CHAPTER 5

ANALYZING THE FACTORS OPPOSING THE RESILIENT BEHAVIOR OF THE RSC

Ever since the development of the RSC concept and its practical implementation in the SCs, it is assumed that organizations will be able to sustain and quickly recover their businesses during and after the disruptions, respectively. However, in reality, it is found that whatsoever strategy the organizations follows in developing a RSC, most of the time, SCs are unable to resist, absorb, or recover from the disturbances, and it tumbles down, causing colossal business and social losses (Agarwal and Seth, 2021; Ali *et al*., 2017; Rajesh, 2018). This failure of the RSC indicates the presence of the inhibiting factors that resists the successful implementation and execution of resilient practices. These inhibiting factors are called barriers of the RSC (Ali *et al*., 2017).

Moreover, according to the force field theory, for the survival, adaptation, and growth of a system, the magnitude and impact of the driving forces should be more than that of the inhibiting forces (Agarwal and Seth, 2021). This is also true for the RSC. Thus, identifying and analyzing the resilient practice (driving forces) along with the inhibiting factors (resisting forces) will help the SCs to overcome the vulnerabilities and the disruption impacts, thus leading to business success through competitive gain during normal as well as disruption conditions. Further, from the literature, it is evident that many of these inhibiting factors are inherited to the SCs in the form of poor network, lack of organizational commitment, poor cooperation among members, etc., and many are situational like a delayed response, poor information, etc., that need to be identified and evaluated.

Though the barriers have a very high impact on the success of the RSC, even then also, it is a minimally discovered concept in the field of the RSC (Agarwal and Seth, 2021). Moreover, identifying the RSC barrier in the context of the Indian manufacturing SC is rare. Thus, a considerable research gap exists regarding identifying and analyzing the RSC barriers. Therefore, this research aims to identify and analyze the barriers of the RSC in the context of the Indian iron and steel manufacturing firm having a global SC network. In this chapter, the main focus is to:

1. Identify the barriers that hinder the RSC capabilities.
2. Identify and quantify the causal dependence relationships among the barriers to the RSC.
3. Identify the most prominent barriers to the RSC.

To carry out above objectives, this research utilizes the conceptual framework of the Fuzzy Decision-making trial and evaluation laboratory (Fuzzy-DEMATEL) approach. In this, the fuzzy logic minimizes the ambiguities present in the human response, thus producing more reliable results. In addition, the DEMATEL approach quantifies and pictorially represents the degree of causal dependence relationships among the barriers of the RSC. Thus, fuzzy DEMATEL proves to be more advantageous over many other multi-criteria decision-making (MCDM) tools, such as analytic hierarchy process (AHP), analytic network process (ANP), r-method, etc. The inputs required for this research are obtained from the seven experts of an Indian manufacturing firm having experience of more than ten years in SC and related activities and acting at the manager post. Two experts are from the raw material handling plant (RMHP), two from the traffic and raw material (TRM) division, and one from marketing, production, and finance, respectively. Each of the experts had crucial responsibility for raw material

availability, time-bound production process, and product delivery to the end customers. These experts play an essential role in strategic and operational decision-making and thus pertain to the business continuity responsibility irrespective of the working environment uncertainty. Hence the responses obtained from the experts are very much trustable. Further, this chapter will contribute largely in understanding the role of barriers in abandoning the successful implementation of RSC and also, it enables the practitioner to strategize their resources and activities to wipe out these inhibiting factors. Figure 5.1 represents the various steps involved in this research.

5.1. Barriers to the RSC

From the earlier research, it has been evident that, how a stressful implication is adopted to develop a RSC, the businesses get affected in the midst of the adversities (e.g., COVID-19, Suez Canal obstruction, *etc*.). The failures of the RSC amid the adversities suggest the presence of some inhibiting factors called barriers (Ali *et al*., 2017; Agarwal and Seth, 2021). These barriers inhibit the success of the RSC by mitigating the successful implementation of the resilient strategies. Further, according to the force field theory, the system's existence is possible only when the forces driving it are more than those resisting it. Thus, identifying the RSC barriers is equally important as identifying and implementing the enablers that obstruct and absorb the disruptions (Rajesh, 2018).

Pareira *et al*. (2014) consider the impacts of the barriers for creating a RSC and explain the importance of poor financial strength, inadequate capacity, poor collaboration, lack of flexibility, poor visibility, insufficient knowledge, poor information sharing, lack of trust, insufficient coordination and control, and long lead time. Moreover, Ali *et al.* (2017) classify the RSC barrier into internal and external barriers and precisely explain

the significance and consequences of the organizational financial constraints, poor information sharing, and poor managerial commitment. A similar study is also carried out by Halkos *et al.* (2018) in the context of the small and medium enterprises of Greek and explains the importance of resource availability, organizational culture, market vulnerability, support among the SC members, *etc*. Rajesh (2018) explains the barriers to the RSCs considering the case of an Indian electronic manufacturing firm. In this, the author has focused on four essential barriers, i.e., barriers related to the human and its judgment, barriers related to the assets and system, barriers related to the operations, and the barriers related to the sourcing. Similarly, Agarwal and Seth (2021) focused on enabling resilience characteristics to an automobile manufacturing firm's SC by interpreting the causal-dependence relationships among the RSC barriers. These barriers are lack of organizational commitment, poor relations with suppliers, inadequate forecasting, poor information sharing, lack of flexibility, inability to change and innovation, infrastructural inadequacy, inferior trading partner's capabilities, and un-availability of the multitasking workforce.

Moreover, Gorane and Kant (2015) and Khullar *et al.* (2020), *etc*., have considered the poor financial health of the SC members as the impactful barrier, whereas Rajesh (2019) and Yinan *et al*. (2014) have considered the centralization of the assets as the most critical barrier for the RSC. Giunipero and Eltantawy (2004) focus on improving the response of the SC members during and after the disruptions, while Blackhurst *et al*. (2005) and Eriksson and McConnell (2011) focused on improving the contingent resources to minimize the disruption impacts. Moreover, according to Yinan *et al*. (2014) and Govindan *et al*. (2013), centralization of the SC activities (such as centralized planning and decision making, single production and distribution facilities, centralized quality control process, *etc*.) also acts as a strong barrier to the RSC and is

causing the delay and sometime breakdown of the SC. Further, the continuous approach for the lean SC caused the eradication of all those resources and capabilities that guard the SC against uncertainties and disruptions, e.g., minimizing redundant capabilities and lead time, single sourcing and dedicated freight service, *etc*., will act as the inhibitors for the RSC (Patel *et al*., 2021a; Pettit *et al*., 2013). Thus, from the above discussion, it is apparent that the RSC is a network-wide concept. Its success depends upon the three parameters, i.e., understanding resilient capabilities, identifying the resilient practices leading to the resilient capabilities, and identifying and analyzing the barriers that inhibit the successful implementation of the resilient practices.

And also, the literature suggests that enormous research exists regarding the development of resilient capabilities and their allied practices. However, very little research focuses on identifying and evaluating the inhibiting factors of the RSC. Further, the literature survey suggests that quantifying the causal dependence relationships among the barriers will significantly contribute to the RSC. And also, implementing the fuzzy logic to minimize the ambiguities involved in the expert's perception will add value to this research (Patel *et al*., 2018). Moreover, identification and analysis of the RSC barrier in the context of the iron and steel industry post the first phase of the COVID-19 pandemic is the need of the developing nation like India.

Not only because the manufacturing sector contributes significantly to the Indian GDP but also because of its importance to the global market, and also, according to the report, India is the world's second-largest producer of steel next to china. Thus the findings of our research would be of great utility to Indian business and the world market. Moreover, the situation created due to COVID-19, coupled with the strict lockdown, caused considerable disruptions to the steel manufacturing firms, however,

many reports like Argus, Business Standard, *etc*., suggest that it is also among the fastest-growing sectors post the first phase of COVID-19.

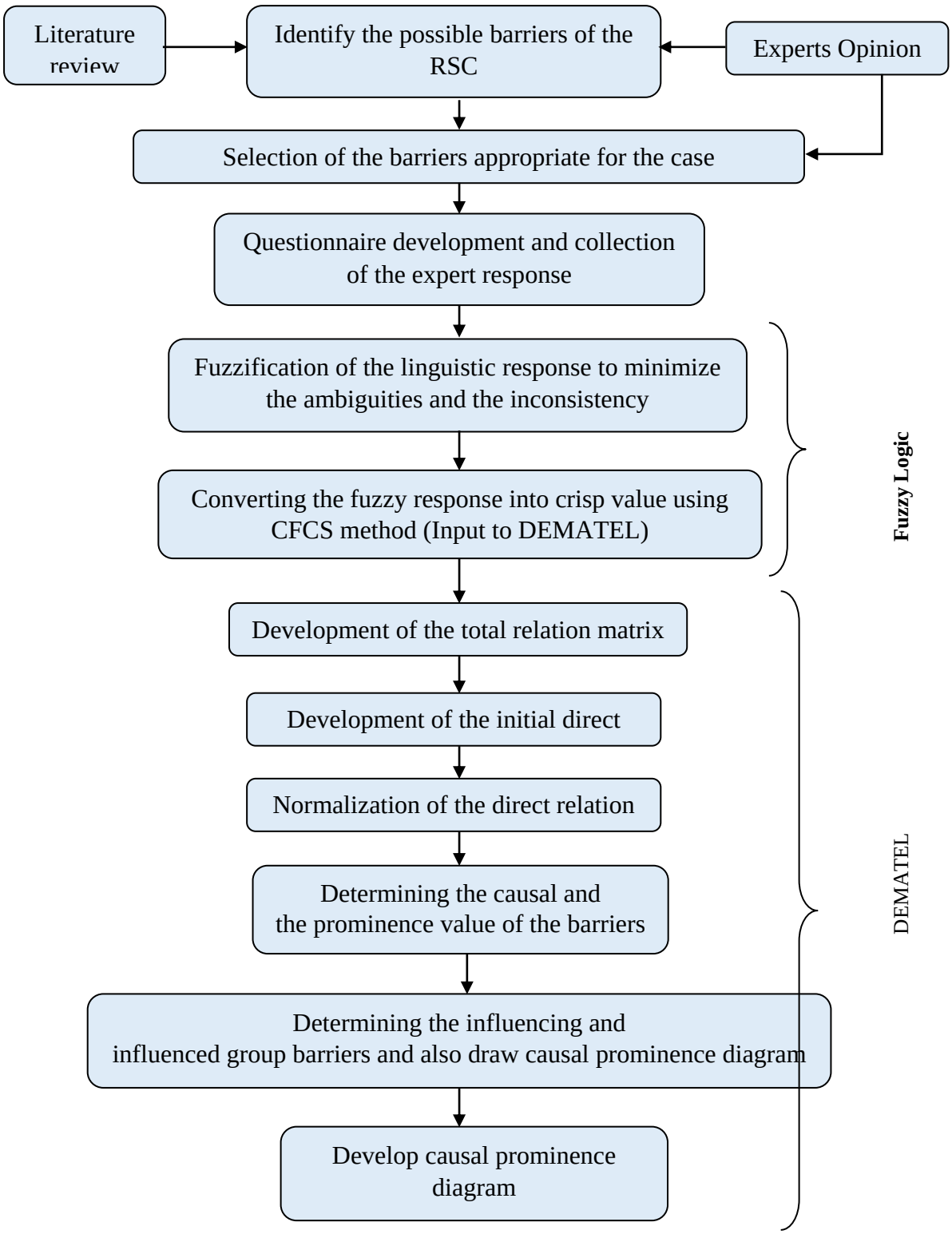

Figure 5.1: A research framework for analyzing the barriers to the RSC

Initially, barriers are identified from the extent of the literature review related to the RSC and barriers of the RSC, such as internal and external barriers, sourcing-related barriers, decision-making-related barriers, financial constraints, *etc*. Further, these barriers are thoroughly discussed with the case organization industry experts in terms of its similarity, impact on RSC, relevance to the case organization, *etc*. After a thorough discussion, experts agree on the following fourteen barriers as the main hindrances to their SCs.

Poor support among SC members (B_1)

Inadequate support from the trading partners during normal and disruptive situations (Simangunsong *et al*., 2012). It may be because of a lack of capabilities and opportunistic behavior. The support may be in the form of risk and reward sharing, knowledge sharing, contract flexibility, *etc*.

Mistrust among the SC members (B_2)

Lack of confidence among SC members regarding their cooperation, performance, competence, integrity, information, and benevolence (Ebrahim-khanjari and Hopp, 2012; Farooq, 2021). The trust that SC members will not act opportunistically promotes a high level of integration, sharing the strategic plan and capabilities, *etc*. (Jain *et al.,* 2017; Rajesh, 2018; Agarwal and Seth, 2021).

Resistance to change and innovation (B_3)

The organizational behavior that denies accepting the newer technology, changing the target customer, entering into the new market, restructuring the SC to collaborate with efficient resource members, *etc*. The acceptance and adaptation of the change and

innovation will lead to advanced capabilities, which further adapt to the challenging market (Agarwal and Seth, 2021; Singh and Singh, 2019).

Poor judgment and inaccurate forecast (B_4)

The managerial inability to anticipate the changing and challenging business environment and correspondingly make the right decision. The accuracy in judgment and forecasting plays an important role in avoiding and mitigating the disruptions and their impact. Thus, it inhibits preparedness and contingency planning against uncertainties. (Rajesh, 2018; Dowty and Wallace, 2010).

Poor SC network (B_5)

The presence of several incompetent, critical, dependent, vulnerable, and geographically distributed SC partners constraints the SC's flexibility, agility, and adaptability. It includes logistics service providers, suppliers, distribution centers, production units, longer lead time, outsourcing units, *etc*. (Cantor *et al*., 2014; Govindan *et al*., 2017; Patel *et al*., 2017; Rajesh, 2018). The presence of agile, adaptable, and flexible SC members is the demand of the RSC.

Poor information sharing (B_6)

Intentionally or unintentionally sharing or receiving distorted, delayed, incomplete, and unreliable information by the SC partners. It is mainly due to the lack of infrastructure and the mistrust among the SC members (Lee *et al*., 2000; Rajesh, 2019). It has been observed that adequate information sharing helps absorb most of the vulnerabilities related to the changing business environment (Patel *et al*., 2021b; Agarwal and Seth, 2021).

Lack of multitasking workforce (B_7)

Unavailability of the multi-skilled workforce due to the poor training and resistant nature of the employees (Markman, 2013; Shibin *et al*., 2016; Agarwal and Seth, 2021). A multitasking workforce provides flexibility during normal business environments and acts as the most important resource during disruptions.

The poor financial health of the organization (B_8)

Unavailability of sufficient financial resources to develop new capabilities before, during, and after the disruptions (Shibin *et al*., 2016; Ortas *et al*., 2014; Agarwal and Seth, 2021).

Lack of managerial commitment (B_9)

Inadequate strategic planning for creating a RSC. It includes delayed strategy implementation, poor human resource training, inappropriate risk management culture, poor anticipation of the vulnerabilities, *etc*. (Ali *et al*., 2017; Rajesh, 2018; Lämsä and Savolainen, 2000).

Centralization of the SC activities (B_{10})

It is the poor distribution of authority and responsibility to the SC members. It focuses on a vertical integration SC that includes centralized decision-making, developing dedicated and fixed facilities (production, warehousing, distribution, *etc*.), gaining high control over the SC members, *etc*. (Rajesh, 2018).

Continuously strive for lean operation (B_{11})

It is the eradication of the resources and capabilities that seem redundant, wasteful, and inefficient during the normal and the anticipated business environment, thus minimizing the capacities that guard and absorbs the disruption (Pettit *et al*., 2013).

Poor risk awareness (B_{12})

It is the inability to recognize and anticipate the risks and disruptions before their occurrence. It results from inadequate information technology and evaluation tools, incompetence, poor managerial commitment, *etc*. (Vilko *et al*., 2014; Rajesh, 2018).

Inadequate response during and after the disruption (B_{13})

It is the inability of the SC members to modify their available capacity, learn and adopt new capabilities, *etc*., to positively and effectively respond to the disruptions, opportunities, and challenges. It includes quick setup, minimizing the lead time, adopting new tools and training, *etc*. (Giunipero and Eltantawy, 2004; Rajesh, 2018).

Lack of contingency planning (B_{14})

It is the poor preparedness against the disruptions. It includes inadequate capability development in terms of poor risk awareness and scenario planning, inadequate human resources training, unavailability of alternatives, *etc*., to tackle the unexpected and expected vulnerabilities (Rajesh, 2018).

5.2. Methodology

In this research, the integrated concept of fuzzy set theory (FST) and the DEMATEL approach helps to identify and evaluate the causal dependence relationships among the

barriers of the RSC. The fuzzy logic helps to deal with the vagueness in human perception without losing any of the information provided by the experts, whereas the DEMATEL approach helps in understanding the complex interdependent relationships among the barriers (Chang *et al*., 2011; Altinirmak *et al*., 2017; Abbasi *et al*., 2013). Our approach is also supported by the Wu and Lee (2007) statement, i.e., making the decision in a fuzzy environment constituting the complex factors using crisp values is very difficult and unreliable. Thus, integrating fuzzy logic with DEMATEL will enhance the value of our research, and the findings will be more dependable. In this approach, first, the expert's response regarding the relationships between the barriers is quantified using FST. Further, each response is defuzzified to obtain a crisp value using the 'converting fuzzy data into a crisp score (CFCS)' approach. The various steps involved in integrated FST and DEMATEL are as explained.

5.2.1. Fuzzy Set Theory (FST)

Zadeh introduced the FST in 1965. Since then, it has been widely used by practitioners and researchers to absorb the vagueness, subjectivity, and the influence of unknown factors involved in the decision-making, expert's response, system behavior, *etc*. In this approach, the expert's linguistic responses are first quantified using a fuzzy linguistic scale (Table 5.1). Two types of fuzzy linguistic scales are available for quantifying the experts' linguistic score, i.e., Triangular and Trapezoidal fuzzy scales. However, the literature suggests that when the research is focused on human judgment, triangular fuzzy numbers (TFN) are given higher priority than the trapezoidal fuzzy number (Altinirmak et al., 2017; Abbasi et al., 2013). Further, according to Chang et al. (2011), fuzzy linguistic variables are part of the human languages. A TFN $\check{A}$ is defined as the triplet (l, m, r) having a membership function $\mu_{\check{A}}$. It is graphically and numerically

represented in Figure 5.2 and equation 5.1, respectively. Fuzzy numbers refer to the fuzzy sets on real line R and with the membership function $\mu_{\check{A}}$, such that $\mu_{\check{A}}(y): R \rightarrow [0,1]$.

$$\mu_{\check{A}}(y) = \begin{cases} 0, & y < l \\ \frac{y-l}{m-l} & l \leq y \leq m \\ \frac{r-y}{r-m} & m \leq y \leq r \\ 0, & y > r \end{cases}$$

(5.1)

Further, the FST is accompanied by a fuzzy aggregation process involving defuzzification as an integral part. The defuzzification process considers the spread, height, and shape of the TFNs as an essential characteristic of fuzzy numbers. However, there are many approaches to defuzzify the fuzzy sets, such as COA (center of gravity or centroid approach), BNP (best non-fuzzy performance), CFCS (converting fuzzy data into crisp score), *etc*.; however, the CFCS approach is found to provide a better crisp value (Altinirmak *et al*., 2017). The CFCS approach was proposed by Opricovic and Tzeng (2003) and is carried out in the following steps.

Let, $A_{ij}^k = (l_{ij}^k, m_{ij}^k, r_{ij}^k)$ be the linguistic score provided by the expert k ($k = 1,2, \ldots, d$) regarding the effect/influence of factor i over factor j, then the defuzzification is carried out in the following five steps. For our research, the response from the seven experts of the case SC organizations are collected; considering the space constraints, the calculations only for the response obtained from expert 1 is presented here. All the responses are defuzzified individually and then aggregated to obtain the direct relation matrix, which will be used as the input in the DEMATEL approach.

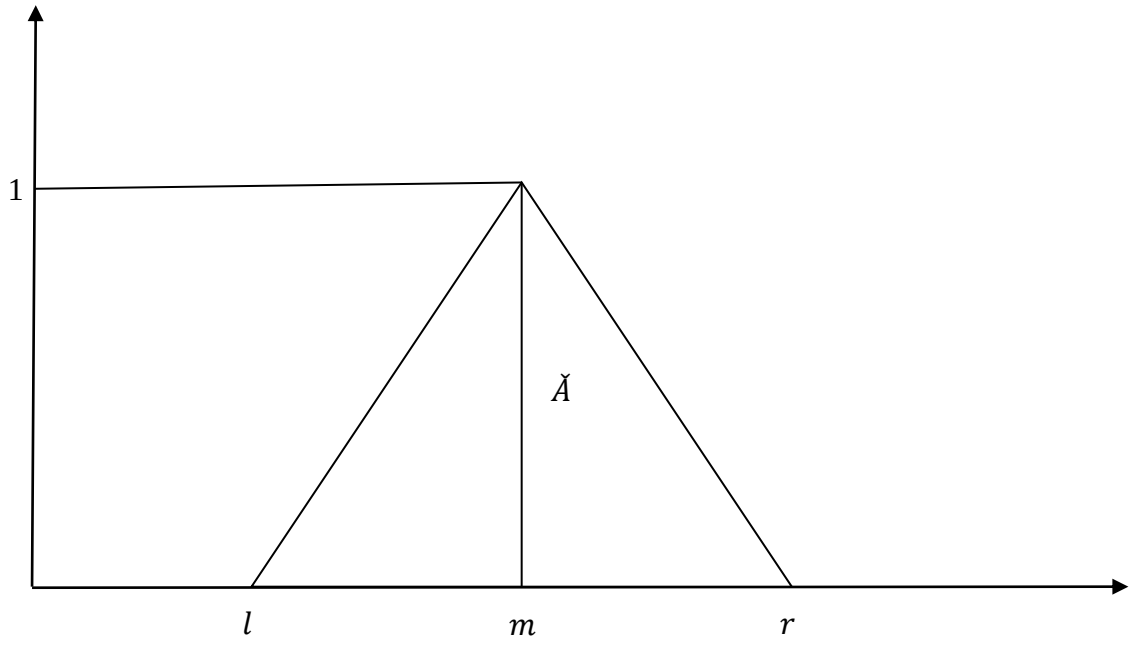

Figure 5.2: Representation of a triangular fuzzy number ($\widetilde{A}$)

5.2.1.1. Normalizing expert's response

The expert's response is normalized using equation 5.2, equation 5.3, and equation 5.4.

$$xl_{ij}^{k} = \frac{l_{ij}^{k} - minl_{ij}^{k}}{\Delta_{min}^{max}} \tag{5.2}$$

$$xm_{ij}^{k} = \frac{m_{ij}^{k} - minl_{ij}^{k}}{\Delta_{min}^{max}} \tag{5.3}$$

$$xr_{ij}^{k} = \frac{r_{ij}^{k} - minl_{ij}^{k}}{\Delta_{min}^{max}} \tag{5.4}$$

Where,

$$\Delta_{min}^{max} = maxr_{ij}^{k} - minl_{ij}^{k}$$

e.g. $xl_{12}^{1} = \frac{0.50-0.0}{1.0-0.0} = 0.50$

The contextual relation matrix (Table 5.2) is developed based on the linguistic response obtained by the experts regarding the influence of the barrier i over the barrier j. Our research used a five-score linguistic scale, ranging from no influence (NO) to very high influence (VH). Where 'NO' relation represents the independence of the compared barrier (*i, j*) over each other; similarly, 'VL,' 'LI,' 'HI,' and 'VH' represents very weak, weak, strong, and very strong causal relation between barrier *i* and barrier *j* respectively. It is to be noted that the diagonal element will always be 'NO' in the contextual relation matrix, and the corresponding elements will be zero (0) (or 0.0,0.0,0.25 in the case of the TFNs) in the direct relation matrix. In the contextual matrix, 'NO' or '0' signifies that barriers are not self-influencing and can be influenced only by the other barriers. In Table 5.2, the relation between B_1 and B_2 is obtained to be HI, which suggests that barrier 1 has a high influence over barrier 2, i.e., when there exists B_1then there is a high probability of the existence of the B_2. In another way, if there is B_1then it will highly promote B_2. Similarly, all other relations can be explained. Once the relation matrix is obtained, it is converted to the fuzzy direct relation matrix by quantifying the linguistic relationships using Table 5.3. In the classical DEMATEL approach, the linguistic terms are quantified using crisp value (0, 1, 2, 3, 4, and 5 or 0, 0.25, 0. 50, 0.75, and 1.0). However, these crisp values are often unable to accurately depict the expert's response; thus, TFNs are used. Where *l* and *r* represent the expert's response interpretations' lower and the upper bound, whereas *m* represents the best possible interpretation. For example, the relations between $B_1$and B_2 in Table 5.2 is HI, which can be directly quantified to 0.75, but many times, different experts perceive differently for the linguistic scale; thus, the best possible way to quantify the linguistics scale is to provide a range of values that can include all the possible interpretations. Therefore, in Table 5.3, the relation between the B_1 and B_2 is provided as (0.50, 0.75, 1).

Table 5.1: Fuzzy linguistic scale

Linguistic terms	Influence score	TFN Fuzzy scale
No influence (NO)	0	0.0,0.0,0.25
Very low influence (VL)	1	0.0,0.25,0.50
Low influence (LI)	2	0.25,0.50,0.75
High influence (HI)	3	0.50,0.75,1.0
Very High influence (VH)	4	0.75,1.0,1.0

5.2.1.2: Determining the left (ls) and right (rs) normalized value

This left and right normalized value is also called the left and right scores and is obtained by using equation 5.5 and equation 5.6, respectively (Opricovic and Tzeng, 2003), and is presented in Table 5.4. The elements in Table 5.4 represent that the crisp value for the corresponding TFN will lie between these left and right scores, respectively. For example, the element corresponds to the relation between B_1 and B_2 (Table 5.4) is 0.6 and 0.8, respectively, which means their crisp value will lie between 0.6 and 0.8 (Table 5.5). Similarly, it is true for all other relations presented in Table 5.4.

Table 5.2: Contextual relation matrix between the RSC barriers

Barriers	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}
B_1	NO	HI	LI	NO	NO	LI	NO	VL	NO	VH	LI	NO	HI	HI
B_2	HI	NO	VL	NO	HI	VH	NO	NO	NO	HI	LI	NO	LI	LI

B_3	LI	NO	NO	LI	LI	VL	HI	LI	NO	HI	VL	LI	VH	HI
B_4	VL	VL	VL	NO	HI	NO	LI	NO	NO	VH	VH	NO	VH	VH
B_5	NO	VL	NO	VL	NO	HI	NO	NO	NO	VL	NO	NO	VH	LI
B_6	HI	VH	LI	VH	HI	NO	LI	NO	NO	LI	LI	LI	HI	HI
B_7	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	VH	LI
B_8	NO	NO	HI	NO	LI	LI	LI	NO	NO	LI	HI	NO	HI	HI
B_9	LI	LI	VH	VH	HI	HI	HI	VL	NO	LI	HI	HI	HI	HI
B_{10}	NO	NO	HI	HI	HI	VL	NO	NO	NO	NO	HI	NO	HI	HI
B_{11}	HI	N0	HI	LI	HI	NO	LI	NO	NO	HI	NO	NO	VH	HI
B_{12}	HI	LI	HI	HI	HI	HI	HI	NO	HI	HI	VH	NO	HI	VH
B_{13}	LI	HI	NO	NO	NO	NO	LI	HI	NO	NO	NO	LI	NO	NO
B_{14}	HI	LI	NO	NO	LI	NO	VH	LI	NO	HI	LI	NO	VH	NO

Table 5.3: Fuzzy direct-relation matrix developed based on the expert response

	B_1	B_2	B_3	B_4	B_5	B_6	B_7
B_1	0,0,0.25	0.50,0.75, 1.0	0.25,0.50, 0.75	0,0.25,0.5 0	0,0,0.25	0.50,0.75, 1.0	0,0,0.25
B_2	0.50,0.75, 1.0	0,0,0.25	0,0,0.25	0,0.25,0.5 0	0,0.25,0.5 0	0.75,1.0,1 .0	0,0,0.25
B_3	0.25,0.50, 0.75	0,0.25,0.5 0	0,0,0.25	0,0.25,0.5 0	0,0,0.25	0.25,0.50, 0.75	0,0,0.25
B_4	0,0,0.25	0,0,0.25	0.25,0.50, 0.75	0,0,0.25	0,0.25,0.5 0	0.75,1.0,1 .0	0,0,0.25
B_5	0,0,0.25	0.50,0.75, 1.0	0.25,0.50, 0.75	0.50,0.75, 1.0	0,0,0.25	0.50,0.75, 1.0	0,0,0.25
B_6	0.25,0.50, 0.75	0.75,1.0,1 .0	0,0.25,0.5 0	0,0,0.25	0.50,0.75, 1.0	0,0,0.25	0,0,0.25
B_7	0,0,0.25	0,0,0.25	0.50,0.75, 1.0	0.25,0.50, 0.75	0,0,0.25	0.25,0.50, 0.75	0,0,0.25
B_8	0,0.25,0.5 0	0,0,0.25	0.25,0.50, 0.75	0,0,0.25	0,0,0.25	0,0,0.25	0,0,0.25
B_9	0,0,0.25	0,0,0.25	0,0,0.25	0,0,0.25	0,0,0.25	0,0,0.25	0,0,0.25
B_{10}	0.75,1.0,1 .0	0.50,0.75, 1.0	0.50,0.75, 1.0	0.75,1.0,1 .0	0,0.25,0.5 0	0.25,0.50, 0.75	0,0,0.25
B_{11}	0.25,0.50, 0.75	0.25,0.50, 0.75	0,0.25,0.5 0	0.75,1.0,1 .0	0,0,0.25	0.25,0.50, 0.75	0,0,0.25
B_{12}	0,0,0.25	0,0,0.25	0.25,0.50, 0.75	0,0,0.25	0,0,0.25	0.25,0.50, 0.75	0,0,0.25

B_{13}	0.50,0.75, 1.0	0.25,0.50, 0.75	0.75,1.0,1 .0	0.75,1.0,1 .0	0.75,1.0,1 .0	0.50,0.75, 1.0	0.75,1.0,1 .0
B_{14}	0.50,0.75, 1.0	0.25,0.50, 0.75	0.50,0.75, 1.0	0.75,1.0,1 .0	0.25,0.50, 0.75	0.50,0.75, 1.0	0.25,0.50, 0.75

	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}
B_1	0,0,0.25	0.25,0.50, 0.75	0,0,0.25	0.50,0.75, 1.0	0.50,0.75, 1.0	0.25,0.50, 0.75	0.50,0.75, 1.0
B_2	0,0,0.25	0.25,0.50, 0.75	0,0,0.25	0,0,0.25	0.25,0.50, 0.75	0.50,0.75, 1.0	0.25,0.50, 0.75
B_3	0.50,0.75, 1.0	0.75,1.0,1 .0	0.50,0.7 5,1.0	0.50,0.75, 1.0	0.50,0.75, 1.0	0,0,0.25	0,0,0.25
B_4	0,0,0.25	0.75,1.0,1 .0	0.50,0.7 5,1.0	0.25,0.50, 0.75	0.50,0.75, 1.0	0,0,0.25	0,0,0.25
B_5	0.25,0.50, 0.75	0.50,0.75, 1.0	0.50,0.7 5,1.0	0.50,0.75, 1.0	0.50,0.75, 1.0	0,0,0.25	0.25,0.50, 0.75
B_6	0.25,0.50, 0.75	0.50,0.75, 1.0	0,0.25,0. 50	0,0,0.25	0.50,0.75, 1.0	0,0,0.25	0,0,0.25
B_7	0.25,0.50, 0.75	0.50,0.75, 1.0	0,0,0.25	0.25,0.50, 0.75	0.50,0.75, 1.0	0.25,0.50, 0.75	0.75,1.0,1 .0
B_8	0,0,0.25	0,0.25,0.5 0	0,0,0.25	0,0,0.25	0,0,0.25	0.50,0.75, 1.0	0.25,0.50, 0.75
B_9	0,0,0.25	0,0,0.25	0,0,0.25	0,0,0.25	0.50,0.75, 1.0	0,0,0.25	0,0,0.25
B_{10}	0.25,0.50,	0.25,0.50,	0,0,0.25	0.50,0.75,	0.50,0.75,	0,0,0.25	0.50,0.75,

	0.75	0.75		1.0	1.0		1.0
B_{11}	0.50,0.75, 1.0	0.50,0.75, 1.0	0.50,0.75,1.0	0,0,0.25	0.75,1.0,1.0	0,0,0.25	0.25,0.50, 0.75
B_{12}	0,0,0.25	0.50,0.75, 1.0	0,0,0.25	0,0,0.25	0,0,0.25	0.25,0.50, 0.75	0,0,0.25
B_{13}	0.50,0.75, 1.0	0.50,0.75, 1.0	0.50,0.75,1.0	0.75,1.0,1.0	0.50,0.75, 1.0	0,0,0.25	0.75,1.0,1.0
B_{14}	0.50,0.75, 1.0	0.50,0.75, 1.0	0.50,0.75,1.0	0.50,0.75, 1.0	0.75,1.0,1.0	0,0,0.25	0,0,0.25

$$xls_{ij}^{k} = \frac{xm_{ij}^{k}}{(1+xm_{ij}^{k}-xl_{ij}^{k})} \quad (5.5)$$

$$xrs_{ij}^{k} = \frac{xr_{ij}^{k}}{(1+xr_{ij}^{k}-xm_{ij}^{k})} \quad (5.6)$$

The ls and rs values are obtained corresponding to the fuzzy direct relation matrix (Table 5.3) and provided in Table 5.4).

E.g., $xls_{12}^{1} = \frac{0.75}{(1+0.75-0.50)} = 0.60$

5.2.1.3. Determining the total normalized crisp values (Table 5.5)

Once the normalized left and right scores are obtained, then the next step is to obtain a total normalized crisp value for the causal relationship between the barriers and is obtained using equation 5.7 (Opricovic and Tzeng, 2003; Chang *et al*., 2011; Parmar and Desai, 2020). The normalization aims to obtain a relative value of the matrix

elements without affecting their essence, such that each element comply with $0 \leq x_{ij}<1$ (where, x_{ij} represents the matrix element) (Si *et al.*, 2018).

$$x_{ij}^{k} = \frac{[xls_{ij}^{k}\left(1-xls_{ij}^{k}\right)+xrs_{ij}^{k}*xrs_{ij}^{k}]}{[1-xls_{ij}^{k}+xrs_{ij}^{k}]}$$

(5.7)

e.g. $x_{12}^{1} = \frac{0.60*(1-0.60)+0.80*0.80}{1-0.60+0.80} = 0.73$

5.2.1.4, Determining the final crisp values

The final step of defuzzification converts the fuzzy relation obtained by the experts regarding the influencing relation between the factors into the crisp value. Equation 5.8) helps in getting the final crisp value, and the outcome is provided in Table 5.6.

$$a_{ij}^{k} = minl_{ij}^{k} + x_{ij}^{k} * \Delta_{min}^{max}$$

(5.8)

e.g. $a_{12}^{1} = 0 + 0.73 * 1 = 0.73$, (since, $\Delta_{min}^{max} = 1 \; and \; minl_{ij}^{k} = 0$)

Thus the final crisp relation matrix is the same as the total normalized fuzzy relation matrix (Table 5.5). Further, Table 5.3, Table 5.4, and Table 5.5 are conceptually similar because all of these are different forms of Table 5.2, i.e., the relation developed by the experts regarding the causal dependence relationships between the barriers. The only difference lies in the quality of the data, which is achieved by operating step 1 to step 4.

Table 5.4: Normalized *ls* and *rs* values obtained from the fuzzy direct-relation matrix

B_i	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}
B_1	0, 0	0.6, 0.8	0.2, 0.4	0,0.2	0.6, 0.8	0.6, 0.8	0,0.2	0.0, 0.2	0,0.2	0.6, 0.8	0.4, 0.6	0.2, 0.4	0.8, 1	0.4, 0.6
B_2	0.6, 0.8	0,0	0.4, 0.6	0.2, 0.4	0.4, 0.6	0.8, 1	0,0.2	0.0, 0.2	0,0.2	0.6, 0.8	0.4, 0.6	0.4, 0.6	0.4, 0.6	0,0.2
B_3	0.6, 0.8	0.2, 0.4	0,0	0,0.2	0.6, 0.8	0,0.2	0.6, 0.8	0.2, 0.4	0.4, 0.6	0.4, 0.6	0,0.2	0,0.2	0.6, 0.8	0.6, 0.8
B_4	0.4, 0.6	0,0.2	0.6, 0.8	0,0	0.6, 0.8	0,0.2	0.4, 0.6	0.4, 0.6	0,0.2	0.4, 0.6	0.6, 0.8	0,0.2	0.8, 1	0.8, 1
B_5	0.6, 0.8	0,0.2	0.6, 0.8	0.4, 0.6	0,0	0.6, 0.8	0,0.2	0.2, 0.4	0,0.2	0.6, 0.8	0.4, 0.6	0.4, 0.6	0.6, 0.8	0.2, 0.4
B_6	0.6, 0.8	0.8, 1	0.6, 0.8	0.6, 0.8	0.4, 0.6	0,0	0.2, 0.4	0.0, 0.2	0,0.2	0.6, 0.8	0.4, 0.6	0.8, 1	0.8, 1	0.8, 1
B_7	0.2, 0.4	0,0.2	0.4, 0.6	0,0.2	0,0.2	0,0.2	0,0	0.4, 0.6	0,0.2	0.4, 0.6	0.6, 0.8	0,0.2	0.6, 0.8	0.2, 0.4
B_8	0.6, 0.8	0,0.2	0.6, 0.8	0,0.2	0,0.2	0,0.2	0,0.2	0.0, 0.0	0,0.2	0.6, 0.8	0.8, 1	00.2	0.6, 0.8	0.4, 0.6
B_9	0.4, 0.6	0.2, 0.4	0.2, 0.4	0.6, 0.8	0.6, 0.8	0.2, 0.4	0.6, 0.8	0.0, 0.2	0,0	0.4, 0.6	0.4, 0.6	0.4, 0.6	0.6, 0.8	0.4, 0.6
B_{10}	0.6, 0.8	0,0.2	0.2, 0.4	0.6, 0.8	0.4, 0.6	0,0.2	0,0.2	0.0, 0.2	0.6, 0.8	0,0	0.6, 0.8	0,0.2	0.6, 0.8	0.4, 0.6
B_{11}	0.6, 0.8	0,0.2	0.6, 0.8	0,0.2	0,0.2	0,0.2	0,0.2	0.0, 0.2	0,0.2	0.6, 0.8	0,0	0.6, 0.8	0.6, 0.8	0.6, 0.8
B_{12}	0.6, 0.8	0,0.2	0.6, 0.8	0.8, 1	0.6, .8	0.6, 0.8	0.6, 0.8	0.4, 0.6	0.6, 0.8	0.6, 0.8	0.8, 1	0,0	0.6, 0.8	0.8, 1
B_{13}	0.6, 0.8	0.6, 0.8	0,0.2	0,0.2	0,0.2	0,0.2	0,0.2	0.4, 0.6	0,0.2	0,0.2	0,0.2	0,0.2	0,0	0,0.2
B_{14}	0.6, 0.8	0,0.2	0.6, 0.8	0.4, 0.6	0,0.2	0,0.2	0.6, 0.8	0.0, 0.2	0,0.2	0.6, 0.8	0.4, 0.6	0.2, 0.4	0.8, 1	0.4, 0.6

Table 5.5: Total normalized crisp value matrix for the fuzzy relation

B_i	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}
B_1	0.00	0.73	0.27	0.03	0.73	0.73	0.03	0.03	0.03	0.73	0.50	0.27	0.97	0.50
B_2	0.73	0.00	0.50	0.27	0.50	0.97	0.03	0.03	0.03	0.73	0.50	0.50	0.50	0.03
B_3	0.73	0.27	0.00	0.03	0.73	0.03	0.73	0.27	0.50	0.50	0.03	0.03	0.73	0.73
B_4	0.50	0.03	0.73	0.00	0.73	0.03	0.50	0.50	0.03	0.50	0.73	0.03	0.97	0.97
B_5	0.73	0.03	0.73	0.50	0.00	0.73	0.03	0.27	0.03	0.73	0.50	0.50	0.73	0.27
B_6	0.73	0.97	0.73	0.73	0.50	0.00	0.27	0.03	0.03	0.73	0.50	0.97	0.97	0.97
B_7	0.27	0.03	0.50	0.03	0.03	0.03	0.03	0.50	0.03	0.50	0.73	0.03	0.73	0.27
B_8	0.73	0.03	0.73	0.03	0.03	0.03	0.03	0.03	0.03	0.73	0.97	0.03	0.73	0.50
B_9	0.50	0.27	0.27	0.73	0.73	0.27	0.73	0.03	0.03	0.50	0.50	0.50	0.73	0.50
B_{10}	0.73	0.03	0.27	0.73	0.50	0.03	0.03	0.03	0.73	0.03	0.73	0.03	0.73	0.50
B_{11}	0.73	0.03	0.73	0.03	0.03	0.03	0.03	0.03	0.03	0.73	0.03	0.73	0.73	0.73
B_{12}	0.73	0.03	0.73	0.97	0.73	0.73	0.73	0.50	0.73	0.73	0.97	0.03	0.73	0.97

B_{13}	0.73	0.73	0.03	0.03	0.03	0.03	0.03	0.50	0.03	0.03	0.03	0.03	0.00	0.03
B_{14}	0.73	0.03	0.73	0.50	0.03	0.03	0.73	0.73	0.03	0.97	0.97	0.03	0.97	0.00

Thus, Table 5.6 is the better transformation of Table 5.2 as it is free from or has minimal ambiguities compared to direct transformation, which considers only the crisp value provided in Table 5.2.

5.2.1.5. Determining the direct-relation matrix

It is obtained by aggregating the defuzzified values of the expert responses using equation 5.9).

$$a_{ij} = \frac{1}{d}(a_{ij}^1 + a_{ij}^2 + \cdots + a_{ij}^3) \tag{5.9}$$

e.g. $$a_{12} = \frac{0.733+0.267+0.733+0.500+0.733+0.733+0.500}{7} = 0.5998$$

This aggregated value of the expert's response is the input to the DEMATEL and is known by the initial direct relation matrix (Table 5.6).

5.2.2. DEMATEL

This method was developed by Battelle Memorial Institute at Geneva research center in 1973. It is based on human judgment and the digraph (directed graph), which separates the factors of the system into the cause group and effect group (Chang *et al.*, 2011). The digraph is the pictorial presentation of the contextual relationships between the factors, and the directed arrow present in the graph shows their dependence relationships. The advantage of DEMATEL over other approaches is that it provides the set of most

influencing factors (in our case, barriers) that need to be controlled to improve the system's overall performance, thus helping in strategic decision-making (Abbasi *et al*., 2013). The steps involved in the DEMATEL approach are as follows:

5.2.2.1: Identification of the factors of the system under consideration

For this research, fourteen barriers of the RSC, i.e., $B_1 \; to \; B_{14}$ is considered, which is thoroughly provided in section 5.1.

5.2.2.2: Development of the relation matrix

The relational matrix is developed by collecting the expert's response regarding the contextual relationships between the factor i and factor j. A five-point linguistic scale, i.e.,$No\ influenc$, $very\ low\ influence$, $low\ influence$, $high\ influence$, and $very\ high\ influence$ (Table 5.1) is used. It is to be noted that the relation between factor i and factor i is always presented by 'no relation.' One of the relation matrixes is provided in Table 5.2. Similarly, seven relation matrixes are developed.

5.2.2.3: Development of the initial direct-relation matrix (A)

The direct relationship matrix is obtained by quantifying the contextual relation provided by the experts using Table 5.3. If more than one expert is involved, the responses are averaged (Equation 5.9) to obtain matrix A (Table 5.6). In our case, the initial direct relation matrix is obtained through step 6 of the CFCS approach and is provided in Table 5.6.

It constitutes the quantified value of the causal-dependence relation between barriers, such that the value in any cell represents the influencing power of the barrier corresponding to its row over the barrier lying in its corresponding column. The

diagonal element will always be zero as this matrix constitutes only the pairwise comparison of the barriers. For example, the relation between, B_1 and B_2, B_1 and B_9, and B_1 and B_{12} presented in Table 5.6 signifies that the presence B_1influences the success of the B_2, B_9, and B_{12} by a factor of 0.60, 0.033, and 0.933, respectively.

Where, $$A = [a_{ij}]_{nxn}$$

$$i, j = 1, 2, \dots n$$

$$n = number\ of\ the\ factors\ under\ consideration$$

5.2.2.4: Calculating the normalized direct-relation matrix (Y)

The direct-relation matrix is normalized using equation 5.10 and is provided in Table 5.7.

$$Y = [y_{ij}]_{nxn} = \frac{A}{\beta} \quad (5.10)$$

Where,

$$\beta = max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}$$

$$= 10.167$$

5.2.2.5: Development of the total relational matrix (T)

Once the normalized direct-relation matrix (Y) is obtained, the total relation matrix is obtained by using equation 5.11. It is provided in Table 5.8.

$$T = Y + Y^1 + Y^2 + \cdots + Y^\infty$$

$$T = Y(I - Y)^{-1} \quad (5.11)$$

5.2.2.6: Identifying the cause group and influence group factors and developing the causal and effect graph

The cause and influence group factors are identified based on their ability to influence (D) and their dependence (R) on other factors. The vector D and vector R are obtained using equation 5.12 and equation 5.13, respectively, where, d_i *and* r_i denotes the magnitude of its influencing ability and influence of other factors over it (factor i).

Table 5.6: Initial direct-relation matrix (A)

Barriers	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}
B_1	0.000	0.600	0.333	0.167	0.433	0.533	0.233	0.033	0.033	0.733	0.600	0.300	0.933	0.600
B_2	0.767	0.000	0.233	0.367	0.500	0.833	0.033	0.033	0.033	0.733	0.600	0.167	0.667	0.300
B_3	0.400	0.233	0.000	0.167	0.667	0.200	0.600	0.167	0.167	0.467	0.200	0.133	0.800	0.633
B_4	0.233	0.133	0.367	0.000	0.700	0.133	0.400	0.467	0.033	0.667	0.700	0.033	0.933	0.900
B_5	0.667	0.367	0.567	0.533	0.000	0.700	0.033	0.167	0.033	0.433	0.333	0.433	0.800	0.567
B_6	0.767	0.867	0.633	0.767	0.533	0.000	0.300	0.033	0.033	0.533	0.467	0.833	0.833	0.733
B_7	0.200	0.033	0.233	0.033	0.033	0.033	0.000	0.133	0.033	0.300	0.533	0.033	0.733	0.233
B_8	0.533	0.033	0.733	0.033	0.133	0.033	0.033	0.000	0.033	0.633	0.833	0.033	0.633	0.533
B_9	0.533	0.300	0.633	0.733	0.633	0.533	0.533	0.233	0.000	0.600	0.433	0.633	0.733	0.633

B_{10}	0.633	0.100	0.600	0.600	0.567	0.267	0.400	0.033	0.333	0.000	0.800	0.333	0.567	0.400
B_{11}	0.533	0.100	0.567	0.467	0.567	0.033	0.033	0.032	0.033	0.733	0.000	0.400	0.733	0.700
B_{12}	0.667	0.133	0.733	0.800	0.733	0.733	0.733	0.200	0.633	0.733	0.800	0.000	0.733	0.900
B_{13}	0.433	0.533	0.033	0.033	0.100	0.100	0.033	0.333	0.033	0.100	0.000	0.000	0.000	0.033
B_{14}	0.633	0.133	0.300	0.200	0.400	0.267	0.667	0.400	0.033	0.733	0.800	0.000	0.900	0.000

$$D = \left[\sum_{j=1}^{n} t_{ij}\right]_{nx1} = \begin{bmatrix} d_1 \\ d_2 \\ . \\ . \\ . \\ d_n \end{bmatrix}$$

(5.12)

$$R = \left[\sum_{i=1}^{n} t_{ij}\right]_{1xn} = [r_1\ r_2 \ldots r_n]$$

(5.13)

e.g. $r_1 = 0.056 + 0.088 + 0.073 + 0.053 + 0.086 + 0.084 + 0.051 + 0.022 + 0.015 + 0.122 + 0.108 + 0.054 + 0.162 + 0.106 = 1.081$

$d_1 = .056 + 0.126 + 0.083 + 0.075 + 0.119 + 0.145 + 0.042 + 0.086 + 0.121 + 0.113 + 0.098 + 0.145 + 0.061 + 0.110 = 1.378$

Further, the prominence and the influencing strength of each of the factors are calculated using equation 5.14 and equation 5.15, respectively; values corresponding to each barrier are provided in Table 5.9, and these strengths are further mapped to obtain the causal and effect graph (or prominence causal diagram), such that prominence

strength is plotted on the horizontal axis and the influencing strength is plotted on the vertical axis. In the prominence causal diagram, only those relations are shown by the arrows whose values are more than the threshold value, preferably to filter out negligible relations.

The threshold value is obtained by summing the 1.5 times the standard deviation of the elements of the total relation matrix to the corresponding mean value (Rajesh and Ravi, 2015). The mean value and the standard deviation of the total relation matrix (Table 5.8) are found to be 0.0746 and 0.000985, respectively, which provides the threshold value of 0.0760.

$$Prominence\ strength = D + R \tag{5.14}$$

$$Influencing\ strength = D - R \tag{5.15}$$

5.2.2.7: Determining the relative priority weights of the barriers (W_i)

The absolute and relative importance of the factors (barriers) is obtained by using equation 5.16 and equation 5.17, respectively, and is provided in Table 5.9).

$$w_i = \sqrt{(D_i + R_i)^2 + (D_i - R_i)^2} \tag{5.16}$$

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{5.17}$$

Where,

w_i= Absolute priority weight of the barrier 'i'.

W_i= Relative priority weights of the factors

Table 5.7: Normalized direct-relation matrix

Barriers	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}
B_1	0.0	0.059	0.033	0.0166	0.043	0.052	0.023	0.003	0.003	0.072	0.059	0.03	0.092	0.059
B_2	0.075	0.0	0.023	0.036	0.049	0.082	0.003	0.003	0.003	0.072	0.059	0.016	0.066	0.03
B_3	0.039	0.023	0.0	0.016	0.066	0.02	0.059	0.016	0.016	0.046	0.02	0.013	0.079	0.062
B_4	0.023	0.013	0.036	0.0	0.069	0.013	0.039	0.046	0.003	0.066	0.069	0.003	0.089	0.089
B_5	0.066	0.036	0.056	0.0052	0.0	0.069	0.003	0.016	0.003	0.043	0.033	0.039	0.079	0.056
B_6	0.075	0.085	0.062	0.075	0.052	0.0	0.03	0.003	0.003	0.052	0.046	0.082	0.085	0.072
B_7	0.02	0.003	0.02	0.003	0.003	0.003	0.0	0.016	0.003	0.03	0.056	0.003	0.075	0.026
B_8	0.049	0.003	0.069	0.003	0.01	0.003	0.003	0.0	0.003	0.062	0.079	0.003	0.066	0.056
B_9	0.052	0.03	0.062	0.075	0.062	0.049	0.056	0.023	0.0	0.059	0.046	0.066	0.072	0.066
B_{10}	0.062	0.01	0.059	0.059	0.056	0.026	0.039	0.003	0.033	0.0	0.079	0.033	0.056	0.039
B_{11}	0.052	0.01	0.056	0.046	0.056	0.003	0.003	0.003	0.003	0.072	0.0	0.039	0.072	0.069
B_{12}	0.066	0.013	0.072	0.079	0.072	0.072	0.072	0.02	0.062	0.075	0.079	0.0	0.075	0.089
B_{13}	0.043	0.052	0.003	0.003	0.01	0.01	0.003	0.033	0.003	0.01	0.007	0.003	0.0	0.003
B_{14}	0.062	0.013	0.03	0.023	0.039	0.026	0.066	0.046	0.003	0.072	0.082	0.003	0.095	0.0

Table 5.8: Total relation matrix

Barriers	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}
B_1	0.056	0.088	0.073	0.053	0.086	0.084	0.051	0.022	0.015	0.122	0.108	0.054	0.162	0.106
B_2	0.126	0.034	0.065	0.073	0.093	0.111	0.032	0.021	0.014	0.123	0.108	0.045	0.138	0.081
B_3	0.083	0.048	0.034	0.044	0.097	0.046	0.081	0.033	0.024	0.088	0.063	0.033	0.139	0.100
B_4	0.075	0.040	0.075	0.032	0.106	0.041	0.065	0.065	0.013	0.114	0.117	0.025	0.158	0.132
B_5	0.119	0.070	0.096	0.088	0.048	0.100	0.036	0.037	0.015	0.098	0.086	0.064	0.155	0.108
B_6	0.145	0.122	0.115	0.121	0.114	0.048	0.071	0.031	0.020	0.126	0.117	0.110	0.185	0.140
B_7	0.042	0.017	0.036	0.017	0.022	0.015	0.011	0.025	0.008	0.051	0.075	0.013	0.104	0.046
B_8	0.086	0.025	0.096	0.027	0.043	0.024	0.026	0.014	0.011	0.099	0.112	0.020	0.118	0.090
B_9	0.121	0.068	0.116	0.121	0.121	0.090	0.096	0.050	0.016	0.130	0.116	0.096	0.172	0.134
B_{10}	0.113	0.041	0.100	0.094	0.101	0.058	0.070	0.024	0.043	0.057	0.127	0.058	0.133	0.094
B_{11}	0.098	0.037	0.091	0.076	0.095	0.033	0.033	0.022	0.015	0.117	0.048	0.058	0.138	0.112
B_{12}	0.121	0.068	0.116	0.121	0.121	0.090	0.096	0.050	0.016	0.130	0.116	0.096	0.172	0.134

	45	60	35	32	40	17	18	51	76	57	57	41	93	67
B_{13}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	61	62	18	15	25	23	11	37	06	30	26	12	27	21
B_{14}	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0
	10	42	68	53	78	52	88	62	13	19	28	27	63	48

5.3. Result and Discussion

A combination of the FST and the DEMATEL approach was employed in this research to obtain the causal-dependence relationships among the barriers of the RSC that typically appear in the manufacturing SC. Fourteen barriers were identified and analyzed based on the response obtained from the experts of the premium manufacturing firms of India. FST was used to quantify the expert's response, as this approach also absorbs the ambiguities present in human judgment. Further, using the DEMATEL, the relations among the RSC barriers are evaluated. The calculation reveals that the factors can be divided into the cause (driver or influencing) group and the effect (driven or influenced) group based on their D-R value. Further, each barrier's prominence value (D+R) is calculated considering their linkage (cause and effect). The D+R value provides the overall importance of the barriers for inhibiting the success of the RSC. Moreover, relative importance weights (Table 5.9) of the barriers are determined by combining the causal and prominence value.

The causal group barriers are ranked based on the D-R values as, B_9>B_{12}>B_6>B_2>B_8>B_4 and also graphically plotted in Figure 5.4. In Figure 5.4, some links are purposely omitted to minimize the number of intersecting links. Further, the findings and the causal dependence relationships diagram are presented before the

experts to get their validations and the links' interpretation. A brief interpretation of the linkages between the barriers is provided in Table 5.10.

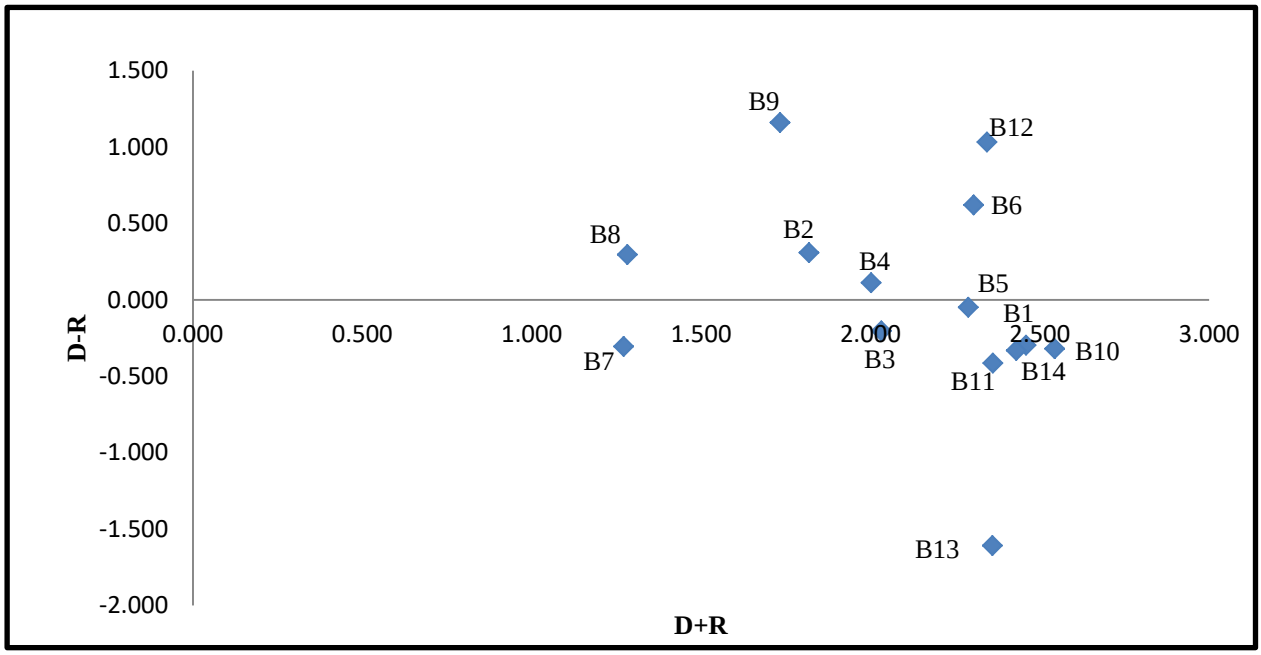

Figure 5.3: Causal prominence diagram

The calculation suggests that the lack of managerial commitment (B_9) is the most crucial barrier, followed by poor risk awareness, poor information sharing, mistrust among the SC members, the poor financial health of the organizations, and poor judgment and inaccurate forecast. The causal group barriers influence most of the other barriers while minimally getting influenced by them. The highest ranking for the lack of managerial commitment shows the importance of the managerial commitment to eradicating or minimizing many of the RSC barriers, thus leading to the successful implementation of the risk-mitigating strategies.

Further, the second-ranking to poor risk awareness points out the importance of understanding and estimating the SC risks. The 'poor risk awareness' and 'poor information sharing' impact the dependent group barriers more than the 'lack of

managerial commitment.' Still, because of their high controllability (impact value), they are ranked after it. The next essential factors belonging to the cause group are the 'mistrust among the SC members,' 'poor financial health,' and 'Poor judgment and inaccurate forecast.' Moreover, the causal relations among the barriers depict that controlling the cause group barriers should be a high priority and may be the first step towards the development of the RSC, as they act as the root cause of the dependent group barriers. The other set of barriers is called the impact group barrier and can be controlled and minimized by controlling the cause group barriers. Their lower impacting value does not signify their inferiority to disseat out the RSC; instead, it only shows that they can be controlled and minimized by controlling the cause group barriers. From Table 5.8, it is evident that the 'inadequate response during and after the disruption' is obtained to be highly influenced by most of the barriers and attains the maximum value of D, i.e., 1.985.

Further, the prominence value of each barrier is calculated by combining their ability to influence other barriers and the impact of another barrier on it. Thus, it represents the cumulative effect of the barriers over the RSC and explains the significance of the barriers in impairing the RSC's implementation and success.

The ranking of the barriers in terms of their prominence values is as follows, $B_{10}>B_1>B_{14}>B_{11}>B_{13}>B_{12}>B_6>B_5>B_3>B_4>B_2>B_9>B_8>B_7$. The 'centralization of the SC activities' achieves the highest ranking, followed by the 'poor support among the SC members,' 'lack of contingency planning, 'continuous strive for the lean operation,' inadequate response during and after disruptions,' *etc*. It can be observed from the rankings that among the top five most prominent barriers, none of them belongs to the

causal group, thus suggesting that the influencing value and the prominence value are the two different parameters to evaluate the barriers.

Table 5.9: Findings of the DEMATEL

Barriers	D	R	D-R	D+R	Criteria weight	Normalize weight
B_1	1.081	1.378	-0.297	2.460	3.069	0.088
B_2	1.064	0.755	0.308	1.819	1.702	0.049
B_3	0.914	1.118	-0.204	2.033	2.087	0.060
B_4	1.057	0.945	0.112	2.002	2.011	0.058
B_5	1.120	1.169	-0.049	2.289	2.622	0.075
B_6	1.463	0.842	0.621	2.305	2.849	0.082
B_7	0.483	0.789	-0.306	1.272	0.856	0.025
B_8	0.790	0.493	0.296	1.283	0.867	0.025
B_9	1.447	0.287	1.160	1.733	2.175	0.063
B_{10}	1.112	1.432	-0.320	2.544	3.288	0.095
B_{11}	0.974	1.388	-0.414	2.362	2.875	0.083
B_{12}	1.688	0.656	1.033	2.344	3.281	0.094
B_{13}	0.376	1.985	-1.609	2.361	4.080	0.117
B_{14}	1.050	1.381	-0.331	2.431	3.009	0.087

One measures the ability of the barriers to influence the others, whereas the other measures the impact of the barriers to influence the RSC. Further, using the vector length method (Sangaiah *et al*., 2015; Seker *et al*., 2017), the priority weights of the barriers and the priority rankings are evaluated (B_{13} > B_{10} > B_{12} > B_1 > B_{14} > B_{11}> B_6 > B_5 > B_9> B_3> B_4 > B_2 > B_8 > B_7) so obtained is slightly differing from the ranking

obtained based on the prominence value. This difference is because of the combined effects of the influencing and prominence values.

Further, the findings of our research are also in accordance with Rajesh (2017), Agarwal and Seth (2021), and Agarwal *et al*. (2021), where authors have discussed the possible barriers in the RSC. Rajesh (2017) focused on the electronics SC and identified the bullwhips due to uncertainties in supply, single sourcing, centralization of assets, and inability to modify operations in response to challenges as the main barriers. Similarly, Agarwal and Seth (2021) identify the non-commitment of the top management, shallow relations with the vendors, incomparable trading partners, opposition to change, and lack of financial resources as the main barriers to the resilient behavior of the automobile SC. Further, Agarwal *et al.* (2021) focus on identifying barriers to Industry 4.0 that prohibit its SC from becoming resilient and identified conflicting behavior of partners, lack of long-term vision and planning, and lack of contingency planning as the most critical hindering factors.

Thus from the above discussion, it is conferred that this research will help the academicians to improve their conceptual understanding of the RSC, its capabilities, practices, and the barriers which inhibit its implementation and success. Even though this research is carried out in the Indian iron and steel manufacturing SC, the concepts provided apply equally to most SCs. Further, the implication of the novel Fuzzy-DEMATEL approach, accompanied by the CFCS and the vector length priority ranking approach, provides a more processed and sophisticated quantification approach that analyzes the essential factors of a system involving human perception as the input. Further, this research provides the most influencing and prominent set of barriers of the RSC that will help the SC practitioners to plan and act accordingly to eradicate and mitigate their impacts. Thus, the development of a truly RSC may become a reality.

Moreover, the cause and effect analysis provided in this research will also help the managers plan the allocation of the resources and the strategies to develop specific capabilities that eradicate barriers and their impacts.

5.4. Conclusion

This research has identified fourteen essential barriers of the RSC corresponding to the iron and steel manufacturing SC. Here, the study is carried out while considering a case of the Indian iron and steel manufacturing SC. A novel Fuzzy-DEMATEL approach accompanied by CFCS and the vector length method is used to evaluate these barriers of the RSC. The outcomes of the research suggest that the lack of managerial commitment, poor risk awareness, poor information sharing, mistrust among the SC members, poor financial health of the organizations, and the poor judgment and inaccurate forecast are the most impactful barriers for the iron and steel manufacturing SC. These barriers need to be mitigated first, followed by the centralization of the SC activities, poor support among SC members, lack of contingency planning, continuous strive for the lean operation, and inadequate response during and after the disruption. The combined fuzzy-DEMATEL-based approach mitigates the ambiguities of human perception and system ambiguities. It helps develop a structural model presenting the causal dependence relation among the barriers and their classification into cause and effect group barriers.

Moreover, this research is equally beneficial to academicians and SC practitioners in conceptualizing and understanding the RSC and its associated barriers and evaluating these barriers and implications in a real case scenario. Further, it will help the academicians carry forward their research in assessing the causal dependence

relationships among the RSC's capabilities, practices, and barriers while considering their sub-attributes.

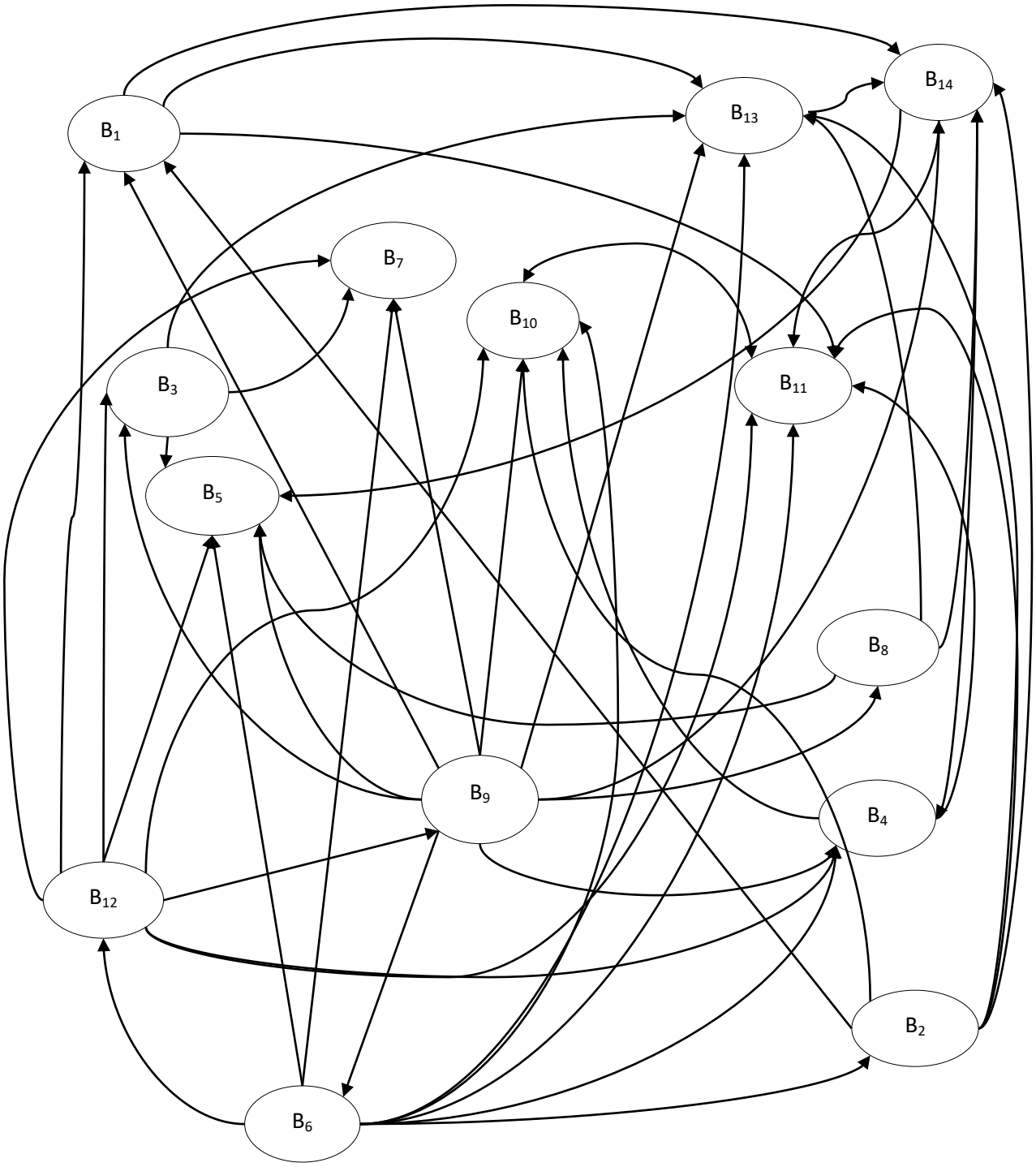

Figure 5.4: Digraph for the barriers of the RSC

Table 5.10: Relation between the barriers

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
Poor support among SC members (B_1)	Mistrust among the SC members (B_2)	0.088	Signifies the opportunistic behavior, poor cooperation, *etc*.
Poor support among SC members (B_1)	Poor SC network (B_5)	0.086	Poor coordination and cooperation during normal as well as disrupted situations.
Poor support among SC members (B_1)	Poor information sharing (B_6)	0.084	Lack of trust and opportunistic behavior.
Poor support among SC members (B_1)	Centralization of the SC activities (B_{10})	0.122	To have more control over the SC activities during normal as well as disrupted situations.
Poor support among SC members (B_1)	Continuously strive for lean operation (B_{11})	0.108	To minimize the cost in consideration of the limitations of resource availability.
Poor support among SC members (B_1)	Inadequate response during and after the disruption (B_{13})	0.162	Inability to absorb the disturbances as well as delay in developing new capabilities.
Poor support among SC members (B_1)	Lack of contingency planning (B_{14})	0.106	Focus on productivity (Centralization and optimal capability utilization) during the normal working process.
Mistrust among the SC members (B_2)	Poor support among SC members (B_1)	0.126	Poor risk and reward sharing.
Mistrust among the SC members (B_2)	Poor SC network (B_5)	0.093	Poor information sharing, self-centered approach, lack of risk and reward sharing, *etc*.
Mistrust among the SC members (B_2)	Poor information sharing (B_6)	0.111	Afraid of losing strategic information that may lead to market loss.
Mistrust among the SC members (B_2)	Centralization of the SC activities (B_{10})	0.123	To improve control and become self-reliant.

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
Mistrust among the SC members (B_2)	Continuously strive for lean operation (B_{11})	0.108	Focus on improving productivity rather than developing redundant capacities.
Mistrust among the SC members (B_2)	Inadequate response during and after the disruption (B_{13})	0.138	Poor coordination and cooperation.
Mistrust among the SC members (B_2)	Lack of contingency planning (B_{14})	0.081	Focus on productivity, Inadequate collaboration, poor information sharing, *etc*.
Resistance to change and innovation (B_3)	Poor support among SC members (B_1)	0.083	Inability to adapt to the changing needs of the SC.
Resistance to change and innovation (B_3)	Poor SC network (B_5)	0.097	Inability to adapt and develop the new opportunities.
Resistance to change and innovation (B_3)	Lack of multitasking workforce (B_7)	0.081	Poor motivation and training.
Resistance to change and innovation (B_3)	Centralization of the SC activities (B_{10})	0.088	Fear of failure, underestimating the advantages of the new capabilities and decentralized SC, *etc*.
Resistance to change and innovation (B_3)	Inadequate response during and after the disruption (B_{13})	0.139	Poor learning and adaptation.
Resistance to change and innovation (B_3)	Lack of contingency planning (B_{14})	0.100	Working on traditional (reactive) approach of risk and disruption management.
Poor judgment and inaccurate forecast (B_4)	Poor SC network (B_5)	0.106	Lack of contingent resources and poor preparedness.
Poor judgment and inaccurate forecast (B_4)	Centralization of the SC activities (B_{10})	0.114	Inadequate realization of risk and benefits associated with the centralized facilities.

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
Poor judgment and inaccurate forecast (B_4)	Continuously strive for lean operation (B_{11})	0.117	Poor estimation of the risk associated with the lean operations.
Poor judgment and inaccurate forecast (B_4)	Inadequate response during and after the disruption (B_{13})	0.158	Poor uncertainty evaluation, inadequate contingency planning, delayed decision making, *etc*.
Poor judgment and inaccurate forecast (B_4)	Lack of contingency planning (B_{14})	0.132	Poor risk and disruption estimation.
Poor SC network (B_5)	Poor support among SC members (B_1)	0.119	Mistrust, poor information sharing, bottleneck operations, lack of coordination, *etc*.
`	Resistance to change and innovation (B_3)	0.096	Poor cooperation, inadequate risk and reward sharing, incompetency of the SC members, *etc*.
Poor SC network (B_5)	Poor judgment and inaccurate forecast (B_4)	0.088	Misinterpretation of the SC member's capabilities, infrastructure support, social and political condition, *etc*.
Poor SC network (B_5)	Poor information sharing (B_6)	0.100	Inadequate infrastructure, poor collaboration, and inappropriate data interpretation.
Poor SC network (B_5)	Centralization of the SC activities (B_{10})	0.098	Mistrust, incapability of the SC members, inadequate response during uncertain events, *etc*.
Poor SC network (B_5)	Continuously strive for lean operation (B_{11})	0.086	Lack of visibility, focus on cost minimization, poor risk management culture, *etc.*
Poor SC network (B_5)	Inadequate response during and after the disruption (B_{13})	0.155	Poor capacity rebuilding, inadequate coordination, poor adaptability, longer lead time, *etc.*
Poor SC network (B_5)	Lack of contingency planning (B_{14})	0.108	Poor visibility, incompetent SC members, inadequate collaboration, *etc*.

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
Poor information sharing (B_6)	Poor support among SC members (B_1)	0.145	Inadequate and delayed information, delayed decision making, mistrust, *etc*.
Poor information sharing (B_6)	Mistrust among the SC members (B_2)	0.122	Inadequate, incomplete, and delayed information.
Poor information sharing (B_6)	Resistance to change and innovation (B_3)	0.115	Mistrust, delayed information, poor opportunity anticipation, etc.
Poor information sharing (B_6)	Poor judgment and inaccurate forecast	0.121	Inadequate, incomplete, and delayed information.
Poor information sharing (B_6)	Poor SC network (B_5)	0.114	Poor anticipation and understanding of the changes, poor preparedness against the vulnerabilities, *etc.*
Poor information sharing (B_6)	Centralization of the SC activities (B_{10})	0.126	Poor visibility and control.
Poor information sharing (B_6)	Continuously strive for lean operation (B_{11})	0.117	Poor anticipation and evaluation of the risks and uncertainties.
Poor information sharing (B_6)	Poor risk awareness (B_{12})	0.11	Poor visibility of bottlenecks, silos, incompetency, *etc.*
Poor information sharing (B_6)	Inadequate response during and after the disruption (B_{13})	0.185	Delay in decision-making and capability development.
Poor information sharing (B_6)	Lack of contingency planning (B_{14})	0.14	Poor understanding and anticipation of SC uncertainties.
Lack of multitasking workforce (B_7)	Inadequate response during and after the disruption (B_{13})	0.104	Unavailability of the desired workforce.

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
The poor financial health of the organization (B_8)	Poor support among SC members (B_1)	0.086	Inability to share risks and rewards.
The poor financial health of the organization (B_8)	Resistance to change and innovation (B_3)	0.096	Inability to invest in new capability development.
The poor financial health of the organization (B_8)	Centralization of the SC activities (B_{10})	0.099	To have more control over SC activities and reduce the cost.
The poor financial health of the organization (B_8)	Continuously strive for lean operation (B_{11})	0.112	To minimize the cost and maximize productivity.
The poor financial health of the organization (B_8)	Inadequate response during and after the disruption (B_{13})	0.118	Inability to absorb the disruption impacts and develop new capabilities post disruptions.
The poor financial health of the organization (B_8)	Lack of contingency planning (B_{14})	0.090	Focus on productivity.
Lack of managerial commitment (B_9)	Poor support among SC members (B_1)	0.121	Poor risk management culture, underestimating the importance of the SC members, etc.
Lack of managerial commitment (B_9)	Resistance to change and innovation (B_3)	0.116	Poor motivation, lack of knowledge, underestimating the advantages of upgrading the capabilities, *etc.*

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
Lack of managerial commitment (B_9)	Poor judgment and inaccurate forecast (B_4)	0.121	Inadequate risk assessment, decision based on beliefs, poor data interpretation, poor coordination, *etc*.
Lack of managerial commitment (B_9)	Poor SC network (B_5)	0.121	Poor risk assessment, decisions based on beliefs, inadequate contingency planning, poorly dispersed stakeholders, *etc*.
Lack of managerial commitment (B_9)	Poor information sharing (B_6)	0.09	Inadequate skill, poor control, un-standardized IT tools, undermining the importance of information sharing, *etc.*
Lack of managerial commitment (B_9)	Lack of multitasking workforce (B_7)	0.096	Lack of motivation, inadequate training program, and facilities, poor recognition to the multi-skilled workforce, *etc.*
Lack of managerial commitment (B_9)	Centralization of the SC activities (B_{10})	0.13	Overestimation of cost benefits, poor risk assessment, poor authority and responsibility distribution, *etc.*
Lack of managerial commitment (B_9)	Continuously strive for lean operation (B_{11})	0.116	Poor risk awareness, focus on productivity, *etc.*
Lack of managerial commitment (B_9)	Poor risk awareness (B_{12})	0.096	Poor risk management culture, SC assessment, and information sharing.
Lack of managerial commitment (B_9)	Inadequate response during and after the disruption (B_{13})	0.172	Poor preparedness, wrong decision, poor risk allocation, *etc*.
Lack of managerial commitment (B_9)	Lack of contingency planning (B_{14})	0.134	Poor risk awareness, inadequate knowledge of risk mitigation, etc.

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
Centralization of the SC activities (B_{10})	Poor support among SC members (B_1)	0.113	Failure of SC members during disruptive events, inadequate decision making, and control.
Centralization of the SC activities (B_{10})	Resistance to change and innovation (B_3)	0.100	Resistive nature of the management, fear of failure, poor cooperation among the SC members, *etc.*
Centralization of the SC activities (B_{10})	Poor judgment and inaccurate forecast (B_4)	0.094	Limited knowledge, skill, and opportunities for up gradation.
Centralization of the SC activities (B_{10})	Poor SC network (B_5)	0.101	Limited buffer against disruptions, delayed decision making, rigidity against the change, *etc.*
Centralization of the SC activities (B_{10})	Continuously strive for lean operation (B_{11})	0.127	Cost optimization, limited flexibility, standardized business operations, *etc.*
Centralization of the SC activities (B_{10})	Inadequate response during and after the disruption (B_{13})	0.133	Limited flexibility, poor disaster planning, minimal external support, *etc.*
Centralization of the SC activities (B_{10})	Lack of contingency planning (B_{14})	0.094	Limitations of resources, inadequate decision-making, constraints in planning, *etc.*
Continuously strive for lean operation (B_{11})	Poor support among SC members (B_1)	0.098	Lack of buffer against uncertain events.
Continuously strive for lean operation (B_{11})	Resistance to change and innovation (B_3)	0.091	Focus on standardized process and cost reduction.
Continuously strive for lean operation (B_{11})	Poor SC network (B_5)	0.095	Unavailability of buffer against the undesired events.
Continuously strive for lean operation (B_{11})	Centralization of the SC activities (B_{10})	0.117	Focus on cost minimization and control maximization.

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
Continuously strive for lean operation (B_{11})	Inadequate response during and after the disruption (B_{13})	0.138	Unavailability of buffer against the undesired events.
Continuously strive for lean operation (B_{11})	Lack of contingency planning (B_{14})	0.112	Minimizing the redundant capacities and resources.
Poor risk awareness (B_{12})	Poor support among SC members (B_1)	0.145	Underestimating the importance of collaboration and cooperation.
Poor risk awareness (B_{12})	Resistance to change and innovation (B_3)	0.135	Inability to understand and estimate the changing business environment.
Poor risk awareness (B_{12})	Poor judgment and inaccurate forecast (B_4)	0.14	Lack of risk assessment and inadequate contingency planning.
Poor risk awareness (B_{12})	Poor SC network (B_5)	0.157	Lack of risk assessment, inappropriate contingency planning, poorly dispersed SC network, *etc.*
Poor risk awareness (B_{12})	Poor information sharing (B_6)	0.193	Poor collaboration, mistrust, opportunistic behavior, underestimating the importance of information sharing, *etc.*
Poor risk awareness (B_{12})	Lack of multitasking workforce (B_7)	0.167	Lack of motivation for the cross-training.
Poor risk awareness (B_{12})	Centralization of the SC activities (B_{10})	0.145	Poor estimation of the risk, vulnerability, and opportunities.
Poor risk awareness (B_{12})	Continuously strive for lean operation (B_{11})	0.135	Poor estimation of the risk, vulnerability and opportunities.
Poor risk awareness (B_{12})	Inadequate response during and after the disruption (B_{13})	0.14	Lack of preparedness and disruption recovery approach.

Barrier i	Barrier j	Influencing value	Influencing relation interpretation
Poor risk awareness (B_{12})	Lack of contingency planning (B_{14})	0.157	Poor anticipation of disruption and its impact.
Lack of contingency planning (B_{14})	Poor support among SC members (B_1)	0.11	Unavailability of contingent resources and poor adaptation.
Lack of contingency planning (B_{14})	Poor SC network (B_5)	0.078	Unavailability of the resources and the capabilities to absorb the variability of SC operations.
Lack of contingency planning (B_{14})	Lack of multitasking workforce (B_7)	0.088	Poor motivation and culture of cross-training.
Lack of contingency planning (B_{14})	Centralization of the SC activities (B_{10})	0.119	To have more control over the SC activities.
Lack of contingency planning (B_{14})	Continuously strive for lean operation (B_{11})	0.128	Unaware of the risk and uncertainty.
Lack of contingency planning (B_{14})	Inadequate response during and after the disruption (B_{13})	0.163	Unavailability of resources and capabilities.

In addition, it also paves the way toward more sophisticated research that focuses on improving the resilient ability at each node point of the SC while imparting resilient practices and controlling the barriers. Further, the resilient capabilities and practices provided in this research will help practitioners align their policies, resources, and networks to develop a truly RSC. The barriers and their priority ranking provided in this research will help the practitioners identify and implement strategies that minimize the barrier's impacts.

Limitations and future scope

Despite providing the elaborated concept of the RSC and its significance in real-case scenarios, this research also has some limitations. This research uses the Fuzzy-DEMATEL approach to understand and estimate the causal dependence relation among the barriers in the Indian context. However, this research can be elaborated on while considering the practices and the barriers of the RSC altogether. Further, sub-barriers can be identified and evaluated to minimize any possible uncertainties in this research regarding selecting the barriers and their evaluation. Moreover, some recent advancements in SC management, like blockchain technology, big data analytics, the internet of things, outsourcing knowledge, objective-oriented collaboration, improved infrastructure for information sharing, *etc*., have gained much attention in the recent literature. These advancements are expected to counter most of these barriers and convert the pseudo-RSC to a truly RSC. Thus, our research can also be elaborated while considering these advancements.