CHAPTER 6

ALLOCATION OF WEIGHT TO AGILITY ENABLERS

After identifying the interrelationship between agility enablers and evaluating agility level of supply chain, next and very important research agenda identified in this dissertation is the maximization of agility in supply chain. Saleeshya and Babu (2011) believe that the overall objective of any organisation is to maximize its agility. The agility of any organisation will depend upon, how well effective management of input resources is available to implement agility in the supply chain. Hence it is a very important research agenda, to maximize the agility of the supply chain. However, the existing literature on maximization of agility has failed to sufficiently address the relevant perspectives, which indicates that agility maximization is a golden opportunity for practitioners to obtain maximum resilience to unforeseen events in the supply chain. With the help of this inspiration an attempt has been made to develop AHP-GP model to maximize the agility of supply chain by deploying the yearly input resources. In this chapter AHP is presented first, as a stand-alone methodology to obtain local and global weights of agility enablers. These outcomes of AHP are embedded in GP to develop the combined AHP-GP model in next chapter.

6.1 Weighting the agility enablers: An AHP approach

Analytic hierarchy process (AHP) is a Multi Criteria Decision Making (MCDM) method, introduced by Saaty (1980) used to determine the relative importance of a set of activities. The method utilizes pair-wise comparisons of agility enablers as well as pair-wise comparisons of the selected criteria. Pair-wise comparisons generate meaningful information about the decision problem, improving consistency in the decision-making process, especially if the process involves group decision-making (Badari, 2001). AHP consists of three main operations namely hierarchy construction, priority analysis and

consistency verification. The AHP model, structured in a hierarchy of three basic levels is shown in Figure 6.1.

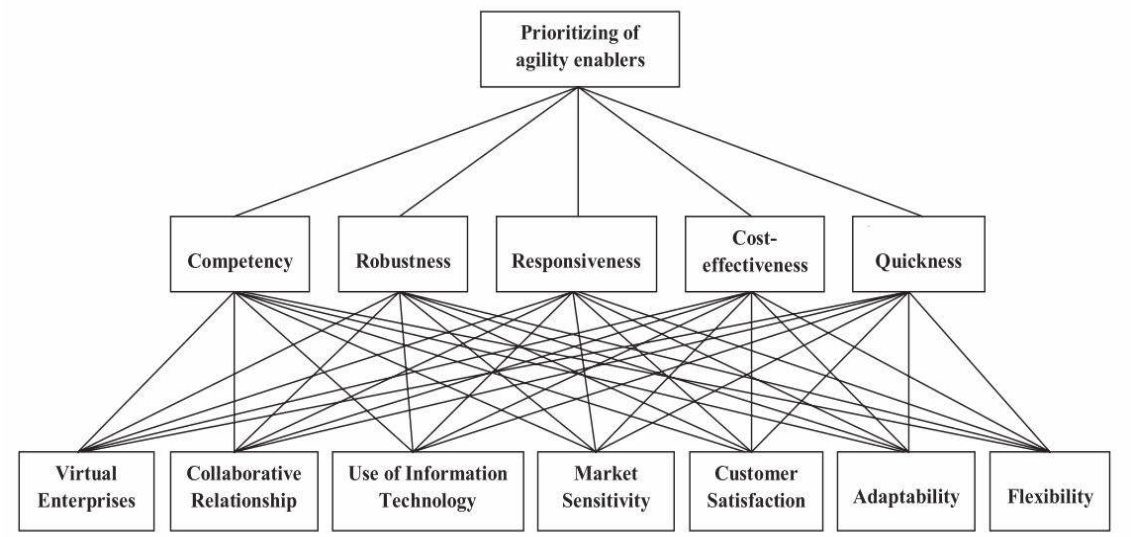

Figure 6.1: Structure of the AHP model

The top level of the hierarchy contains the goal of the problem, followed by the selection criteria at second level and finally, the third level lists the alternatives. In this study, the goal of the AHP problem is to prioritise ASC enablers. The goal of the problem is influenced by a variety of criteria which can be tangible (i.e., objective) as well as non-tangible (i.e., subjective) (Rao, 2007). For the present problem the selection criteria competency, robustness, responsiveness, cost-effectiveness and quickness are selected which are shown in Table 6.1. The decision alternatives, the options from which a choice is made, are the seven agility enablers which are as follows:

- Virtual Enterprises (VE)
- Collaborative Relationship (CR)
- Use of Information Technology (IT)
- Market Sensitivity (MS)
- Customer Satisfaction (CS)
- Adaptability (AD)
- Flexibility (FL)

The definitions of these seven enablers and their effects on the performance of supply chain are already explained in Chapter 1.

Table 6.1: Selection criteria for agile supply chain enablers

Selection criteria	Definition	References
Competency	Capability of effective and efficient accessibility to the organization's targets goals.	Yaghoubi (2011), Zhang (2011), Sharifi and Zhang (1999), Tseng and Lin (2011)
Robustness	Ability to withstand variations and disturbances and direct it to take advantage of these fluctuations to maximize the profit.	Yauch (2011), Naylor et al., (1999), Tseng and Lin (2011)
Responsiveness	Ability to identify changes and respond to them quickly.	Carvalho (2012), Yaghoubi (2011), Zhang (2011), Tseng and Lin (2011)
Cost-effectiveness	Ability to respond to unexpected changes in cost-effective manner.	Tseng and Lin (2011), Ganguly et al., (2009)
Quickness	Capability to execute an operation in shortest time	Yaghoubi (2011), Sharifi and Zhang (1999)

Once the model is built, the decision-maker evaluates the elements by making pair-wise comparisons. A pair-wise comparison is the process of comparing the relative importance of the criteria with respect to goal as well as relative importance of alternatives with respect to each of the criterion. The pair-wise comparison is established using a nine-point Saaty scale. When all the comparisons are completed, decision maker calculates the priorities and measure the consistency of judgment. Generally the consistency ratio should be less than 0.10.

6.2 Performing AHP analysis

AHP analysis encompasses collection of data for pair-wise comparisons, estimation of global and local scores of agility enablers, and estimation of consistency of the comparison matrix. The pair-wise comparison is established using nine-point scale as suggested by

Saaty (1980) which is already tabulated in Chapter 3. This scale indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared.

6.2.1 Collection of data for pair-wise comparison

The AHP is often used in group settings where group members either engage in discussion to achieve a consensus or express their own preferences (Forman and Peniwati, 1998). The group discussion process has several advantages over aggregation of individual ratings. For the prioritization of ASC enablers, pair-wise comparison of ranking criteria and pair-wise comparison of enablers with respect to each of the criterion is required. Response from single expert for pair-wise comparison contains a total of six matrices. As the number of experts increases, total number of matrices also increases with the multiple of six. Hence individual response from multiple experts will make the problem complex and lengthy. Erkut and Moran, (1991) believe that group discussion process facilitates a common understanding of the meaning and significance of each criterion. This commonality of understanding is not achieved through aggregating the inputs of individual evaluations. The group is often able to clarify misunderstandings and differences in interpretation of the data so that there is a more uniform understanding of the facts. In addition, a group process utilizes the dynamics of powerful influence within the decision-making.

Therefore, for the present problem group discussion process has been preferred to reach consensus for the pair-wise comparison of criteria and alternatives rather than individual preferences by experts. In group discussion process, the group establishes a single set of weights for the decision criteria and then rates the decision alternatives. For the group discussion, various management techniques (such as brain storming, nominal group technique etc) can be used to collect the data. In order to collect the data for pair-wise

comparison, author of the present dissertation approached the respondents of the case-organization. Before the commencement of comparison, the objective of the survey was briefly introduced to the targeted respondents to ensure that they fully understood the survey questionnaire, overall goals and objectives of the research and how data would be used. There were four executives from the case organization who have given their precious time for brain storming session. Each executive has more than 20 years of experience in the supply chain domain. They were asked to give pair-wise comparison with reference to the Saaty's nine-point scale. At the end of brain storming session pair-wise comparisons of criteria (Table 6.2) and pair-wise comparisons of enablers with respect to each criterion (Table 6.3 to 6.7) were obtained.

Table 6.2: Pair-wise comparison of ranking criteria

	A	B	C	D	E
Competency (A)	1	1/3	3	5	5
Robustness (B)	3	1	5	5	5
Responsiveness (C)	1/3	1/5	1	1	1
Cost effectiveness (D)	1/5	1/5	1	1	1
Quickness (E)	1/5	1/5	1	1	1

Table 6.3: Pair-wise comparison of enablers with respect to competency (A)

	VE	CR	IT	MS	CS	AD	FL
VE	1	3	7	7	3	3	3
CR	1/3	1	5	5	1	3	3
IT	1/7	1/5	1	1	1/5	1/3	1/3
MS	1/7	1/5	1	1	1/5	1/3	1/3
CS	1/3	1	5	5	1	3	3
AD	1/3	1/3	3	3	1/3	1	1
FL	1/3	1/3	3	3	1/3	1	1

Table 6.4: Pair-wise comparison of enablers with respect to robustness (B)

	VE	CR	IT	MS	CS	AD	FL
VE	1	1	3	1	1/5	1/3	3
CR	1	1	3	1	1/3	1/3	1
IT	1/3	1/3	1	1/3	1/3	1/5	3
MS	1	1	3	1	1/3	1/3	3
CS	5	3	3	3	1	1	5
AD	3	3	5	3	1	1	5
FL	1/3	1	1/3	1/3	1/5	1/5	1

Table 6.5: Pair-wise comparison of enablers with respect to responsiveness (C)

	VE	CR	IT	MS	CS	AD	FL
VE	1	5	3	5	5	3	3
CR	1/5	1	1/3	1	3	1/3	1/3
IT	1/3	3	1	3	3	3	3
MS	1/5	1	1/3	1	3	1/3	1/3
CS	1/5	1/3	1/3	1/3	1	1/3	1/3
AD	1/3	3	1/3	3	3	1	1
FL	1/3	3	1/3	3	3	1	1

Table 6.6: Pair-wise comparison of enablers with respect to cost-effectiveness (D)

	VE	CR	IT	MS	CS	AD	FL
VE	1	1	1/3	5	3	3	5
CR	1	1	1/3	3	1/3	5	5
IT	3	3	1	5	1	5	5
MS	1/5	1/3	1/5	1	1/3	1	1
CS	1/3	3	1	3	1	3	3
AD	1/3	1/5	1/5	1	1/3	1	3
FL	1/5	1/5	1/5	1	1/3	1/3	1

Table 6.7: Pair-wise comparison of enablers with respect to quickness (E)

	VE	CR	IT	MS	CS	AD	FL
VE	1	3	5	3	5	5	3
CR	1/3	1	3	1	3	3	3
IT	1/5	1/3	1	1/3	1	1	3
MS	1/3	1	3	1	3	3	3
CS	1/5	1/3	1	1/3	1	1	3
AD	1/5	1/3	1	1/3	1	1	1
FL	1/3	1/3	1/3	1/3	1/3	1	1

6.2.2 Priority weights for criteria and priority weights for enablers with respect to each criterion

Based on the responses collected from the experts, pair-wise comparison matrices are developed for further analysis. Table 6.2 shows a matrix of pair-wise comparison of ranking criteria and Table 6.3 to 6.7 shows matrices of pair-wise comparisons of enablers with respect to each criterion. After obtaining the pair-wise judgements, next step is to calculate the priority weights of selection criteria and priority weights of enablers with respect to each criterion. The procedure of obtaining priority weights of the five criteria and priority weights of seven agility enablers with respect to each of the five criteria is as explained below.

The pair-wise comparison matrix is normalized by dividing the elements of each column by the sum of the corresponding column. Then, the average of each row will give the corresponding priority vector or priority weight. Table 6.8 shows the normalized matrix of paired comparison and calculation of priority weights of selected criteria and Table 6.9-6.13 show normalized matrix of paired comparison and calculation of priority weights of enablers with respect to each criterion.

Table 6.8: Normalized matrix and calculation of priority weights of selection criteria

	A	B	C	D	E	∑ of row	Average = ∑ / **5**
A	0.212	0.173	0.273	0.385	0.385	1.428	0.285
B	0.634	0.518	0.454	0.384	0.384	2.374	0.475
C	0.070	0.103	0.091	0.077	0.077	0.418	0.084
D	0.042	0.103	0.091	0.077	0.077	0.390	0.078
E	0.042	0.103	0.091	0.077	0.077	0.390	0.078
	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1		∑ = 1

Table 6.9: Normalized matrix and calculation of priority weights of enablers (*w.r.t.* competency)

	VE	CR	IT	MS	CS	AD	FL	∑ of row	Average = ∑ / **7**
VE	0.382	0.494	0.280	0.280	0.494	0.257	0.257	2.444	0.349
CR	0.127	0.165	0.200	0.200	0.165	0.257	0.257	1.371	0.196
IT	0.055	0.033	0.040	0.040	0.033	0.029	0.029	0.259	0.037
MS	0.055	0.033	0.040	0.040	0.033	0.029	0.029	0.259	0.037
CS	0.127	0.165	0.200	0.200	0.165	0.257	0.257	1.371	0.196
AD	0.127	0.055	0.120	0.120	0.055	0.086	0.086	0.649	0.093
FL	0.127	0.055	0.120	0.120	0.055	0.085	0.085	0.649	0.092
	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1		∑ = 1

Table 6.10: Normalized matrix and calculation of priority weights of enablers (*w.r.t.* robustness)

	VE	CR	IT	MS	CS	AD	FL	∑ of row	Average = ∑ / 7
VE	0.086	0.097	0.164	0.103	0.059	0.098	0.143	0.749	0.107
CR	0.086	0.097	0.164	0.103	0.098	0.098	0.048	0.693	0.099
IT	0.029	0.032	0.054	0.035	0.098	0.059	0.143	0.449	0.064
MS	0.086	0.097	0.164	0.103	0.098	0.098	0.143	0.788	0.113
CS	0.426	0.290	0.164	0.311	0.294	0.294	0.238	2.019	0.288
AD	0.258	0.290	0.272	0.311	0.294	0.294	0.238	1.957	0.280
FL	0.029	0.097	0.018	0.034	0.059	0.059	0.047	0.343	0.049
	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1		∑ = 1

Table 6.11: Normalized matrix and calculation of priority weights of enablers (*w.r.t.* responsiveness)

	VE	CR	IT	MS	CS	AD	FL	∑ of row	Average = ∑ / 7
VE	0.385	0.306	0.529	0.306	0.238	0.333	0.333	2.430	0.347
CR	0.077	0.061	0.059	0.061	0.143	0.037	0.037	0.475	0.068
IT	0.128	0.184	0.176	0.184	0.143	0.333	0.333	1.481	0.211
MS	0.077	0.061	0.059	0.061	0.143	0.037	0.037	0.475	0.068
CS	0.077	0.020	0.059	0.020	0.047	0.037	0.037	0.297	0.042
AD	0.128	0.184	0.059	0.184	0.143	0.111	0.111	0.922	0.132
FL	0.128	0.184	0.059	0.184	0.143	0.112	0.112	0.922	0.132
	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1		∑ = 1

Table 6.12: Normalized matrix and calculation of priority weights of enablers (*w.r.t.* cost-effectiveness)

	VE	CR	IT	MS	CS	AD	FL	∑ of row	Average = ∑ / 7
VE	0.165	0.114	0.103	0.262	0.474	0.164	0.218	1.499	0.214
CR	0.165	0.114	0.102	0.158	0.053	0.273	0.218	1.081	0.154
IT	0.494	0.344	0.306	0.263	0.157	0.273	0.218	2.055	0.294
MS	0.033	0.038	0.061	0.053	0.053	0.054	0.043	0.335	0.048
CS	0.055	0.344	0.306	0.158	0.157	0.164	0.130	1.314	0.188
AD	0.055	0.023	0.061	0.053	0.053	0.054	0.130	0.429	0.061
FL	0.033	0.023	0.061	0.053	0.053	0.018	0.043	0.283	0.041
	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1		∑ = 1

Table 6.13: Normalized matrix and calculation of priority weights of enablers (*w.r.t.* quickness)

	VE	CR	IT	MS	CS	AD	FL	∑ of row	Average = ∑ / 7
VE	0.385	0.474	0.349	0.474	0.348	0.332	0.176	2.540	0.363
CR	0.128	0.157	0.209	0.157	0.210	0.200	0.176	1.239	0.177
IT	0.077	0.053	0.070	0.053	0.070	0.067	0.176	0.565	0.081
MS	0.128	0.157	0.209	0.157	0.209	0.200	0.176	1.239	0.177
CS	0.077	0.053	0.070	0.053	0.070	0.067	0.176	0.565	0.081
AD	0.077	0.053	0.070	0.053	0.070	0.067	0.060	0.447	0.064
FL	0.128	0.053	0.023	0.053	0.023	0.067	0.060	0.405	0.057
	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1	∑ = 1		∑ = 1

6.2.3 Calculation of consistency ratio for each of the comparison matrices

The next step is to calculate a Consistency Ratio (C_R) to measure how consistent the judgements have been relative to large samples of purely random judgements. The method for calculating consistency ratio is explained in Chapter 3. Applying expression explained in Chapter 3, consistency ratio for each of the comparison matrices are calculated and

tabulated in Table 6.14. From table it is observed that, consistency ratio for each comparison matrix is less than Saaty's empirical suggestion (which is 0.10). Hence it can be concluded that good consistency is found in the judgments made by experts.

Table 6.14: Consistency Ratio (C_R) of the each of the comparison matrices

Comparison matrix	Consistency Ratio (C_R)
Pair-wise comparison of ranking criteria	0.030
Pair-wise comparison of enablers with respect to competency	0.025
Pair-wise comparison of enablers with respect to robustness	0.058
Pair-wise comparison of enablers with respect to responsiveness	0.059
Pair-wise comparison of enablers with respect to cost-effectiveness	0.083
Pair-wise comparison of enablers with respect to quickness	0.048

6.2.4 Estimating global and local scores

Priority weights of enablers with respect to each criterion can be called as local weights of enablers. Table 6.15 shows resulting priority weights for each enabler by each criterion. Overall AHP weights (which can be called as global weights) of the agility enablers can be obtained by multiplying the priority weights of enablers to the priority weights of selected criteria (Table 6.16), summing over all criteria. Table 6.17 shows overall AHP weights of the agility enablers.

$$w_i = \sum_{j=1}^{5} (w_{ij} * w_j) \qquad (6.1)$$

$$w_i = \begin{bmatrix} 0.349 & 0.107 & 0.347 & 0.214 & 0.363 \\ 0.196 & 0.099 & 0.068 & 0.154 & 0.177 \\ 0.037 & 0.064 & 0.211 & 0.294 & 0.081 \\ 0.037 & 0.113 & 0.068 & 0.048 & 0.177 \\ 0.196 & 0.288 & 0.042 & 0.188 & 0.081 \\ 0.093 & 0.280 & 0.132 & 0.061 & 0.064 \\ 0.092 & 0.049 & 0.132 & 0.041 & 0.057 \end{bmatrix} * \begin{bmatrix} 0.285 \\ 0.475 \\ 0.084 \\ 0.078 \\ 0.078 \end{bmatrix}$$

$$w_i = \begin{bmatrix} 0.224 \\ 0.134 \\ 0.088 \\ 0.087 \\ 0.217 \\ 0.181 \\ 0.069 \end{bmatrix}$$

Table 6.15: Resulting priority weights for each enabler by each criterion

Decision variables (agility enablers)	(x_i)	Selection criteria of agile supply chain enablers				
		Competency	Robustness	Responsiveness	Cost-effectiveness	Quickness
Virtual Enterprises	x_1	0.349	0.107	0.347	0.214	0.363
Collaborative Relationship	x_2	0.196	0.099	0.068	0.154	0.177
Use of IT	x_3	0.037	0.064	0.211	0.294	0.081
Market Sensitivity	x_4	0.037	0.113	0.068	0.048	0.177
Customer Satisfaction	x_5	0.196	0.288	0.042	0.188	0.081
Adaptability	x_6	0.093	0.280	0.132	0.061	0.064
Flexibility	x_7	0.092	0.049	0.132	0.041	0.057
	Total	1.000	1.000	1.000	1.000	1.000

Table 6.16: Resulting priority weights for each criterion

Criterion decisions	Priority weights
Competency	0.285
Robustness	0.475
Responsiveness	0.084
Cost-effectiveness	0.078
Quickness	0.078
Total	0.100

Table 6.17: Overall AHP weights of the decision alternatives

Decision variables (agility enablers)	(x_i)	AHP weighting	Decision preference
Virtual Enterprises	x_1	0.224	First preference
Collaborative Relationship	x_2	0.134	Fourth preference
Use of IT	x_3	0.088	Fifth preference
Market Sensitivity	x_4	0.087	Sixth preference
Customer Satisfaction	x_5	0.217	Second preference
Adaptability	x_6	0.181	Third preference
Flexibility	x_7	0.069	Seventh preference
	Total	1.000	

6.3 Generality of the findings obtained from comparisons of enablers and criteria

The results of this chapter are consolidated in Table16 and 17. Table 16 shows priority weights of the criteria and Table 17 shows overall weights and decision preference of seven ASC enablers. From Table 16, it was analysed that criteria robustness has maximum priority (0.475) based on the fact that the case-organisation being considered in this study can strongly withstand variations and disturbances arrived in the business environment. For example, while considering demand pattern of the case-organisation, there is uncertainty in customer demand. Due to this uncertainty, the case-organisation analyses the demand pattern; forecasts demand for two years based on previous data and hence, procure components and spares accordingly. In general it can be concluded that to be a robust organisation means to have the resilience and flexibility to be able to turn things around, to make changes, and to swiftly take up business opportunities and address challenges. Companies that have organisational robustness are often better at rolling out strategies, quicker to adapt and more able to deliver results. Competency (0.285) is the second most important criteria. It is because the case-organisation can effectively and efficiently achieve its target goals. Target goals include an on-time delivery, producing a high-quality product, safety of workers and so on. It was evident that case-organisation delivers a completed high-quality product on the schedule that fulfil the commitments to customers

and also strives to reduce the potential for injury on the manufacturing floor. Hence it can be concluded that competency is the extensive set of abilities that provide productivity, efficiency, and effectiveness of activities towards the aims and goals of the organizations. Remaining three criteria namely responsiveness (0.084), cost-effectiveness (0.078) and quickness (0.078) were found to be of secondary or lesser importance. It is mainly due to reasons that case-organisation take more time and money to identify and respond to changes and disturbances. Companies, who adapted to unexpected changes effectively, respond them in a cost-effectiveness manner at high speed, are better able to manage disruption and consistently meet their customers' expectations. Enabling responsiveness, cost-effectiveness and quickness relies on the process of identifying, capturing, and transforming.

Table 17 indicates that an enabler virtual enterprise (0.224) is the most important enabler among the seven ASC enablers and hence is ranked first. The evident reason is that the case-organisation focuses more on the virtual enterprise by alliance to some other companies to share their skills or core competencies and resources in order to better respond to customer demand. In general organizations materialize through the selection of skills and assets from different firms and their synthesis into a single business entity. The second highest overall priority weight is of the customer satisfaction (0.217). Customer satisfaction is one of the most important enabler due to the reason of key issues to survival. Case-organisation continuously understands and provides what their customers want. It provides quality assurance, customer service and also takes regular feedback from customers. Other organizations also focus on customer satisfaction as a satisfied customer might well become a repeat buyer and spread positive word-of-mouth might create new customers for a business (Joseph Yu et. al, 2005). Adaptability has third highest global weight which is equal to 0.181. Hence, adaptability was given third preference. From

Table 17, it can be seen that adaptability is closer to virtual enterprises and customer satisfaction. This implies that case-organisation also prefer adaptability in their supply chain. The case-organisation correctly predicts and responds to an unexpected change in their business environment. Hence it can be concluded that adaptability is very important enabler for organizations to deal with new environmental conditions and to identify and capitalize emerging markets and technology opportunities (Charkravarthy, 1992).

Collaborative Relationship is next to adaptability with priority weight 0.134 and with fourth decision preference. Here, collaborative relationship refers to close and coordinated relationships between the case-organisation and their supply chain partners. It is observed that with the help of collaborative relationship, the risk in supply chain can be managed effectively. Firms are building collaborative relationships with their major business partners in order to achieve efficiency, flexibility, and sustainable competitive advantage (Nyaga et. al, 2010). Next three enablers *i.e.* use of information technology (0.088), marketing sensitivity (0.087) and flexibility (0.069) are derived as fifth, sixth and seventh decision preference respectively. Comparison of their priority weights (Table 17) shows that these three enablers are almost close to each other and hence, enjoy almost equal importance. These three enablers may also important for the case-organisation but decision maker focuses according to their preferences. In general firms are increasingly dependent on information technology, marketing sensitivity and flexibility for enhancing supply chain performance, for reading and responding to real demand and for ensuring smooth undisrupted supply of product from supplier to the end user.

6.4 Comparison of results obtained from ISM and AHP

Though seven ASC enablers are same in Chapter 4 and Chapter 6 but the base of findings are different. In Chapter 4 interrelationship among seven enablers are established using ISM and in Chapter 6 weights of seven enablers are identified by using AHP. ISM

provides hierarchy of the importance of ASC enablers with respect to themselves and AHP proveds importance of ASC enablers with respect to attributes. Chapter 4 results give relative importance between ASC enablers which shows that 'Use of IT' and 'Market Sensitivity' have high driving power and hence it drives all other enablers. However, in Chapter 6 the same two enablers 'Use of IT' and 'Market Sensitivity' obtain lowest weight with respect to five selection criteria which are competency, robustness, responsiveness, cost-effectiveness and quickness. It means that these two enablers highly influence other enablers but with reference to five criteria these two do not contain higher weightage.

6.5 Concluding remarks

The global and local priority weights of the seven agility enablers with respect to each of the criterion are obtained through AHP analysis. These outcomes of AHP are embedded in GP to develop the AHP-GP model in next Chapter in order to maximize the agility of supply chain deploying input resources. Hence, the derived priorities with respect to each of the five criteria will be used in the combined model to serve as the contribution that each criterion makes to each agility enabler.