CHAPTER 3

ESTIMATING THE UTILITY OF THE RESILIENT PRACTICES FOR RSC

3.1. Conceptual Framework

In the previous chapter, the RSC's capabilities and practices have been discussed. And also develops a hierarchical structural model representing the causal dependence relationships among these practices. The resilient practices lying at the higher level have a high ability to influence the other practices. This causal dependence relationship-based hierarchical structure shows the close adherence among the resilient practices, thus justifying their suitability for the development of the RSC. Moreover, these resilient practices are also clustered based on their commonality in driving and dependence power, i.e., driving, dependence, linkage, and independent group practices. However, from the previous chapter, it is not clear how significantly the individual resilient practices enable the resilient capabilities in the SCs. In addition, some of the recent literature suggests the importance of virtual enterprising and market sensitivity in enabling the resilience ability of the SC. Thus, it is also required to include these two resilient practices, i.e., virtual enterprising and market sensitivity, to enable the resilient capabilities of the SCs. Further, to realize the RSC, it is vital to develop a model that could provide the importance of resilient practices for developing the resilient capabilities into the RSC.

Virtual enterprising is a group of organizations with different capabilities that come together for a specified period to serve a common purpose or industrial goal (Matsuda et al., 2020; Ishfaq et al., 2019; Samdantsoodol *et al*., 2017; Huang et al., 2013). It includes the retailers, manufacturers, suppliers, and other service providers' strategic

alliance to optimize and brings competency to the SC (Matsuda *et al*., 2019). It enables the end-to-end real-time information sharing and control and is governed by the modern disruptive technologies, like the Internet of Things, Blockchain Technology, etc. In addition, Abimbola and Khan (2019) define market sensitivity as the firm's ability to perceive their customers better and the markets they serve. It enables quick adaption to the market and is achieved by working with the actual demand rather than forecasting based on past sales. Moreover, it also promotes rapid decision deployment, minimizes product development cycle time, and enables product postponement based on customer demand (Zedadra *et al*., 2019). Moreover, it promotes the success of the new product, sales, and profitability through the collaborative approach of the SC members facilitated by information sharing, risk and revenue sharing, and agility enables market sensitivity (Ateke *et al*., 2017; Patel et al., 2017; Faisal, 2005).

Thus, identifying and evaluating the contribution of individual resilient practices in enabling the resilient capabilities will assure that the chosen resilient practices will lead to the resilient capabilities of the SCs. In addition, it also provides the picture regarding the contribution of individual resilient practices in enabling the specific resilient capabilities to the SCs, which may further help the decision-makers align the organizational resources towards the improvement of the desired resilient capabilities. Therefore, in this chapter, the quality function deployment (QFD) methodology is employed to estimate the importance of individual practices in promoting the resilient capabilities of the SC. The advantage of using QFD over other available quantitative tools is that, while estimating the importance weight of practices, it simultaneously considers the impact of their correlation and their importance in enabling resilient capabilities to the SC.

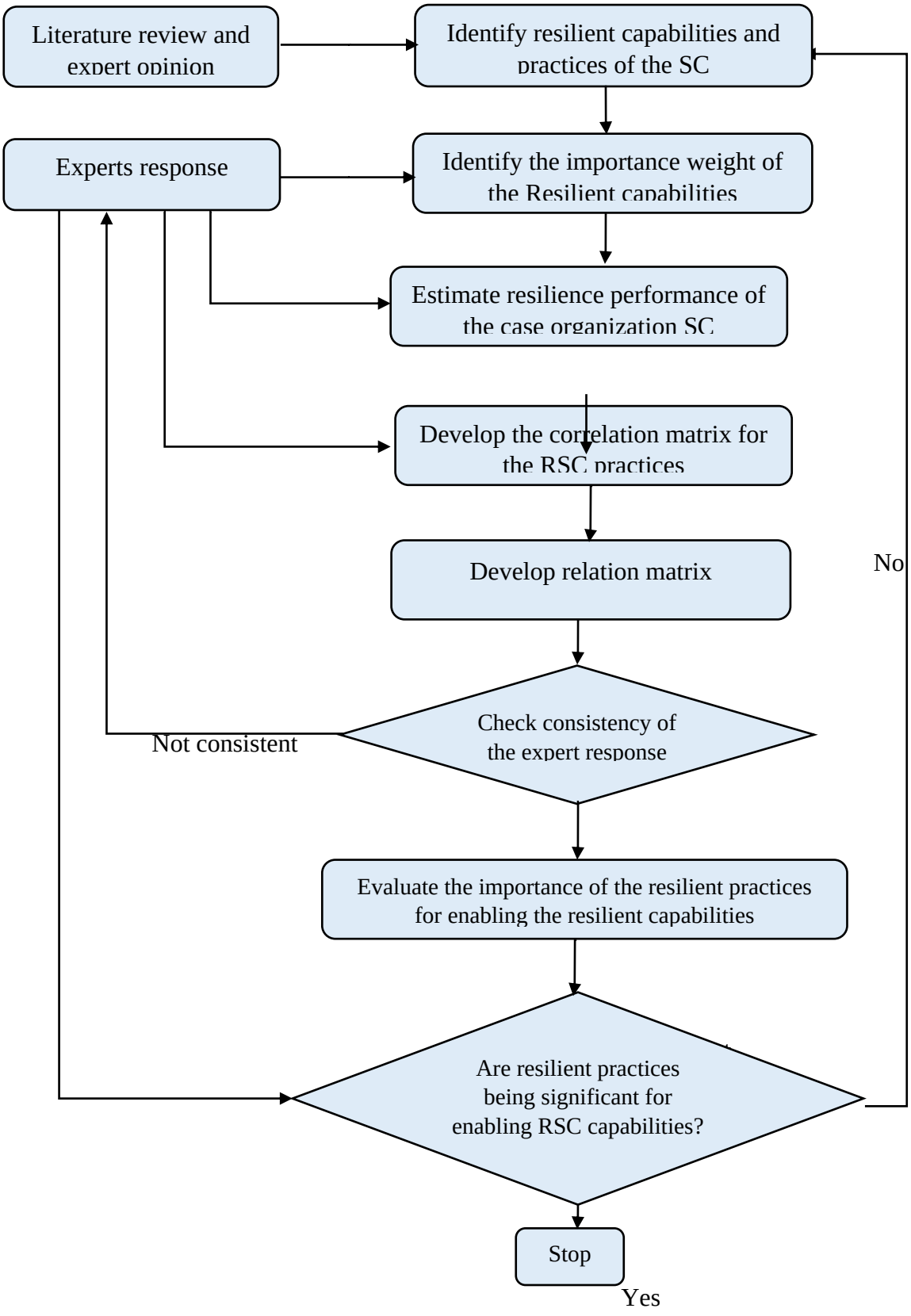


Figure 3.1. Framework for the study

Herein, I have considered the nineteen resilient practices and four resilient capabilities of RSC, such that each of these practices and capabilities applies to the iron and steel manufacturing industry.

From the literature, it is apparent that the resilience concept of the SC is a multi-dimensional phenomenon and is achieved by following the various resilient practices and correspondingly developing its resilient capabilities into it. Further, the literature suggests that all the resilient practices are essential for creating a RSC. However, evaluating the relative importance of one resilient practice over another with respect to the case organization will help practitioners and decision-makers prioritize and control their resource allocation and SC activities. From chapter 3, it is observed that many of the practices are influencing one another; however, their relationships are only symbolically represented. Thus, it is required to quantify these causal-dependence relationships on more visible numerical scales. Therefore, this chapter attempts to quantify the correlation between the resilient practices; subsequently, it also quantifies the importance of the resilient capabilities for enabling the RSC.

Further, the contribution of individual resilient practices for enabling the resilient capabilities of the SC is identified. Subsequently, the importance rating for these practices is evaluated while considering the relative importance weight of the resilient capabilities. The input required for this study is collected from the experts of the case organization using a semi-structured Google form-based questionnaire. The various steps involved in this study are provided in Figure 3.1.

3.2. Methodology

Akao (1990) developed the QFD approach in the late 1960s and early 1970s and was initially used to customize demand based on the customer specifications or required design parameters and capabilities (Delice and Güngör, 2010). The success of this tool has been emphasized by several researchers in various fields such as manufacturing, operational and strategic decision making, environmental policies, logistic management, SC risk management, quality assessment of technologies, etc. (Chan and Wu, 2002; Ramirez *et al*., 2017). In this approach, the customer requirements/organizational goals are considered as 'WHATs.' And the capabilities/design attributes/technical parameters needed to achieve 'WHATs' are called 'HOWS.' To date, the researchers have discussed several forms of QFD; however, the most widely used QFD models contain the following six information (i) WHATs- provided on the left-most column of the HOQ. In our case, the organizational goal is to develop a RSC, which comprises the four resilient capabilities (Table 3.1), i.e., readiness (C_1), robustness (C_2), rapidity (C_3), and the recovery (C_4). (ii) HOWs-provide at the beam section of the HOQ. This study considers resilient practices as tools to achieve resilient capabilities. In this research, nineteen resilient practices of the SC are chosen that enable the four resilient capabilities. These resilient practices are provided in Table 3.1. (iii) The relative importance of the WHATs- is provided in the column right to the room of the HOQ. (iv) Correlations between the HOWs-provided on the roof of the HOQ, (v) Relationship between WHATs and HOWs- is provided in the relation matrix, also called the room of the HOQ. The relationship matrix provides each resilient practice's contribution to enabling the SC's resilient capabilities. (vi) Assessment-Assessment or performance rating of the case organization concerning the RSC capabilities is provided in the column right to the capabilities importance weight column. The concise, pictorial

representation of the QFD approach comprises all of the above six information in a structured form called the house of quality (HOQ) and is represented as Figure 3.1 (Chowdhury and Quaddus, 2016). The steps involved in this research work are as follows:

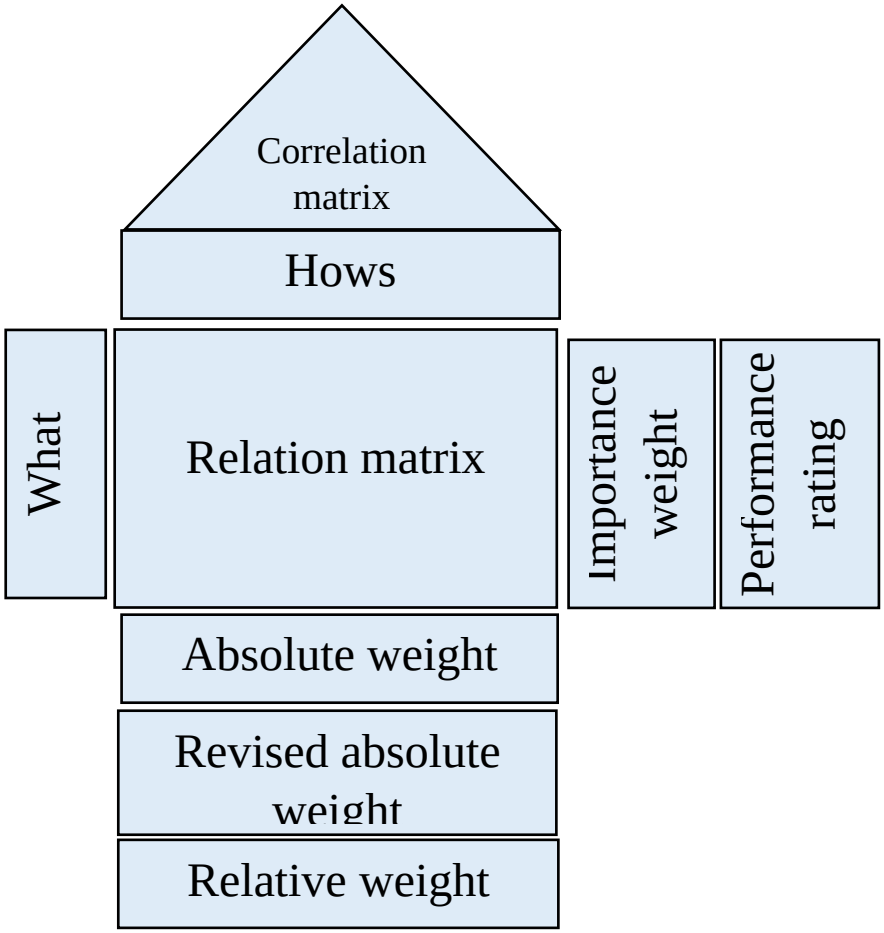


Figure 3.2: House of Quality

3.2.1. Estimating the importance of the resilient practices

The importance of the resilient practices are identified based on its contribution in enabling the resilient capabilities to the SC. It is carried out in the following steps.

3.2.1.1. Identification of the customer requirements (WHATs) and design requirements (HOWs)

The WHATs and HOWs are the resilient capabilities (C_1 to C_4)) and resilient practices (P_1 to P_{19}) respectively and are provided in Table 3.1.

Table 3.1: Resilient Capabilities and Resilient Practices of the RSC

Resilient Capabilities (CRs/WHATs)	**Resilient Practices (DRs/HOWs)**
Readiness (C_1)	Flexibility (P_1)
Robustness (C_2)	Postponement (P_2)
Rapidity (C_3)	Visibility (P_3)
Recovery and Growth (C_4)	Agility (P_4)
	Collaboration (P_5)
	Information sharing (P_6)
	Strategic stocking (P_7)
	Redundancy (P_8)
	Risk management culture (P_9)
	Assortment planning (P_{10})
	Dynamic pricing (P_{11})
	Silent product rollover (P_{12})
	Warehouse and inventory management (P_{13})
	Adaptability (P_{14})
	Economic supply incentives (P_{15})
	Improve financial strength (P_{16})
	Supply chain restructuring (P_{17})
	Virtual Enterprising (P_{18})
	Market Sensitivity (P_{19})

3.2.1.2. Determination of the importance weight of WHATs

The importance weight of the RSC capabilities is evaluated based on the expert response collected on a five-point rating scale (Singh and Samuel, 2020; Kumar and Antony, 2006). The relative importance weight of the capabilities is calculated using equation 3.1 and is provided in Table 3.2. The relative importance for (C_1) is 0.24.

$$A_i = \frac{a_i}{\sum_{i=1}^{n} a_i} \quad (3.1.)$$

Where,

i= 1, 2, 3, 4

a_i =Average rating value corresponds to the capability C_i

3.2.1.3. Evaluating the resilience performance of the case organization with respect to the resilient capabilities (P_{Res})

In this step, an attempt is made to evaluate the performance of the case organization SC with respect to the four resilient capabilities. Herein, a self-assessment approach is used, in which experts are requested to rate their organization's performance (p_i) with respect to each of the resilient capabilities on a five-point rating scale. The expert's responses are normalized using equation 3.2, and using equation 3.3 (also called weighted sum method), the performance of the case organization SC is evaluated.

$$NP_i = \frac{p_i}{P_{max}} \quad (3.2)$$

$$P_{Res} = A_i * NP_i \quad (3.3)$$

Where,

p_i=Performance rating of the case organization SC with respect to the capability i.

p_{max}= Maximum possible value of the performance rating.

NP_i= Normalized performance rating of the case organization SC with respect to the capability i

Therefore,

$$P_{Res} = 0.66 * 0.24 + 0.71 * 0.26 + 0.60 * 0.23 + 0.60 * 0.27$$

$$= 0.66$$

3.2.1.4. Identification of the correlation between resilient practices (g_{jk})

The correlation between the resilient practices is obtained from the experts on the scale of the *Strong (9), Moderate (3), Little (1),* or *No (0)* correlations, where j and k represent the resilient practices, such that, $j \neq k$ (Chowdhury and Quaddus, 2015; Faisal, 2013; Chan and Wu, 2002). The expert's response is aggregated and is provided in Table 3.3 and the roof of the HOR (Figure 3.3). For example, the correlation between P_1 and P_2 is obtained to be 1.6. Further, the correlation between the resilient practices is normalized and is presented in Table 3.4. This normalized correlation value is used as the input for estimating the revised importance weights of the resilient practices.

3.2.1.5. Determination of relationships between RSC practices and capabilities (R_{ji})

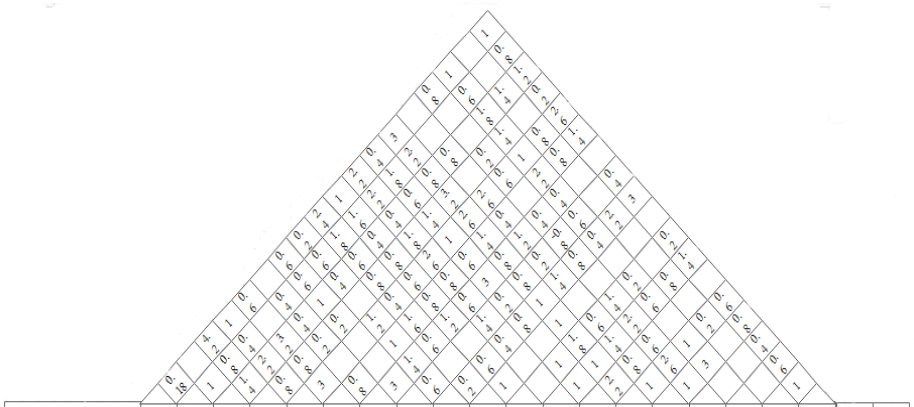
The relationship between the RSC practices and capabilities is obtained from the experts of the case organization on a scale of *Strong (9), Moderate (3), Little (1),* and

No (0) relationship (Chowdhury and Quaddus, 2015; Faisal, 2013; Chan and Wu, 2002), and is provided in the relational matrix of the HOR in Figure 3.3 and Table 3.5.

Table 3.2: Weights and the performance ratings of the CRs.

Customer requirements (CRs)	Relative importance weight (A_i)	Normalized performance (NP_i)
C_1	0.24	0.66
C_2	0.26	0.71
C_3	0.23	0.60
C_4	0.27	0.60

In this, the experts are requested to provide the importance or utility of resilient practices in enabling the resilient capabilities of the SCs. For example, the $Flexibility$ (P_1) plays an important role in enabling the readiness (C_1) and robustness (C_2) capability to the SC; however, it has relatively lesser importance for rapidity $(C_3)$and the recovery (C_4) capabilities of the SCs.



$C_i \Downarrow$ $P_j \Rightarrow$	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	A_i	P_i
C_1	6.6	6.2	7.8	4.2	7.8	7.8	7.8	7.8	7.8	2.2	2.2	9.0	9.0	3.0	6.6	7.8	1.4	7.8	9.0	0.24	0.66
C_2	7.8	6.6	7.8	7.8	7.8	7.8	7.8	7.8	5.4	7.8	7.8	9.0	9.0	9.0	7.8	9.0	3.0	9.0	9.0	0.26	0.71
C_3	4.2	1.0	6.6	9.0	9.0	4.2	4.2	3.4	9.0	3.4	2.6	9.0	2.2	7.8	7.8	7.8	7.8	2.2	3.4	0.23	0.60
C_4	4.2	2.2	7.8	7.8	7.8	7.8	7.8	4.2	5.4	2.6	1.4	7.8	4.6	9.0	7.8	6.6	6.6	6.6	6.6	0.27	0.60
Absolute weight	5.71	4.03	7.52	7.21	8.08	6.97	6.97	5.82	6.80	4.04	3.53	8.68	6.25	7.28	7.51	7.79	4.69	6.50	7.06		
Revised absolute weight	6.51	4.67	8.23	7.93	9.08	7.77	7.52	6.19	7.48	4.43	4.06	9.53	6.88	8.36	8.15	8.23	5.33	6.83	7.0		
Relative weight	0.048	0.035	0.061	0.059	0.067	0.058	0.056	0.046	0.055	0.033	0.030	0.071	0.051	0.062	0.060	0.061	0.040	0.051	0.057		

Figure 3.3. House of resilience (HOR)

Table 3.3. Correlation between the resilient practices (g_{jk})

P_j	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}
P_1	0.0	1.6	0.0	4.2	1.0	0.6	0.0	0.6	0.2	2.4	1.0	2.2	0.4	3.0	0.0	0.8	1.0	0.0	1.0
P_2	1.6	0.0	1.0	0.8	0.4	0.0	0.4	0.6	0.6	1.8	1.6	2.2	1.8	2.2	0.0	0.0	0.6	0.0	0.8
P_3	0.0	1.0	0.0	1.4	2.2	3.2	0.4	1.0	0.4	0.6	0.4	0.4	0.6	0.8	0.8	0.0	1.8	1.4	1.2
P_4	4.2	0.8	1.4	0.0	0.8	0.8	0.2	0.2	0.0	0.8	0.8	1.8	1.4	3.2	0.0	0.2	1.4	0.0	0.2
P_5	1.0	0.4	2.2	0.8	0.00	3.0	0.0	0.0	1.2	0.4	0.6	2.6	1.0	2.6	2.6	0.6	1.0	0.8	2.6
P_6	0.6	0.0	3.2	0.8	3.0	0.0	0.8	0.0	1.0	1.6	0.8	0.8	0.6	1.4	0.4	0.0	2.2	0.8	1.4
P_7	0.0	0.4	0.2	0.2	0.0	0.8	0.0	3.0	1.4	0.6	1.2	0.6	3.0	0.8	1.2	0.4	0.4	0.0	0.0
P_8	0.6	0.6	1	0.2	0	0	3	0	0.6	0	0	1.4	0.2	0.8	0.2	-0.8	0.6	0	0.4
P_9	0.2	0.6	0.4	0.0	1.2	1.0	1.4	0.6	0.0	0.2	0.6	0.4	0.8	1.0	1.4	0.8	0.4	2.2	3.0
P_{10}	2.4	1.8	0.6	0.8	0.4	1.6	0.6	0	0.2	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.2	0.0
P_{11}	1	1.6	0.4	0.8	0.6	0.8	1.2	0	0.6	1.0	0.0	0.0	1.0	1.8	0.6	1.4	0.2	0.0	0.2
P_{12}	2.2	2.2	0.4	1.8	2.6	0.8	0.6	1.4	0.4	0.0	0.0	0.0	1.0	1.0	1.4	2.2	0.6	0.8	1.4
P_{13}	0.4	1.8	0.6	1.4	1.0	0.6	3.0	0.2	0.8	0.0	0.0	1.0	0.0	2.2	0.8	0.6	0.0	0.0	0.0
P_{14}	3	2.2	0.8	3.2	2.6	1.4	0.8	0.8	1.0	1.0	0.0	1.0	2.2	0.0	1.0	2.6	1.0	0.2	0.6
P_{15}	0	0	0.8	0	2.6	0.4	1.2	0.2	1.4	0.0	0.0	1.4	0.8	1.0	0.0	1.0	3.0	0.0	0.8
P_{16}	0.8	0.0	0.0	0.2	0.6	0.0	0.4	-0.	0.8	0.0	0.0	2.2	0.6	2.6	1.0	0.0	0.0	0.0	0.4

P_{17}	1.0	0.6	1.8	1.4	1.0	2.2	0.4	0.6	0.4	0.0	0.0	0.6	0.0	1.0	3.0	0.0	0.0	0.0	0.6
P_{18}	0.0	0.0	1.4	0.0	0.8	0.8	0.0	0.0	2.2	0.2	0.0	0.8	0.0	0.2	0.0	0.0	0.0	0.0	1.0
P_{19}	1.0	0.8	1.2	0.2	2.6	1.4	0.0	0.4	3.0	0.0	0.0	1.4	0.0	0.6	0.8	0.4	0.6	1.0	0.0

Table 3.4. The normalized value of correlation between the resilient practices (g'_{jk})

P_j	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}
P_1	0.0	0.2	0.0	0.5	0.1	0.1	0.0	0.1	0.0	0.3	0.1	0.2	0.0	0.3	0.0	0.1	0.1	0.0	0.1
P_2	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.1	0.0	0.1
P_3	0.0	0.1	0.0	0.2	0.2	0.4	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.2	0.2	0.1
P_4	0.5	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.4	0.0	0.0	0.2	0.0	0.0
P_5	0.1	0.0	0.2	0.1	0.0	0.3	0.0	0.0	0.1	0.0	0.1	0.3	0.1	0.3	0.3	0.1	0.1	0.1	0.3
P_6	0.1	0.0	0.4	0.1	0.3	0.0	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.2	0.0	0.0	0.2	0.1	0.2
P_7	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.2	0.1	0.1	0.1	0.3	0.1	0.1	0.0	0.0	0.0	0.0
P_8	0.1	0.1	0.1	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.2	0.0	0.1	0.0	-0.1	0.1	0.0	0.0
P_9	0.0	0.1	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	0.2	0.3
P_{10}	0.3	0.2	0.1	0.1	0.0	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
P_{11}	0.1	0.2	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.2	0.1	0.2	0.0	0.0	0.0
P_{12}	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	2	2	0	2	3	1	1	2	0	0	0	0	1	1	2	2	1	1	2
P_{13}	0.0	0.2	0.1	0.2	0.1	0.1	0.3	0.0	0.1	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.0	0.0	0.0
P_{14}	0.3	0.2	0.1	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.0	0.1	0.3	0.1	0.0	0.1
P_{15}	0.0	0.0	0.1	0.0	0.3	0.0	0.1	0.0	0.2	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.3	0.0	0.1
P_{16}	0.1	0.0	0.0	0.0	0.1	0.0	0.0	-0.1	0.1	0.0	0.2	0.2	0.1	0.3	0.1	0.0	0.0	0.0	0.0
P_{17}	0.1	0.1	0.2	0.2	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.0	0.0	0.0	0.1
P_{18}	0.0	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
P_{19}	0.1	0.1	0.1	0.0	0.3	0.2	0.0	0.0	0.3	0.0	0.0	0.2	0.0	0.1	0.1	0.0	0.1	0.1	0.0

3.2.1.6. Determination of the initial ratings of resilient practices of the RSC (D_j)

The initial ratings of the resilient practices of the RSC are obtained by using equation 3.2, i.e., considering the importance weight of the resilient capabilities (A_i) along with the importance of the resilient practices (R_{ji}) for enabling the resilient capabilities to the SCs. The initial ratings of the resilient practices are provided at the base of the HOQ.

$$D_j = \sum_{i=1}^{n} A_i R_{ji} \qquad (3.2)$$

For example,

$$D_1 = 0.24 * 6.6 + 0.26 * 7.8 + 0.23 * 4.2 + 0.27 * 4.2 = 5.712$$

Table 3.5: The relationship between the factors and the resilience capabilities (Relationship matrix) (R_{ji})

SC Practices (P_j)	Resilient capabilities (C_i)			
	Readiness (C_1)	Robustness (C_2)	Recovery (C_3)	Rapidity (C_4)
P_1	6.6	7.8	4.2	4.2
P_2	6.2	6.6	1.0	2.2
P_3	7.8	7.8	6.6	7.8
P_4	4.2	7.8	9.0	7.8
P_5	7.8	7.8	9.0	7.8
P_6	7.8	7.8	4.2	7.8
P_7	7.8	7.8	4.2	7.8
P_8	7.8	7.8	3.4	4.2
P_9	7.8	5.4	9.0	5.4
P_{10}	2.2	7.8	3.4	2.6
P_{11}	2.2	7.8	2.6	1.4
P_{12}	9.0	9.0	9.0	7.8
P_{13}	9.0	9.0	2.2	4.6
P_{14}	3.0	9.0	7.8	9.0
P_{15}	6.6	7.8	7.8	7.8
P_{16}	7.8	9.0	7.8	6.6
P_{17}	1.4	3.0	7.8	6.6
P_{18}	7.8	9.0	2.2	6.6
P_{19}	9.0	9.0	3.4	6.6

Where,

$$A_i = \frac{a_i}{\sum_{i=1}^{n} a_i},$$

$i =$ Corresponds to the resilient capabilities ($i = 1, 2 \ldots n, n = 4$)

j = Corresponds to the resilient practices ($j = 1,2, \ldots, m, m = 19$)

$a_i =$ Absolute importance weight of the i^{th} resilient capability

$A_i =$Relative importance weight of the i^{th} resilient capability

R_{ji}= Element of the relationship matrix corresponds to the role of resilient practice j for enabling the resilient capability i.

3.2.1.7. Determination of the final ratings of the resilient practices (D'_j)

The final rating of the resilient practices is the revised value obtained by considering the correlation between the resilient practices. It is calculated using equation 3.3. This step considers the normalized value of correlation between the resilient practices.

Further, this revised value of the ratings is normalized using equation 3.4 to obtain the relative importance of the individual resilient practices for enabling the resilient capabilities of the SCs, and it is provided at the base of the HOQ and in Table 3.7.

$$D'_j = D_j + \frac{1}{19-1} \sum_{\substack{k=1 \\ k \neq j}}^{m} g'_{jk} * D_k \qquad (3.3)$$

where,

$$j = 1,2, \ldots, m;\ k = 1,2, \ldots n$$

$$m = n = 19$$

For example,

$$D_1' = 5.71 + \frac{1}{18}(0.18 * 4.03 + 0 * 7.52 + 0.47 * 7.21 + \cdots + 0.11 * 7.06) = 6.50$$

Table 3.6: Normalized relationship between the factors and the resilience capabilities (R_{ji}')

SC Practices (P_j)	Resilient capabilities (C_i)			
	Readiness (C_1)	Robustness (C_2)	Recovery (C_3)	Rapidity (C_4)
P_1	0.73	0.87	0.47	0.47
P_2	0.69	0.73	0.11	0.24
P_3	0.87	0.87	0.73	0.87
P_4	0.47	0.87	1.00	0.87
P_5	0.87	0.87	1.00	0.87
P_6	0.87	0.87	0.47	0.87
P_7	0.87	0.87	0.47	0.87
P_8	0.87	0.87	0.38	0.47
P_9	0.87	0.60	1.00	0.60
P_{10}	0.24	0.87	0.38	0.29
P_{11}	0.24	0.87	0.29	0.16
P_{12}	1.00	1.00	1.00	0.87
P_{13}	1.00	1.00	0.24	0.51
P_{14}	0.33	1.00	0.87	1.00
P_{15}	0.73	0.87	0.87	0.87
P_{16}	0.87	1.00	0.87	0.73
P_{17}	0.16	0.33	0.87	0.73
P_{18}	0.87	1.00	0.24	0.73
P_{19}	1.00	1.00	0.38	0.73

Table 3.7: Importance rating for the resilient practices

P_j	Initial importance ratings (D_j)	Revised importance ratings (D_j')	Relative importance rating (RD_j)
P_1	5.71	6.51	0.048
P_2	4.03	4.67	0.035
P_3	7.52	8.23	0.061
P_4	7.21	7.93	0.059
P_5	8.08	9.08	0.067
P_6	6.97	7.77	0.058
P_7	6.97	7.52	0.056
P_8	5.82	6.19	0.046
P_9	6.80	7.48	0.055
P_{10}	4.04	4.43	0.033
P_{11}	3.53	4.06	0.030
P_{12}	8.68	9.53	0.071
P_{13}	6.25	6.88	0.051
P_{14}	7.28	8.36	0.062
P_{15}	7.51	8.15	0.060
P_{16}	7.79	8.23	0.061
P_{17}	4.69	5.33	0.040
P_{18}	6.50	6.83	0.051
P_{19}	7.06	7.73	0.057

$$RD_{j=}\frac{D_j'}{\sum_{w=1}^{19} D_w} \qquad (3.4)$$

$$RD_1 = \frac{6.51}{6.51 + 4.67 + 8.23 + 7.93 + 9.08 + 7.77 + 7.52 + 6.19 + 7.48 + 4.43 + 4.06 + 9.53 + +6.88 + 8.36 + 8.15 + 8.23 + 5.33 + 6.83 + 7.73}$$

=0.048

3.2.2. Consistency check of the data

In this study, the expert's response is collected to judge the applicability of the nineteen resilient practices for enabling the four resilient capabilities to the case organization SCs. Considering the subjectivity associated with the RSC concept and the individual perceptions of the experts, there is the possibility of inconsistency in the collected data. And also, according to Kim *et al*. (1997) and Shin and Kim (1997), the authenticity and validity of the results depend upon the consistency of the collected data. Thus, to justify the validity of the findings, it is required to check the consistency of the collected expert response. In this study, I have used the consistency check approach discussed by Shin *et al.* (2002). The steps involved in this approach are as follows:

Step 1: Normalization of the relationship matrix (R'_{ji}): It provides the relative value for the importance of resilient practices for enabling the resilient capabilities of the SC and is obtained by dividing each column's element with the maximum value of that column, i.e., 9. The normalized relationship matrix so obtained is presented in Table 3.6.

Step 2: Calculation of the similarity coefficient between every pair of the resilient practices having a non-zero relationship in the roof matrix (S_{jk}): S_{jk} is obtained using equation 3.5.

$$S_{jk} = 1 - \frac{\sum_{i=1}^{m} |R'_{ji} - R'_{ki}|}{d} \qquad (3.5)$$

Where,

$$S_{12} = 1 - \frac{|0.73 - 0.69| + |0.87 - 0.73| + |0.47 - 0.11| + |0.47 - 0.24|}{4}$$

=0.81

S_{jk}: Similarity coefficient between the correlated resilient practices factors (Appendix A).

R'_{ji}: Normalized relationship coefficient between the resilient practices and the resilient capabilities, such that $0 \leq R'_{jk} \leq 1$ (Table 3.6).

d: The number of cells of the relationship matrix, for which either $R_{ji\ or}\ R_{jk} \neq 0$. Hence, $d <= n$.

g_{jk}= Correlation between the resilient practices.

Step 3: Calculating the consistency index: It is the statistical correlation between non-zero relationships coefficients (g_{jk}) in the roof matrix and the corresponding similarity coefficients (S_{jk}) calculated in step 2. The statistical correlation is computed using SPSS-21 and is found to be 0.176 with a p-value of 0.03, suggesting a positive correlation at a 95% confidence level. Hence, the result so obtained from the above calculations is valid (Shin *et al.*, 2002).

3.3. Result and discussion

This chapter has evaluated the importance of resilient practices for enabling resilient capabilities for the SCs. Here, four resilient capabilities and nineteen resilient practices are considered (Figure 3.3), among which seventeen are taken from chapter 3, and considering the expert's opinion, market sensitivity and virtual enterprising are obtained to be the additional essential practices for RSC. Further, to evaluate the utility of the resilience practices, I have used quality function deployment (QFD) and developed a house of resilience (HOR). The advantage of using QFD over other available

quantitative tools is its ability to pictorially present all the factors of a system along with their importance weights and causal dependence relationships in a single frame.

From Figure 3.3, it is evident that experts of the case organization SC are giving maximum importance to the recovery and growth ability (C_4), followed by the robustness (C_2), readiness (C_1), and lastly, the rapidity (C_1). Though RSC capabilities gains different ranking, but there is very slight variation in their quantified values. The closeness in the importance weight suggests that all these four capabilities act as the pillars of the RSC, having different functionality. Moreover, the highest-ranking of the recovery and growth capabilities among the other capabilities signifies that the experts consider disruptions as unavoidable events, and recovery of the SC from the disruptions is their highest priority. In addition, it is often observed that the recovery from the major disruptions is possible not because of initial preparedness but rather because of the instantaneous innovative ideas and planning. Further, the second priority for robustness suggests that experts give importance to the ability of the SC to maintain business continuity by absorbing and mitigating the vulnerabilities and disruptions associated with the SC. The third rank to the readiness capability signifies the preparedness of the SC against the uncertainties and vulnerabilities. In addition, the lower rank of the readiness capability compared to the recovery and robustness capabilities suggests that practitioners consider the cost incurred in developing readiness as the opportunity cost. Further, the last rank to the rapidity capability of the SC signifies that it is governed by the success of all three other resilient capabilities of the SCs, i.e., readiness, robustness, and recovery.

Further, the correlation matrix presented in Table 3.4 almost resembles the reachability matrix obtained in chapter 3, thus justifying the close relationships and their utility for

the RSC. And also, the correlation value is not very high, thus justifying the non-substitutability of the resilient practices. From the correlation matrix, all the resilient practices are found to be positively correlated except the 'redundancy of the facilities and the 'improving financial position.' The positive correlation signifies the supportive relationships among the resilient practices; thus, it smoothens the development of RSC. However, the negative correlation between the two resilient practices will have a negligible impact on the overall development of RSC because of its minimal magnitude. The negative correlation between the redundancy and improved financial position is because the experts consider the redundancy as the source of the opportunity cost. In contrast, to improve the financial position, the practitioners try to minimize the inefficiency present at every level of the SC.

And also, to enable these four capabilities to a SC, nineteen practices of the RSC are identified, also called the RSC factors. Such that, each factor has a positive impact in enabling the resilient capabilities in the SC. Further, the roof section of Figure 3.3 suggests that most of the factors are correlated, which indicates that the chosen factors are part of the RSC, and also each of them contributes to one another success. The elements of the relationship matrix Table 3.6 suggest that the considered resilient practices highly support the realization of the resilient capabilities of the SCs. The two least value elements of the relationship matrix are the relation corresponding to the postponement practice and the recovery capability and the supply chain restructuring practice and the readiness capability. This is because the postponement strategy assumes the delaying of the SC activities and leads to imparting the absorptiveness and adaptions in the SC during the uncertainty of supply and demand while minimally supporting the recovery. Similarly, restructuring the SC is rare during the normal business environment while play significant during disruptions.

Moreover, the importance rating of the resilient practices provided at the base of the HOR and in Table 3.7 signifies the utility of the individual resilient practices for enabling the resilient capabilities of the SCs, such that their importance rating ranges from 0.071 to 0.030. Higher the value of the importance rating signifies higher utility of the corresponding resilient practices. In this study, silent product rollover obtains to be the highest priority, followed by the collaboration among the SC members, adaptability of the SC, improving the financial position of the SC, etc. Similarly, the lowest priority weight resilient practices are assortment planning, dynamic pricing, postponement strategy, etc. The highest priority to the silent product rollover signifies that the success of the case organization SC is highly derived from the uniqueness of the product they supply; this is because of the cutthroat competition in the iron and steel industry.

Similarly, the second rank to the collaboration suggests the importance of the combined decision making, decentralization of the authority, sharing of the risks and rewards, etc. Further, analyzing every resilient practice, it observed that each contributes significantly to the RSC capabilities, thus proving their usability for the RSC. After discussing with the experts regarding the lower value of the importance rating corresponding to the resilient practices like assortment planning, dynamic pricing, postponement planning, etc., it has been observed that these resilient practices are very much applicable to the case organization SC as similar to the other resilient practices. However, the difference lies only in the benefits they provide during disruptions and the frequency of their implementations during various situations. Further, the quantified values of the importance rating for each of the resilient practices are very close, thus explaining the adequacy of all these nineteen practices for imparting resilient capabilities to the SC.

Further, an attempt is made using a self-appraisal-based approach to enquire about the resilience score of the case organization SC. In this, expert's satisfaction level is collected regarding the four resilient capabilities of their SC to combat uncertainty associated with the SC and related activities, along with the situation created in the advent of undesirable events. Further, the findings reveal that the experts of the case organization feel that their SC is about 66% percent resilient against the uncertainties and the disruptions. This lower level of the performance of the case organization signifies the presence of the voids that inhibits it from becoming a definitely resilient SC. These voids are called barriers to the RSC. Further, the consistency test performed using the SPSS justifies the validity of the findings.

Theoretical and managerial implications

This chapter brings about a novel approach that pictorially and quantitatively represents the components of a system in a logical framework. It enables the decision-makers to understand the causal dependence relationships along with the priority ranking of each element. This may further help the decision-maker in policy-making and strategizing their available capacities. Moreover, the approach used for evaluating the case organization's resilient performance will help the managers measure their preparedness and performance before and after the significant disruptions. Here, the resilient capabilities and their enabling resilient practices are analyzed, such that most of the resilient practices are found to be very much correlated, and also they are highly contributing to the resilient capabilities. Thus enabling a resilient SC. Hence, this chapter suggests the case organization SC experts to strategize their available capacities as per the priority rankings of the resilient practices to enable the resilient capabilities of their SC. Moreover, the resilience score obtained for the case organization SC is 0.66%,

which suggests that the resilience level is not satisfactory, and extra effort is needed to make the SC true or definitely resilient. Further, the research will help the experts in developing new capabilities for their SC and efficiently allocate the resources to minimize the risk and vulnerabilities. And also, it will help in avoiding, mitigating, and recovering from significant disruptions quickly.

3.4. Conclusion

From the TISM model of chapter 3, it is apparent that most of the resilient practices are interdependent; however, it was unable to quantify their degree of inter-dependency. In addition, the usability of the resilient practices for enabling the resilient capabilities is also not estimated. Therefore, this chapter has quantified these interdependence relationships and developed a correlation matrix. Moreover, each resilient practice's importance is evaluated based on its ability to impart resilient capabilities to the SCs. The findings reveal that the experts are giving maximum importance to the recovery and robustness of the SC, followed by the readiness and rapidity. This is because recovery allows the business to start all over again post disruptions, while robustness absorbs the uncertainties as well as the low-impact shorter disruptions.

In comparison, readiness requires investment in anticipation of future disruptions, whereas rapidity is assumed to be the SC's capability that brings effectiveness and efficiency. The relation matrix and the priority weights of each resilient practice justify their significance for enabling the resilient capabilities of the SC. Hence, practitioners need to frame their policies and assign the resources to improve the implementation and performance of all these, respectively. Further, the resilience performance level of the case organization SC is not very satisfactory; thus, it is required to identify and cure the voids present in the SC.

Limitations and future scope

Moreover, this work needs to be further extended by identifying the attributes of resilient practices so that their implementation can become a reality. Since all the resilient practices jointly lead to the development of the resilient capabilities in the SC, the resilience score of the SC needs to be evaluated at the resilient practices and the attribute level. So that their contribution can be assessed and subsequently, the non-performing sections of the SC can be identified. Moreover, it is also required to identify the inhibiting factors that hinder the successful implementation of resilient practices resulting in poor resilience levels.