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Analysis of barriers of sustainable supply chain management in electronics industry: An interpretive structural modelling approach

Rakesh R. Menon, V. Ravi *

Department of Humanities, Indian Institute of Space Science and Technology, Department of Space, Valiamala P.O., Kerala State, Thiruvananthapuram, 695 547, India

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A B S T R A C T

In the past, industries were concentrating only on the economic aspects of a business. Many organizations are now addressing the social and environment impact of their supply chain for which they are adopting sustainability in their supply chain. The process of transformation to a sustainable supply chain will encounter some barriers which need to be eliminated or mitigated. To successfully manage these obstacles, it is crucial to know and study these barriers in specific context. This research aims to identify and analyse major barriers hampering sustainability implementation in the case of electronics industry in India. Through literature review and experts' opinion eleven barriers are identified and classified into categories of Policy, Human resource and Technology. The hierarchical structure and interrelationship among these barriers is established using Interpretive Structural Modeling (ISM) methodology. A major finding in this research is that lack of awareness on benefits of sustainability, lack of regulations and enforcement of environment standards and lack of commitment from top management are significant barriers in implementation of a sustainable supply chain. The driving and driven powers of these barriers and their interdependence is determined. Using MICMAC analysis, five barriers were recognized to be the driver variables, three barriers as dependent variables and three as linkage variables. The barrier lack of performance metrics/evaluation standards on sustainability is having strong dependence power and least driving power implying that it is highly influenced by other variables. It is found that most of the barriers in the policy category are independent with high driving and influencing power. The research draws attention to formulate targeted policies at both government and organizational level in the electronics industry for successful implementation of sustainable supply chain management. The modeling gives an insight to organizations in confronting barriers and to manage their resources in an efficient and effective way while making their supply chains sustainable. The paper concludes with findings and future scope of research being discussed.

1. Introduction

Management of supply chains is now not restricted to producing and selling goods with affordable supplies, competitive resources, consumer demand, investment and regulations. Organizations have to address the social and environmental impact of their supply chain which has now become an influencing factor with government, stakeholders, customers and businesses. Along with economic goals, there are calls for human welfare and planet protection when organizations offer their products and services. Sustainability has been introduced in the supply chain as suppliers' unsustainable behaviour brings social and economic liability to supply chain and the product (Kumar and Rahman, 2015; Seuring and Muller, 2008). Organizations become capable of achieving social commitments and environment standards by moving towards a sustainable supply chain management. Companies are committing to the cause of sustainability not only due to other pressures but they are also due to benefits supply chain sustainability can give. In general, it is seen in literature that more attention has been paid to environment related issues than social aspects like diversity, equity, human well-being, quality of life, working condition and community relations (Mani et al., 2016) in sustainable supply chain management (SSCM).

Whenever changes are made in the supply chain, organizations would face some challenges and obstacles in managing it. The promulgation of sustainability in supply chain brings operational challenges, product quality changes and supply chain disturbances (Lee and Klassen, 2008). As such during implementation of sustainable practices, there are barriers which need to be overcome. Barriers could be in the form of lack of commitment from top management, resistance to change from

* Corresponding author.
E-mail addresses: rakesh_r_menon@yahoo.com (R.R. Menon), ravi.iist.isro@gmail.com (V. Ravi).

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employees, unavailability of new technology, materials and process, high implementation cost etc.

It is seen that the opinion on these barriers change among organizations and also with industry. Hence based on industry, the influences and impact of barriers differ (Diabat et al., 2013). To deal with these barriers it is necessary to analyse these barriers and understand interrelationships among them. Some barriers would be driving barriers and influence other barriers while some would be driven and affected by other barriers.

Literature reveals that there are research papers on barriers in sustainable supply chain. Ravi and Shankar (2005) analysed 11 barriers to reverse logistics in the case of automobile industries and found lack of awareness about the reverse logistics and lack of top management commitment to have highest influence. In apparel industries using decision-making trial evaluation laboratory (DEMATEL) method Zhu et al. (2012) investigated the barriers to eco-friendly apparel production. Govindan and Bouzon (2018) listed 37 drivers and 36 barriers of reverse logistics using stakeholder theory. Majumdar and Sinha (2019) framed contextual relationships among twelve barriers of green textile and apparel supply chain and found complexity of green process and system design to possess highest driving power. The evaluation of barriers in implementing a sustainable supply chain for different industrial sectors is important to enable the sector to tackle them (Govindan et al., 2014). It is seen from literature that barriers specifically to implementation of sustainability in Indian context for the electronics industry have not been fully explored till date. The use and production of electronic items in India has increased exponentially in the last decade. This has made the electronic industry one of rapidly growing sectors in India. Considering production, consumption and export, the electronic industry is one of fastest growing industries (Dimitrakakis et al., 2009). There is a much larger requirement to consider the environmental impact of this industry. Also, Asian manufacturers will have to face considerable social and environmental issues in coming years (Mangla et al., 2017). This has motivated us to study barriers of sustainability in the supply chain of Indian electronics industry in this research.

Thus, a survey of literature was conducted and barriers of sustainable supply chain in the electronics industry were identified. Through discussion and replies to questionnaires by three experts from industry and an academic expert, eleven barriers specifically found in the electronics industry in India have been shortlisted. Experts' opinion and literature review was used to develop the relationship matrix. Using interpretive structural modeling (ISM) methodology, driving and driven powers of barriers were found. ISM can be used to study the direct and indirect relationship between various factors of different organizations (Jolhe and Babu, 2014). The complications of factors can be structured by the

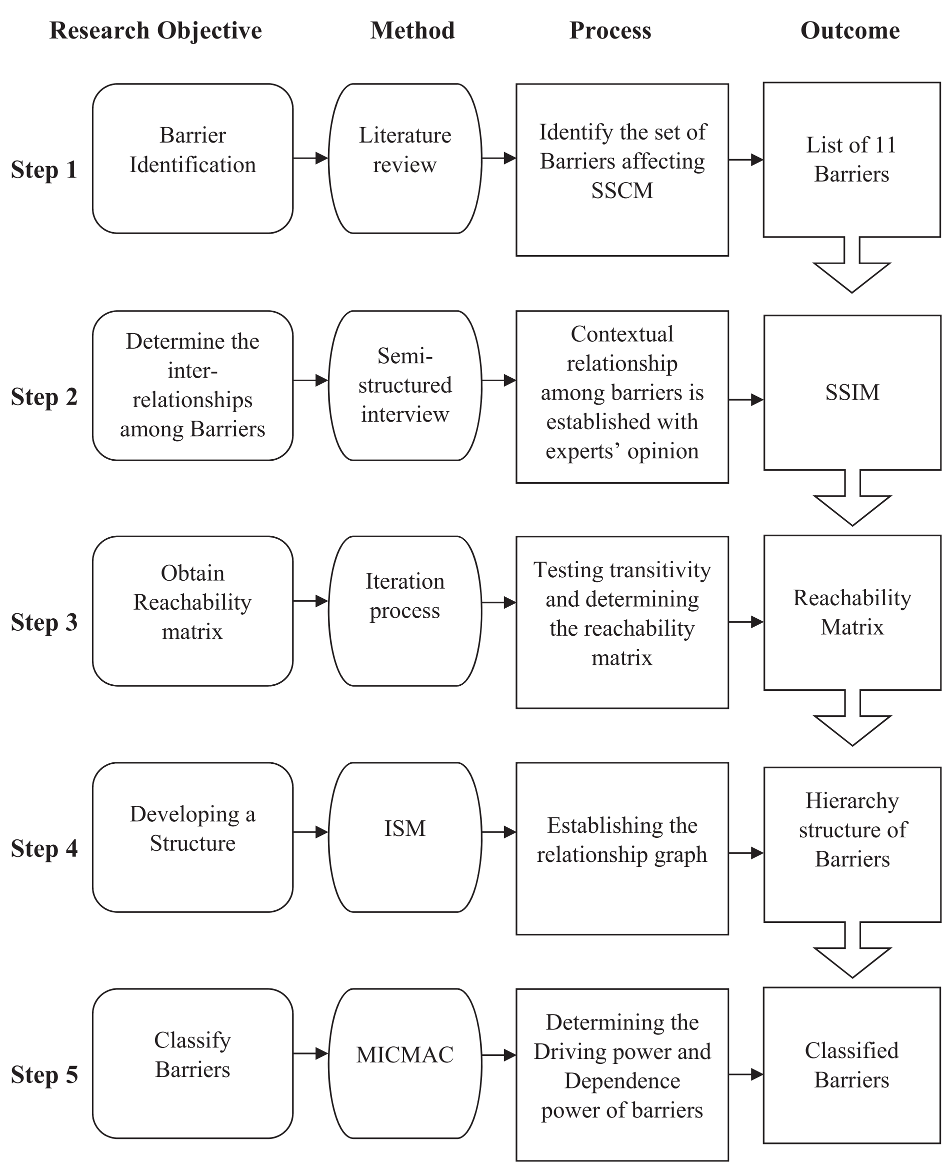

Fig. 1. Research flow.

ISM model (Jharkharia and Shankar, 2005). The research flow in this study is depicted in Fig. 1.

In this paper, barriers of sustainability in Indian electronics industry were identified. The interrelationship among barriers is established by an ISM model and managerial implications of this study are discussed. This investigation can enable firms to have a comprehensive understanding of interrelationship among the barriers so that they can carry out sustainability programs in the organization. The prioritization of barriers can guide firms on allocation of resources related to attaining the sustainability goals. The barriers are categorized to understand the functional aspects and classified as independent, dependent and linkage variables. Companies can adopt sustainability measures specific to the nature of the electronic industry considering their shorter product life cycle, increasing consumption pattern, energy efficiency and related disposal issues. Depending on the effect of barriers, organizations can work to eliminate these barriers stage wise. This study will help Indian electronic industry in minimization of barriers while moving towards a sustainable supply chain.

The objective of this study are as follows:

- Identify the barriers in implementation of a sustainable supply chain in electronics industries in Indian context
- Determine through a structured model the interrelationships among barriers and find their driving and driven power.

This paper is further organized as follows. Literature related to SSCM and its barriers is discussed in Section 2. The methodology used in this research is described in Section 3. Results of this research are presented in Section 4. Implications discussed in Section 5 followed by Conclusions and scope of future research in Section 6.

2. Literature review

This section presents literature related to SSCM and discusses barriers for its implementation in Indian electronics industry.

2.1. Sustainable supply chain management (SSCM) in Indian electronic industry

The issue of sustainability has become a global apprehension leading to organizations changing their supply chain arrangements to include social, environment and economic impacts of their supply chain (Carter and Rogers, 2008; Carter and Easton, 2011). Brundtland Report in 1987 defines sustainability as development which meets the needs of the present without compromising the ability of future generations to meet their own needs. The three pillars of sustainability known as Triple Bottom line (TBL) are economic, social and environment. There is a growing pressure on businesses to take care of the environmental and social implications of their products and process (Kleindorfer et al., 2005). The implementation of a sustainable supply chain involves many areas in the supply chain like operations, procurement, engineering and logistics. Sustainability concept is now part of various government policies and company strategies. A sustainable supply chain incorporates safety, good governance and mitigates supply chain risk. It comprises reducing energy and water usage, consuming renewable energy and decreasing hazardous waste generation (Jayant and Azhar, 2014; Rauer and Kaufmann, 2015). Seuring and Muller (2008) define SSCM as cooperation of organizations in supply chain along with information, material and capital flow for attaining objectives in social, environment and economic dimensions considering the requirements of customers and stakeholders. The integration of sustainability aspects to a supply chain involves taking steps that are socially and environmentally responsible rather than focussing on the economic benefits only (Namagembe et al., 2019). Such steps over a period of time will result in improved efficiency, company image and thus increase the economic performance (Mitra and Datta, 2014). Also being an interdisciplinary area, sustainable supply chain has been of interest both to researchers and managers in industry (Sarkis et al., 2011).

2.1.1. Overview of electronics industry in India

One of the biggest and fastest developing industries in the world is the electronics industry (Wath et al., 2010). The increasing use of electronic products and issues in its disposal has put this industry in ambit of legislation and society pressure in implementing sustainability. The rate of innovation and R&D activities is comparatively high in this industry. Due to this very nature, electronics industries are increasing using physical resources (Chancerel et al., 2009; Yin et al., 2014). The resource consumption is happening at a rate which is beyond what earth can bear (Sheoran & Kumar, 2020). Asia generated the highest quantity of e-waste in 2019 at 24.9 Mt while India generated 2nd highest in Asia at 3230 kt (Forti et al., 2020). India's economy is growing and it is expected that it would be the 3rd largest economy among nations of the world (United States Department for Agriculture Economic Research Service – USDA). India is promoting domestic production by introducing ‘Digital India’, ‘Atmanirbhar Bharat’ and ‘Make in India’ policies. Growing economy, demand for newer technology and urbanization have been working in favour of the electronics industry in the country. But it is also grappling with the issues of complex regulations, procedures and infrastructure facilities (Singh et al., 2018). On the other hand, the required measures to contain impact on the environment due to growth in the electronics industry remain insufficient (Hankammer and Steiner, 2015). India has legislations such as E-Waste Management Rules, 2016 to contain e-waste. However, it is grappling with issues of sustainability awareness, recycling facilities and incorrect data in carrying out the implementation. An attempt is made in this research to analyse the barriers affecting implementation of sustainable supply chain in Indian electronics industry.

2.2. Identification of key barriers to implement SSCM

Literature reveals that there have been studies on barriers and enablers in Sustainable supply chain management SSCM. Seidel et al. (2010) studied enablers and barriers for an organizations adoption of sustainable business practises in IT companies. Faisal (2010) studied the approach to introduce SSCM by framing the enablers. Diabat and Govindan (2011) studied key drivers related to implementation of green supply chain. Luthra et al. (2016) analysed fifteen barriers in adopting sustainability in the case of plastic manufacturing firms in India.

The context of barriers has been used in research of SSCM and supplier development. For this study, a barrier is defined as a factor which is an obstacle that prevents access of sustainability in supply chain context. These factors obstruct a company's endeavour in adopting sustainable practices. For this paper, the barriers that affect implementation of a sustainable supply chain in the electronics industry are shortlisted from literature review and experts' opinion. Through consultation and brainstorming sessions with the experts, the most essential barriers were shortlisted considering the industrial sector in Indian context. In our study, eleven barriers of sustainable supply chain shown in Fig. 2 are shortlisted. Based on experts' knowledge of SSCM and electronics industry the barriers were analysed to establish their functional traits. Brainstorming sessions were then held to categorize these barriers. While doing so previous schemes available in literature were thoroughly referred (Govindan et al., 2014; Snoek, 2017; Govindan and Hasanagic, 2018; Majumdar and Sinha, 2019; Gupta et al., 2020). The shortlisted barriers were then grouped in three categories viz. Policy, Human Resource and Technology for easier management during implementation phase. These barriers classified into categories are described in brief with their literature references as shown in Table 1.

The barriers to SSCM are further discussed as follows.

2.2.1. Lack of commitment from top management

Top management commitment in providing resources and encouraging initiatives is required for implementation of sustainability in the

Fig. 2. Barriers in implementation of a Sustainable supply chain.

supply chain. Top management impacts the policy formulation, training programs and technology advancement (Luthra et al., 2013). Limited support of top management in its approach towards sustainability is a barrier for SSCM (Giunipero et al., 2012; Turker and Altuntas, 2014). The leadership should be able to provide mandate, incentives and education on company's goal of supply chain sustainability. Top management needs to fix specific targets and lay a roadmap to attain the goals of sustainability. If the short term and long term goals are not in sync it can disrupt SSCM implementation (Walker and Jones, 2012). Top management can ensure that financial goals do not completely subdue the environmental and social goals.

2.2.2. *Financial constraints*

Implementation of sustainability in the supply chain may require adapting to new systems which requires financial investment. Financial support is required for SSCM and lack of finance is a serious constraint (Hervani et al., 2005; AlKhidir and Zailani, 2009). Many times, sustainable infrastructure requires high capital outlay though it is argued that these costs can be recovered in the long run. Lack of funds is one of barriers for implementing sustainable projects and introducing sustainable manufacturing practices. High investments are required and processes such as eco-friendly packaging costs tend to be higher. There is also cost involvement in recycling, collecting used products and disposal of hazardous waste.

2.2.3. *Organizational culture inhibitive to sustainability/CSR*

An existing culture not conducive to sustainable development interrupts in SSCM implementation. Culture consists of values, beliefs, attitudes and peoples' behaviour that differs from kind or group of people (McSweeney, 2002). Different countries and even different industries have varied outlook on sustainability based on their own culture (Zhu and Sarkis, 2006). Based on country and society, the attitude and perception varies towards importance given to implementation of sustainability in the supply chain. Corporate social responsibility (CSR) undertaken by organizations combine social and environment concerns with its economic goals and also in their relationships with supply chain members. CSR being voluntary is impacted by culture and society. Cultural differences act as a major barrier in implementation of a sustainable supply chain.

Table 1
Barriers to SSCM implementation.

Sl.No.	Barrier	Description	References	Category
1.	Lack of commitment from top management	In absence of commitment from top management, there is no priority or sufficient resource allocation for sustainability aspects. There is no direction to frame policy and achieve goals related to sustainability.	Sajjad et al. (2015); Delmonico et al. (2018); Caldera et al. (2019)	Policy
2.	Financial Constraints	Financial constraints deter initial high investments required, loan support and lower return on investment for sustainability programs.	Mangla et al. (2017), Nhemachena and Murimbika, 2018; Bhanot et al. (2017)	Policy
3.	Organizational culture inhibitive to sustainability/CSR	Organisational culture and values giving importance to the social and environmental dimensions.	Paulraj et al. (2017); Delmonico et al. (2018); Soni et al. (2020); Sajjad et al. (2020),	Human resource
4.	Lack of new technology/materials and processes on sustainability	New and innovative technology, materials and processes to reduce waste, increase efficiency, improve safety systems and cut pollution levels.	Govindan et al. (2014); Movahedipour et al. (2017); Majumdar and Sinha (2018); Soni et al. (2020)	Technology
5.	Lack of awareness of benefits of sustainability	Lack of knowledge on the environmental harmful products and benefits of implementing sustainability programs	Soda et al. (2015); Mangla et al. (2017); Narayanan et al. (2019)	Human resource
6.	Lack of green purchasing	There is not due consideration and weightage given to sustainability criteria in purchase of input material.	ElTayeb et al. (2010); Guenther et al. (2013); Rostamzadeh et al. (2015); Delmonico et al. (2018)	Policy
7.	Lack of regulations and enforcement of environment standards	The enforcement of sustainable policies is not supported by strong legislation and support from the government.	AlSanad (2018); Raut et al. (2019); Narayanan et al. (2019)	Policy
8.	Lack of R&D on sustainability	Lack of research and development on recycling methods, reusability of products and	Stewart et al. (2016); Demirel and Kesidou (2019); Gupta et al. (2020)	Technology

(*continued on next page*)

Table 1 (*continued*)

Sl.No.	Barrier	Description	References	Category
		lesser polluting methods. Research and development help in reducing energy and resource consumption.		
9.	Lack of training/ human expertise on sustainability	There is a lack of experts and professionals in various areas of SSCM. Training and expertise is required to guide and implement the sustainability aspects.	Mangla et al. (2017); Neri et al. (2018); Digalwar et al. (2020); Khan et al. (2020)	Human resource
10.	Resistance to change and adopting innovation in sustainability	There is in general resistance to move from traditional practices and adapt innovation by staff. There is fear of failure and opposition to changes that need to be carried out.	Christensen et al. (2015); Stewart et al. (2016); Muduli et al. (2020); Khan et al. (2020)	Human resource
11.	Lack of performance metrics/ evaluation standards on sustainability	It is difficult to quantify and measure sustainability standards. The evaluation methods to verify sustainability performance are not uniform.	Al Zaabi et al. (2013); Touboulic and Walker (2015); Ninno Muniz et al. (2020)	Technology

2.2.4. *Lack of new technology, materials and processes*

Lack of advanced technology has been considered as a major reason for environmental deterioration (Wang et al., 2016; Mittal and Sangwan, 2014). Industries need to know about the new developments and use cleaner technologies to reduce pollution and wastage in the production process (Mudgal et al., 2010). Introduction or change of technology, processes or materials will require allotment of resources. But it is found that in the long term this might turn out to be advantageous. Industries need to optimise the processes and carry out technical improvements to increase its sustainability impact.

2.2.5. *Lack of awareness of benefits of sustainability*

Organizations tend to see the initial cost for sustainability implementation and generally oversee the benefits sustainability in the supply chain brings in long term. Low eco-literacy and unawareness about the environment management practices act as barriers (Herren and Hadley, 2010; Revell and Blackburn, 2007). Lack of awareness of reverse logistics is a major barrier in the implementation of reverse logistics operations (Ravi and Shankar, 2005). Lack of awareness in society on the benefits of sustainability does not encourage companies. Pressure from society can bring awareness to companies for making improvements in its sustainability performance.

2.2.6. *Lack of green purchasing*

Green purchasing is the purchase of products and services which reduce the negative effect on the environment and humans compared to competing products and services. Apart from usual purchasing criteria of cost, quality and time, green purchasing examines the issues of sustainability in purchase of inputs in a supply chain. (Kannan et al., 2008). There is limited research on low adoption and practices of green purchasing by firms (Hsu and Hu, 2008; Srivastava, 2007). Initial higher cost and no standard guidelines result in lack of green purchasing in organizations.

2.2.7. *Lack of regulations and enforcement of environment standards*

Government enforcement is necessary for an effective implementation of legislation in countries. Lack of regulation and adoption of environment friendly policies deters SSCM (AlKhidir and Zailani, 2009; Zhu et al., 2012; Ghazilla et al., 2015). Having strong compliance and enforcement has become an important part in designing policies to promote sustainable growth. Regulations and policies give a common compliance and performance outline in a country, but there are different across countries forcing companies to increase the effort and resources for adhering to different compliances. Apart from regulations, lack of government assistance to adopt sustainable manufacturing practises is a barrier (Prakash and Barua, 2015; Govindan et al., 2013). Regulations can be enforced by offering tax subsidies, incentives or other economic benefits to complying industries.

2.2.8. *Lack of R&D on sustainability*

Research and Development on sustainability in industries can improve safety aspects and environmental contribution by decreasing usage of energy as well as reducing wastages. The availability of natural resources is limited. Hence industries must research and develop processes in such a way that any type of resource is utilized optimally. The shortcoming in designing systems to reduce the consumption of energy and resources is a barrier in bringing sustainability (Russel, 2017; Perron, 2005). Organizations may not allocate necessary resources to R&D focussing on sustainability which impedes the pace of its implementation.

2.2.9. *Lack of training/human expertise on sustainability*

A major barrier in implementing SSCM is human related factors like no proper training, lack of qualified staff and inadequate knowledge. (Bohdanowicz et al., 2011). A certain level of expertise is required to incorporate social and environmental practices in an organisation. Training is much better than organizations trying to influence their suppliers in other ways. The success in implementation of green supply chain management can be improved by infusing literacy about sustainable practices among supply chain partners (Zabbi et al., 2013; Kumar et al., 2013). It also helps suppliers know the sustainability standards in the industry. Human resource development can be done by eco-literacy programs which become an important strategy for sustainability implementation. (Luthra et al., 2013; Govindan et al., 2014). In electronics industry for processes like recycling, proper skill acquisition through training is required (Wath et al., 2010; Yeh and Xu, 2013).

2.2.10. *Resistance to change and adopting innovation in sustainability*

Resistance to change and adopting innovation acts as a barrier for implementation of a sustainable supply chain (Gaziulusoy et al., 2013). A big impediment in innovation is the tendency to avoid change. The prevailing tradition, attitude and structure needs to be altered when bringing a change. There is also lack of trust and uncertainty associated during the transition phase. At consumer level also, benefits need to be communicated and change has to be accepted. Generally, there is a fear among people in moving to a new system and unwillingness to acquire new skills. It is found that innovation can solve many environmental issues but is often met with resistances (Acciaro et al., 2014).

2.2.11. *Lack of performance metrics/evaluation standards on sustainability*

In any industry, a measurement system is important to measure efficiency of the system. Lack of knowledge in assessing and gauging the social and environmental effect is an important barrier in sustainability implementation (Cetinkaya et al., 2011). The monitoring and measurement of sustainability is complex. Due to lack of guidance regarding environmental standards, companies are not aware of the ways and attributes to be measured (Shaw et al., 2010). Based on assessment criteria and indicators, there has to be development of common sustainability metrics. The accounting reports should also factor in the sustainability for evaluation along with economics. The environmental and social effect not being considered in traditional accounting methods is a big drawback in evaluation. (El Saadany et al., 2011).

2.3. Barrier studies in other industries

The barriers and their influence varies based on industry and region as seen in literature. Eleven barriers of reverse logistics in automobile industries were analysed and interactions among them was studied by Ravi and Shankar (2005). Al Zaabi et al. (2013) in a study of fastener manufacturing industry found that cost for environmentally friendly packaging, complex design to reduce consumption of resources and energy and lack of clarity regarding sustainability require utmost importance for SSCM implementation. Govindan et al. (2014) from the responses of Industrial participants in Tamilnadu, India and using Analytical Hierarchy Process (AHP) method found that technology category barrier is the most crucial in implementation of Green supply chain management. The specific barrier Complexity to measure and monitor environmental practices of suppliers was found to be the major obstacle in Green supply chain management (GSCM) adoption. Raut et al. (2018) found that in the Indian oil and gas sector barriers management commitment and leadership and knowledge and training were having high driving power, lack of green initiatives and lack of corporate social responsibility were having highest dependence power. The modeling of barriers interrelationship in Bangladesh leather industry by Moktadir et al. (2018) revealed that lack of awareness of local customers in green products and lack of commitment from top management had high causal effect. Narayanan et al. (2019) identified and prioritized the barriers of rubber products manufacturing industry in Kerala. It was found that lack of government initiatives and lack of benchmark on sustainability measurement as the major barriers for SSCM implementation in this sector. Delmonico et al. (2018) explored the barriers to sustainable public procurement in Brazil and concluded that the category of organisational culture as the crucial one. Soni et al. (2020) studied the barriers to sustainable supply chain management in Indian marble and stone industry and found that non supporting nature of commercial banks, practice of corruption and poor environmental awareness are the influencing barriers.

2.4. Research gap

Due to rapid growth of industry in developing countries, the pollution levels are increasing in these countries and implementation of sustainability in supply chains has become essential (Namagembe et al., 2019). There is literature which supports that introducing sustainability in the supply chain will have a beneficial effect but due to the barriers, organizations are not inclined to implement it. Electronics companies will come across these barriers during SSCM implementation and tackling all of them simultaneously is a challenge (Ghadge et al., 2017). The sustainability issues in the supply chain of electronics industries is typical due e-waste, hazardous chemicals, recycling process, transportation etc. It is seen that the studies on sustainable supply chain management practices are limited in developing countries (Ahmed and Najmi, 2018). There is a lack of adequate research on the barriers and strategies to overcome them for implementing sustainability in the electronics industry's supply chain specific to the Indian context. This necessitates to study the issues in implementing a sustainable supply chain in electronics industries in India. The research will assist in knowing the interrelationship among barriers in a structured way and suggest ways to remove them.

3. Method

Interpretive Structural Modeling (ISM) is a modelling technique by which the specific relationship among related elements can be structured and presented in diagraph form. ISM has been used as a modeling method to analyse green value chains, total quality management and reverse logistics (Mangla et al., 2018). The application of method is useful when there are factors with uncertain relationship affecting a subject by converting them to a comprehensible and structured (Raut et al., 2019). In comparison to other MCDM methods, ISM does not need the level of dominance to investigate interrelationship among factors (Raut et al., 2019). Unlike ISM, in Analytical Hierarchy Process (AHP), the interactions and indirect effects are not addressed (Zayed and Yaseen, 2020). Analytical Network Process (ANP) may not reflect all dependencies as removal of possible interactions within the cluster is difficult (Wu, 2008). It is different from alternate methods of Decision making trial and evaluation laboratory (DEMATEL) and social network analysis (SNA) in that it prioritises the factors apart from establishing relationships in a complex system (Abuzeinab et al., 2017). The ISM method is used as it frames the diagraph by combining the computational, theoretical and conceptual capability (Narayanan et al., 2019). The ISM method determines the mutual interactions and relationship among factors and it is a robust tool requiring a comparatively lesser amount of data (Panigrahi & Sahu, 2018). Quantitative data is not required for ISM. In this method, a model is prepared by structuring a number of different and directly related variables influencing the system. ISM is an interactive learning process and it helps in analysing inter-relationship among the variables (Bouzon et al., 2015). The sequence of steps followed in ISM methodology are presented in Fig. 3.

3.1. Interpretive structural model development

In this research to identify the contextual relationship among barriers of sustainable supply chain implementation in electronics industry, four experts were consulted. The selection of 4 experts is based on literature which states that the number of samples does not have to be too big for ISM (Shen et al., 2016) and can be few as two experts (Ravi and Shankar, 2005). For a diverse and comprehensive opinion, three experts from industry and a fourth expert from academia were approached. The three industrial experts were having an experience in the range of 15–20 years in the electronics industry and working in senior managerial level. They have been involved in implementation of sustainability practices in areas of green purchasing, quality assurance and technology development. These experts are having an experience of more than fifteen years in sustainability related areas of supply chain in the electronics industry. The academic expert is an associate professor having experience over 15 years with research interests in sustainable supply chain management.

Step 1. The factors which influence the system are found and shortlisted.

For this research, the barriers to implementation of a sustainable supply chain were identified by literature review. By consultation and brainstorming sessions with experts, eleven barriers that affect the sustainability implementation in the supply chain of Indian electronics industry were identified and categorized. These barriers are shown in Table 1.

Step 2. From these factors, contextual relationship among them is determined.As per ISM method, contextual relationship is determined amongst variables through expert's opinion. Expert's opinion is evolved by using management methods like nominal technique, brainstorming and some others. Focussed group discussion method was used to find the contextual relationship among various barriers.

Step 3. Structural Self-Interaction Matrix - A Structural Self-Interaction Matrix (SSIM) is formulated for factors to establish a pair-wise

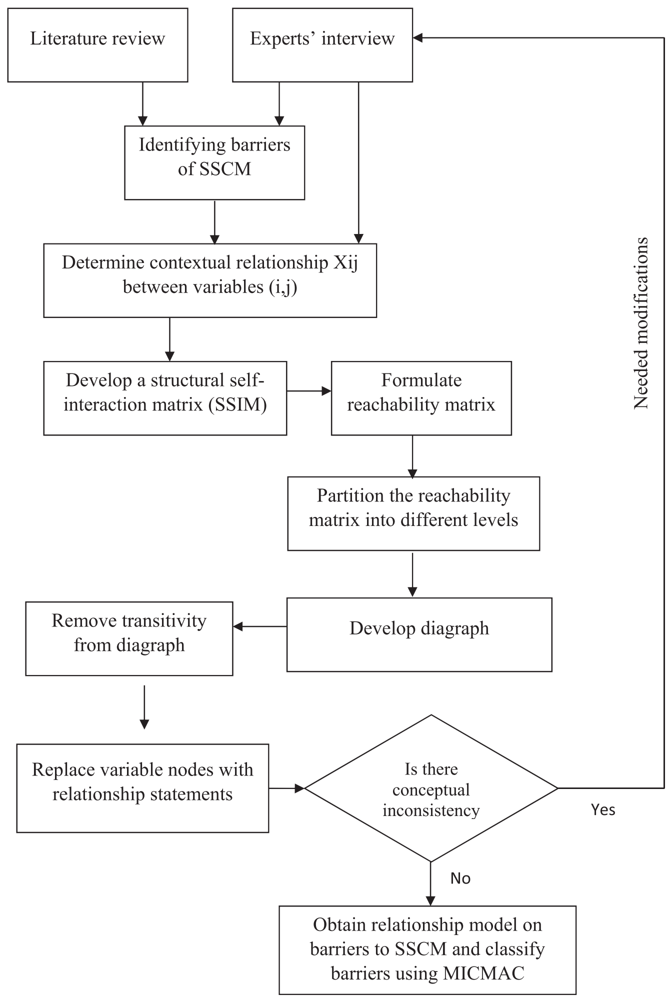

Fig. 3. Flow diagram for ISM method.

relationship within them.

A contextual relationship of "leads to" type is used for analysing the barriers of sustainable supply chain variables. This way one variable will lead to another and using this one can establish the contextual relationship. Considering the contextual relationship of variables, the relation between two variables say *i* and *j* is worked out by probing the presence of relationship of variables *i* and *j*. In ISM, the flow of relationship among variables i and j is denoted using four symbols: These symbols are V, X, A and O. Their usage depends on the way barrier i and j help to achieve or not achieve each other, which is as follows:

- V: A forward relationship where variable i will lead to variable j
- A: A reverse relationship where variable j will lead to variable i
- X: A relationship where variable i leads to variable j and vice versa and
- O: There is no relationship between variable i and j and they are independent of each other.

The SSIM for the barriers in the implementation of sustainable supply chain so obtained is given in Table 2.

Barrier 9 helps in alleviating Barrier 10. This relationship in the SSIM table is shown by symbol V. This denotes that lack of training/human expertise alleviates resistance to change and adopting innovation in sustainability. In general, there is resistance to change and accepting a new system which can be solved by training and guidance. Therefore, lack of training will alleviate the resistance of employees to change and adopt innovation while implementing sustainability thus being shown by symbol V.

Barrier 4 and Barrier 10 help alleviate each other. This relationship in the SSIM table is shown by symbol X. Resistance to change and adopting innovation will lead to lack of new technology/materials and processes on sustainability. Similarly lack of new technology/materials and processes will inhibit change and innovation adoption.

Barrier 2 and Barrier 11 are not related to each other and this relation is shown by symbol O in the SSIM matrix. The barriers financial Constraints and lack of performance metrics/evaluation standards have no relationship between them and hence O is marked.

Similarly, the contextual relationships are established for all the 11 barriers identified for the sustainability implementation (Table 2) in SSIM.

Step 4. Reachability matrix -The Reachability matrix is prepared from SSIM by checking transitivity of the matrix. Transitivity rule states that if a factor P has a relation with Q and Q has a relation with R, then P also has a relation with R.

The information of SSIM is converted into a binary matrix i.e. 1 and 0 based on rules. This matrix is called the initial reachability matrix and

Table 2
Structural self-interaction matrix (SSIM).

→ ↓Barriers	11	10	9	8	7	6	5	4	3	2
1. Lack of commitment from top management	V	O	V	V	A	V	A	V	V	V
2. Financial Constraints	O	V	V	V	O	V	A	V	X	
3. Organizational culture inhibitive to sustainability/CSR	V	V	V	V	O	V	A	V		
4. Lack of new technology/materials and processes on sustainability	V	X	O	A	A	A	A			
5. Lack of awareness of benefits of sustainability	V	V	V	V	V	V				
6. Lack of green purchasing	V	O	V	X	A					
7. Lack of regulations and enforcement of environment standards	V	V	V	V						
8. Lack of R&D on sustainability	V	V	X							
9. Lack of training/human expertise on sustainability	V	V								
10. Resistance to change and adopting innovation in sustainability	V									
11. Lack of performance metrics/evaluation standards on sustainability										

here V, A, X, O are replaced by either 1 or 0. The substitution is done based on the conditions as given in Table 3.

For e.g. Table 3 can be explained as 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. Similarly, 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 and so on. Substitution as above is done resulting in initial reachability matrix as shown in Table 4.

The initial reachability matrix so arrived has to be checked for transitive links which may be present among the variables. For eg. in Table 4, barrier 9 influences barrier 8 and barrier 8 influences barrier 6. Therefore, it can be inferred that barrier 9 has an effect on barrier 6 and the relation is changed to 1 in final reachability matrix. The final reachability matrix after checking of transitivities is shown in Table 5. The driving power of a barrier and its dependence is also depicted in Table 5. The driving power of a particular barrier is found from the total barriers it helps to achieve and this includes the considered barrier itself. The dependence on the other hand is the total of barriers helping it to achieve and includes itself. The values against each barrier for driving and dependency power will be applied in MICMAC analysis which categorizes the barriers into four groups of autonomous, dependent, linkage, and independent.

Step 5. Level partitions - Partitioning of final reachability matrix into different levels.

From the final reachability matrix, the reachability and antecedent set (Warfield, 1974) for each barrier is found out. Reachability set consists of the variable itself and the variables it assists to achieve. An antecedent set consists of the variable itself and those variables that help to reach it. The intersection of these sets is obtained for all variables. After figuring out the top-level variable, it is removed from the other remaining variables. At level I, as seen in Table 6 is lack of performance metrics/evaluation standards on sustainability (Barrier 11). Since Barrier 11 is at Level I, it will come on the top of the ISM model.

Again in the next iteration, the intersection of reachability set and antecedent set is identified. Iteration 2 shown in Table 7 reveals that second level motivation is found at variable 4 and 10. Hence they will occupy the second level and be removed in ensuing iterations. This process is repeated and variables removed in each level. This is continued till the levels of each variable are obtained. The levels of barriers decide their position in the ISM model. These levels help in building the digraph and final model of ISM. The barriers, along with their reachability set, antecedent set, intersection set and the levels for barriers are enumerated in Tables 6–12.

Step 6. Formation of ISM-based model - A diagraph is prepared based on the relationship in reachability matrix and by removing the transitive links. The diagraph is developed to an ISM model by converting factorial nodes to statements. The obtained ISM model is verified for presence of any conceptual discrepancy and if required the changes are done to remove it.

From the final reachability matrix, a structural model is developed. To depict the relationship among two barriers, i and j, an arrow is drawn from i to j and the resulting graph is called digraph. The digraph is finally converted into an ISM model as shown in Fig. 4.

It is observed from Fig. 4 that lack of awareness of benefits of sustainability (Barrier 5) is at the bottom indicating it significantly affects the system. In this model, all the eleven barriers come in 7 levels. Lack of awareness of benefits of sustainability (Barrier 5) is at level 7 and Lack of regulations and enforcement of environment standards (Barrier 7) is at level 6. This indicates that lack of awareness about sustainability (Barrier 5) influences regulation and enforcement of sustainability (Barrier 7). Lack of performance metrics/evaluation standards on sustainability (Barrier 11) is on the top of figure i.e. level I.

Table 3
Rules for initial reachability matrix formulation.

	Substitution in Reachability matrix	
Value of (*i*, *j*) in SSIM	(*i*, *j*) entry	(*j*, *i*) entry
V	1	0
A	0	1
X	1	1
O	0	0

4. Results

The ISM model obtained in Fig. 4 arranges the barriers in the supply chain of electronics industries in seven levels and shows the relationship between them. The barriers in upper levels are driven by barriers at lower levels. Lack of awareness of benefits of sustainability (Barrier5) is a key barrier as it has the highest influence being at level 7, the lowest level in the ISM model. Awareness on the benefits of sustainability should be promoted by Industry bodies, NGOs and Governments. The study by Mathiyazhagan et al. (2013) found that lack of environmental awareness of suppliers to be the most influencing barrier for Green supply chain management (GSCM) implementation in automobiles industries of South India. Kumar and Dixit (2018) found that lack of awareness for recycling and lack of policies and regulation as the root cause barriers in confronting e-waste problems. Programs and activities to enhance awareness about sustainability across all levels and their benefits to the society should be extensively undertaken.

The next fundamental barrier that comes at level 6 is lack of regulations and enforcement of environment standards (Barrier7). Barrier 5 leads to lack of regulations and enforcement of environment standards as lack of awareness dilutes the enforcement. Only when people are aware of the benefits, there would be measures taken for regulation and strict enforcement. The public raises their concern on the environment to the Government and the Government should bring stringent laws as well as see that it is properly enforced by industries. It is seen that the acceptability of regulations and policies is very low by electronics industries though they are significant influencers (Ravi and Shankar, 2014). Regulations on electronic waste management, proper disposal etc. can be strengthened and support in storage, eco-friendly recycling infrastructure should be enhanced. Schemes such as extended producer's responsibility (EPR) should be widened. Mitra and Datta (2014) pointed out that there was lack of awareness on environmental sustainability and the regulatory framework was also lacking for adoption of GSCM in Indian manufacturing industries. Luthra et al. (2016) evaluated the barriers in sustainable consumption and production using Government support and policies' as the most important for plastic manufacturing organization in India.

The above barriers lead to level 5 of lack of commitment from top management. Lack of commitment from top management (Barrier1) happens when they feel that there is lack of regulation and enforcement. This is in line with Majumdar and Sinha (2019) that top management is not inclined in their commitment to sustainable supply chain management in absence of stringent regulations. Top management commitment is the main behavioural element which influences other factors in implementation of green supply chain management practices in Indian mining industries (Muduli et al., 2013). This is reflected at level 4 in the derived ISM Fig. 4.

At level 4, Financial constraints (Barrier2) and organizational culture inhibitive to sustainability/CSR (Barrier 3) are affected by Lack of commitment from top management (Barrier1). The top management in an organisation allocates funds which are required for implementation of sustainability. Top management attitude gives direction to the culture in an organization and its obligation towards corporate social responsibilities. Thus Lack of commitment from top management (B1) drives Financial constraints (B2) and organizational culture inhibitive to sustainability/CSR (B3).

The disposal and recycling processes requires financial investment. With rapidly changing product design and shorter life cycle of electronics

Table 4
Initial reachability matrix.

Barriers	1	2	3	4	5	6	7	8	9	10	11
1. Lack of commitment from top management	1	`1	1	1	0	1	0	1	1	0	1
2. Financial Constraints	0	1	1	1	0	1	0	1	1	1	0
3. Organizational culture inhibitive to sustainability/CSR	0	1	1	1	0	1	0	1	1	1	1
4. Lack of new technology/materials and processes on sustainability	0	0	0	1	0	0	0	0	0	1	1
5. Lack of awareness of benefits of sustainability	1	1	1	1	1	1	1	1	1	1	1
6. Lack of green purchasing	0	0	0	1	0	1	0	1	1	0	1
7. Lack of regulations and enforcement of environment standards	1	0	0	1	0	1	1	1	1	1	1
8. Lack of R&D on sustainability	0	0	0	1	0	1	0	1	1	1	1
9. Lack of training/human expertise on sustainability	0	0	0	0	0	0	0	1	1	1	1
10. Resistance to change and adopting innovation in sustainability	0	0	0	1	0	0	0	0	0	1	1
11. Lack of performance metrics/evaluation standards on sustainability	0	0	0	0	0	0	0	0	0	0	1

Table 5
Final reachability matrix.

Barriers	1	2	3	4	5	6	7	8	9	10	11	Driver Power
1. Lack of commitment from top management	1	1	1	1	0	1	0	1	1	1	1	**9**
2. Financial Constraints	0	1	1	1	0	1	0	1	1	1	1	**8**
3. Organizational culture inhibitive to sustainability/CSR	0	1	1	1	0	1	0	1	1	1	1	**8**
4. Lack of new technology/materials and processes on sustainability	0	0	0	1	0	0	0	0	0	1	1	**3**
5. Lack of awareness of benefits of sustainability	1	1	1	1	1	1	1	1	1	1	1	**11**
6. Lack of green purchasing	0	0	0	1	0	1	0	1	1	1	1	**6**
7. Lack of regulations and enforcement of environment standards	1	1	1	1	0	1	1	1	1	1	1	**10**
8. Lack of R&D on sustainability	0	0	0	1	0	1	0	1	1	1	1	**6**
9. Lack of training/human expertise on sustainability	0	0	0	1	0	1	0	1	1	1	1	**6**
10. Resistance to change and adopting innovation in sustainability	0	0	0	1	0	0	0	0	0	1	1	**3**
11. Lack of performance metrics/evaluation standards on sustainability	0	0	0	0	0	0	0	0	0	0	1	**1**
Dependence power	**3**	**5**	**5**	**10**	**1**	**8**	**2**	**8**	**8**	**10**	**11**	

products, the allocation of finance to different areas is a challenge. New technologies and optimization techniques should be developed to reduce the financial constraints. Industry and academia can collaborate on projects to find better solutions. The culture of sustainability should be moulded with organizational culture so that sustainability practices are transferred throughout the supply chain. Organizational Culture can boost participation and innovative approaches towards sustainability (Muduli et al., 2013). This leads to Lack of green purchasing (Barrier6), Lack of R&D on sustainability (Barrier8) and lack of training/human expertise on sustainability (Barrier9) being influenced by financial constraints (Barrier2) and organizational culture inhibitive to sustainability/CSR (Barrier3).

Lack of new technology/materials and processes on sustainability (Barrier4) is on level 6 above lack of green purchasing (Barrier6) and lack of R&D on sustainability (Barrier8). This relation is because new developments in technology, materials and processes related to sustainability are alleviated by R&D and green purchasing. On the same level 6, resistance to change and adopting innovation (Barrier10) in sustainability (Barrier10) is alleviated by Lack of R&D on sustainability (Barrier8) and lack of training/human expertise on sustainability (Barrier9). Lack of R&D was observed to be a critical barrier in implementation of green production practises in Small and Medium Enterprises (Ghazilla et al., 2015). Absence of new technology/materials/processes and innovation adoption would lead to lack of performance metrics/evaluation standards on sustainability (Barrier11) which is therefore placed on the top of the Fig. 4. It is found that all technology category barriers Lack of R&D on sustainability (Barrier 8), Lack of new technology/materials and processes on sustainability (Barrier 4) and lack of performance metrics/evaluation standards on sustainability (Barrier 11) are in the top 5, 6 and 7 levels indicating that technology barriers are mostly influenced by other barriers.

Table 6
Iteration 1.

Barrier	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 6, 8, 9, 10, 11	1, 5, 7	1	
2	2, 3, 4, 6, 8, 9, 10, 11	1, 2, 3, 5, 7	2, 3	
3	2, 3, 4, 6, 8, 9, 10, 11	1, 2, 3, 5, 7	2, 3	
4	4, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	4,10	
5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	5	5	
6	4, 6, 8, 9, 10, 11	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	
7	1, 2, 3, 4, 6, 7, 8, 9, 10, 11	5, 7	7	
8	4, 6, 8, 9, 10, 11	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	
9	4, 6, 8, 9, 10, 11	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	
10	4, 10, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	4, 10	
11	11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	11	I

Table 7
Iteration 2.

Barrier	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 6, 8, 9, 10	1, 5, 7	1	
2	2, 3, 4, 6, 8, 9, 10	1, 2, 3, 5, 7	2, 3	
3	2, 3, 4, 6, 8, 9, 10	1, 2, 3, 5, 7	2, 3	
4	4, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	4,10	II
5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	5	5	
6	4, 6, 8, 9, 10	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	
7	1, 2, 3, 4, 6, 7, 8, 9, 10	5, 7	7	
8	4, 6, 8, 9, 10	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	
9	4, 6, 8, 9, 10	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	
10	4, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	4, 10	II

Table 8
Iteration 3.

Barrier	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 6, 8, 9	1, 5, 7	1	
2	2, 3, 6, 8, 9	1, 2, 3, 5, 7	2, 3	
3	2, 3, 6, 8, 9	1, 2, 3, 5, 7	2, 3	
5	1, 2, 3, 5, 6, 7, 8, 9	5	5	
6	6, 8, 9	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	III
7	1, 2, 3, 6, 7, 8, 9	5, 7	7	
8	6, 8, 9	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	III
9	6, 8, 9	1, 2, 3, 5, 6, 7, 8, 9	6, 8, 9	III

Table 9
Iteration 4.

Barrier	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3	1, 5, 7	1	
2	2, 3	1, 2, 3, 5, 7	2, 3	IV
3	2, 3	1, 2, 3, 5, 7	2, 3	IV
5	1, 2, 3, 5, 7	5	5	
7	1, 2, 3, 7	5, 7	7	

4.1. MICMAC analysis

The purpose of the MICMAC (Matrix of Cross-Impact Multiplications Applied to Classification) analysis is to analyse the driver power and dependence power of variables. The variables are classified into four categories, autonomous, dependent, linkage and independent (Fig. 5).

Table 10
Iteration 5.

Barrier	Reachability set	Antecedent set	Intersection set	Level
1	1	1, 5, 7	1	V
5	1, 5, 7	5	5	
7	1, 7	5, 7	7	

Table 11
Iteration 6.

Barrier	Reachability set	Antecedent set	Intersection set	Level
5	5, 7	5	5	
7	7	5, 7	7	VI

Table 12
Iteration 7.

Barrier	Reachability set	Antecedent set	Intersection set	Level
5	5	5	5	VII

Variables having weak driving power and weak dependence power comes under Quadrant 1 - autonomous category. The main characteristic of these variables are that they may have a few links that might be strong and do influence the structure much. Dependent variables - Quadrant 2 possess weak driving power but strong dependence power. A linkage variable - Quadrant 3 possesses strong driving power and strong dependence power. Fourth category - Quadrant 4 includes the “independent” which have strong driving power but weak dependence.

The driving power and the dependence of each of these barriers are shown in Table 5. The presence of 1 along the columns and rows of this table specifies the dependence and driving power, respectively. Thereafter, the diagram of driving power vs. dependence power for the barriers is made which is shown in Fig. 5. For example, from Table 5, it is seen that organizational culture inhibitive to sustainability/Corporate Social Responsibility (Barrier 3) is having a driving power of 8 and dependence power of 5. Thus, it is appropriately placed in quadrant 4 in Fig. 5. In the same way, all eleven barriers based on their driving and dependence power are placed in this Fig. 5.

From the MICMAC analysis shown in Fig. 5, no barriers are found in the autonomous quadrant. Thus, all barriers under consideration in this study are relevant and have an influence in the implementation of sustainability in the electronics industry. The lack of performance metrics/evaluation standards on sustainability (Barrier11), lack of new technology/materials and processes on sustainability (Barrier4) and resistance to change and adopting innovation in sustainability are in the dependent quadrant (Barrier10) which have high dependence power but low driving power. The high dependence power shows that these barriers can be influenced by other barriers but they are not guiding others. Lack of green purchasing (Barrier6), lack of R&D on sustainability (Barrier8) and lack of training/human expertise on sustainability (Barrier9) are in the linkage quadrant revealing they are unstable. The barriers in this quadrant are generally unstable and action on these barriers not only influences others but also has a feedback on them (Yadav and Barve, 2015).

Lack of awareness of benefits of sustainability (Barrier5), lack of regulations and enforcement of environment standards (Barrier7), lack of commitment from top management (Barrier1), financial constraints (Barrier 2), organizational culture inhibitive to sustainability/CSR (Barrier3) are in independent quadrant thereby suggesting that they have high driving power but low dependence. These barriers are crucial to drive the implementation of sustainability in the electronics industry. It is evident from literature that government regulations/enforcement, top management commitment and awareness play a much larger role in sustainability implementation. They are crucial and hence are required to be paid more attention.

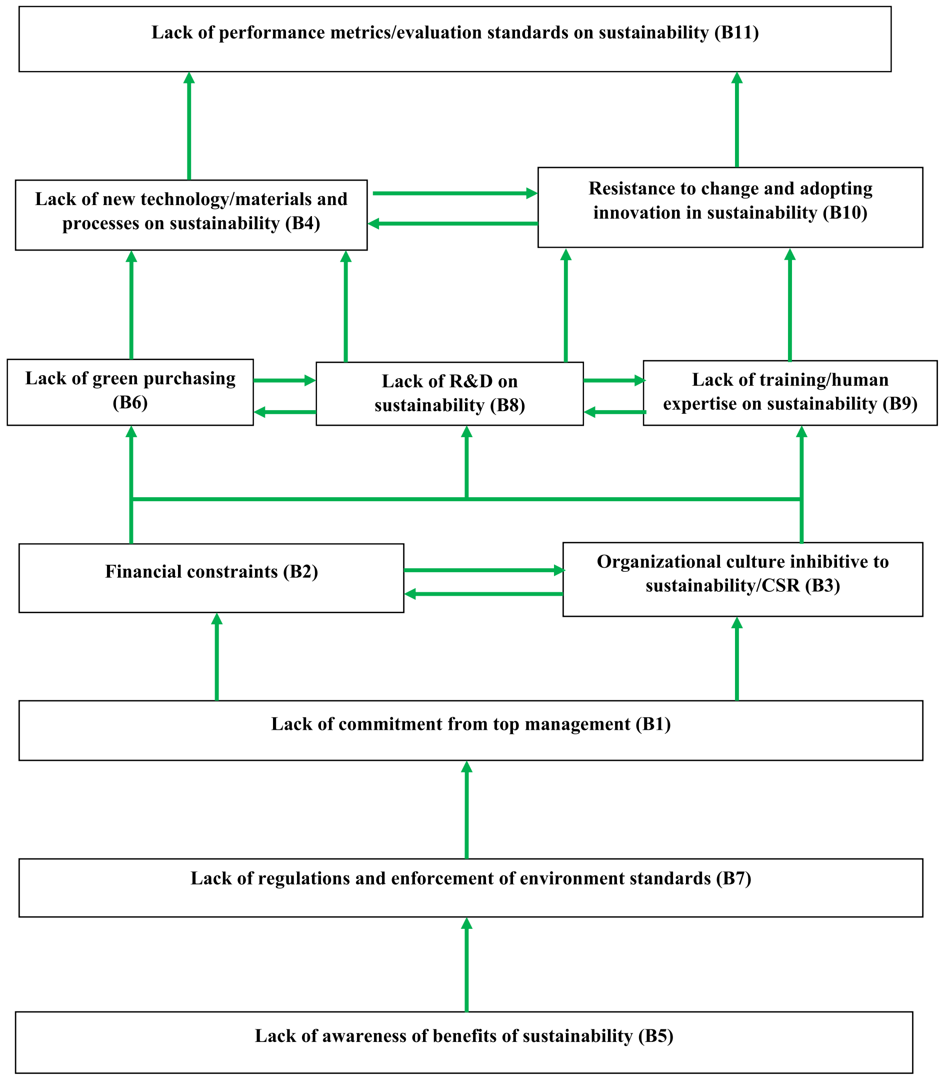

Fig. 4. ISM-based model for the barriers in implementation sustainable supply chain.

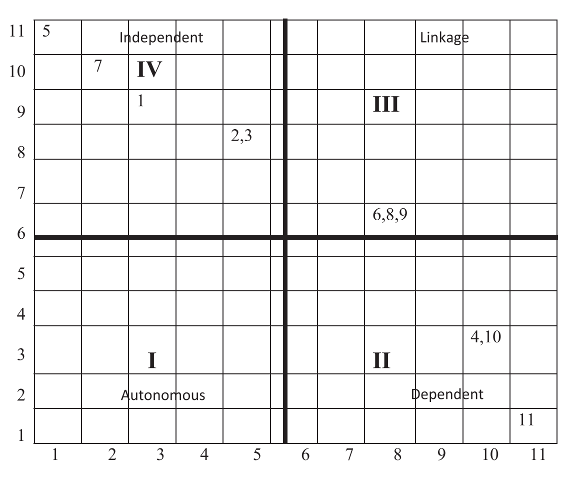

Fig. 5. Driving power and dependence diagram.

The position of barrier category based on the results of MICMAC analysis is shown in Fig. 6. It is found that most of the barriers in the Policy category are in the independent quadrant indicating that policy barriers are having high driving and influencing power. Therefore, the policy related areas at both government and organizational level are to be formulated and strengthened in electronics industries to remove barriers in implementation of a sustainable supply chain management. The focus on policy areas will assist in mitigating the other barriers that are present. Managing these crucial barriers will also influence the other barriers and hence the overall system can be controlled better. The ISM model developed is in general for the electronic industry but can be applied across supply chains in similar industries.

5. Managerial implications

The results obtained in this paper have various practical and academic implications. The paper analyzes the various critical barriers in implementation of a sustainable supply chain. It models the relationship between barriers encountered while industries try to introduce SSCM. The barriers are also classified in different areas giving managers an understanding of how the barriers individually and as categories affect sustainability implementation in Indian electronics industries. Managers can know which barriers need their immediate attention and how the other barriers would be influenced. The outcome in this research reveals the driving and driven powers along with their dependence or independence on other barriers. Administrators need to develop strong policies and regulations to achieve sustainability. These policies are to be strengthened to ensure enforcement in organizations. The developed ISM

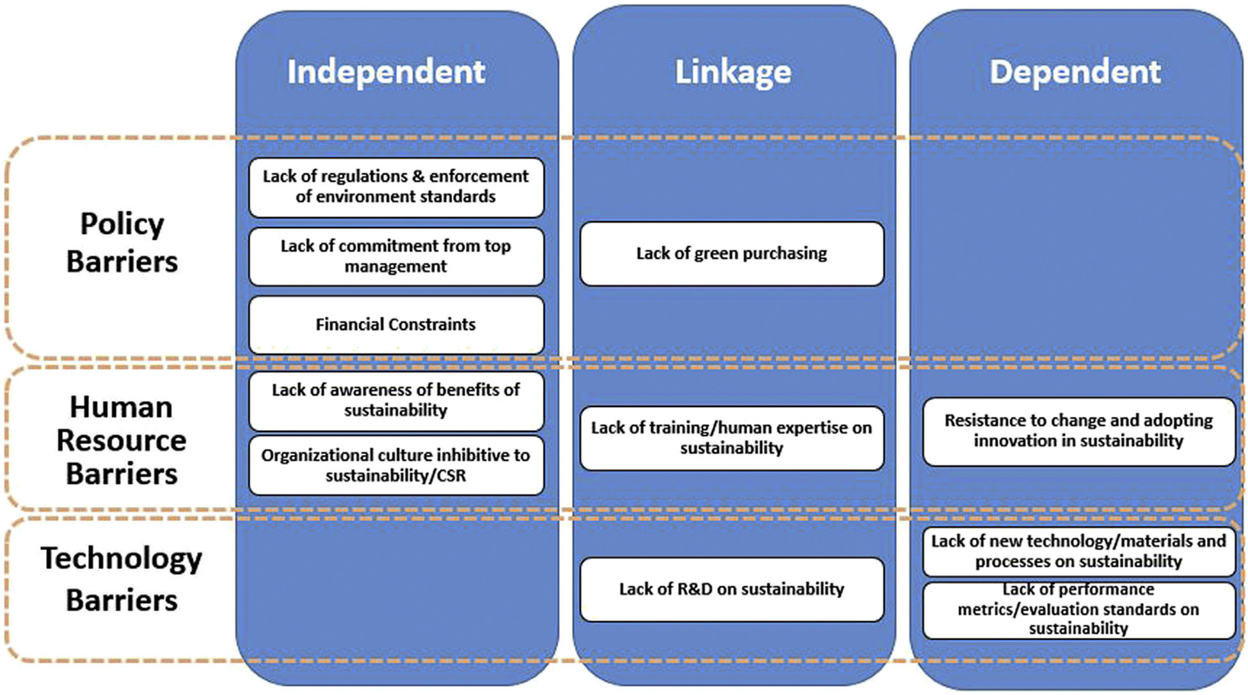

Fig. 6. MICMAC analysis classified to Barrier categories.

model can help managers to devise strategies and develop solutions in tackling barriers to successfully implement a sustainable supply chain.

6. Conclusion

Sustainability has become a global issue and industries world over are now moving towards a sustainable supply chain. Companies have to consider people and the planet along with profit to remain in business. The firms are moving towards sustainability not only due to pressures but also because supply chain sustainability gives many advantages to them. Electronics industry is growing rapidly worldwide and particularly in India. The use of electronic devices is growing in developing countries resulting in a higher rate of depletion of physical resources and e-waste generation. Due to the specific nature of the industry and the consumption pattern of electronic goods, it is imperative for Indian electronic industries to come up with sustainability practices in their supply chain. These industries are going to face many barriers while implementing sustainability. The paper addresses the problem first by identifying the barriers in implementation of a sustainable supply chain in electronics industries in Indian context. Then a structured model showing the interrelationships among these barriers is constructed using ISM method. The driving and driven powers of the barriers as well as their interdependence is also established. Further, applying MICMAC analysis the dependent, linkage and independent barriers are determined.

With the help of literature review and four experts, eleven barriers encountered during SSCM implementation were identified. Based on their functional traits the barriers were categorized in group of Policy, Human resource and Technology for easier management during implementation phase. Results from ISM reveal that Lack of awareness of benefits of sustainability is a key barrier as it has the highest influence being at the lowest level in the ISM model. The order of influence is followed by lack of regulations and enforcement of environment standards and lack of commitment from top management. Thus, the most important barriers that need to be addressed during SSCM implementation are Lack of awareness of benefits of sustainability, lack of regulations and enforcement of environment standards, lack of commitment from top management. These barriers drive financial constraints and organizational culture inhibitive to sustainability/CSR. Lack of green purchasing, lack of R&D on sustainability and lack of training/human expertise on sustainability are linkage barriers indicating they are driven by the independent barriers as well as they themselves influence barriers at a higher level of the ISM model. The linkage barriers characterize all three categories of Policy, Human resource and Technology barriers. Technoloy category barriers, viz., lack of performance metrics/evaluation standards on sustainability and lack of new technology/materials and processes on sustainability along with resistance to change and adopting innovation in sustainability are influenced by other barriers.

As an outcome of this work, activities and programs promoting awareness on the socio-environment impact of electronic goods at all levels and the benefits of sustainability adoption to the society is strongly recommended. The analysis reveals that mainly policy category barriers are independent and they have high driving power. It is suggested that targeted policies at both government and organizational level be formulated as well as strengthened for the electronics industries to remove barriers in implementation of a sustainable supply chain management. Programs like extended producer's responsibility (EPR) and recycling should be encouraged in the electronics industry. Managerial implications and mitigating strategies are discussed to overcome the barriers. The finding can motivate further academic research in strategies to overcome the barriers and formulation of policies at various levels for electronics industries in India.

The ISM model and MICMAC analysis will help electronic companies to know which barriers need to be tackled on priority and given more attention while introducing sustainability in the supply chain. This framework gives an understanding on the link between barriers, their position and their dependence/independence in the system. The complexities involved in sustainability implementation are high and the framed model can guide on the criticality of barriers that will be faced.

In this research, the barriers in implementation of sustainable supply chain in the Indian electronics industry are identified and analysed using ISM model. In taking the opinion of experts, there is a possibility of bias and hence in future study, the number of experts can be increased and results compared. The study finds the relationship between factors but the strength of this relationship is not known because of ISM method limitations. This model needs to be statistically validated and this can be done through Structural Equation Modelling (SEM) or other approaches.

For future research, the relationship between more barriers and their categories can be studied. Further, barriers in other industries can be identified and other multi criteria decision making (MCDM) methods can be considered for analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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