of clean technology' are identified as dependent drivers from Figure 5. These drivers have weak driving potential but strong dependence power.
- There is no driver positioned in the third cluster. Absence of linkage drivers indicates none of the drivers are unstable in nature.

- It is further observed from Figure 5 that drivers ‘societal concern for environmental protection’, ‘government regulations’, ‘investors pressure’, ‘eco-literacy amongst supply chain partners’, ‘ availability of clean technology’ and ‘support and initiatives from various organisations’ are positioned in fourth cluster. These drivers have strong driving power and weak dependence. Managers and decision makers should treat these drivers as key drivers for successful transition of traditional SCM to GSCM.

9 Conclusions

This study identifies various driving factors for the implementation of GSCM practices in Indian mining industries. The result of this study can help the managers to take strategic and tactical decisions to incorporate green practices in their traditional supply chain practice which have become critical success factors in companies’ sustainable development, today. More often companies, while trying to follow the operating strategies of their competitors, take quick decisions regarding the adoption of new technologies without analysing their own strength. This kind of decisions may prove to be suicidal some times. Interested companies must know the factors which accelerate GSCM implementation in their organisation and their interrelationship. The iterative process of ISM modelling approach provides an understanding as to how the various drivers interact with each other. The drivers with higher driving power are more of strategic orientation, while on the other hand the variables categorised as dependent are more towards performance and result orientation. Thus, superior results can be achieved by continuously improving the driving enablers. The variables societal concerns for environmental protection and government regulations being at the bottom of hierarchy indicates that these are most important drivers so the government and various societies should work together for creating GSCM awareness and provide necessary infrastructural and financial support that will be helpful for initiation of sustainable development practices in Indian mining supply chains.

10 Limitations and scope of future work

Though the present ISM model gives valuable managerial insight, still it is not statistically validated. Structural equation model (SEM) which has the ability to validate this kind of model will be used in the future. ISM is used to prepare the initial model as the same cannot be done using SEM. Again this model fails to identify the extent of impact of each driver on GSCM adoption by Indian mining industries. Hence Graph theoretic and matrix approach can be used in future research for quantification of the impact of each driver on GSCM adoption.

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