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Identification and analysis of barriers to achieve supply chain resilience in manufacturing industry: an ISM and MICMAC approach

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Abstract

Supply chain resilience (SCR) demonstrates when the supply chain network is capable to withstand, adapt, and recover from disturbances in order to fulfill consumer demand and guarantee performance. Due to the growing complexity of modern supply chains and subsequently increasing probability of experiencing a disruption, understanding of SCR is increasingly important for supply chain managers. The research study uses an interpretive structural modeling (ISM) and MICMAC approach for directing and supporting managers and policy-makers of manufacturing industries. In the background of a developing world using previous literature and expert mining, this study empirically established the barriers to achieve SCR with their corresponding sources in industry by taking the Bangladeshi manufacturing sector as an example. The findings reflect the dysfunctional existence of variables in the sense of their effect on each other, their interactions, and themselves. The factors identified as barriers in the proposed framework and their interrelationships illustrate the multi-dimensional aspect of prevention of SCR achievement. The findings demonstrate the criticality of evaluating data as a collective entity instead of seeing the barriers in isolation. This study highlights theoretical and managerial implications of barriers to achieve SCR.

Key words

Achievement; barriers; supply chain resilience; risk management; manufacturing industry; Bangladesh; ISM-MICMAC

1. Introduction

In today's global and highly complex and volatile environments supply chains are faced with multiple incidents that threaten to interrupt supply chains operating operations and jeopardize productive and effective results. The worldwide scope of supply chains, shorter life cycles of goods, and rising consumer expectations have made organizations aware that disruptions in the supply chain will cause adverse organizational and financial impacts. Disruption risks are events that occur from natural disasters, such as storms, earthquakes, or floods, or from man-made catastrophes, such as supplier shutdown, terrorist attacks, and major fire at a manufacturing plant or labor strikes. Building supply chain resilience (SCR) may help to minimize and resolve risk by designing techniques that enable the supply chain to return from a disturbance to its original or an even better functional state (Hudnurkar et al., 2017); (Soosay & Hyland, 2015).

Supply chain risk management (SCRM) is concerned with the identification of risk factors across the supply chain and the implementation of methods to resolve them. A recent MIT Scale Network analysis showed that about 60 percent of executives either did not regularly work on SCRM or did not feel that the risk management activities of their organization were successful (Kamalahmadi & Parast, 2016). Standard risk assessment is primarily focused on risk recognition and statistical statistics, while many risks are uncertain and unknowable and there could be no statistical details. In the last decade, SCR has shifted from an emerging topic, and in recent years, the notion of supply chain resilience has attracted further attention to resolve this issue. This allows an company to look at the capacities of the entire supply network to thrive, evolve and expand while faced with transition and uncertainty (Soosay & Hyland, 2015).

The concept of SCR and its achievement are continuously developing and are still being debated extensively. The lack of research about achievement of SCR in manufacturing industry is the problem area that this research study will address. Research shows that the achievement of SCR can be hindered by distinct barriers. Identifying factors affecting SCR in form of barriers is necessary that could be helpful to achieve SCR in the Bangladeshi manufacturing industry. Manufacturing industries are required to reduce or eliminate such barriers for sustainability in longer run.

The goal of this study is to fill the gap of previous researches by creating a comprehensive model that uses Interpretive Structural Modelling (ISM) and Matrice d’ Impacts Croises –

Multipication Applique a classement (MICMAC) approach to explain the barriers of SCR and their interactive contextual relationships. The main objectives of this paper are:

1. Identifying and defining barriers of supply chain resilience;
2. Categorizing the barriers according to their sources;
3. Modeling the barriers of SCR using interpretive structural modeling (ISM);
4. Performing MICMAC analysis to classify barriers of SCR into four clusters;
5. Discuss the implications of the research and suggest directions for future research work.

Rest of the paper is structured in the following manner. The next section discusses literature review of the related work. The research methodology used is then explained in detail. Then SCR barriers are categorized and performed ISM and MICMAC analysis. Finally, the discussion and conclusions are presented along with the implications and future research direction of the study.

2. Literature review

The literature review section has been divided into three sub-parts to better understand the SCR concept. The first part explains the general concept of SCR with the details of necessity to adopt SCR in manufacturing industries. In the second part barriers to achieve SCR have been described. The third part deals with the existing work on the ISM-MICMAC and other approaches that deal with SCR barriers with correlations and research gaps among the research papers existing in the literature.

2.1 Supply chain resilience (SCR)

Previously, resilience was not an eminently known concept in the business world, and to some extent, its meaning is still limit to a minority of researchers and practitioners within the supply chain management field. This concept has emerged from a fusion of disciplinary concepts and ideas which began in material science to describe the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading (Pereira et al., 2014). The concept of resilience has been explored within the social sciences in three primary branches: social, psychology, and economics. Because of its wide range of application to different subjects and organizational approaches resilience has become a multidimensional and multidisciplinary phenomenon in the last 40 years (Ponomarov & Holcomb, 2009)

Supply chain resilience is the ability to proactively plan and design the supply chain networks for predicting unexpected disruptions, respond adaptively to any unwanted event alongside maintaining control over structure and function and go beyond to a post robust state of operations, if possible a more better one than that prior to that disruption, thus ensuring a competitive advantage (Tukamuhabwa et al., 2015). It is, therefore, becoming compulsory for firms to build supply chain resilience (SCR) as a pivotal capability to respond adaptively to challenges, adversities, and disruptions and squeeze complexity to create sustained customer value in settings where organizations and their advantages are often unaspirated (Gölgeci & Kuivalainen, 2020).

2.2 Barriers to achieve SCR:

Identification of barriers prior to the implementation of any quality improvement technique within any organizational environment is extremely important as controlling the barriers after implementation becomes a difficult chore for the management sector (G. Yadav & Desai, 2017). Throughout the literature search go through over the SCR barriers it is observed that various authors contributed worthy works to identify the set of SCR barriers.

Traditional approaches are based on centralized access control in digital asset management do not suited well in collaborative environment as it does not allow any organization to take full control over entire digital assets because of its various trust level existing among the organizations. Though Centralization of assets help organizations to reduce their inventory level but would possibly reason of reducing the capability of supply chain resilience (Rana & Rana, 2020); (Rajesh, 2018); (Davis-Sramek et al., 2015); (Elisabeth Sundin, 2016).Disproportionate assets describe a situation where economic assets of any organization or company significantly exceed the assets it should possess after considering for the assets that it previously owned and income from all legal sources. So it can damaged sustain product or service level considering a barrier to achieve supply chain resilience (Pal et al., 2019); (Lanier et al., 2019); (Rajesh, 2018); (Poulsen & Lema, 2017).Dispersed and unclear ownership can increase the level of risk by affecting quick response system at the occurrence of any disruption in supply chain network and can act as a barrier to achieve resilience in supply chain networks (Pal et al., 2019); (Lanier et al., 2019); (Rajesh, 2018); (Poulsen & Lema, 2017).At the corporate level to secure supply chains most of the company rely on insurance especially for the risky assets. As risky asset can be caused for any uncertainty most often, insurance can help a firm to stay afloat financially after a major disruption (Gornall & Strebulaev, 2018); (Giannakis & Papadopoulos, 2016).

The supply chain looks like an uprooted tree instead of looking like a pipeline or chain where the extensive network of customers and suppliers are the branches and roots of the tree. In managing any awkward situation it is impossible to reach all the branches (Wang & Chung, 2020); (Liao et al., 2017); (J. Ali, 2008).With continuous improvement of the operating margins risk management processes will become weak when environmental conditions change and new risks arise and also unable to identify and address risks with the right measures (Stevens & Johnson, 2016); (Rajesh, 2018); (Batarfi et al., 2016).When any disruptions occurs in supply chain networks there need capability to respond quickly to back to the normal operating state and sometimes there needs to have scope of modify the operations in response to challenges and quickly change the inputs (Hosseini et al., 2019); (Shareef et al., 2020); (Rajesh, 2018).It is one of the biggest challenge to any manufacturing industry to produce outputs with minimum resources and having capacity or inventory flexibility which helps them to defend any types of uncertainty and good quality of products also a great weapon against any kind of disruptions (Giannakis & Papadopoulos, 2016); (Simchi-Levi et al., 2018); (Health Organization, 2018).An organization that seeks to take advantage of economies of scale in its inbound supply chain networks by adopting a single sourcing strategy or higher capacity utilization at the source might suffer in the long run from an increased negative impact of supply chain disruptions (Rajesh, 2018); (Ivanov, 2017); (Reuß et al., 2017); (Wagner & Bode, 2006).Postponement entails delaying or reject the actual commitment of resources to maintain flexibility and delay incurring costs and having such opportunity can reduce the impact of any disruption immediately (Ramón-Lumbierres et al., 2020); (Jabbarzadeh et al., 2019).

Broad generalizations is the root cause of arising many different types of uncertainty and adopting a strategy like Complying with service level agreements can be reason of suffering in the long run to absorb the action of any disruption (Silvestre et al., 2020); (Rajesh, 2018).Complying with service level agreements (Chen & Thomas, 2018), lack of risk awareness and wrong assumptions (Di Baldassarre et al., 2016), nature of the people to work on self-interests (Qu et al., 2020), unfamiliarity with the ways to manage supply chain risk (Giannakis & Papadopoulos, 2016), status obliviousness of operating assets and environment (Zhu et al., 2019), direness of people to expand their level of responsibility (Collan & Michelsen, 2020) these human resource lacking are also consider as the barriers to achieve resilience in supply chain networks. The planning section and distribution channel has a significant effect on supply chain resilience so underestimating the risks of outsourcing and vertical integrations (Tsay et al., 2018), Exaggeration of demands on product shortages (Ma et al., 2019), Poor judgments and inaccurate forecasts (Bayraktar et al., 2020), Lack of proper contingency plans (Fan et al., 2019), Inability to quickly change mode of delivering outputs (Pan & Choi, 2016), Bullwhips due to uncertainties in supply (Ivanov, 2018) are considered as barriers of SCR. Information distortions (Mancilla & Sepúlveda, 2017), Inappropriate responses to deliberate intrusion (Resilience & Chain, n.d.),Incapability to absorb fluctuations in cash flow (Canyakmaz et al., 2017) are stated as barriers of supply chain resilience as strong information and response system and absorbable cash flow fluctuation system can help to get back after any disruptions.

2.3 Research gaps and contribution

In current literature, there is little research available in this area. The degree of importance of each barrier to achieve SCR might not be the same owing to the country-specific scenarios. The extensive literature review showed a significant interest among scientific researchers and academia; more essentially, they listed the SCR barriers with some structural model. By using grey clustering and vikor approaches the author R. Rajesh provides a list of barriers to resilience in supply chain and measure the risk accurately with a ranking last (Rajesh, 2018). But this was a case study in a specific industry and only focused on this specific industry with only consideration of manufacturing supply chain. Carla Roberta Pereira, Martin Christopher, Andrea Lago Da Silva discuss about the barriers of supply chain resilience but only focused on the role of procurement (Pereira et al., 2014). Imran Ali, Sev Nagalingam & Bruce Gurd stated about the enablers of supply chain resilience but this was only for perishable product supply chains (I. Ali et al., 2017). Imran Ali, Ismail Gölgec and Shashi, Piera Centobelli, Roberto Cerchione3, Myriam Ertz in their separate paper emphasize on supply chain resilience but not follow any structural model of its barriers (Shashi et al., 2020); (I. Ali & Gölgeci, 2019).

It is clear that the barriers to achieve SCR using ISM-MICMAC approach in any context has not been investigated in the literature. Contributions of this paper, at first, are to identify the barriers to achieve SCR using structured literature review and experts mining. Secondly, an interpretive structure model by taking the perspective of Bangladeshi manufacturing industries is proposed which demonstrates interrelations among the barriers using ISM-MICMAC techniques.

Table 1 The barriers to achieve SCR in manufacturing industries

code	Barriers of supply chain resilience	Authors
1	Centralization of assets	(Rana & Rana, 2020); (Rajesh, 2018); (Davis-Sramek et al., 2015); (Oh et al., 1997)
2	Disproportionate assets	(Pal et al., 2019); (Lanier et al., 2019); (Rajesh, 2018); (Clarke & Boersma, 2017)
3	Dispersed and unclear ownerships	(Saberi et al., 2019); (Wieland et al., 2020); (Rajesh, 2018); (Powell et al., 2019)
4	Lack of insurance for the risky assets	(Gornall & Strebulaev, 2018); (Heckmann et al., 2015)
5	Extensive networking	(Wang & Chung, 2020); (Liao et al., 2017); (Rajesh, 2018); (O'Donnell, 2004)
6	Continuous improvement of the operating margins	(Stevens & Johnson, 2016); (Rajesh, 2018); (Kwon et al., 2016)
7	Inability to return to normal operating states rapidly	(Hosseini et al., 2019); (Rajesh, 2018); (Kamalahmadi & Parast, 2016)
8	Inability to modify operations in response to challenges	(By et al., n.d.); (Shareef et al., 2020); (Odukoya, 2019)
9	Incapability to produce outputs with minimum resources	(Giannakis & Papadopoulos, 2016); (Rajesh, 2018); (Acquaye et al., 2018)
10	Capacity or inventory inflexibilities	(Simchi-Levi et al., 2018); (Palareti et al., 2016); (Rajesh, 2018)
11	Single sourcing	(Rajesh, 2018); (Ivanov, 2017); (Eydi & Fazli, 2019)
12	Poor quality of product	(P. Yadav et al., 2018); (Health Organization, 2018);
13	Higher capacity utilization at the source	(Rajesh, 2018); (Adland et al., 2018); (Code, n.d.); (Reuß et al., 2017)
14	Inability to quickly change inputs	(Khojasteh, 2018); (Terkaj & Tolio, 2019); (Rajesh, 2018)
15	No scope of postponement	(Ramón-Lumbierres et al., 2020); (Rajesh, 2018); (Rajesh, 2017)
16	Broad generalizations	(Silvestre et al., 2020); (Klein et al., 2019); (Rajesh, 2018); (Gardner et al., 2019)
17	Complying with service level agreements	(Chen & Thomas, 2018); (Caggiano et al., 2009); (Rajesh, 2018)
18	Lack of risk awareness and wrong assumptions	(Di Baldassarre et al., 2016); (Andersson & Pardillo-Baez, 2020); Rajesh, 2018)
19	Underestimating the risks of outsourcing and vertical integrations	(Tsay et al., 2018); (Luck, 2019); (Rajesh, 2018); (König & Spinler, 2016)
20	Exaggeration of demands on product shortages	(Ma et al., 2019); (Abou Maroun et al., 2019)
21	Nature of the people to work on self-interests	(Qu et al., 2020); (Liu et al., 2020); (Rajesh, 2018); (Busse, 2016)
22	Direness of people to expand their level of responsibility	(Collan & Michelsen, 2020); (Rajesh, 2018)
23	Unfamiliarity with the ways to manage supply chain risks	(Giannakis & Papadopoulos, 2016); (Rajesh, 2018); (Revilla & Saenz, 2017)
24	Status obliviousness of operating assets and environment	(Zhu et al., 2019); (Rajesh, 2018); (Ahmed et al., 2019)
25	Poor judgments and inaccurate forecasts	(Bayraktar et al., 2020); (Cannella et al., 2018); (Rajesh, 2018); (Klett, 2020)
26	Inability to quickly change mode of delivering outputs	(Pan & Choi, 2016); (Allaoui et al., 2019); (Rajesh, 2018)
27	Incapability to absorb fluctuations in cash flow	(Canyakmaz et al., 2017); (Rajesh, 2018); (Tsai, 2017); (Kouvelis et al., 2019)
28	Inappropriate responses to deliberate intrusion	(Resilience & Chain, n.d.); (Rajesh, 2018); (Lemay et al., 2018)
29	Lack of proper contingency plans	(Fan et al., 2019); (Kamalahmadi & Mellat-Parast, 2016);
30	Information distortions	(Mancilla & Sepúlveda, 2017); (Dai et al., 2016)
31	Bullwhips due to uncertainties in supply	(Ivanov, 2018); (Ojha et al., 2019); (Rajesh, 2018)

3. A PROPOSED RESEARCH FRAMEWORK

In this part, as shown in Figure 1, we proposed a conceptual framework to analyze the barriers associated with SCR identified by us. There is both a reliable nomenclature and a clear scope in this framework (Ahmad et al., 2019). This framework provides a true picture of the issues in identification and analysis of SCR barriers in the context of Bangladesh. Based on our research structure and related processes, we have outlined some of the recommendations made by (Platts & Gregory, 1990). The main steps in the proposed research framework are stated below:

1. The purpose of this work are related to the collection of literature including the procedures relating to the existing framework, the identification of the barriers, and the applicability of the research methodologies.
2. Each structural method is supported by the literature and is confirmed by expert's opinion. There are two phases of the proposed research framework. Phase 1 identifies and selects the barriers of SCR by a structured review of the literature. In the second phase, more barriers are added specially in context of Bangladesh by experts mining and identified barriers based on existing literature are justified with specific data.
3. In this step the relationships among the identified barriers are investigated and developed a hierarchical levels for the barriers to achieve SCR by using an ISM and MICMAC approach. Details about the integration of the ISM-MICMAC methodology is given in section 3.1.
4. These research results are useful for managers and specialists and decision makers in any organization. This structure helps managers and decision makers to (a) select appropriate barriers to achieve SCR, (b) identify the relationships among barriers, and (c) develop hierarchical levels of the barriers to achieve SCR.

3.1 Research methodology

Interpretive structural modelling (ISM) is a well-established methodology to assess the interrelationships among the specific items and their degree of associations ISM is an interactive learning process. This is an interactive learning process in which a set of different directly and indirectly related elements are structured into a comprehensive systematic model. Based on relationship, an overall structure is hauling out from the complex set of variables (Jayalakshmi.B, 2013); (Attri et al., 2013).

The Matrice d'impacts croisés multiplication appliquée á un classment (MICMAC) method was developed by Michel Godet and François Bourse. MICMAC a cross-impact matrix multiplication applied to classification is a structural prospective analysis used to study indirect relationships. MICMAC analysis is used to classify the factors and validate the factors found from ISM in the study to reach their results and conclusions (Ahmad et al., 2019).

Table 2 Applications of ISM-MICMAC approach

Author	Area of Application
(Bux et al., 2020)	Promoting sustainability through corporate social responsibility
(Ullah & Narain, 2020)	implementation of mass customization
(K. Singh & Misra, 2020)	Developing an agricultural entrepreneur inclination model
(Kadam & Bandyopadhyay, 2020)	Modelling passenger interaction process (PIP) framework
(R. K. Singh et al., 2020)	Modelling Supply Chain Flexibility
(Ray & Khaba, 2020)	ethical issues of green procurement
(Babu et al., 2020)	Modelling the supply chain risk variables
(S. Yadav & Singh, 2020)	blockchain for sustainable supply chain
(Palaniappan et al., 2020)	factors influencing AM application
(Waqas et al., 2020)	Modeling and optimization of rolling process
(Garg et al., 2019)	Analysis of Green Supply Chain Management Enablers
(Kailash et al., 2019)	Benchmarking of internal supply chain management
(Alora & Barua, 2019)	supply chain disruption risk classification and prioritization
(Bhosale & Kant, 2016)	modelling the supply chain knowledge flow enablers
(Sindhwani & Malhotra, 2017)	Modelling and analysis of agile manufacturing system
(Sindhwani et al., 2018)	Modelling and analysis of energy efficiency drivers
(Authors, 2017)	Risks assessment in thermal power plants
(Tripathi & Singh, 2018)	Analysis of barriers to women entrepreneurship
(Kumar et al., 2019)	Determinants of rural livelihood interventions

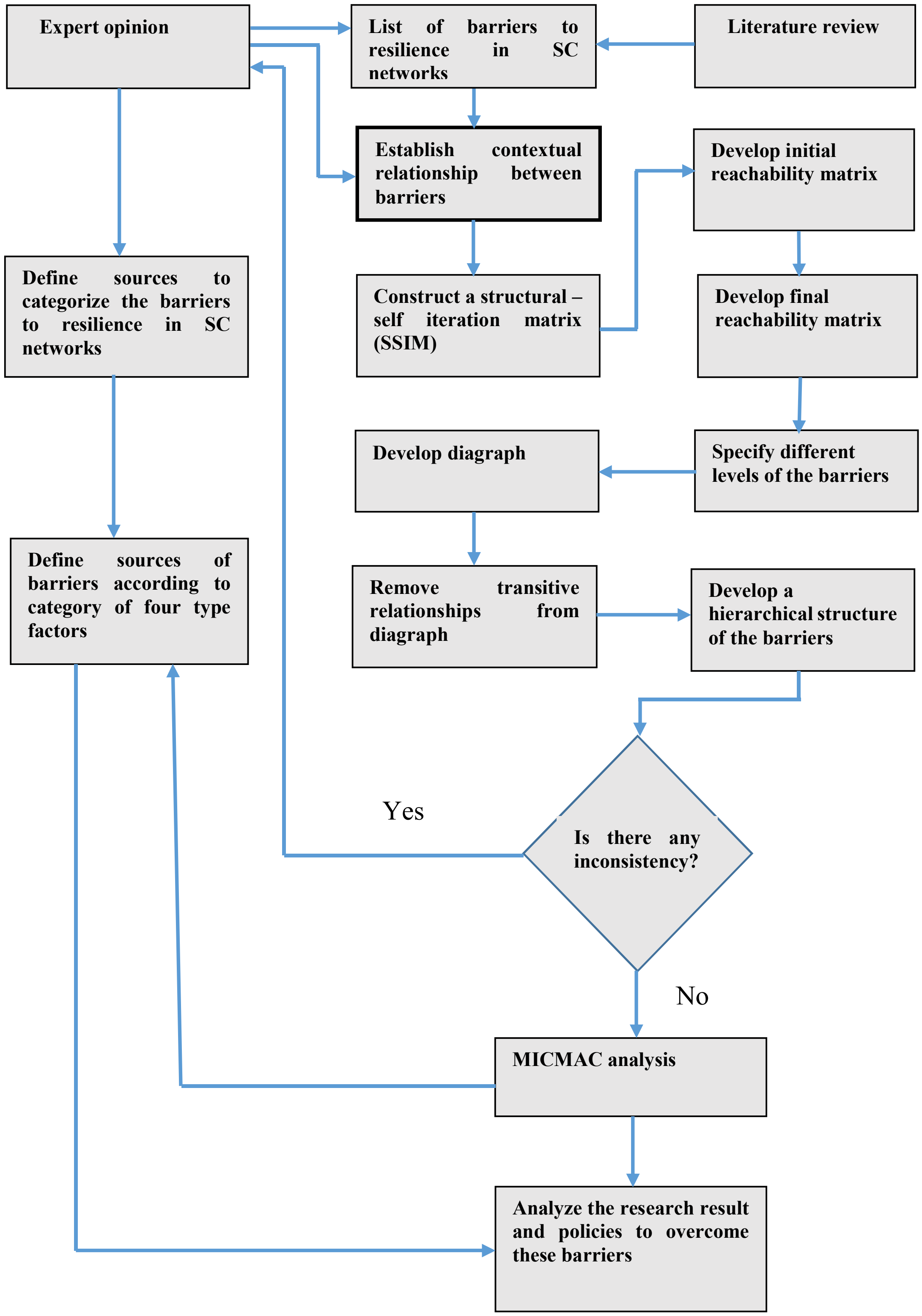

Fig. 1 Proposed research framework to analyze SCR barriers

The ISM and MICMAC integrated methodology includes various steps (Qu et al., 2020) that are explained in relation to the current study (to study the barriers to achieve SCR). The mixed approach involves the following steps (Authors, 2017):

Step 1: Recognize the variables linked to the problem addressed in the research.

Step 2: Develop a contextual connection among all the identified variables in step 1 for pair wise test.

Step 3: Develop structural self-interaction matrix (SSIM) of listed identified factors through pairwise relationship among them.

Step 4: Develop initial reachability matrix using structural self-interaction matrix (SSIM) and transformed into transitivity matrix. The transitivity relation among variables is a fundamental hypothesis made in ISM. To develop transitivity matrix, transitivity relations are considered among listed factors.

Step 5: Partitioned the reach-ability matrix into different levels.

Step 6: Drawn a directed graph by removal of transitive links on the basis of association found in the reach-ability matrix.

Step 7: The resulting digraph is transformed into an interpreted structure model.

Step 8: Reviewed and checked for conceptual inconsistency in the developed model. Some essential modifications can be made as required with the help of experts.

Step 9: Performed the MICMAC analysis to categorize all barriers in four clusters to check the consistent association.

3.2 Data collection:

Past studies on ISM in developing the contextual relationship among the variables suggests that it utilizes expert opinions based on several management techniques like brainstorming, nominal techniques etc., (Kumar et al., 2019). Initially thirty experts were approached by mail, phone and social media for explaining the research concept and objectives of this research, after frequent phone calls and communication via social media and discussion with industrial experts and academia, only sixteen were participated in the research. In this study sixteen experts, eight each from industrial sector within Bangladesh and the academia, were consulted for identifying the contextual relationships among the barriers. The reason for their selection was they were well experienced and practicing with growth and development of supply chain resilience in Bangladeshi industries as well as have sufficient knowledge about the various barriers to achieve SCR. All the experts belong to top and middle management level having an experience of working with barriers of SCR. As there arose 465 questions, experts provided answers over multiple rounds via google form for impossibility of giving answers of 465 questions at a time. At the end of each round, a moderator or a facilitator prepared a summary of all the answers. All individual responses were consolidated.

Finally one response was created based on expert's response and brain storming among authors and experts in an online live session.

4. Application of the recommended research framework

This study aims to identify and analyze the significant SCR barriers in the context of Bangladesh. The objective is achieved by at first collecting relevant studies on SCR barriers in different contexts and available in different journals related to risk management, sustainability, supply chain uncertainty, organizational and business strategy, and sustainable practices and then validated these barriers by experts. After that, we used the suggested framework for a deeper investigation of the research problem; the following are the details

4.1 Categorization of SCR barriers

In present study, SCR barriers has been categorized according to their sources name as human resources, source process, plan process, manufacturing facilities, make process, financial factors, ownership and assets management, distribution process, information and response system (Hudnurkar et al., 2017). In the human resources those barriers are included which are related to lack of skills, employee dissatisfaction, employee turnover and ignorance about risk management to the workers. In source process, the included barriers are related to sourcing type, sourcing Flexibility, supplier quality. In Plan process those barriers are considered which are based on integration, forecasting, strategy. In Manufacturing facilities those barriers are included which are related to process stability, plant obsolescence, maintenance. Operational disruptions, Design Change and Capacity related barriers are grouped in make process. In Financial factors those barriers are stated which are related to interest rate, cash flow, fiscal risk, asset impairment risk. In ownership and assets management, asset distribution and ownership related barriers are included. In distribution process, demand volatility due to bullwhip effect and inability to change mode of delivering output are considered. In information and response system those barriers are included which are related to information distortion and response quickly and correctly. The category of SCR barriers shown in figure 2.

Table 3 Categorization of SCR barriers according to their sources

Sources	Id.	Barriers to resilience in supply chain networks
Human resources	H1	Nature of the people to work on self-interests
	H2	Direness of people to expand their level of responsibility
	H3	Unfamiliarity with the ways to manage supply chain risks
	H4	Status obliviousness of operating assets and environment
Source process	S1	Single sourcing
	S2	Higher capacity utilization at the source
	S3	No scope of postponement
	S4	Underestimating the risks of outsourcing and vertical integrations
Plan process	P1	Extensive networking
	P2	Broad generalizations
	P3	Lack of risk awareness and wrong assumptions
	P4	Poor judgments and inaccurate forecasts
	P5	Lack of proper contingency plans
Manufacturing facilities	Mf1	Incapability to produce outputs with minimum resources
	Mf2	Capacity or inventory inflexibilities
	Mf3	Exaggeration of demands on product shortages
Make process	Mp1	Continuous improvement of the operating margins
	Mp2	Inability to return to normal operating states rapidly
	Mp3	Inability to modify operations in response to challenges
	Mp4	Poor quality of product
	Mp5	Inability to quickly change inputs
Financial factors	F1	Lack of insurance for the risky assets
	F2	Complying with service level agreements
	F3	Incapability to absorb fluctuations in cash flow
Ownership and assets management	O1	Centralization of assets
	O2	Disproportionate assets
	O3	Dispersed and unclear ownerships
Distribution process	D1	Inability to quickly change mode of delivering outputs
	D2	Bullwhips due to uncertainties in supply
Information and response system	I1	Inappropriate responses to deliberate intrusion
	I2	Information distortions

4.1 Modeling and clustering CSR barriers through ISM-MICMAC

In this section, ISM hierarchy model is developed for the identified thirty one barriers to achieve SCR. This hierarchical structure will help to better understand the interrelationships among the variables. Moreover, MICMAC technique is used to classify the variables based upon their influence and dependence.

The ISM approach starts with formation of Structural self-interaction matrix, SSIM. SSIM contained information regarding contextual relationship of elements by expert opinion. The subsistence of a relation and associated direction between any two barriers (i and j) is asked to the experts. We use four symbols to show the pair wise directional relationship between the barriers (i and j); these symbols are described below

1. V—The barrier (i) will help to reach barrier (j);
2. A—Barrier (j) will help to reach barrier (i);
3. X—Barrier (i) and (j) will help in reaching each other;
4. O—Barriers (i) and (j) are not associated with each other.

The SSIM for barriers to achieve SCR was developed according to these symbols and expert inputs (Table 4)

The next step is the establishment of initial reachability matrix (IRM). So, we converted the SSIM entries through binary numbers (0 and 1). The conversion was based on a certain logic which described as following

If (i, j) entry in the SSIM is	the (i, j) entry IRM becomes	the (j, i) entry in IRM becomes
V	1	0
A	0	1
X	1	1
O	0	0

According to this, table 5 lists the initial reachability matrix (IRM) for SCR barriers. After that, we convert IRM to final reachability matrix (FRM) using the transitivity rule Table 6. The transitivity in factors relation is an essential assumption in the model which explains that if an element A is connected to B and B is associated to C, then A is essentially associated to C and to maintain consistency by incorporating transitivity, 1* is replaced at required places.

In next step final reachability matrix was used to partition the barriers into various levels. The reachability and antecedent sets were derived from the FRM. The reachability set contained the barrier itself and other barriers that are affected by this barrier and the antecedent set of barriers was a combination of the barrier elements itself and other barriers that may affect it. In addition, with the integration of the reachability and antecedent sets for each barrier, the intersection set for each barrier was derived from these sets to determine the leveling of different barriers. When the reachability and intersection set was found as a subset of the antecedent set assigned that barrier to Level 1. After achieving the barriers of level 1, these were eliminated from both reachability and antecedent sets. Until all the barriers assigned to at least one level this process of partitioning is carried out. . Table 7 shows the reachability and antecedent sets with level partition for SCR barriers. Using the information of the FRM and level partitioning, a digraph was prepared where the barriers were represented by nodes, and relationships among them were presented by arrows figure 2. Based on these findings replacing the nodes of the directed graph with the name of the barriers the hierarchal levels in the ISM model are developed, as shown in Figure 3.

In next by calculating the row and column entries in the final reachability matrix (FRM), the driving power, and dependencies power were obtained shown in Table 6. . The driving power and dependence power provide support in clustering factors through MICMAC (cross impact matrix multiplication applied to classification) analysis. . The MICMAC study chart represents the driving force and the dependence force of the barriers (Figure 4). The 31 barriers are divided into four groups, as described in figure 4. The different categories are as follows:

1. Autonomous barriers: This group of barriers has weak driving power as well as dependence power and generally disconnected from the structure. In this study, there are no barriers in this group so all 31 recognized barriers have a substantial impact to achieve SCR.

2. Dependent barriers: barriers with weak driving power but strong dependence power are kept into this group and is at the top of the hierarchical ism model. In this cluster we have two barriers- inability to quickly change mode of delivering outputs (26) and exaggeration of demands on product shortages (20).

3. Linkage barriers: factors with high strong driving and dependence power are kept into this cluster. in this cluster we have twenty two barriers and are in the middle of the ism hierarchical model, including direness of people to expand their level of responsibility (22), extensive networking (5), lack of proper contingency plans (29), bullwhips due to uncertainties in supply (31), capacity or inventory inflexibilities (10), higher capacity utilization at the source (13), lack of risk awareness and wrong assumptions (18), lack of insurance for the risky assets (4),disproportionate assets (2),poor judgments and inaccurate forecasts (25),underestimating the risks of outsourcing and vertical integrations (19),incapability to absorb fluctuations in cash flow (27),single sourcing (11),inability to return to normal operating states rapidly (7),information distortions (30),inappropriate responses to deliberate intrusion (28),complying with service level agreements (17), no scope of postponement (15), inability to quickly change inputs (14), inability

to modify operations in response to challenges (8), poor quality of product (12), incapability to produce outputs with minimum resources (9). As these barriers are unstable, they require careful investigation and in implementation of SCR practitioners or management sector of any organization should continually observe them.

4. Driving barriers: this cluster of barriers has a strong driving power and weak dependence power towards system and is at the bottom of the ism hierarchical model. in this cluster we have seven barriers including centralization of assets (1), dispersed and unclear ownerships (3), continuous improvement of the operating margins (6), broad generalizations (16), nature of the people to work on self-interests (21), unfamiliarity with the ways to manage supply chain risks (23), status obliviousness of operating assets and environment (24). These are the fundamental cause of other barriers. Any organization to achieve SCR needs to focus more on these barriers because they can support the elimination of other barriers that occur at the middle and top level of the ISM hierarchal model. As several other dependent barriers are affected by the barriers which have higher driving power, requires attention to these barriers on a priority basis.

Finally, the barriers to achieve supply chain resilience were compiled according to their association with other clusters and here the driving barriers lead to linkage barriers which in turn lead to dependent barriers. The barriers directional effect with their sources according to the MICMAC analysis is shown in Figure 5.

Table 4 Structural self-interaction matrix (SSIM) of SCR barriers

code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		V	A	V	V	0	V	V	V	V	V	V	0	V	0	0	0	0	0	0	0	0	0	0	0	0	0	V	V	0	0
2			A	0	V	0	V	A	V	0	0	V	A	A	0	0	0	0	0	V	0	0	0	0	0	0	0	0	A	0	0
3				V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
4					0	0	V	V	V	0	0	V	V	0	0	A	V	0	A	V	0	0	0	0	0	0	X	0	A	0	0
5						0	V	V	V	0	0	V	0	V	V	A	0	0	0	V	0	0	0	0	0	0	V	V	V	V	V
6							V	V	V	0	0	V	0	X	0	A	0	0	0	V	0	0	0	0	0	0	V	0	A	0	0
7								X	A	0	0	V	0	A	0	A	V	A	A	A	A	A	A	A	A	V	X	A	A	A	A
8									V	0	0	V	0	X	A	A	A	A	0	V	A	A	A	A	A	0	V	0	A	0	0
9										A	A	V	0	A	V	A	A	A	A	V	A	A	A	A	A	0	X	0	A	A	A
10											0	0	0	0	A	A	0	A	0	V	A	A	A	A	0	V	V	0	A	0	0
11												A	0	V	V	0	V	0	V	V	0	0	0	0	V	V	V	V	A	0	0
12													0	A	A	A	A	A	A	0	A	A	A	A	A	A	A	0	A	A	0
13														0	0	A	0	0	0	0	0	0	0	0	0	0	V	0	A	0	0
14															X	A	0	0	V	V	0	A	A	A	0	0	0	0	A	0	0
15																0	V	A	A	V	0	0	0	0	A	0	V	0	A	A	A
16																	V	V	0	V	0	0	0	0	0	V	V	V	V	V	V
17																		0	0	A	A	A	A	A	A	A	A	A	A	A	A
18																			V	V	0	0	A	X	A	0	0	0	A	A	A
19																				V	0	0	0	0	A	0	0	A	A	A	0
20																					A	A	A	A	A	0	A	A	A	A	A
21																						0	0	0	0	V	0	0	A	0	0
22																							A	A	0	0	0	0	A	0	0
23																								X	0	0	0	0	A	0	0
24																									0	0	V	0	A	0	0
25																										0	0	0	V	A	0
26																											0	0	A	0	0
27																												X	A	X	0
28																													A	A	X
29																														X	V
30																															V
31																															

Table 5 Initial reachability matrix (IRM) of SCR barriers

code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
2	0	1	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	0	0	0	1	0	0	1	1	1	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0
5	0	0	0	0	1	0	1	1	1	0	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1
6	0	0	0	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0
8	0	1	0	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
9	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
10	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0
11	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	1	0	1	1	0	0	0	0	1	1	1	1	0	0	0
12	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
14	0	1	0	0	0	0	1	0	1	0	0	1	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0
16	0	0	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	1	0	0	0	0	0	1	1	1	1	1	1
17	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0
19	0	0	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0
22	0	0	0	0	0	0	1	1	1	1	0	1	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	1	1	1	1	0	1	0	1	0	0	1	1	0	1	0	1	1	1	0	0	0	0	0	0	0
24	0	0	0	0	0	0	1	1	1	1	0	1	0	1	0	0	1	1	0	1	0	1	0	1	0	0	1	0	0	0	0
25	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	0	1	1	1	1	0	0	1	0	1	0	0	0	1	0	0
26	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
27	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1	0	1	0
28	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	1	1	0	0	1
29	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
30	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1
31	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	1	1	0	1

Table 6 Final reachability matrix (FRM) of SCR barriers

code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	DRP[a]
1	1	1	0	1	1	1*	1	1	1	1	1	1	1*	1	1*	0	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1*	1*	29
2	0	1	0	1*	1	1*	1	1*	1	1*	1*	1	1*	1*	1*	0	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	28
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	31
4	0	1*	0	1	1*	0	1	1	1	1*	1*	1	1	1*	1*	0	1	1*	1*	1	0	0	0	0	1*	1*	1	1*	1*	1*	1*	23
5	0	1*	0	1*	1	1*	1	1	1	1*	1*	1	1*	1	1	0	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1	1	1	1	1	28
6	0	1*	0	1*	1*	1	1	1	1	1*	1*	1	1*	1	1*	0	1*	1*	1*	1	0	0	0	0	1*	1*	1	1*	1*	1*	1*	24
7	0	1*	0	1*	1*	0	1	1	1*	0	1*	1	1*	1*	1*	0	1	1*	1*	1*	0	0	0	0	1*	1	1	1*	1*	1*	1*	22
8	0	1	0	1*	1*	0	1*	1	1	1*	1*	1	1*	1	1*	0	1*	1*	1*	1	0	0	0	0	1*	1*	1	1*	1*	1*	1*	23
9	0	1*	0	1*	0	0	1	1*	1	1*	1*	1	1*	1*	1	0	1*	1*	1*	1	0	0	0	0	1*	1*	1	1*	1*	1*	1*	22
10	0	0	0	1*	0	0	1*	1*	1	1	1*	1*	1*	1*	1*	0	1*	1*	1*	1	0	0	0	0	1*	1	1	1*	1*	1*	1*	21
11	0	1*	0	1*	1*	1*	1*	1*	1	1*	1	1*	1*	1	1	0	1	1*	1	1	1*	1*	1*	1*	1	1	1	1	1*	1*	1*	28
12	0	1*	0	1*	0	0	1*	1*	1*	1*	1	1	0	1*	1*	0	1*	1*	1*	1*	0	0	1*	0	1*	1*	1*	1*	1*	1*	1*	22
13	0	1	0	1*	1*	0	1*	1*	1*	0	1*	1*	1	1*	1*	0	1*	1*	1*	1*	0	0	0	0	1*	1*	1	1*	1*	1*	1*	22
14	0	1	0	1*	1*	0	1	1*	1	1*	1*	1	1*	1	1	0	1*	0	1	1	0	0	0	0	1*	1*	1*	1*	1*	1*	1*	22
15	0	1*	0	1*	1*	0	1*	1	1*	1	1*	1	1*	1	1	0	1	1*	1*	1	0	0	0	0	1*	1*	1	1*	1*	1*	1*	23
16	0	1*	0	1	1	1	1	1	1	1	1*	1	1	1	1*	1	1	1	1*	1	1*	1*	1*	1*	1*	1	1	1	1	1	1	29
17	0	1*	0	1*	1*	0	1*	1	1	1*	1*	1	0	1*	1*	0	1	0	1*	1*	0	0	0	0	1*	1*	1*	1*	0	1*	0	19
18	0	1*	0	1*	1*	0	1	1	1	1	1*	1	1*	1*	1	0	1*	1	1	1	0	1*	0	1	1*	1*	1*	1*	0	1*	0	23
19	0	1*	0	1	0	0	1	1*	1	1*	1*	1*	1*	1*	1	0	1*	0	1	1	0	0	0	0	0	1*	1*	1*	0	1*	0	18
20	0	1*	0	1*	0	0	1	1*	1*	0	1*	1*	0	1*	1*	0	1	0	0	1	0	0	0	0	0	1*	1*	1*	0	1*	0	15
21	0	1*	0	1*	1*	0	1	1	1	1	1*	1	0	1*	1*	0	1	0	1*	1	1	0	0	0	1*	1	1*	1*	0	1*	0	20
22	0	1*	0	1*	1*	0	1	1	1	1	1*	1	0	1	1*	1*	1	0	1*	1	0	1	0	0	1*	1*	1*	1*	0	1*	0	21
23	0	1*	0	1*	1*	1*	1	1	1	1	1*	1	0	1	1*	0	1	1	1*	1	0	1	1	1	1*	1*	1*	1*	0	1*	0	24
24	0	1*	0	1*	1*	0	1	1	1	1	1*	1	1*	1	1*	0	1	1	1*	1	0	1	0	1	1*	1*	1	1*	1*	1*	1*	25
25	0	1*	0	1*	1*	1*	1	1	1	1*	1*	1	1*	1*	1	0	1	1	1	1	1*	1*	1	1*	1	1*	1*	1*	1	1*	1*	28
26	0	1*	0	0	0	0	1*	1*	1*	0	1*	1	0	1*	1*	0	1	0	1*	1*	0	0	0	0	1*	1	1*	1*	0	0	0	15
27	0	1*	0	1	0	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	0	1	1*	1*	1	1*	1*	1*	1*	1*	1*	1	1	1*	1	1*	27
28	0	1*	0	1*	0	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	0	1	1*	1	1	1*	1*	1*	1*	1*	1*	1	1	1*	1*	1	27
29	0	1	0	1	1*	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1*	1	1	1	1	1	1	28
30	0	1*	0	1*	1*	1*	1	1*	1	1*	1*	1	1*	1*	1	0	1	1	1	1	1*	1*	1*	1*	1	1	1	1	1	1	1	28
31	0	1*	0	1*	1*	1*	1	1*	1	1*	1*	1*	1*	1*	1	0	1	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1	1	1*	1	28
DPP[b]	2	30	1	30	23	14	31	31	31	27	31	31	24	31	31	3	31	24	30	31	13	16	14	15	29	31	31	31	23	30	23	743

* Adding transitivity

DRP[a] Driving power

DPP[b] Dependence power

Table 7 Level partitions of SCR barriers

Barriers	***Reachability set***	**Antecedent set**	**Intersection set**	**Level**
1	*1,2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	1,3	1	VIII
2	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,6,7,8,9,11,12,13,14,15,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	IV
3	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	3	3	VIII
4	*2,4,5,7,8,9,10,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,27,28,29,30,31*	*2,4,5,7,8,9,11,12,13,14,15,17,18,19,20, 25,27,28,29,30,31*	IV
5	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,11,13,14,15,16,17,18,21,22,23,24, 25,29,30,31*	*2,4,5,6,7,8,11,13,14,15,16,17,18,21,22,23,24, 25,29,30,31*	VI
6	*2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 25,26,27,28,29,30,31*	*1,2,3,5,6,11,16,23,25,27,28,29,30,31*	*2,5,6,11,25,27,28,29,30,31*	VII
7	*2,4,5,7,8,9,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,7,8,9,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	III
8	*2,4,5,7,8,9,10,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,7,8,9,10,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	II
9	*2,4,7,8,9,10,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,8,9,10,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	II
10	*4,7,8,9,10,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,8,9,10,11,12,14,15,16,17,18,19,21,22,23,24, 25,27,28,29,30,31*	*4,8,9,10,11,12,14,15,17,18,19, 25,27,28,29,30,31*	V
11	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	III
12	*2,4,7,8,9,10,11,12,14,15,17,18,19,20,23, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,7,8,9,10,11,12,14,15,17,18,19,20,23, 25,26,27,28,29,30,31*	II
13	*2,4,5,7,8,9,11,12,13,14,15,17,18,19,20, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,18,19, 24, 25,27,28,29,30,31*	*2,4,5,7,8,9,11,13,14,15,18,19, 25,27,28,29,30,31*	V
14	*2,4,5,7,8,9,10,11,12,13,14,15,17,19,20, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,7,8,9,10,11,12,13,14,15,17,19,20, 25,26,27,28,29,30,31*	II
15	*2,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 25,26,27,28,29,30,31*	II
16	*2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	3,16,22	16,22	VIII
17	*2,4,5,6,7,8,9,10,11,12,14,15,17,19,20, 25,26,27,28,30*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,6,7,8,9,10,11,12,14,15,17,19,20, 25,26,27,28,30*	II
18	*2,4,5,7,8,9,10,11,12,13,14,15,17,18,19,20,22,24, 25,26,27,28,30*	*1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,18,23,24, 25,27,28,29,30,31*	*2,4,5,7,8,9,10,11,12,13,14,15,18,24, 25,27,28,30*	V

Barriers	*Reachability set*	Antecedent set	Intersection set	Level
19	*2,4,7,8,9,10,11,12,13,14,15,17,19,20, 26,27,28,30*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,7,8,9,10,11,12,13,14,15,17,19, 26,27,28,30*	IV
20	*2,4,7,8,9,11,12,14,15,17, 25,27,28,30*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,24, 25,27,28,29,30,31*	*2,4,7,8,9,11,12,14,15,17, 25,27,28,30*	I
21	*2,4,5,7,8,9,10,11,12,14,15,17,19,20,21, 25,26,27,28,30*	*1,2,3,5,11,16,21, 25,27,28,29,30,31*	*2,11,21, 25,27,28,30*	VI
22	*2,4,5,7,8,9,10,11,12,14,15,16,17,19,20,22, 25,26,27,28,30*	*1,2,3,5,11,16,18,22,23,24, 25,27,28,29,30,31*	*2,5,11,16,22,25,27,28,30*	VI
23	*2,4,5,6,7,8,9,10,11,12,14,15,17,18,19,20,22,2 3,24, 25,26,27,28,30*	*1,2,3,5,11,12,16,23, 25,27,28,29,30,31*	*2,5,11,12,23, 25,27,28,30*	VII
24	*2,4,5,7,8,9,10,11,12,13,14,15,17,18,19,20,22, 24, 25,26,27,28,29,30,31*	*1,2,3,5,11,12,16,18,23, 25,27,28,29,30,31*	*2,5,11,12,18,25,27,28,29,30,31*	VII
25	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,2 1,22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,21 ,22,23,24, 25,26,27,28,29,30,31*	IV
26	*2,7,8,9,11,12,14,15,17,19,20, 25,26,27,28*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,7,8,9,11,12,14,15,17,19,20, 25,26,27,28*	I
27	*2,4,6,7,8,9,10,11,12,13,14,15,17,18,19,20,21, 22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,6,7,8,9,10,11,12,13,14,15,17,18,19,2 0,21,22,23,24, 25,26,27,28,29,30,31*	III
28	*2,3,4,6,7,8,9,10,11,12,13,14,15,17,18,19,20,2 1,22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,3,4,6,7,8,9,10,11,12,13,14,15,17,18,19 ,20,21,22,23,24, 25,26,27,28,29,30,31*	III
29	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,2 1,22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,24, 25,27,28,29,30,31*	*2,4,5,6,7,8,9,10,11,12,13,14,15,24, 25,27,28,29,30,31*	VI
30	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,2 1,22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20,21,22,23,24, 25,27,28,29,30,31*	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19 ,20,21,22,23,24, 25,27,28,29,30,31*	III
31	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,2 1,22,23,24, 25,26,27,28,29,30,31*	*1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20,21,22,23,24, 25,26,27,28,29,30,31*	*2,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19 ,20,21,22,23,24, 25,26,27,28,29,30,31*	VI

Due to prolongation, other repetitions have been not mention.

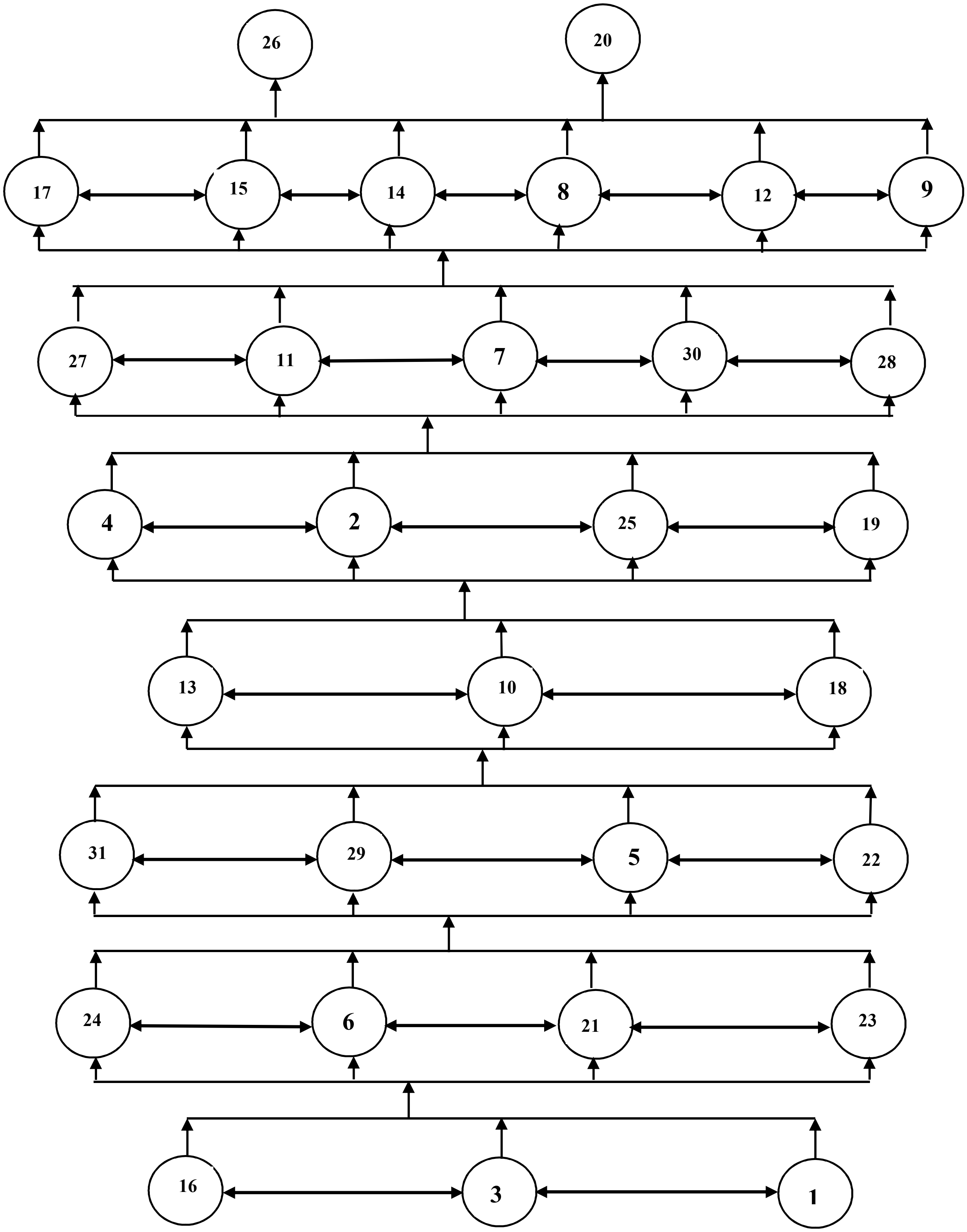

Fig. 2 Diagraph

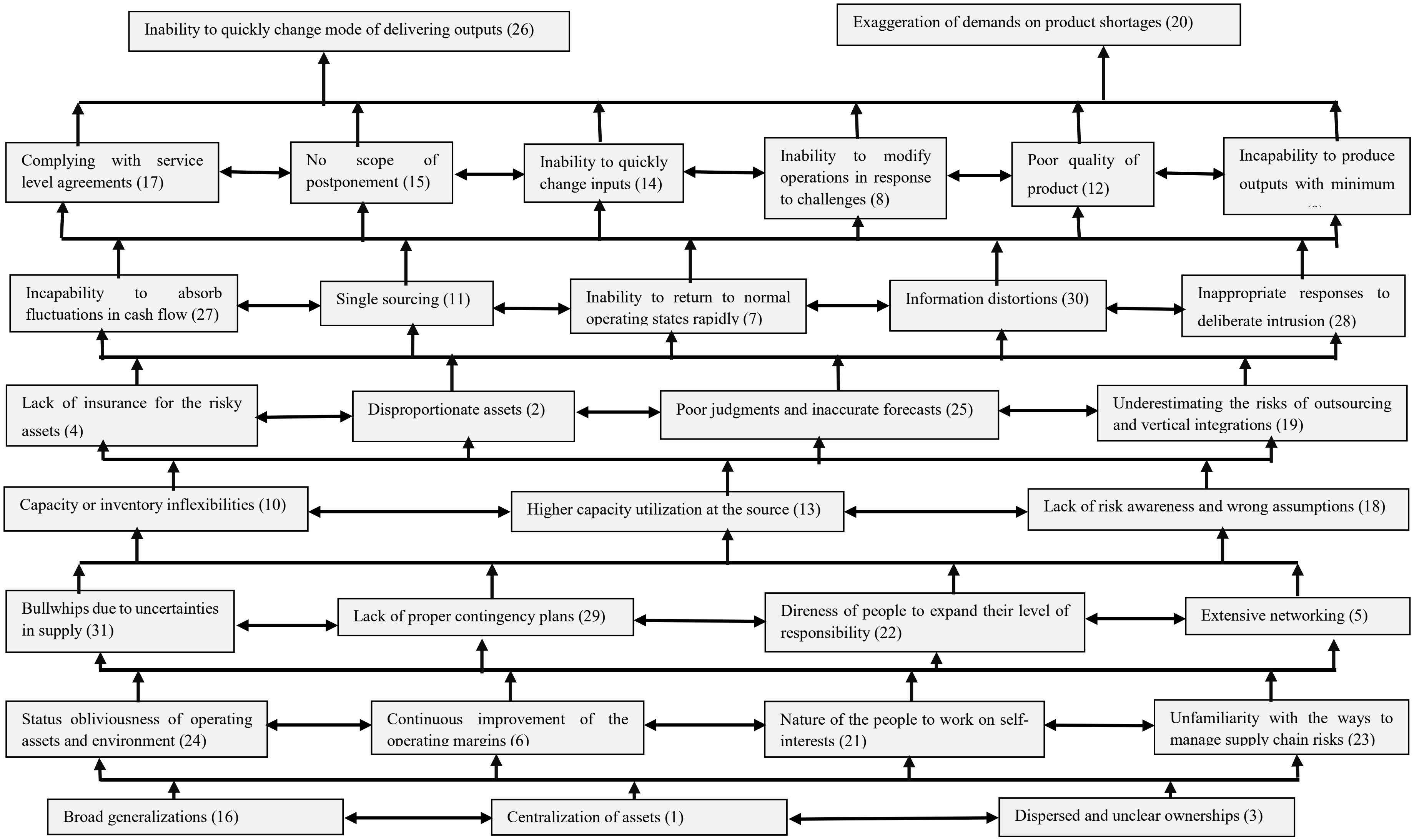

Fig. 3 ISM-based hierarchical model

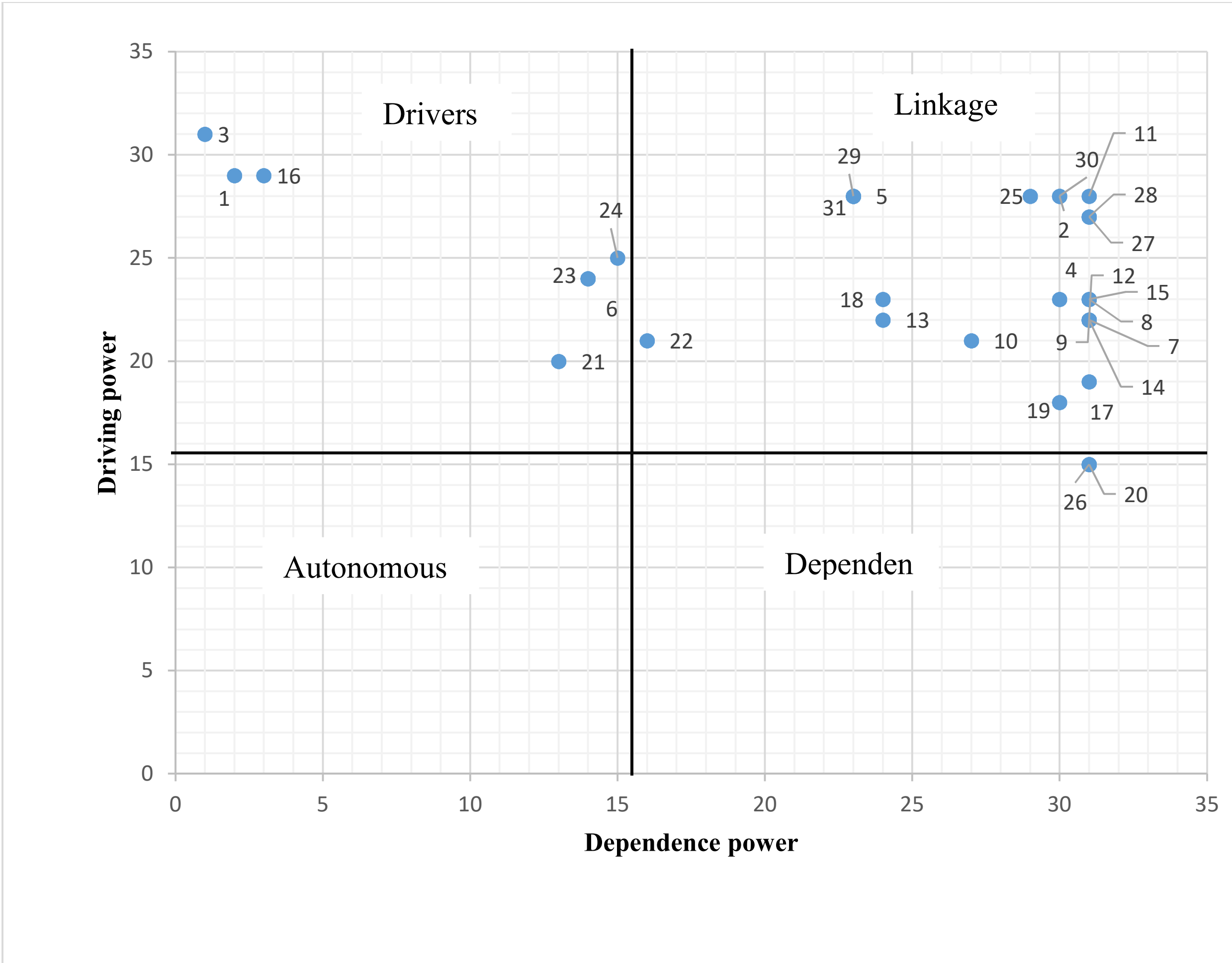

Fig. 4 MICMAC diagram.

Dependent barriers

Barriers	sources
❖ Inability to quickly change mode of delivering outputs (26)	Distribution process
❖ Exaggeration of demands on product shortages (20)	Manufacturing facilities

Linkage barriers

Barriers	sources
❖ Direness of people to expand their level of responsibility (22)	Human resources
❖ Extensive networking (5)	Plan process
❖ Lack of proper contingency plans (29)	Plan process
❖ Bullwhips due to uncertainties in supply (31)	Distribution process
❖ Capacity or inventory inflexibilities (10)	Manufacturing facilities
❖ Higher capacity utilization at the source (13)	Source process
❖ Lack of risk awareness and wrong assumptions (18)	Plan process
❖ Lack of insurance for the risky assets (4)	Financial factors
❖ Disproportionate assets (2)	Ownership and assets management
❖ Poor judgments and inaccurate forecasts (25)	Plan process
❖ Underestimating the risks of outsourcing and vertical integrations (19)	Source process
❖ Incapability to absorb fluctuations in cash flow (27)	Financial factors
❖ Single sourcing (11)	Single sourcing
❖ Inability to return to normal operating states rapidly (7)	Make process
❖ Information distortions (30)	Information and response system
❖ Inappropriate responses to deliberate intrusion (28)	Information and response system
❖ Complying with service level agreements (17)	Financial factors
❖ No scope of postponement (15)	Source process
❖ Inability to quickly change inputs (14)	Make process
❖ Inability to modify operations in response to challenges (8)	Make process
❖ Poor quality of product (12)	Make process
❖ Incapability to produce outputs with minimum resources (9)	Manufacturing facilities

Driving barriers

Barriers	sources
❖ Centralization of assets (1)	Ownership and assets management
❖ Dispersed and unclear ownerships (3)	Ownership and assets management
❖ Continuous improvement of the operating margins (6)	Make process
❖ Broad generalizations (16)	Plan process
❖ Nature of the people to work on self-interests (21)	Human resources
❖ Unfamiliarity with the ways to manage supply chain risks (23)	Human resources
❖ Status obliviousness of operating assets and environment (24)	Human resources

Fig. 5 Association between categories of SCR barriers based on MICMAC

5. Result and Recommendation

Supply chain resilience is associated with market and risk management performance and it has significant impact on financial and non-financial performance. The existence of a resilient supply chain is one of the most important aspects of coping with uncertainties in supply chain networks. Despite the enthusiastic embrace of SCR in the developed countries, its implementation in developing countries lags far behind and in Bangladesh this concept of SCR has not been widely adopted. Therefore, this study empirically analyzes the barriers to achieve SCR in Bangladesh. This is an applied research where using the research literature 31 barriers were selected to achieve SCR. Then, these barriers were entered in questionnaire and were provided to the supply chain experts. To analyze the relationships among the barriers to achieve resilience in supply chain networks, we used an integrated methodology involving ISM and MICMAC are discussed below.

A large number of the barriers of SCR have high levels of driving force and are positioned in the independent and linkage quadrants of the MICMAC diagram. As a result, they are characterized by their dependence on each other and their ability to influence other variables within the model. Two variables have high level of dependence power with low level of driving power are positioned in the dependent quadrant which demonstrates they rely heavily on other factors. The positioning of these variables within the MICMAC diagram and their formation in the final ism model indicates a level of volatility that concludes if any action is taken on these variables, it will have a corresponding reaction on other variables. for example if a manager of any organization considered lack of proper contingency plans (29)) as a barrier to achieve SCR then other relating variables such as bullwhips due to uncertainties in supply (31), extensive networking (5) and direness of people to expand their level of responsibility (22) could potentially become an issue due to their close relationships within the linkage quadrant. On the first level of the ISM model are exhibit high dependence power thus they are positioned at the higher position in the ISM model. However it is their lower driving power that creates the sense of vulnerability as they depend on all other variables precede them. The high position for factors such as Inability to quickly change mode of delivering outputs (26) and Exaggeration of demands on product shortages (20) in the model suggests that these factors are heavily dependent on other factors that below them. As their maximum level of dependency these barriers are strongly impacted by other related barriers in the ISM model and have been established by other research studies as the key barriers of SCR.

The results of the ISM methodology extracted eight levels, as shown in Table 7. At Level VII and level VIII the more independent barriers are positioned, in the form of broad generalizations (16) which source is plan process; under the source ownership and assets management two barriers centralization of assets (1) and dispersed and unclear ownerships (3); under the source human resources three barriers status obliviousness of operating assets and environment (24), nature of the people to work on self-interests (21) and unfamiliarity with the ways to manage supply chain risks (23); continuous improvement of the operating margins (6) which source is make process. The MICMAC analysis shows high levels of driving power for these barriers with lower levels of dependence power. For example if an organization is facing the barriers which source is ownership and assets management like dispersed and unclear ownerships (3) and centralization of assets (1) ,we may conclude from the ISM study that the results of those variables with a greater driving power region are likely to trigger. There are three barriers under the source of human resources which indicates how necessary it is for all workers in the company to have a certain degree of knowledge about risk management, operational assets and environment awareness with their self-interest under control during their working. The gradual enhancement of the margins of operations has a great impact on achieving SCR.

Accordingly, at level VI bullwhips due to uncertainties in supply (31) which source is distribution process; two barriers under the source of plan process are lack of proper contingency plans (29) and extensive networking (5); direness of people to expand their level of responsibility (22) within the source human resources, these barriers play a vital role in SCR adoption in any organizations of Bangladesh. The bullwhips due to uncertainties in supply can lead to either inefficient manufacturing or unnecessary inventory. As each manufacturer needs to meet the demand of its supply chain customers, this barrier need to overcome with higher prioritization. The manager of an organization should consider lack of proper contingency plans (29) and extensive networking (5) with great care as these can hamper in correlation among the supply chain networks. The direness of individuals to increase their degree of transparency can be a very important factor to achieve large production in rapid time.

Level IV and V can be justified as another extension of the previous level. Two barriers within the source plan process, lack of risk awareness and wrong assumptions (18) and poor judgments and inaccurate forecasts (25). Two barriers under the source process higher capacity utilization at the source (13) and underestimating the risks of outsourcing and vertical integrations (19). There are also barriers capacity or inventory inflexibilities (10) in the source manufacturing facilities, lack of insurance for the risky assets (4) in the source financial factors, disproportionate assets (2) in the source assets management.

Level III and II can be justified as these barriers do not affect others much, but are influenced by other variables in a greater pace excluding two variables of level I. Two barriers within the source process single sourcing (11) and no scope of postponement (15). Four barriers within the source make process inability to return to normal operating states rapidly (7), inability to modify operations in response to challenges (8), poor quality of product (12) and inability to quickly change inputs (14). Under the source financial factors two barriers incapability to absorb fluctuations in cash flow (27) and complying with service level agreements (17). Information distortions (30) and information distortions (30) are in the source of information and response system. And another barrier incapability to produce outputs with minimum resources (9) in the source manufacturing facilities.

Accordingly, at level I inability to quickly change mode of delivering outputs (26) in the source distribution process and exaggeration of demands on product shortages (20) which source is manufacturing facilities. This level has minimum driving power score and the maximum dependence power score, putting it in the dependent quadrant and at the top of the ISM model. This variable is greatly affected by other variables in the model below, as the ISM approach implies.

6. Conclusion

This research has investigated the various barriers that can prevent the adoption of SCR in any manufacturing industry of Bangladesh. In order to accomplish this goal, we conducted literature surveys and gathered expert reviews, categorized the barriers according to their origins following which an integrated approach ISM-MICMAC model was applied in this study. The final model that categorizes each barrier and describes contextual relationships among those barriers by the use of ISM and MICMAC was provided to enable managers and academics of any manufacturing industry to understand the idea and to become acquainted with the relationships that can cause in achievement of SCR. This research was able to provide additional perspective and contextualization of the main relationships between barriers of SCR by the use of ISM and MICMAC approach.

The findings were interesting in the context of Bangladesh and demonstrated the real situation in developing countries regarding the achievement of SCR. the results illustrate the unpredictable existence of SCR barriers in the context of their effect on each other, their interactions, and themselves. The MICMAC diagram defined each variable's driving and dependency force and allocated it to a particular quadrant on the diagram. The subsequent location of the variables indicates that the majority of variables are correlated with a high degree of driving power. High driving force is attributed to high levels of control over relevant variables. Those barriers with the highest degree of dependency power populate the levels at the upper end of the ISM hierarchical model, meaning that they would be affected if any of the associated barriers at the lower levels are subject to achieve SCR. If there is any inconsistency in high driving power barriers, high level dependent barriers must be monitored with great care.

This research has a variety of theoretical contributions. First, this study has gathered all related studies on SCR adoption especially in the context of manufacturing industry, reviewed and analyzed the literature to extract the barriers of SCR. Second, add some barriers through expert mining and categorized according to their origins with the help of expert. Third, this is the first research that has explored the barriers of SCR and derived its framework using ISM-MICMAC for the manufacturing industries in the context of Bangladesh. The companies that fail to adopt SCR will struggle hard in forthcoming days and risk their survival. The manufacturing industries seeking ways to adopt SCR would get benefited from this study. Manufacturing industries can better plan where to begin and how to systematically minimize the possible barriers to achieve SCR by using the hierarchies and interrelationships represented in the ISM model.

This research is not without limitations. In this study, ISM and MICMAC framework has been developed with thirty one variables as barriers to achieve SCR in the Bangladesh. Future studies could expand the methodology of the ISM and develop a framework for strategies to address these SCR barriers. We are able to define inter-relationships between variables through an ISM approach, but cannot measure their effect. The DEMATEL methodology can be used to assess the effect of each element. Structural equation modeling (SEM) can be used in the future to find a linear structural relationship between variables and model validation.

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