CHAPTER VI

DEVELOPMENT OF AN IMPLEMENTATION PLAN FOR MANAGING MANUFACTURING FLEXIBILITIES

6.1 Introduction

This chapter presents inferences drawn from empirical study carried out in manufacturing organizations of north India, case studies conducted in various manufacturing industries, synthesis of inferences, learning from various phases of the study, and use of learning issues in a structured manner within the boundaries of a qualitative model, to develop workable and effective management process for achieving manufacturing flexibility in Indian context. The inferences from each of the above phases have been compiled and listed. With a careful analysis, the overlapping and similar inferences have been scrutinized to develop a list of independent learning issues. These learning issues have then been taken as options for a qualitative modeling involving Option Field Methodology (OFM), Option Profile Methodology (OPM), Analytic Hierarchy Process (AHP) and Fuzzy Set Theory (FST). Following this, an implementation plan has been developed for managing different manufacturing flexibility showing preferred strategies under various conditions of optimism, pessimism, and realism.

6.2 Synthesis of Learning Issues

Learnings from empirical study and four case studies has been synthesized and presented in the form of issues enumerated below.

Issues concerning Business Strategy and Initiatives

- Customer focus and commitment has been considered as the highly important business initiative by majority of the organizations.
- The role of technology and win-win situations with suppliers has been equally and significantly targeted by the organizations.
- Organizations have largely considered the importance of inducing flexibility in the manufacturing and design as an instrument for achieving competitiveness.
- Reduction in product cost and reliable quality at competitive price has emerged as the prime priorities for the organizations.

- Impact of market fluctuations and competitive excellence has emerged as prominent factors, for offering new or significantly improved products.

- Cross-functional teams wherever required have helped organizations in achieving business competitiveness.

- Recognizing the potential of technology and innovation, organizations have continuously harnessed the power of its knowledge capital.

- Seamlessly future proofing capital investments assures evolutionary capabilities of manufacturing infrastructure.

- The R&D initiatives have enabled the organizations to develop their own technology, designs and patents.

- With the association of research institutes, organizations aim to co-develop advanced futuristic product technologies to retain their position in the market.

- The organizations affirm their commitment of seamless integration of marketplace, workplace, and environment concerns with business operations.

- The organizations have attained the certifications from various international and national bodies and agencies for excellence in processes, products and operations, leading to achievement of business performance including quality, flexibility, productivity and competitiveness.

**Issues concerning Technology Adoption**

- The important factors for the implementation of AMT’s include:
  - improvement in design and manufacturing capabilities
  - achievement of manufacturing flexibilities
  - Quality leadership in the market place.

- Speed of delivery and number of customized product offered has significantly increased due the adoption of new technology.
The market share and net profit of the organizations have revealed a considerable improvement as a result of adopting new technology.

Use of IT enabled systems helped the organizations to promote E-sourcing, enhance manufacturing flexibility, control waste and improve employee connect.

Organizations have adopted the technology from their alliance partners to reduce lead-time to new product introductions.

Organizations have largely invested in the Infrastructural technology so as to integrate their business operations within, with their suppliers and OEMs.

To reduce the dependency on external suppliers, as a reason to adopt new technology, has emerged as of the lowest concern for the organizations.

The high cost of new technology has been found as a main barrier for its adoption. The lack of information on new technology and customer non-responsiveness to new products has little effect in adopting the new technology.

The cost of the existing and future product innovations have shown an upward trend, which can be resulted due to the high cost of technology acquisition in short term.

**Issues concerning Sourcing Practices**

- Supplier involvement has significantly and positively influenced the outcome of the organizations in terms of added flexibility, low cost and high profits.
- A participative and collaborative approach with the suppliers has emerged as a key factor for the growth of any manufacturing organization.
- Reduction in operating cost and speed of capacity changeover in manufacturing system has been considered as the leading factor to adopt the sourcing practices.
- Adaptability to customer’s need and requirement has been considered as important factor to adopt the sourcing practices.
- An organization’s ability to produce a quality product at a reasonable cost and in a timely manner is influenced by its suppliers’ capabilities.
Supplier responsiveness to demand fluctuations and supplier modification capabilities have significantly influenced the supplier selection process.

Suppliers’ technological competences, improvement in product variety and low delivery time have been the important factors to adopt different sourcing practices.

Organizations strive to establish a long-term strategically managed relationship with key suppliers, which in turn have a positive impact on the organization performance.

Competitive scope of the suppliers has been a key area for the supplier selection.

Supplier’s integration in manufacturing system has low to moderate impact on an organization performance in terms of loss of control, confidentiality dependency and lead to organizational complicacies.

Speed of delivery of innovative products has seen a considerable upside movement with the adoption of sourcing practices.

Suppliers are being trained to evolve as innovation drivers by engaging them at new product designing stage.

Shift has been witnessed from capacity to system supplier.

Organizations have witnessed the marginal decrease in product cost and substantial increase in net profit as a result of adopting and developing sourcing practices.

Cross-functional and cross-organization efforts to increase flexibility and eliminate uncertainties have created the level of performance needed to create competitive advantage.

The organizations have identified a group of suppliers for implementing an ERP solution enabling seamless sharing of information and promoting e-business, flexibility and competitiveness as a measure for vendor consolidation.

Longstanding strategic partnerships with key technology providers, allows the organizations to access new technologies.
Issues concerning Manufacturing Flexibility

- Majority of the organizations have a competence to considerably achieve the manufacturing flexibility at the tactical level.
- The organizations moderately rely on adoption and further development of manufacturing technology and infrastructure in house to achieve tactical and strategic level flexibilities.
- The responsiveness of the organizations to the customer demands and operating efficiently at different levels of output has emerged as the most important, amongst flexibility-oriented tasks.
- The considerable use of strategic sourcing has helped the organizations to achieve the strategic level flexibility, in course leads to the introduction of new products with minimal lead-time.
- Cross-functional teams have been found to be the key area of interest for achieving manufacturing flexibility.
- Adoption of ERP system has helped the organizations in achieving manufacturing flexibility and performs better in the global market.
- Some of the organizations (large scale) can handle the different delivery sequences quickly and efficiently to satisfy customer demands and creating new markets.

Issues concerning Volume Flexibility

- Significant investment in Infrastructural technology and the involvement of vendors in providing capacity support has helped the organizations in achieving volume flexibility.
- Most of the organizations have a capacity to handle volume changes and product configurations quickly and efficiently during the manufacturing process to accommodate customer preferences.
- Process improvement can be introduced in the manufacturing system without creating disturbances.
• Use of soft, administrative and intermediate technologies have resulted in strengthen the organization capabilities to handle rapid increase in production volumes and adjust the level of production quickly and profitably.

• Supplier involvement in modifying products has significantly shown a positive impact in managing the frequent volume fluctuations without sacrificing the quality of the different products.

• Volume flexibility has a significant correlation with the modification and delivery flexibility.

**Issues concerning Modification Flexibility**

• The augmentation of facilities with advanced manufacturing technology has helped the organizations to achieve the modification flexibility.

• The strategic use of organizational infrastructural resources has positively influenced the attainment of modification flexibility.

• The majority of organizations are capable of producing minor alterations in product design to meet customization.

• The cost of the modified or new product and transition penalties in course has been an area of concern for the organizations.

• Supplier assistance in minor product and process design changes and managing rapid changes in product variety have resulted in strengthening the organization capabilities to manage the achievement and development of modification flexibility.

**Issues concerning Delivery Flexibility**

• The role of strategic sourcing is found to be statistically significant in developing the delivery flexibility.

• Cross-functional teams with the key suppliers has paid off in achieving fast delivery of innovative products and hence delivery flexibility.

• Supplier assistance in managing product and process changes for an organization played an imperative role as a prerequisite in developing delivery flexibility.
- The organizations maintain long term sourcing arrangement with key suppliers for achieving delivery flexibility.

- Flexibility of suppliers in effectively managing the market fluctuations for the deliverance of innovative products has been helpful for the organizations.

- The impact of supplier competencies has been found influential for the development of delivery flexibility in an organization.

- Delivery flexibility has a high and significant correlation with the achievement of volume and modification flexibility.

- A company with high delivery flexibility may be able to operate more economically, if it has already developed a high degree of volume and modification flexibility.

6.3 Methodology for Modeling – A Management Process

A qualitative model using Options Field Methodology (OFM), Options Profile Methodology (OPM), Analytic Hierarchy Process (AHP) and Fuzzy Set Theory (FST), has been developed and applied to the situation to meet the objectives, as shown in fig. 6.1, in a flexible system methodology framework (Sushil, 1993). A brief description of the model is given below.

**Figure 6.1 Qualitative modeling approach**

The modeling began with listing of options as a solution to flexible management of new technology for strategic success. The list was converted into a conceptual design. OFM/OPM (Warfield 1979, 1982, 1990) and was largely used as a basis for this purpose.
Finally, the alternative options profiles developed were been ranked using AHP (Saaty, 1980) and FST (Zadeh, 1965).

6.3.1 **Options Field / Options Profile Methodology (OFM/OPM)**

In order to adopt the method of idea writing (which Warfield termed idea management) to design, Warfield (1979) introduced a methodology for the conceptual design of systems which results into a portrayal on one page of the products of a conceptual design a foot. This portrayal shows not only what is accepted in the design but also what options are rejected. The Options Field Methodology and the Options Profile Methodology provide means for thorough development of design situation, descriptions and design target description.

They involve discovery and identification of dimensionality of the situation, and facilitate matching dimensionality of the target with dimensionality of the design situation. Various steps involved in these two methodologies are described below:

**Options Field Methodology (OFM)**

a) *Construction of a polystructure*: The completed options field is a polystructure. Its construction begins with the generation and classification of a set of options. This set may be generated using modified idea writing in response to a carefully formulated triggering question. This question defines the context and must, therefore, reflect substantial insight into the design situation. The question must be neither too broad nor too narrow. It must stimulate creative and productive responses that do not stray from the topic under consideration.

b) *Initial structuring (placing options in categories)*: Once a set is developed, the initial structuring begins. The initial structuring is for placing options into categories. A relationship that may be used for this initial structuring is “in the same category as”. Theory of dimensionality is used for placing the options into categories.

The structural theory of dimensionality of situations and processes introduces options field and options profile as byproducts of design activity. Options field is a triply structured-quad, since it is a four levels structure, whose levels are named as Target, Cluster, Dimension and Options reading from the top to bottom (Fig. 6.2).
It is triply structured because its structure incorporates three distinct relationships (Warfield, 1990) described as membership in a dimension for classifying options into dimensions interdependence for classifying dimensions into interdependent cluster and time preference relationship” for relating dimensions to each other in clusters.

![Diagram of structure quad](image)

**Figure 6.2 Four level structure quad.**

c) *Identifying the design dimensions:* After the set of categories has been achieved, it is reasonable to believe that learning has occurred. At this point, it is appropriate to ask whether every category should be taken as a dimension of the design. The criteria for making this decision is to ask whether some option(s) in that category really must be specified in order to provide adequate definition of the alternative represented by choosing one or more options from each dimension, or whether any particular category is not essential to the definition of the target.

d) *Discovering Clusters of dependent dimensions:* Once the group has settled on the dimensions of the target, a second structuring occurs. Now the set of dimensions is structured. The relationship used is “independent of”. Two dimensions are defined to be independent if a choice of one or more options in one of the dimensions does not rule out any choices in the other dimension. If two dimensions are interdependent, the choice of options in one may be restricted by the choice of options in the other. Following this structuring, there is a defined set of clusters, each cluster consisting of a set of dimensions, and each dimension consisting of a set of similar options.
e) *Establishing a choice-making sequence for clusters:* Now the third structuring begins. This structuring takes the clusters as elements to be structured. The structuring relationship involves the sequence in which choices of options should be made. A suitable relationship is “should be considered first in making choices of options.”

f) *Sequencing dimensions within clusters:* A fourth structuring is carried out now. In this, structuring is carried out separately for each cluster and initial decision-making sequence among dimensions in each cluster is defined.

g) *Displaying the completed options field:* It is then appropriate to organize the options field by placing dimensions in the order determined with name of each dimension heading a list of options therein and with the cluster clearly identified.

**Options Profile Methodology (OPM)**

Options Profile is the visual representation of an alternative consisting of a set of chosen options with at least one option coming from each dimension in the options field. Each option that has been selected is so designated by a line drawn from the bullet in front of the selected option down to the tie line. In applications, it is common to construct several options profiles for a given options field. Each options profile represents one design alternative. In choosing options, choices are made in the sequence determined in formulating the way options field is represented.

Having made the profiles, next task is to list various objectives of the design or targets. Following this, contribution of each profile to each objective is determined by paired comparison. Analytical Hierarchy process is employed for the purpose. A brief description of the AHP is given below.

**6.3.2 Analytic Hierarchy Process (AHP)**


**Paired Comparison**

Paired comparison is based on the idea that a complex issue can be effectively examined if it is hierarchically decomposed into its parts. The elements are compared with each
other, thus providing an opportunity for a pair-wise comparison for evolving the structure into an nxn reciprocal judgment matrix. In the matrix, one begins with an element on the left and compares how much more important it is than an element on top. When compared with itself, the ratio is one. When compared with another element, if it is more important than that element, an integer value, as discussed below, is used. If, however, it is less important, then reciprocal of the previous integer value is used. In either case, reciprocal value is entered in the transpose position of the matrix. Thus, only n (n-1)/2 judgments are considered where n is the total number. The respondent is to concentrate on only two elements at a time. A scale of 1 to 9 is used for giving judgment value according to the following guidelines:

\[
a_{ij} = \begin{cases} 
1 & \text{if } i \text{ and } j \text{ are equally important.} \\
3 & \text{if } i \text{ is weakly more important than } j. \\
5 & \text{if } i \text{ is strongly more important than } j. \\
7 & \text{if } i \text{ is very strongly more important than } j. \\
9 & \text{if } i \text{ is absolutely more important than } j.
\end{cases}
\]

Value of 2, 4, 6 and 8 are used to compromise between two judgments.

The weightages of the features are obtained by calculating the Eigen Vector weights for the judgment matrix. An index of consistency is calculated to provide information on how serious is violations of numerical and transitive consistency. The results could be used to seek additional information and re-examine the data used in constructing the scale in order to improve consistency. The consistency index (CI) is \( \frac{X_{\text{max}} - n}{n - 1} \) where n is the number of elements being compared and Xmax is the largest Eigen value of the judgment matrix. Dividing CI by the random consistency number for the same size matrix, consistency ratio CR can be obtained. The value of CR should be around 10% or less to be acceptable. In some cases, a maximum value of 20% may be tolerated. If CR is not within this range, participants should study the problem and revise their judgment. The average consistencies for different order random matrices are given below (Saaty and Kearns, 1985).

<table>
<thead>
<tr>
<th>Size of matrix</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Consistency</td>
<td>0</td>
<td>0</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>0.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
</tr>
</tbody>
</table>
6.3.3  **Fuzzy Set Theory (FST)**

a)  *Fuzzy set Theory (FST)* developed by Zadeh (1965) is based on recognition that certain sets have imprecise boundaries. Fuzzy sets and sub-sets are those ill specified and non-distinct collection of objects with unsharp boundaries in which transition from membership to non-membership is gradual rather than abrupt. A fuzzy set is characterized by a membership function, defined as a real number in the interval (0,1). For example, a membership measure \((X) = 0.5\) suggests that \(X\) is a member of set \(A\) to a degree 0.5 on a scale where 0 is no membership at all, and 1 is complete membership. Thus, a fuzzy set can be reduced to a crisp set by transforming memberships to extremes of the range zero or one. FST has been successfully applied to automata theory, system analysis, decision theory, man-machine systems, modeling of industrial processes etc. In this study, it has been used for the purpose of ranking of options profiles in an integrated form with analytical hierarchy.

b)  *Ranking of alternatives using FST*: The fuzzy set methodology for multi-criteria decision making is used to analyze various options. The fuzzy set techniques are designed such that quantitative and non-quantitative factors, and the view points of the interest groups can be readily incorporated into the decision making process. Ranks of the options in a group process are achieved through a dominance matrix designed for the purpose.

In order to represent the views of each of the interest group, a position matrix is prepared from the responses of all the experts in the group by giving numerical values to the qualitative assessment. Average value of each element representing the group response is worked out by multiplying membership function value of each alternative as given by the respondents with assigned weight i.e. the eigen vector weight as determined by AHP. This way some of the bias in the matrix can be eliminated. The weighted matrices for each of the interest group are thus, prepared.

There are three ways to aggregate the weighted matrix viz. optimistic, average and pessimistic aggregation. The highest value among various group responses represents the optimistic value, the lowest value represents the pessimistic value and the average of all the values represents the mean value.
An n x n matrix ‘D’ called dominance matrix is prepared to display the dominance structure between all possible pairs of options. The element dij is the number of features for which membership value of option j dominates or is greater than option i. A dash is entered for the diagonal dij element. If the Kth column is summed, the total number of dominances of option K over all options is obtained. Similarly, if the Kth row is summed, the number of times the Kth option is being dominated by all other options is determined.

Outcomes that are more favorable have higher column sums and lower row sums. In cases where an option is very close to another option on the basis of aggregate weighted position matrix, the dominance among the options exists only if the membership value of the second option is outside the specified limit. The options can be considered equivalent with respect to that feature. This range may be set for each problem (for example ± 5 percent of the membership value) but should not be too large, otherwise lot of information is likely to be lost. As in the case of weighted position matrices, three dominance matrices namely optimistic dominance matrix, pessimistic dominance matrix and mean dominance matrix are prepared.

The ranks of options are normally decided by examining ranks obtained from extent of dominance and also extent of being dominated by other options. Although any of the optimistic, pessimistic and average approaches can be used but there are shortcomings in each. The best course of action for a decision maker in such a situation may be to use a Hadley’s criteria of cautious optimism (Hadley, 1967). The decision maker may choose different coefficients of optimism (16). If ‘A’ is the dominance weight of the option as determined from optimistic matrix and B that of the pessimistic dominance matrix, weight of the option according to Hadley criterion is determined by the relationship: W = α x A + (1-α) x B.

Since the process of choosing the coefficient of optimism (16) in the Hadley criterion of ‘Cautious Optimism’ is a judgment based approach, ranks of the options from the dominance matrix is considered on the basis of dominance and ignoring the considerations of being dominated.
6.4 Qualitative Modeling using OFM, OPM, AHP, and FST

The learning issues as given in section 6.2 have been analyzed and restructured to convert them into following options of the OFM.

1. Design and development of new products
2. Customized products for new market creation
3. Access to new customers/ new market creation
4. Gain competitive excellence
5. Adoption, adaptation and further development of technology through local R&D efforts.
6. Delivery of innovativeness in design of products
7. Adoption of new technology for the new product design and development
8. Implementing quality systems procedures and practices
9. Cross functional teams with external suppliers for innovation in product design and development
10. Improvement in delivery of product variety
11. Introduction of process improvements in the manufacturing system
12. Rapid handling of increasing production volumes
13. Developing capacity to handle varied output volumes for the different products
14. Cost cutting and value analysis
15. Quality of the product not affected by changes in volume
16. Level of production volume be changed quickly
17. Transformation of new product design into production quickly
18. Capability of producing minor alterations in product design to meet customization
19. The time required to change to a modified product or product mix is short
20. The variety of modules/components enable many different products to be configured
21. Responsiveness to customers demand
22. To produce wide variety of product mix simultaneously
23. Development / fostering of next generation technology
24. Adoption of ERP and information technologies
25. Association with research institutes and technology partners.
26. Redesigning the existing manufacturing system within the available facilities
27. Investment in multipurpose machines
28. Technology acquisitions, adoption, adaptation, collaboration, tie-ups.
29. System design and implementation
30. Adoption of new technology in manufacturing systems
31. Use of specialized technology and capabilities of supplier(s)
32. Reduce operating cost and risk of business
33. Developing tier-1 and tier-2 suppliers to implement cost cutting technique
34. Economic and viable strategies
35. Adoption of infrastructure and information and communication technologies to improve flexibility
36. Investment in Soft technologies and administrative approaches
37. Acquiring world class technologies
38. High cost of new technology as a barrier for technology adoption
39. Involvement of supplier(s) in manufacturing
40. Involvement of supplier(s) in design and new product development process
41. Supplier responsiveness to demand fluctuations (volume changes, capacity etc.)
42. Supplier modification capabilities
43. Supplier integration in design
44. Design and innovative capabilities of supplier
45. Technological competence of suppliers
46. Vendor consolidation and development
47. Organization rely on small but high quality suppliers
48. Length of relationship
49. Participative and collaborative approach with the suppliers
50. Speed of capacity changeover and adaptability to customer needs
51. Early involvement of suppliers triggers innovations at the designing stage
52. Continuum shift from capacity supplier to system supplier
53. Longstanding strategic partnerships with key technology providers
54. Customer focus and commitment
55. Innovation and change
56. Win-win situations with suppliers
57. Integration of economic, environmental and social imperatives
58. Collaboration(s)/ Accreditation/ certification of the organization
59. Market share and net profit of the organizations
60. Flexibility in manufacturing
61. Quality planning and improvement
62. Market leadership through pro activeness
63. Use of flexible procedure and practices
64. Develop teams to make changes in system and continuously improve it
65. Reduction in production costs
66. Reduce the impact of market fluctuations
67. Economic viability study for adopting new technology
68. Average sales growth
69. Seamlessly future proofing capital investments
70. Use of value analysis/value engineering and system approaches
71. Improved processes and quality
72. To adapt itself or its organizational structure
<table>
<thead>
<tr>
<th>Innovation, design and development</th>
<th>Market responsiveness</th>
<th>Vendor consolidation and development</th>
<th>Business strategy and performance</th>
<th>Keeping pace with technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Design and development of new products</td>
<td>• Introduction of process improvements in the manufacturing system</td>
<td>• Involvement of supplier(s) in manufacturing</td>
<td>• Customer focus and commitment</td>
<td>• Development / fostering of next generation technology</td>
</tr>
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<td>• Involvement of supplier(s) in design and new product development process</td>
<td>• Innovation and change</td>
<td>• Adoption of ERP and infrastructural technologies</td>
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<td>• Access to new customers/ new market creation</td>
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<td>• Win-win situations with suppliers</td>
<td>• Association with research institutes and technology partners.</td>
</tr>
<tr>
<td>• To gain competitive excellence</td>
<td>• Large product mix</td>
<td>• Supplier modification capabilities</td>
<td>• Integration of economic, environmental and social imperatives</td>
<td>• Redesigning the existing manufacturing system within the available facilities</td>
</tr>
<tr>
<td>• Adoption, adaptation and further development of technology through local R&amp;D efforts’</td>
<td>• Quality of the product not affected by changes in volume</td>
<td>• Supplier integration in design</td>
<td>• Collaboration(s)/Accreditation/certification of the organization</td>
<td>• Investment in multipurpose machines</td>
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<tr>
<td>• Delivery of innovativeness in design of products</td>
<td>• Level of production volume be changed quickly</td>
<td>• Design and innovative capabilities of supplier</td>
<td>• Market share and net profit of the organizations</td>
<td>• System design and implementation</td>
</tr>
<tr>
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<td>• Transformation of new product design into production quickly</td>
<td>• Technological competence of suppliers</td>
<td>• Flexibility in manufacturing</td>
<td>• Adoption of new technology in manufacturing systems</td>
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<td>• Use of specialized technology and capabilities of supplier(s)</td>
</tr>
<tr>
<td></td>
<td>• The time required to change to a new product</td>
<td>• Speed of capacity changeover in manufacturing system</td>
<td>• Length of relationship</td>
<td>Technology acquisitions, adoption,</td>
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<td></td>
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<td>• Participative and collaborative approach with the suppliers</td>
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<td>• Develop teams to make changes in system and continuously improve</td>
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<tr>
<td>Innovation, design and development</td>
<td>Market responsiveness</td>
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<td>Business strategy and performance</td>
<td>Keeping pace with technology</td>
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<tr>
<td>- Improvement in delivery of product variety</td>
<td>- modified product or product mix is short</td>
<td>- and adaptability to customer needs</td>
<td>- Reduction in production costs</td>
<td>- adaptation, collaboration, tie-ups, etc</td>
</tr>
<tr>
<td>- Role of strategic sourcing with key suppliers in innovation and design</td>
<td>- The variety of modules/component s used, enable many different products to be configured</td>
<td>- Early involvement of suppliers triggers innovations at the designing stage</td>
<td>- Reduce the impact of market fluctuations</td>
<td>- Adoption of infrastructure and information and communication technologies to improve flexibility</td>
</tr>
<tr>
<td>- Implementing quality systems procedures and practices</td>
<td>- Responsiveness to customer’s demand</td>
<td>- Continuum shift from capacity supplier to system supplier</td>
<td>- Economic viability study for adopting new technology</td>
<td>- Investment in Soft technologies and administrative approaches</td>
</tr>
<tr>
<td>- To produce wide variety of product mix simultaneously</td>
<td>- Longstanding strategic partnerships with key technology providers</td>
<td>- Developing tier-1 and tier-2 suppliers to implement cost cutting techniques</td>
<td>- Average sales growth</td>
<td>- High cost of new technology as a barrier for technology adoption</td>
</tr>
<tr>
<td>- Outsourcing based approach</td>
<td>- Use of value analysis/value engineering and system approaches</td>
<td>- To adapt itself or its organizational structure</td>
<td>- Seamless future proofing capital investments</td>
<td>- Develop in-house research and development capabilities</td>
</tr>
<tr>
<td>- Strategic Sourcing based approach</td>
<td>- Improved processes and quality</td>
<td>- Reduce operating cost and risk of business</td>
<td></td>
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<tr>
<td>- Design Technology based approach</td>
<td>- Keeping track of competitors policies and practices</td>
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<td>- Manufacturing Technology based approach</td>
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<td>- Infrastructural Technology based approach</td>
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</table>

*Figure 6.3 Options Profile methodology*
6.4.1 Putting the Options into Categories

These options were then put into various categories and the categories were named too. The categories are:

a) Customized products for new market creation

b) Delivery of innovativeness in design of products

c) Development of technology in house and sourcing practices

d) Process and product improvements

e) Reduction of lead time to product development

f) Flexibility in manufacturing

g) Development / fostering of next generation technology

h) Technology acquisitions, adoption, adaptation, collaboration, tie-ups, etc

i) System design and implementation

j) Investment in soft and hard technologies

k) Develop in-house research and development capabilities

l) Customer focus and commitment

m) Market leadership through pro activeness

n) Techno-socio-environmental aspect

o) Economic and viable strategies

p) Quality systems standards

q) Supplier responsiveness and modification capabilities

r) Design and innovative capabilities of supplier

s) Participative and collaborative approach with the suppliers

6.4.2 Dimensions of the Design

The above categories were scrutinized to include them or exclude any of them for the design. All of these have been included and considered as the dimensions of the design.
6.4.3 Clustering

The dimensions were put into broader categories called clusters. The principles have already been explained. These are shown in the next section.

6.4.4 Sequencing of Clusters and Dimensions within Clusters

Following the clustering of the dimensions, the clusters were put into sequence as per the importance of an area. The sequencing of dimensions within clusters was then carried out. The resultant clusters with sequenced dimensions are given below:

i. Innovation, design and development
   a. Customized products for new market creation
   b. Delivery of innovativeness in design of products
   c. Development of technology in house and sourcing practices

ii. Market responsiveness
   a. Process and product improvements
   b. Flexibility in manufacturing
   c. Reduction of lead time to product development

iii. Vendor consolidation and development
   a. Supplier responsiveness and modification capabilities
   b. Design and innovative capabilities of supplier
   c. Participative and collaborative approach with the suppliers

iv. Business strategy and performance
   a. Customer focus and commitment
   b. Market leadership through pro activeness
   c. Techno-socio-environmental aspect
   d. Economic and viable strategies
   e. Quality systems standards

v. Keeping pace with technology
   a. Development / fostering of next generation technology
   b. Technology acquisitions, adoption, adaptation, collaboration, tie-ups, etc
   c. System design and implementation
d. Investment in Soft and hard technologies

e. Develop in-house research and development capabilities

6.4.5 Options Profile Methodology

Various profiles or courses of action planned to achieve different dimensions of manufacturing flexibility at tactical and strategic level, for the purpose of this study are delineated as follows:

I. **Outsourcing based approach (OS)**, i.e. achieving manufacturing flexibility primarily by outsourcing of sub strategic non-core activities in manufacturing and these may include:
   - Supplier responsiveness to schedule volume changes and process design changes
   - Supplier assistance in process improvement and speed of capacity changeover in manufacturing system
   - Supplier involvement in managing rapid change in product variety

II. **Strategic Sourcing based approach (SS)**, i.e. achieving manufacturing flexibility primarily by involving supplier in manufacturing, design and development aspects. In strategic sourcing, the competencies provided by the supplier network contain a high degree of knowledge and are those most complementary to in-house core competencies.
   - Strategic sourcing targets the acquisition of supplier capabilities in alignment with purchasing, manufacturing, and corporate needs, with considerable lower risk exposure and greater responsiveness.

Furthermore, activities commonly associated with strategic sourcing include partnerships, cross-functional activities, joint planning meetings, and shared information systems.

III. **Design Technology based approach (TD)**, i.e. achieving manufacturing flexibility primarily by investment in manufacturing design technology and these may include:
   - Computer aided engineering (CAE)/ Computer aided testing
   - Computer aided design (CAD)
IV. **Manufacturing Technology based approach** ($T_M$), i.e. achieving manufacturing flexibility primarily by investment in manufacturing technology and these may include:

- Flexible manufacturing system (FMS)
- Computer aided manufacturing (CAM)
- Computerized numerical control machines (CNC)
- Robotics and Group technology

V. **Infrastructural Technology based approach** ($T_I$), i.e. achieving manufacturing flexibility primarily by investment in infrastructural technology and these may include:

- Intermediate technologies (AMHS, AS/RS)
- Soft technologies to schedule production (MRP, MRPII, KANBAN/ JIT)
- Administrative technologies (ERP, ABC, OA)

After deciding upon various profiles, the next task performed has been to find out the options from each cluster contributing to each profile. For this purpose, completed option fields have been displayed. A tie line has been drawn on the bottom. Each option contributing to a profile has been joined to the tie line through its bullet. This has been shown in Figure 6.3.

**6.4.6 Analytic Hierarchy Process Modeling**

Manufacturing flexibility at tactical and strategic level in the scope of this research have already been discussed and analyzed in chapter IV of the study. These include achievement of:

i) Volume flexibility

ii) Modification flexibility

iii) Delivery flexibility

Next, paired comparison method of analytical hierarchy process has been applied to find out the weightages of each objective. Three respondents compared each objective with each other, independently. These were: technology manager of Maruti Suzuki India
limited, Gurgaon, R&D manager Punjab Tractors Limited and the researcher himself. The respondents compared the objectives on a qualitative scale of the difference between the importances of two criteria. They, however, wrote the response in quantitative terms by converting the qualitative response using the following scale.

<table>
<thead>
<tr>
<th>Equally important</th>
<th>Weakly more important</th>
<th>Strongly more important</th>
<th>Very strongly more important</th>
<th>Absolutely more important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

Matrices of these values as filled by the respondents are given in Appendix - G. These matrices also show the calculation of Eigen vector and the weights of the objectives. The weightings given by the respondents were quite consistent and the consistency ratio was found to be well within the limit of 10%.

The matrix containing weights of all the objectives as decided by various respondents is given in Table 6.1.

<table>
<thead>
<tr>
<th>Respondent Objective</th>
<th>Researcher</th>
<th>Sourcing Manager</th>
<th>Technology Manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Flexibility</td>
<td>0.081</td>
<td>0.221</td>
<td>0.105</td>
</tr>
<tr>
<td>Modification Flexibility</td>
<td>0.188</td>
<td>0.319</td>
<td>0.258</td>
</tr>
<tr>
<td>Delivery Flexibility</td>
<td>0.731</td>
<td>0.460</td>
<td>0.637</td>
</tr>
</tbody>
</table>

The role of delivery flexibility has been found to be the largely important, followed by modification and volume flexibility. This could be attributed to the fact that the organizations these days are more focused towards the deliverance of new or customized products quickly and flexibly for achieving competitive excellence in the dynamic business environment. Fast obsolesces of the existing technology and competitor strategies have also influenced the organizations to shift their focus towards strategic level flexibilities.

The relative weight scored by volume flexibility is less than other two types of flexibilities i.e. modifying flexibility and delivery flexibility. The reason can be recognized to the fact that these days the organizations easily restructure their existing processes quickly to the varying customer demands. Additionally, the role of supplier involvement at tactical level can be managed with ease.
6.4.7 *Fuzzy Set Theory*

After determining the weights of the objectives, the next step has been to make position matrices. In these matrices, the qualitative value of contribution of each profile or course of action to each objective has to be decided. Again, the three respondents have done this exercise. The position matrices along with the weights determined earlier are given in Appendix - H. From the position matrices, weighted position matrices have been determined. This has also been done individually for the matrix from each respondent. The weight of the objective as determined earlier has been multiplied by value of each position of the position matrix and weighted values have been obtained. Appendix - I shows the weighted position matrices.

From these weighted position matrices, optimistic, average and pessimistic weighted position matrices have been made using Fuzzy Set Theory. For optimistic matrix, the highest value of each position has been selected, for pessimistic the lowest values and for average matrix, the average values have been selected. Tables 6.2 to 6.4 show these values.

### Table 6.2 Optimistic weighted position matrix

<table>
<thead>
<tr>
<th>Profile &amp; Objectives</th>
<th>Outsourcing based approach</th>
<th>Strategic Sourcing based approach</th>
<th>Design Technology based approach</th>
<th>Manufacturing Technology based approach</th>
<th>Infrastructural Technology based approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Flexibility</td>
<td>0.1548</td>
<td>0.0663</td>
<td>0.0663</td>
<td>0.1548</td>
<td>0.1548</td>
</tr>
<tr>
<td>Modification Flexibility</td>
<td>0.1808</td>
<td>0.1808</td>
<td>0.1808</td>
<td>0.2232</td>
<td>0.1595</td>
</tr>
<tr>
<td>Delivery Flexibility</td>
<td>0.2192</td>
<td>0.6576</td>
<td>0.5115</td>
<td>0.2192</td>
<td>0.3220</td>
</tr>
</tbody>
</table>

### Table 6.3 Pessimistic weighted position matrix

<table>
<thead>
<tr>
<th>Profile &amp; Objectives</th>
<th>Outsourcing based approach</th>
<th>Strategic Sourcing based approach</th>
<th>Design Technology based approach</th>
<th>Manufacturing Technology based approach</th>
<th>Infrastructural Technology based approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Flexibility</td>
<td>0.0729</td>
<td>0.0243</td>
<td>0.0243</td>
<td>0.0524</td>
<td>0.0567</td>
</tr>
<tr>
<td>Modification Flexibility</td>
<td>0.0942</td>
<td>0.1319</td>
<td>0.0942</td>
<td>0.1291</td>
<td>0.1291</td>
</tr>
<tr>
<td>Delivery Flexibility</td>
<td>0.1380</td>
<td>0.3220</td>
<td>0.3185</td>
<td>0.1380</td>
<td>0.1911</td>
</tr>
</tbody>
</table>
Table 6.4 Average weighted position matrix

<table>
<thead>
<tr>
<th>Profile</th>
<th>Outsourcing based approach</th>
<th>Strategic Sourcing based approach</th>
<th>Design Technology based approach</th>
<th>Manufacturing Technology based approach</th>
<th>Infrastructural Technology based approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume Flexibility</td>
<td>0.1073</td>
<td>0.0407</td>
<td>0.0407</td>
<td>0.0933</td>
<td>0.1019</td>
</tr>
<tr>
<td>Modification Flexibility</td>
<td>0.1448</td>
<td>0.1574</td>
<td>0.1448</td>
<td>0.1614</td>
<td>0.1402</td>
</tr>
<tr>
<td>Delivery Flexibility</td>
<td>0.1828</td>
<td>0.5176</td>
<td>0.3840</td>
<td>0.1828</td>
<td>0.2441</td>
</tr>
</tbody>
</table>

Based on above optimistic, pessimistic and average weighted position matrices, other matrices have been computed at various degrees of optimism (80%, 60%, 40% and 20%) and tabulated in Appendix – J.

India, at the moment, is passing through a transition phase. After the IT boom, a manufacturing revolution has been well underway in the Indian economy, spurred on by the increasing presence of multinationals, scaling up of operations by the domestic companies and expanding domestic market. The sector has been averaging 9 per cent in the last four years (2004-08), with a record 12.3 per cent in 2006-07. India's manufacturing base, which is the fourth-largest among emerging economies, is among the fastest growing and has seen more investments as a proportion of gross domestic product than any country except China. However, global competition has already reached the unprecedented levels and India has to fully develop its manufacturing industry in line with global leaders in coming years. In such circumstances, a pessimistic approach in managing manufacturing flexibility is not expected to succeed. On the other hand, a pure optimistic approach may also not yield the desired results because of the lack in Infrastructural and technological competence, deficiency in structural factors and the level of buyer-supplier orientation existing in the country. Additionally, current scenario in the global market in terms of economic imbalances and manufacturing recession also put a cap for the implementation of optimistic approach to certain extent. In such a scenario, a cautious optimism approach with quite a high degree of optimism may be employed.

The outcome of weighted position matrices for optimism, pessimistic, average and different cautious approaches have been compiled in the Table 6.5, which depicts the comparative association between different flexibilities and various profiles.
Table 6.5 Preferred strategies under cautious optimism for achieving various flexibilities

<table>
<thead>
<tr>
<th>Objective &amp; Flexibility</th>
<th>Optimistic</th>
<th>80% Optimistic</th>
<th>60% Optimistic</th>
<th>40% Optimistic</th>
<th>20% Optimistic</th>
<th>Pessimistic</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Flexibility</td>
<td>T1-OS-TM</td>
<td>OS- T1-TM</td>
<td>OS- T1-TM</td>
<td>OS- T1-TM</td>
<td>OS- T1-TM</td>
<td>OS- T1-TM</td>
<td>OS- T1-TM</td>
</tr>
<tr>
<td>Modification Flexibility</td>
<td>Tm- Td- SS</td>
<td>Tm- SS-Td</td>
<td>Tm- SS-Ti</td>
<td>Tm- SS-Ti</td>
<td>Tm- SS-Ti</td>
<td>SS- Tm- Ti</td>
<td>Tm- SS-Ti</td>
</tr>
<tr>
<td>Delivery Flexibility</td>
<td>SS- Td- Ti</td>
<td>SS- Td- Ti</td>
<td>SS- Td- Ti</td>
<td>SS- Td- Ti</td>
<td>SS- Td- Ti</td>
<td>SS- Td- Ti</td>
<td>SS- Td- Ti</td>
</tr>
</tbody>
</table>

(OS- Outsourcing based approach; SS- Strategic sourcing based approach; Td - Design technology based approach; Tm- Manufacturing technology based approach; Ti, Infrastructural technology based approach)

The following observations have been outlined from the Hadley’s matrix of cautious optimism as detailed in Table 6.5.

- Outsourcing of sub strategic activities in manufacturing and investment in infrastructural and manufacturing technology has significantly influenced the achievement of volume flexibility in Indian large and medium scale manufacturing organizations in most of the optimism conditions. Involvement of suppliers in managing volume changes requests has emerged as a foremost aspect followed by investment in infrastructural and manufacturing technology.

- Investment in manufacturing and design technology has primarily influenced the achievement of modification flexibility in most of the matrices conditions closely followed by involvement of supplier in managing minor product and process modifications requests. However, in pessimistic conditions, the role of supplier has become strategic in nature and the organizations tend to use the knowledge and technological competencies of supplier base. Further, the outsourcing of manufacturing activities and investment in manufacturing technology has moderately influenced the achievement of modification flexibility in pessimistic conditions.

- Rapid delivery of innovative products, customized products for creation of new market and delivery differentiations has been the key aspects of the delivery
flexibility. The strategic role of supplier base has emerged to be the primary and most important aspect in achieving delivery flexibility. The organizations tend to maintain a long-term relationship and achieve delivery flexibility by involving supplier in manufacturing and design and development aspects. Further, the investment in design technology and infrastructural technology has influenced the achievement of delivery flexibility.

Following this, dominance matrices have been prepared. In these matrices, the dominance of each course of action over the others has been tabulated. The cell value denotes that a course of action dominates other courses of action in how many criteria and it is dominated by another course of action in how many criteria. In the matrix, profile written on the top, dominates the profile written on the left. Thus, row sum depicts the number by which a criterion is dominated and the column sum depicts the number by which the profile dominates all other profiles.

The matrices are presented in Table 6.6 to Table 6.9.

### Table 6.6 Dominance matrix - optimistic

<table>
<thead>
<tr>
<th>Profile</th>
<th>OS</th>
<th>SS</th>
<th>T_D</th>
<th>T_M</th>
<th>T_I</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>--</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SS</td>
<td>1</td>
<td>--</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>T_D</td>
<td>1</td>
<td>1</td>
<td>--</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>T_M</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>T_I</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Column Sum</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Rank</td>
<td>V</td>
<td>II</td>
<td>III</td>
<td>I</td>
<td>III</td>
</tr>
</tbody>
</table>

In the optimism dominance matrix, ‘manufacturing technology based approach’ has emerged as the preferred strategy for achieving manufacturing flexibility at strategic and tactical level. Further, ‘design technology based approach’, and ‘Infrastructural technology based approach’ have occupied the second position, followed by outsourcing and strategic sourcing based approach.
Table 6.7 Dominance matrix - pessimistic

<table>
<thead>
<tr>
<th>Profile</th>
<th>OS</th>
<th>SS</th>
<th>TD</th>
<th>TM</th>
<th>TI</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>--</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>SS</td>
<td>1</td>
<td>--</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TD</td>
<td>1</td>
<td>2</td>
<td>--</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>TM</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>--</td>
<td>2</td>
</tr>
<tr>
<td>TI</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td>Column Sum</td>
<td>4</td>
<td>8</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Rank</td>
<td>II</td>
<td>I</td>
<td>V</td>
<td>III</td>
<td>II</td>
</tr>
</tbody>
</table>

The result of pessimistic matrix depicts the significant importance of strategic sourcing and infrastructural technology for achieving manufacturing flexibility at strategic and tactical level.

Table 6.8 Dominance matrix - average

<table>
<thead>
<tr>
<th>Profile</th>
<th>OS</th>
<th>SS</th>
<th>TD</th>
<th>TM</th>
<th>TI</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>--</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SS</td>
<td>1</td>
<td>--</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>TD</td>
<td>1</td>
<td>2</td>
<td>--</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>TM</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>--</td>
<td>2</td>
</tr>
<tr>
<td>TI</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Column Sum</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Rank</td>
<td>III</td>
<td>I</td>
<td>V</td>
<td>II</td>
<td>III</td>
</tr>
</tbody>
</table>

In average dominance matrix, ‘manufacturing technology based approach’, ‘design technology based approach’, and ‘infrastructural technology based approach’ have emerged as the preferred strategies as all the three have been ranked as number one, followed by ‘strategic sourcing based approach’ that seems to be a emerging approach in the large scale Indian manufacturing organizations.

The similar dominance matrices for various degrees of optimism (80%, 60%, 40% and 20%) have been compiled in Appendix – K. The results of Hadley’s dominance matrix of cautious optimism are also in line with the optimistic and the average matrix.

The results of all the dominance matrices have been summarized in Table 6.9.
### Table 6.9 Hadley’s matrix of cautious optimism

<table>
<thead>
<tr>
<th>Rank Profile</th>
<th>Optimistic</th>
<th>80% Optimistic</th>
<th>60% Optimistic</th>
<th>40% Optimistic</th>
<th>20% Optimistic</th>
<th>Pessimistic</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outsourcing based approach, OS</td>
<td>V</td>
<td>III</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>Strategic Sourcing based approach, SS</td>
<td>II</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Design Technology based approach, T_D</td>
<td>III</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Manufacturing Technology based approach, T_M</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>III</td>
<td>III</td>
<td>III</td>
<td>II</td>
</tr>
<tr>
<td>Infrastructural Technology based approach, T_I</td>
<td>III</td>
<td>III</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
</tbody>
</table>

The results indicate that strategic sourcing based approach has affirmed as the most preferred strategy whereas design technology based approach has occupied the last (fourth) position for managing the manufacturing flexibility under all degrees of optimism. Infrastructural technology based approach and manufacturing technology based approach have occupied almost equal rank under various degrees of optimism. The dominance matrix for a high degree of optimism (80%) seems to be the most realistic strategy. In these matrices, strategic sourcing based approach has emerged as the most preferred strategy; manufacturing technology based approach has got the second rank, whereas infrastructural based approach, outsourcing based and design technology based approaches combined have come into sight as the preferred strategies ranked as number three and four respectively.

### 6.5 Discussion and Development of the Generic Plan

The manufacturing sector in India has been witnessing a paradigmatic shift in the recent years from mass production to mass customization resulting from ‘smarter’ production technologies and sourcing initiatives that are tailored to the needs of specific designs and customers. The manufacturing industry has been passing through a transformation phase where each organization is focusing its business strategy and processes towards the achievement of competitive excellence and providing customers with the optimized products quickly and flexibly. Underneath the current scenario, the impact of advanced manufacturing technology and sourcing practices have become imperative for achieving flexibility competence; cost competitiveness, quality conformance and delivery
differentiations for the organizations. Further, firms are likely to attain flexibility in manufacturing, deliver new or modified product and process design quickly and cost effectively as a result of their technological competence and planned use of supplier based sourcing practices. Though, the deployment of sourcing practices have attained marginal lead in delivery, flexibility and net profit aspect, new technology go ahead moderately in quality and market share. A system shift has been witnessed towards the achievement of strategic success with the rapid delivery of innovative and customized products to the customers. Results of qualitative modeling, which are in fact an outcome of opinion of the experts, taken in structured way depict the relative impact of technology and sourcing based approaches in achieving the volume, modification and delivery.

6.5.1 Preferred Approaches for achieving Volume flexibility

The strategic purpose of volume flexibility is to help cope with aggregate demand uncertainty. Volume flexibility permits the firm to adjust production upwards and downwards within wide limits. The outcome of the results in the domain of qualitative modeling portrays the relative importance of new technology and sourcing practices intended for achieving volume flexibility. The following approaches have found to be significantly important in order of their occurrence for the achievement of volume flexibility.

i. Outsourcing based approach

ii. Infrastructural technology based approach

iii. Manufacturing technology based approach

It has been inferred that for achieving volume flexibility, the foremost attention has to be given to outsourcing of sub strategic manufacturing activities. Systematic employment of sourcing practices has facilitated the firms to exploit the ability of their suppliers for quickly responding to the uncertainties in the dynamic market. The greater the deployment and use of sourcing practices (such as outsourcing, supply and distribution networks, and strategic alliances) are present within the organization; the greater the source of volume flexibility is available to the organization. Strategic sourcing also has a limited positive influence on the achievement of volume flexibility.

This has been followed by technology investment in manufacturing infrastructure including the explicit use of soft, administrative and intermediate technologies, in result strengthening the organization capabilities to handle rapid increase in production volumes.
and adjust the level of production quickly and profitably. Information and communication technology has played a significant role in achieving volume flexibility by the seamlessly integrating the various processes and information within and outside the organization. Integrated production control systems, such as manufacturing resource planning (MRP II) and enterprise resource planning systems (ERP), reduce inventories and raw materials, work-in progress and finished goods. Additionally, the organizations have redesigned their existing system and structure within the available facilities, for effectively managing the volume capacity and variability. Furthermore, the investments in AMHS, AS/RS and activity based costing (ABC) systems have moderately assisted the organizations to handle volume fluctuations in the dynamic market place.

Subsequently, the investment in manufacturing technology has assisted the organizations to achieve volume flexibility. Organizations have invested in upgrading their manufacturing capabilities by installing FMS, CNCs and Robots at their workplace for effectively managing the related capacity and demand issues. Role of manufacturing technology has always been imperative for the organizations to build their capacity and ability to handle demand fluctuations.

The systematic plan for explicating the role of technology and sourcing practices for achieving volume flexibility has been developed and presented in figure 6.4. It has been illustrated that the impact of outsourcing of manufacturing has a significant impact on the achievement of volume flexibility and further facilitated by the introduction of investment in infrastructural technology. Next, the manufacturing technology in supplement to outsourcing and infrastructure technology has largely impacted the attainment of volume flexibility. As the focus of an organization shift towards the accomplishment of core competencies (including lean and agile manufacturing, rapid product and process innovations and mass customization) as a result to the addition of manufacturing facilities in design and development stage and strategic sourcing aspect, the focus of the manufacturing firms have limited and constrained the scope of volume flexibility to some extent.

The framework depicts the results in the optimized environment where a manufacturing organization uses a blend of technology and sourcing as a part of their business strategy for achieving flexibility competence. It is further understood that for implementing the design technology in a manufacturing system, an organization must have attained the
desired level of competence in infrastructural and manufacturing technology vis-à-vis outsourcing prior to the strategy sourcing.

![Graph showing systematic plan for technology-sourcing-volume flexibility framework](image)

**Figure 6.4 Systematic plan for technology-sourcing-volume flexibility framework**

6.5.2 *Preferred Approaches for achieving Modification flexibility*

The following approaches have found to be significantly important in order of their occurrence for the achievement of modification flexibility.

i. Manufacturing technology based approach

ii. Strategic sourcing based approach

iii. Design technology based approach

The investment in manufacturing technology has primarily influenced the achievement of modification flexibility, closely followed by the strategic sourcing. This includes the augmentation of manufacturing facility with increased employment of advanced manufacturing technology and supplier competencies.

The potential benefits which can accrue from investments in advanced manufacturing technology, have become increasingly evident with growing global competition. AMT plays a major role in quality and flexibility improvements in large and medium scale enterprises. AMTs are a source of strategic competitive benefits, such as improved quality, greater flexibility, and cost reduction and may be used to alter the rules of competition in industries, in effect creating an environment in which the firm has a competitive edge based on its use. In this environment, the firms can frequently introduce
new or modified production processes and products with large numbers of varieties and features. They are, thereby, competing simultaneously along all manufacturing capability dimensions, leading to advantages in terms of modification flexibility. Work-in-progress and changeover time are becoming shorter through simplified change of tools, dies and product variants. Faster speed can also be gained through integrating design activities and manufacturing. Greater product variety can be derived from flexible and modular production set-up, but also from the use of group technology and flow oriented layouts. Introduction of modified products can occur more frequently through use of computer-aided manufacturing (CAM), since the manufacturing and design lead times may be shortened. Mass customization results from smarter production technology, which is tailored to the needs of specific designs and customers. The fact that there is less downtime required to shift between families of products or components can result in greater modification flexibility.

Further the role of supplier at strategic level has largely and positively impacted the achievement of modification flexibility. The cross functional and cross organizational synergies with the suppliers have created a level of performance needed to create competitive advantage and quickly deliver modifications in existing products, processes and design. Minor product and design modifications have been accomplished through the acquisition of supplier technological and performance capabilities. In addition, the adoption of design technology has moderately augmented the organizations capability to introduce modified products with high level of flexibility.

The systematic plan for explicating the role of technology and sourcing practices for achieving modification flexibility has been developed and presented in figure 6.5. The manufacturing technology in facilitation with the employment of strategic sourcing has significantly impacted the achievement of modification flexibility. Furthermore, the impact of infrastructure technology and outsourcing has been illustrated as moderately positive in the figure. Finally, the investment in design technology in addition to the infrastructure and manufacturing technology reasonably enhance the firm ability to respond to the customers changing demands for modified products. An organization, based upon its business strategy and market requirements can manage the modification flexibility by selecting a blend of technology and sourcing based approaches.
The ability of an organization to respond to market changes and rapid delivery of innovative, customized products has been felt as the prerequisite for achieving delivery flexibility and flexibility competence by most of the manufacturing organizations in the era of globalization. The following approaches have been found to be significant importance in order of their occurrence for the achievement of delivery flexibility.

i. Strategic sourcing based approach

ii. Design technology based approach

iii. Infrastructural based approach

The strategic role of supplier base has emerged to be the most important aspect in achieving the delivery flexibility. The organization and the supplier share corporate incentives specific to their integrative collaboration for improving business focus, accessing world-class capabilities and accelerate re-engineering benefits under the umbrella of strategic sourcing. The organizations tend to maintain a long-term relationship and achieve delivery flexibility by involving suppliers in manufacturing as well as design and development aspects. The findings suggest that strategic sourcing may be quite important to manufacturing organizations trying to compete through delivery flexibility competence. Supplier involvement in product design and supplier
responsiveness to rapid delivery of innovative products has found to benefit delivery flexibility.

Further, the investment in design technology has influenced the achievement of delivery flexibility. Introduction of new products can occur more frequently through use of computer-aided design, since the design lead times may be shortened. The design lead times and delivery of innovative products can significantly be shortened with the use of technology investment in manufacturing design. Design technologies, such as CAD, CAE, and the internet, support product design and engineering. They enable firms to work selectively with external designers, suppliers, and customers to compress product development and commercialization. The application of group technology and CAPP has improved process design, which enables firms to make a variety of related parts. The investment in this portal of technology will lead to the development of core competencies and hence market capabilities of the organizations. Improvements in overall quality may be achieved through automated inspection and testing, better production, information and the more accurate delivery performances.

This has been followed by technology investment in manufacturing infrastructure including the explicit use of soft, administrative and intermediate technologies. These will result in strengthening the organization capabilities to handle the shortening of the overall throughput time, allowing accurate delivery performances to be achieved. These technologies such as local area networking and enterprise-wide resource planning allow a flow of information and coordinated decision-making between functions within a firm and between firms and facilitate the flexibility competence of the firm. Apart from these, the role of technology investment in manufacturing has moderately influenced the attainment of delivery flexibility. Manufacturing technologies, such as CNC, CAM, and AMHS, make production easier and faster.

The systematic plan for explicating the role of technology and sourcing practices for achieving delivery flexibility has been developed and presented in figure 6.6. The impact of strategy sourcing has been found to be of utmost importance followed by the design technology as an instrument for achieving delivery flexibility.
6.5.4 Development of Technology-Sourcing -Flexibility Systematic Plan

Based upon the Hadley’s matrix of cautions optimism for dominance matrices employing optimism, average, pessimistic and cautious optimism approaches, presented in Table 6.9, inferences have been evolved concerning the impact of various approaches for achieving strategic and tactical level manufacturing flexibilities. These inferences have further paved the way for the development of technology-sourcing-flexibility systematic plan.

An optimistic dominance matrix approach has brought out the role of manufacturing technology at first place followed by the strategic sourcing. Investment in infrastructural and design technologies further strengthen the capabilities of the organization to achieve manufacturing flexibilities at tactical and strategic level.

In pessimistic approach, the role of strategic sourcing has played a significant role in achieving various tactical and strategic level flexibilities. The organizations focus their business towards the virtual organizations in this type of approach, with little in house investment in high-end manufacturing and design technologies. The role of supplier consistency, flexibility, competence and strategic relationships has paved the way to the achievement of various flexibilities. The organizations in addition also focuses on the outsourcing the manufacturing facilities and investment in infrastructural technology for achieving volume flexibility. These types of the organizations are referred as assemblers.
in the manufacturing industry. The investment in design technology has a least priority for these types of the organizations.

However, in case of average optimism the role of strategic sourcing and manufacturing technology has significantly influenced the accomplishment of manufacturing flexibilities at tactical and strategic level. The investment in infrastructural technology, outsourcing and design technology has also been considered important in order of their occurrence.

Further, Hadley's cautious optimism for 80%, 60%, 40% and 20% optimism level dominance matrices have also been considered for the studying the impact of different approaches on different flexibility dimensions. Analysis of different optimism levels have revealed the necessity of employing the varied technology and sourcing based approaches for the achievement of volume, modification and delivery flexibility. The current market scenario for the manufacturing industry may not yield the desired result for pure optimism approach because of underdeveloped manufacturing infrastructure and constrained research opportunities in the country. The high cost of technology acquisition, meager technological capabilities and restricted indigenization has also limited its scope and implementation. Finally, pure pessimistic approach may also not expected to succeed because suppliers’ integration in manufacturing and design system will lead to organizational complicacies, loss of control and confidentiality dependency. In such scenario, a cautious optimism approach with high degree of optimism has been employed.

The following approaches have found to be significantly important in order of their occurrence for the achievement of manufacturing flexibilities at tactical and strategic level.

i. Strategic sourcing based approach
ii. Manufacturing technology based approach
iii. Infrastructural technology and outsourcing based approach

There is a growing recognition of the deployment of sourcing practices for achieving the manufacturing flexibility. It is clear that sourcing has the potential to influence an organization’s flexibility in responding to market demands. The role of strategic sourcing has emerged to be a key area of focus where the organizations maintains a win-win situation with their key suppliers for effectively managing manufacturing flexibility needs at tactical and strategic level. Higher level of supplier competencies in technology and
allied areas in some of the processes has facilitated the strategic sourcing arrangement with key suppliers by the organizations. As a result the organizations can quickly respond to the changing market requirement, reduce time to market the new product mix and focus on strengthening their core competences. As representing a general trend, these factors expand the range of development options open to the organizations and increase the importance of the role of suppliers in the product and process development processes.

Further, the organizations must focus on the various aspects of technology, although in varied importance, for building and enhancing their core competencies. The role of manufacturing technology has been imperative for the organizations to become responsive to market fluctuations. Manufacturing technology, when properly implemented, monitored and evaluated, can improve the operating efficiency and effectiveness of the adopting organizations in terms of its manufacturing capabilities and flexibility. After putting the manufacturing technologies in place the organizations must focus on design technology through implementation of CAD/CAE and local R&D efforts for localization and indigenization of adopted technologies.

Infrastructural technology has considerably helped the organizations to integrate their operations and processes within the organizations and among the key suppliers, leading to cost reduction, enhanced flexibility and high profitability. Also, at tactical level, outsourcing of sub strategic manufacturing activities has helped the organizations to achieve flexibility at plant or tactical level.

Finally, based upon the outcome of qualitative analysis, a systematic plan for technology-sourcing-flexibility relation has been finally evolved and presented in figure 6.7, for achieving tactical and strategic level manufacturing flexibility. It has been concluded that the balanced and simultaneous use of new technology and sourcing practices has significantly helped the organizations to effectively manage the different manufacturing flexibilities. A system shift has been witnessed towards the significant and optimistic impact of strategic sourcing for managing the rapidly changing manufacturing flexibility needs. Moreover, the systematic implementation of manufacturing technology has also considerably enhance the flexibility competence of the organizations and followed by other technology and sourcing based approaches. The manufacturing organizations can follow the outcome of the proposed plan logically and sincerely for the accomplishment of business objectives related to flexibility aspect.
6.6 Concluding Remarks

The chapter presents at one place an extract of the vital essentials of this research effort especially outlining the design, conceptualization, implementation, analysis and interpretation of the results for achieving manufacturing flexibility at tactical and strategic level. Although the findings, which are based on the empirical study, case studies and qualitative modeling of medium and large scale firms are in the context of manufacturing organizations of north India, much of the implications and suggested management approaches are generic and can be applicable to manufacturing industries in India and to a little extent to other less developed countries.