

CHAPTER-5

ASSESSMENT AND PRIORITIZATION OF SCR VARIABLES

After establishing the interrelationship among SCR variables, the next objective is to assess and prioritize the identified SCR variables. Indian manufacturing organisations are under immense pressure due to supply chain disruption, globalization, rapid change in technology and competition. These complexities cause the Indian manufacturing organisations to face different types of SCR variables associated with their supply chain network. Every SCR variable has a different effect on the performance of supply chain, which is mainly due to their different levels of impact and different probability of occurrence. Before selecting the appropriate risk management strategy, it is essential for supply chain managers to proactively plan for each type of SCR variable and to determine its priority. Millet and Wedley (2002) conducted four case studies for modelling risk by using the Analytic Hierarchy Process (AHP) approach and provided a guideline for decision-makers to select the appropriate method while dealing with risk or uncertainty. Similar literature on SCRM indicated the various models on SCRM and the same have been implemented in different industries. Very few research studies related to prioritization and evaluation of risks in the context of Indian manufacturing organisations are available. There are several SCR variables associated with the Indian manufacturing organisations, but due to resource constraint, it is not feasible for the organisations to give equal attention to all SCR variables. It creates a need to prioritize the SCR variables for successful implementation of SCRM in the Indian manufacturing context. In this research work, an attempt has been made for the assessment as well as for prioritization of significant SCR variables associated with the case organisation. In this chapter, the AHP methodology has been applied to prioritize the

SCR variables to help the SC managers to proactively work on SCR.

5.1 ASSESSMENT OF SCR VARIABLES: AN AHP APPROACH

AHP is a Multi-Criteria Decision Making (MCDM) tool introduced by Saaty (1980). It is a structured technique used for solving complex decision-making problems. It is widely used by researchers to prioritize/to rank/to weigh alternatives by evaluating the criteria and sub-criteria from a given set. AHP converts the empirical data into a mathematical form. In the field of supply chain management, researchers have applied the AHP technique, for evaluation of supplier, selection of plant location, selection of distribution channel, for assessment and prioritization of manufacturing flexibilities, and so on (Gaudenzi and Borghesi, 2006; Schoenherr *et al.*, 2008; Sharma and Bhat, 2012; Sofyalıoğlu, and Kartal, 2012; Samvedi *et al.*, 2013). To understand and implement the SCR Process, several questions may arise for supply chain managers like: What are the major SCR variables? How to evaluate the impact of SCR variables? How to prioritize them? etc.. A structured SCR-AHP model can answer these questions. The main objectives of this research are: to identify the significant supply chain SCR variables of a small scale Indian manufacturing organisation; and to determine the relative importance of these SCR variables through AHP, so that SC managers can allocate their resources to efficiently implement SCR. AHP methodology mainly consists of four basic operations namely, formation of hierarchical model, pair-wise comparison, determination of priority weights and consistency analysis as explained in Section 3.2.

5.1.1 Formation of hierarchical model

A hierarchical model is a graphical representation of the objective/Goal, their criteria and sub-criteria (if any) and the alternatives. The SCR-AHP model, which consists of three levels, is comprehensively developed for small-scale Indian manufacturing case organisation. In this hierarchical model, 1. prioritization of risk variables, as a goal is placed

the first level, 2. the five evaluation criteria, namely, occurrence, severity, detectability of risk, risk management cost and risk controllability are placed at the second level while 3. seven significant SCR variables namely Environmental risk (ER), Information technology risk (IR), Supply risk (SR), Process risk (PR), Transportation risk (TR), Delay risk (DE), and Demand risk (DR) are placed at the third level of the hierarchical model. The structured SCRM-AHP hierarchical model is shown in Figure 5.1. From the figure, it is clearly shown that the objective of prioritizing the SCR variables are carried out by evaluating the SCR variables with respect to each criterion. This step is followed by the collection of pair-wise data.

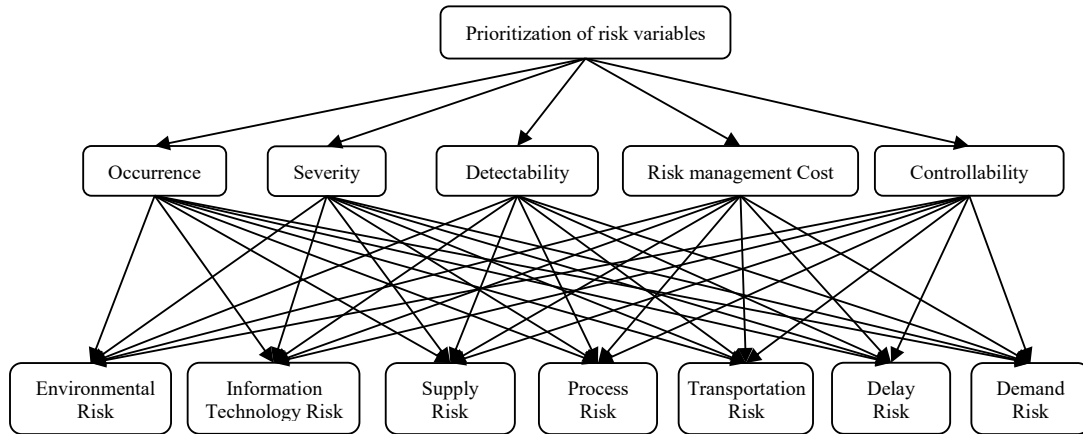


Figure 5.1 Hierarchical model for prioritization of SCR variables

5.1.2 Collection of Pair-wise comparisons

After the formation of the hierarchical model, the next step is to collect pair-wise comparisons of criteria with respect to goal and pair-wise comparisons of alternatives with respect to each of the criterion. To achieve a consensus on pair-wise comparisons, group discussion technique was used with the same group of experts. To collect pair-wise data, experts from the case organisation and academia were approached to provide the data. As suggested by Saaty (1980), a nine-point scale (Table 3.1), was used to collect pair-wise comparison data. After the group discussion, the pair-wise comparison data were collected and shown in Table 5.1 to 5.6. These tables were used as an input for analysis of the next

level of this methodology.

Table 5.1 compares all the five evaluation criteria with respect to other criteria. It can be seen that diagonal cell values like (C_1, C_1) , (C_2, C_2) , etc. are 1, showing equal importance or not significant in pairwise comparison. Rest other cell values shows pairwise comparison like (C_1, C_3) is 3 showing that C_1 is moderately important than C_3 , while (C_3, C_1) is a reciprocal of cell (C_1, C_3) value i.e. $1/3$ or 0.33 . Similarly, data of pair-wise comparisons of all SCR variables were developed and shown in Table 5.2 to 5.6.

Table 5.1 Pair wise comparison of criteria (C_i)

	C_1	C_2	C_3	C_4	C_5
Occurrence (C_1)	1.00	0.50	3.00	3.00	3.00
Severity (C_2)	2.00	1.00	3.00	2.00	3.00
Detectability (C_3)	0.33	0.33	1.00	0.33	1.00
Cost (C_4)	0.33	0.50	3.00	1.00	3.00
Controllability (C_5)	0.33	0.33	1.00	0.33	1.00

Table 5.2 Pair-wise comparison of SCR variables w.r.to Occurrence (C_1)

	ER	IR	SR	PR	TR	DE	DR
ER	1.00	0.33	0.33	0.20	0.33	1.00	0.33
IR	3.00	1.00	0.33	0.33	0.20	1.00	0.33
SR	3.00	3.00	1.00	1.00	1.00	3.00	1.00
PR	5.00	3.00	1.00	1.00	1.00	3.00	1.00
TR	3.00	5.00	1.00	1.00	1.00	3.00	1.00
DE	1.00	1.00	0.33	0.33	0.33	1.00	0.33
DR	3.00	3.00	1.00	1.00	1.00	3.00	1.00

Table 5.3 Pair-wise comparison of SCR variables w.r.to Severity (C_2)

	ER	IR	SR	PR	TR	DE	DR
ER	1.00	1.00	3.00	3.00	4.00	5.00	3.00
IR	1.00	1.00	3.00	3.00	3.00	5.00	2.00
SR	0.33	0.33	1.00	1.00	2.00	3.00	1.00
PR	0.33	0.33	1.00	1.00	1.00	3.00	1.00
TR	0.25	0.33	0.50	1.00	1.00	2.00	1.00
DE	0.20	0.20	0.33	0.33	0.50	1.00	0.33
DR	0.33	0.50	1.00	1.00	1.00	3.00	1.00

Table 5.4 Pair-wise comparison of SCR variables w.r.to Detectability (C_3)

	ER	IR	SR	PR	TR	DE	DR
ER	1.00	0.33	0.33	0.20	0.50	1.00	0.50
IR	3.00	1.00	0.50	1.00	1.00	1.00	1.00
SR	3.00	2.00	1.00	1.00	1.00	3.00	1.00

PR	5.00	1.00	1.00	1.00	1.00	3.00	1.00
TR	2.00	1.00	1.00	1.00	1.00	3.00	1.00
DE	1.00	1.00	0.33	0.33	0.33	1.00	0.33
DR	2.00	1.00	1.00	1.00	1.00	3.00	1.00

Table 5.5 Pair-wise comparison of SCR variables w.r.to Cost (C_4)

	ER	IR	SR	PR	TR	DE	DR
ER	1.00	3.00	3.00	3.00	3.00	5.00	3.00
IR	0.33	1.00	1.00	1.00	1.00	3.00	1.00
SR	0.33	1.00	1.00	1.00	1.00	3.00	1.00
PR	0.33	1.00	1.00	1.00	1.00	3.00	1.00
TR	0.33	1.00	1.00	1.00	1.00	3.00	1.00
DE	0.20	0.33	0.33	0.33	0.33	1.00	0.33
DR	0.33	1.00	1.00	1.00	1.00	3.00	1.00

Table 5.6 Pair-wise comparison of SCR variables w.r.to Controllability (C_5)

	ER	IR	SR	PR	TR	DE	DR
ER	1.00	0.33	0.33	0.20	0.33	0.20	0.33
IR	3.00	1.00	0.50	0.50	0.33	0.20	0.33
SR	3.00	2.00	1.00	1.00	1.00	0.33	1.00
PR	5.00	2.00	1.00	1.00	1.00	0.33	1.00
TR	3.00	3.00	1.00	1.00	1.00	0.33	1.00
DE	5.00	5.00	3.00	3.00	3.00	1.00	0.33
DR	3.00	3.00	1.00	1.00	1.00	3.00	1.00

5.1.3 Determine priority weights

After obtaining the pair-wise comparison data from the experts (Table 5.1 to 5.6), the next step is to determine the normalized weight of each criterion and each SCR variable with respect to each criterion. The priority weights for each criterion and each SCR variable with respect to each criterion is to be calculated from these normalized weights. The approach for calculation of these weights was discussed in Chapter 3. Each element of these pair-wise comparison matrixes is divided by the sum of cell values of its corresponding column to obtain the normalised relative weight of that element. For example, normalized weight for Occurrence (C_1) is found as $0.250 \{1/(1.00 + 2.00 + 0.33 + 0.33 + 0.33)\}$. Once the normalised relative weight of each element is obtained, the priority weight is obtained by averaging the corresponding row. For example, priority weight for Occurrence (C_1) is found as $0.260 \{(0.250 + 0.188 + 0.273 + 0.450 + 0.273)/5\}$.

Tables 5.7 to 5.12 show the normalised matrix and calculation of priority weights of each criterion and each SCR variable with respect to each criterion. These relative weights help to prioritize the SCR variables for better implementation of supply chain risk management. Thus, this model evaluates all the SCR variables with respect to each criterion and determines their priority weights.

Table 5.7 Normalised matrix and priority weights of criteria (C_i)

	C_1	C_2	C_3	C_4	C_5	<i>Priority weight</i>
Occurrence (C_1)	0.250	0.188	0.273	0.450	0.273	0.290
Severity (C_2)	0.500	0.375	0.273	0.300	0.273	0.362
Detectability (C_3)	0.083	0.125	0.091	0.050	0.091	0.087
Cost (C_4)	0.083	0.188	0.273	0.150	0.273	0.173
Controllability (C_5)	0.083	0.125	0.091	0.050	0.091	0.087

Table 5.8 Normalised matrix and priority weights of SCR variables w.r.to Occurrence (C_1)

	ER	IR	SR	PR	TR	DE	DR	<i>Priority weight</i>
ER	0.053	0.020	0.067	0.041	0.068	0.067	0.067	0.055
IR	0.158	0.061	0.067	0.068	0.041	0.067	0.067	0.076
SR	0.158	0.184	0.200	0.205	0.205	0.200	0.200	0.193
PR	0.263	0.184	0.200	0.205	0.205	0.200	0.200	0.208
TR	0.158	0.306	0.200	0.205	0.205	0.200	0.200	0.211
DE	0.053	0.061	0.067	0.068	0.068	0.067	0.067	0.064
DR	0.158	0.184	0.200	0.205	0.205	0.200	0.200	0.193

Table 5.9 Normalised matrix and priority weights of SCR variables w.r.to Severity (C_2)

	ER	IR	SR	PR	TR	DE	DR	<i>Priority weight</i>
ER	0.290	0.270	0.305	0.290	0.320	0.227	0.321	0.289
IR	0.290	0.270	0.305	0.290	0.240	0.227	0.214	0.262
SR	0.097	0.090	0.102	0.097	0.160	0.136	0.107	0.113
PR	0.097	0.090	0.102	0.097	0.080	0.136	0.107	0.101
TR	0.072	0.090	0.051	0.097	0.080	0.091	0.107	0.084
DE	0.058	0.054	0.034	0.032	0.040	0.045	0.036	0.043
DR	0.097	0.135	0.102	0.097	0.080	0.136	0.107	0.108

Table 5.10 Normalised matrix and priority weights of SCR variables w.r.to Detectability (C_3)

	ER	IR	SR	PR	TR	DE	DR	<i>Priority weight</i>
ER	0.059	0.045	0.065	0.036	0.086	0.067	0.086	0.063
IR	0.176	0.136	0.097	0.181	0.171	0.067	0.171	0.143
SR	0.176	0.273	0.194	0.181	0.171	0.200	0.171	0.195
PR	0.294	0.136	0.194	0.181	0.171	0.200	0.171	0.193
TR	0.118	0.136	0.194	0.181	0.171	0.200	0.171	0.167
DE	0.059	0.136	0.065	0.060	0.057	0.067	0.057	0.072

DR	0.118	0.136	0.194	0.181	0.171	0.200	0.171	0.167
-----------	-------	-------	-------	-------	-------	-------	-------	-------

Table 5.11 Normalised matrix and priority weights of SCR variables w.r.to Cost (C_4)

	ER	IR	SR	PR	TR	DE	DR	<i>Priority weight</i>
ER	0.349	0.360	0.360	0.360	0.360	0.238	0.360	0.341
IR	0.116	0.120	0.120	0.120	0.120	0.143	0.120	0.123
SR	0.116	0.120	0.120	0.120	0.120	0.143	0.120	0.123
PR	0.116	0.120	0.120	0.120	0.120	0.143	0.120	0.123
TR	0.116	0.120	0.120	0.120	0.120	0.143	0.120	0.123
DE	0.070	0.040	0.040	0.040	0.040	0.048	0.040	0.045
DR	0.116	0.120	0.120	0.120	0.120	0.143	0.120	0.123

Table 5.12 Normalised matrix and priority weights of SCR variables w.r.to Controllability (C_5)

	ER	IR	SR	PR	TR	DE	DR	<i>Priority weight</i>
ER	0.043	0.020	0.043	0.026	0.043	0.037	0.067	0.040
IR	0.130	0.061	0.064	0.065	0.043	0.037	0.067	0.067
SR	0.130	0.122	0.128	0.130	0.130	0.062	0.200	0.129
PR	0.217	0.122	0.128	0.130	0.130	0.062	0.200	0.141
TR	0.130	0.184	0.128	0.130	0.130	0.062	0.200	0.138
DE	0.217	0.306	0.383	0.390	0.391	0.185	0.067	0.277
DR	0.130	0.184	0.128	0.130	0.130	0.556	0.200	0.208

5.1.4 Consistency analysis of the pair-wise comparison matrices

The priority weights are derived from the pair-wise comparison based on the judgments of the experts. There may be some inconsistency in data to a limited extent due to expert opinions. A consistency test is, therefore, carried to ascertain the consistency of the data. Consistency Ratio (CR) index is widely used to evaluate the consistency of the pair-wise comparison data. The detailed process for consistency ratio analysis is explained in Chapter 3. By applying the process as explained in Chapter 3, consistency analysis is done for each pair-wise comparison matrix and the same shown in Table 5.13. Saaty (1990) suggested that a CR value equal to or less than 0.10 indicates that the pair-wise comparison data are consistent and acceptable. For this data of the case-organisation, it is found that the CR value of each element is below 0.10, which indicates that the pair-wise comparison data received from the experts were consistent.

Table 5.13. Consistency ratio (*CR*) of each of the comparison matrices

Pair-wise comparison matrix	Consistency ratio (<i>CR</i>)
Pair wise comparison of criteria (<i>C_i</i>)	0.052
Pair wise comparison of SCR variables w.r.to Occurrence (<i>C₁</i>)	0.024
Pair wise comparison of SCR variables w.r.to Severity (<i>C₂</i>)	0.013
Pair wise comparison of SCR variables w.r.to Detectability (<i>C₃</i>)	0.027
Pair wise comparison of SCR variables w.r.to Cost (<i>C₄</i>)	0.005
Pair wise comparison of SCR variables w.r.to Controllability (<i>C₅</i>)	0.079

5.1.5 Calculation of the overall priority weights

The last step of AHP methodology is to determine the overall priority weight of each SCR variable. The priority weight of each SCR variable with respect to each criterion and priority weight of each criterion is summarized in Table 5.14 and 5.15, respectively.

Table 5.14. Priority weights of each SCR variable w.r.to each criterion

SCR variables	Priority weights of each SCR variable w.r.to each criterion				
	Occurrence (<i>C₁</i>)	Severity (<i>C₂</i>)	Detectability (<i>C₃</i>)	Cost (<i>C₄</i>)	Controllability (<i>C₅</i>)
ER	0.055	0.289	0.063	0.341	0.040
IR	0.076	0.262	0.143	0.123	0.067
SR	0.193	0.113	0.195	0.123	0.129
PR	0.208	0.101	0.193	0.123	0.141
TR	0.211	0.084	0.167	0.123	0.138
DE	0.064	0.043	0.072	0.045	0.277
DR	0.193	0.108	0.167	0.123	0.208

Table 5.15. Priority weights of each criterion

Criteria	Priority weight
Occurrence (<i>C₁</i>)	0.290
Severity (<i>C₂</i>)	0.362
Detectability (<i>C₃</i>)	0.087
Cost (<i>C₄</i>)	0.173
Controllability (<i>C₅</i>)	0.087

Overall priority weight of each SCR variable can be calculated by multiplying the priority weight of the SCR variable (Table 5.14) with the priority weight of the criteria (Table 5.15).

Calculation of Overall weight of SCR Variables is as follows;

$$W_i = \begin{bmatrix} 0.055 & 0.289 & 0.063 & 0.341 & 0.040 \\ 0.076 & 0.262 & 0.143 & 0.123 & 0.067 \\ 0.193 & 0.113 & 0.195 & 0.123 & 0.129 \\ 0.208 & 0.101 & 0.193 & 0.123 & 0.141 \\ 0.211 & 0.084 & 0.167 & 0.123 & 0.138 \\ 0.064 & 0.043 & 0.072 & 0.045 & 0.277 \\ 0.193 & 0.108 & 0.167 & 0.123 & 0.208 \end{bmatrix} * \begin{bmatrix} 0.290 \\ 0.362 \\ 0.087 \\ 0.173 \\ 0.087 \end{bmatrix}$$

$$W_i = \begin{bmatrix} 0.189 \\ 0.156 \\ 0.146 \\ 0.147 \\ 0.139 \\ 0.072 \\ 0.149 \end{bmatrix}$$

Based on these overall priority weights, the ranking of each SCR variable is obtained. Overall priority weights of SCR variables and their rankings are tabulated in Table 5.16 and the same are graphically represented in Figure 5.2.

Table 5.16. Overall priority weights and rankings of SCR variables

SCR Variables	Overall priority weight	Rank
Environmental risk	0.189	1
Information technology risk	0.156	2
Supply risk	0.146	5
Process risk	0.147	4
Transportation risk	0.139	6
Delay Risk	0.072	7
Demand risk	0.149	3

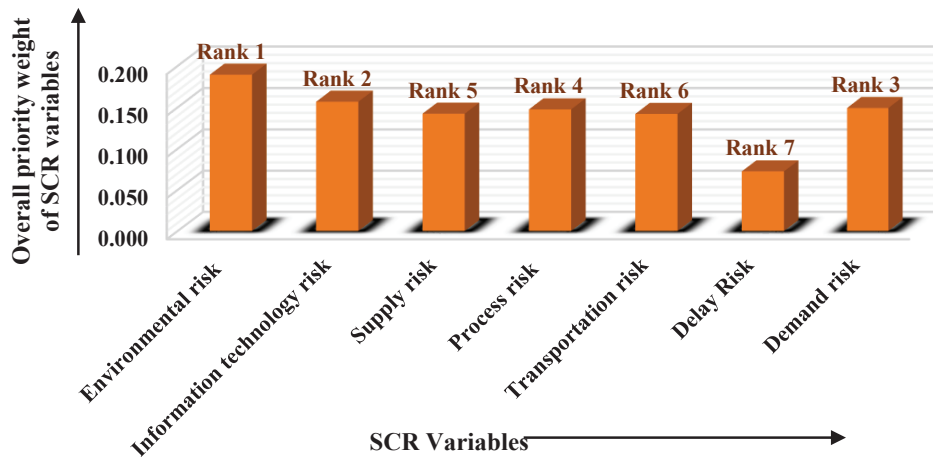


Figure 5.2 Overall priority weights and rankings of SCR variables

5.2 CONCLUSION

In the literature, large number of SCR variables were identified by researchers, but after discussions with industry experts from the case-organisation, only seven significant SCR variables were considered for development of AHP model. The overall priority weights of SCR variables have been established with the help of the AHP approach. Table 5.15 illustrates the consolidated position of the priority weight of each criterion. Table 5.16 illustrates the consolidated position of the overall priority weight and ranking of each SCR variable. The same is shown graphically in Figure 5.2. It is clear from this figure that Environmental Risk ‘ER’ and Information Technology Risk ‘IR’ are assigned higher priorities, while Demand Risk ‘DR’, Transportation Risk ‘TR’, Supply Risk ‘SR’ and Process Risk ‘PR’ are assigned lower priorities. It is evident that demand and information plays crucial role in planning and coordinating SC operations and so that associated risk priorities were found to be high. Table 5.17 summarize the results obtained from ISM and AHP techniques. It is evident that the SCR variables with high driving power are given more weight/high priority i.e. Environmental Risk ‘ER’ and Information Technology Risk ‘IR’. While, SCR variables with high dependence power are given less weight/low priority. So, the hierarchy established through ISM & classification obtained by MICMAC seems to be align with the priority results of AHP.

Table 5.17. Summary of the results obtained from ISM and AHP techniques

SCR Variables	ISM results		AHP results	
	Dependence Power	Driving Power	Priority weight	Rank
Environmental risk	1	7	0.189	1
Information technology risk	2	6	0.156	2
Supply risk	5	5	0.146	5
Process risk	6	2	0.147	4
Transportation risk	5	5	0.139	6
Delay Risk	7	1	0.072	7
Demand risk	5	5	0.149	3

Results of this research are useful to understand the major selection criteria and the main SCR variables, which may improve the supply chain performance of the case-organisation. From table 5.15, Severity (C_2 , 0.362) and Occurrence (C_1 , 0.290) were found to be the main selection criteria for the assessment of SCR variables. This shows that the case-organisation should strongly consider these two as the main selection criteria while implementing the SCRM. Risk Management Cost (C_4 , 0.173) was found to be another preferred selection criteria for evaluating the SCR variables for the case-organisation. Detectability (C_3 , 0.087) and Controllability (C_5 , 0.087) were found to be the least important selection criteria for the case-organisation. From Table 5.17, Environmental risk (0.189) and Information technology risk (0.156) were found to be the most critical SCR variables for the case-organisation. Therefore, supply chain managers have to be very careful while dealing with these SCR variables and to anticipate these SCR variables by sharing the information with the upstream and downstream partners of supply chain. Figure 5.2 and Table 5.17 confirm that Demand risk (0.149), Process Risk (0.147), Supply risk (0.146) and Transportation risk (0.139) have almost the same overall priority weights, which means these SCR variables have a moderate impact on the supply chain of the case-organisation. Delay Risk (0.072) was found to be the least ranked SCR variable. These results will help the supply chain managers to prioritize the SCR variables during implementation of SCRM. For effective SCRM, risk-level of the supply chain is required to be identified. This will also help the SC managers to select the appropriate risk management strategy. Next chapter presents the work to this extent.