CHAPTER VI

DEVELOPMENT OF AN IMPLEMENTATION PLAN FOR BUILDING TECHNOLOGICAL CAPABILITY

6.1 INTRODUCTION

This chapter presents inferences drawn from empirical study carried out in manufacturing industries 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 strategies for technology adoption and adaptation 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, a qualitative model has been developed for building technological capability showing preferred strategies under various conditions of optimism, pessimism, and realism.

6.2 SYNTHESIS OF LEARNING ISSUES

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

- Companies adopt and adapt new technologies mainly with these objectives:
  - to increase competitiveness,
  - to reduce costs
  - to increase product quality, and
  - to increase productivity

- Companies can build their technological capabilities by managing their technology adoption and adaptation in a flexible manner.
6.2.1 Issues concerning technology adoption

Specific issues that have emerged out of study of processes and practices at firm-level regarding technology adoption are:

- New technology is adopted to match the future requirement.
- New technology is adopted when its performance is proved.
- New technology is adopted for most important processes.
- Alternate process that can be developed in house for making new technology cost effective are considered before adopting new technology.
- Analysis based on past trends is carried out before going for new technology.
- Economic viability of new technology and analyze its quantitative and qualitative effects is studied.
- Consequential changes in related products and processes are considered.
- Manpower is involved from beginning of adopting new technology.
- Encouragement for adopting new technologies through government and its agencies is desired.
- Adoption of new cleaner technologies is required to meet government regulations related to environment or pollution control.
- Some incentives for cleaner technologies in industry policies are desired.
- Adoption of new technology is necessitated by opportunities and threats caused by the globalization.
- Easy availability of new technology due to globalization contributes for its adoption.
- Top management support is an indispensable prerequisite for new technology adoption.
- Formal manufacturing strategies address new technology adoption needs.
- Well defined objectives of new technology helps in its adoption.
- Understanding of new technology benefits is desired.
- Well defined technology adoption policies is desired.
- Inclusion of training of the employees at all levels in technology adoption policies is desired.
• Regular updation of technology adoption policies is desired.
• Human factor plays a crucial role in new technology adoption.
• In-house engineers actively participate in new technology adoption.
• Positive attitude of employees towards objectives of new technology adoption smoothens the process.
• For adopting new technology, formally qualified personnel are desired.

6.2.2 Issues concerning technology adaptation

• Redesigning the production systems to achieve ergonomics and safety layout of machines, standardization of equipment, effective use and presentation of controls and instrumentation and to ensure the smooth flow of materials is needed.
• Redesigning the organization structure, internal shifting of people and recruiting suitable persons from outside for successful adaptation of new technologies is needed.
• Imparting training to personnel and designing new methods of performance and efficiency measurement are also needed.
• Making efforts for employees’ acceptability of new technology are needed.
• Implementing some changes in product design and features, plans and procedures during technology adaptations.
• Staffing and production flexibilities considerably affect the adaptability of new technology.
• The effectiveness of the technology adaptation process can be considerably enhanced by empowerment; extensive training; open communication within the company; job security to employees; and rewards and recognitions.
• Government’s role in adaptation of new technology is very limited.
• The top management support is vital for technology adaptation.
• Readiness of top management for taking short term risks for long term benefits is desired.
• Availability of skilled workers helps in easy adaptation of new technology.
• Technocratization facilitates technology adaptation.
• Employees’ willingness to accept changes is beneficial for technology adaptation.
• In-house R&D is very important for new technology adaptation.
• Technology adaptation policies are lacking.

6.2.3 Issues concerning technological capabilities

• Awareness about role of technology in companies’ competitiveness is a must.
• Monitoring external technology events and trends is desired.
• Defining individual technological strengths and building up a unique advantage in each specific area are desired.
• Formulation of a technology strategy is a key part of the overall business strategy.
• Collection of information on range of available technological options, quick choice among competing solutions and identification of most appropriate sources to fulfill the needs are required.
• Deployment of resources to exploit the selected technological option is carried out by two options: (a) development of in-house technology facilitated by R&D, and (b) acquisition of new technology through joint venture / technology licensing.
• Implementation of acquired technology via its adaptation or reconfiguration.
• Review of technology projects and processes within the firm to learn from success or failures.
• Maintenance and nurturing links with different kinds of external organizations for getting many technology related services is desired.
• Carrying out continuous improvements in all technological related activities and components is desired.
• Effective utilization of available technologies for transformation of raw material into finished goods.
• Utilization of relevant technologies in distribution, service and sale of products.
• Development of process development technologies by reverse engineering the acquired technology with product / process innovations.

6.3 METHODOLOGY FOR MODELING

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, 1994). A brief description of the model is given below.
The modeling began with listing of options as a solution to flexible management of new technology adoption and adaptation for building technological capabilities. The list was converted into a conceptual design. OFM/OPM (Warfield 1979, 1982, 1990) was largely used as a basis for this purpose. Lastly, the alternative options profiles developed were ranked using AHP (Saaty, 1980) and FST (Zadeh 1965).

### 6.3.1 Options field / Options profile methodology

In order to adapt the method of idea writing to design as Warfield (1979) – using the team idea management – introduced a methodology for the conceptual design of systems which results into a portrayal on one page of the products of a conceptual design. 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.

**Figure 6.1 Qualitative modeling**

<table>
<thead>
<tr>
<th>OFM</th>
<th>OPM</th>
<th>AHP</th>
<th>FST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generating various options</td>
<td>Deciding various profiles or courses of action.</td>
<td>Deciding the objectives or features of design.</td>
<td>Quantifying the contribution of each profile to each objective by making position matrices.</td>
</tr>
<tr>
<td>Putting options in categories</td>
<td>Assigning options from options fields to profiles.</td>
<td>Deciding weightage of features though paired comparison.</td>
<td>Making weighted position matrices.</td>
</tr>
<tr>
<td>Clustering the dimensions and sequencing</td>
<td></td>
<td></td>
<td>Ranking the profiles under various schemes by dominance.</td>
</tr>
</tbody>
</table>

**Figure 6.2 Four level structure quad**

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 neither be 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 the purpose of 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.

c) *Naming the categories:* Following the placing of options into categories, options are displayed as sets, arrayed vertically in anticipation of developing a name for each category that will be placed at the head of the appropriate column options.

d) *Identifying 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.
Discovering Clusters of dependent dimensions: Once the group has settled on the dimensions of the target, a second structuring occurs. Now it is the set of dimensions that 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.

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.”

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.

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 a \( n \) by \( n \) reciprocal judgment matrix. In this 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 of elements. 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:

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

Values 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 seriousness of 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 \( X_{\text{max}} \) 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 as given by Saaty and Kearns (1985) are:

<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 blurred 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 \( \mu(X) = 0.5 \) 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, systems 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 viewpoints 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 represent 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 d_{ij} 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 d_{ij} element. If the K^{th} column is summed, the total number of dominances of option K over all options is obtained. Similarly, if the K^{th} row is summed, the number of times the K^{th} option is being dominated by all other options is determined. More favorable outcomes 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. 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 : \[ W = \alpha \times A + (1-\alpha) \times B. \]

Since the process of choosing the coefficient of optimism 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. Consider increased competitiveness as first objective of new technology adoption and adaptation.
2. Consider improved product quality as second objective.
3. Consider improved productivity as third objective.
5. Adopt new technology to match the future requirement.
6. Adopt new technology when its performance is proved.
7. Adopt new technology for most of the important processes.
8. Consider those alternate processes that can be developed in house for making new technology cost effective.
9. Conduct analysis of the past trends before going for new technology.
10. Study economic viability of new technology
11. Analyze quantitative and qualitative effects of new technology.
12. Consider consequential changes in related products and processes.
13. Involve the manpower from the very beginning of new technology adoption.
15. Adopt new and cleaner technologies because of environment or pollution related regulations of government
16. Avail incentives for new technology adoption through industry policies.
17. Consider opportunities or threats of the globalization for new technology adoption.
18. Consider availability of new technology due to globalization.
19. Consider availability of top management’s support for new technology adoption.
20. Develop formal manufacturing strategies to include new technology adoption needs.
21. Understand the benefits of new technology.
22. Define clearly the objectives of new technology.
23. Formulate and use the technology adoption policies.
24. Regularly update technology adoption policies.
25. Identify role of Human factor in new technology adoption.
26. Involve manpower in the process of new technology adoption
27. Make participation of in-house engineers in new technology adoption.
28. Align the attitude of employees towards objectives of new technology adoption.
29. Provide formal education and training programmes for employees at all levels through technology adoption policies.
30. Redesign the production systems to achieve ergonomics and safety layout of machines,
31. Standardize the equipment
32. Plan effective use and presentation of controls and instrumentation
33. Ensure smooth flow of materials.
34. Redesign the organization structure for adaptation
35. Shift people internally for adaptation
36. Recruit suitable persons from outside for adaptation.
37. Impart extensive training to concerned personnel.
38. Design new methods of performance and efficiency measurement.
39. Put efforts to make new technology acceptable to employees.
40. Implement changes in manufacturing during technology adaptations.
41. Alter product design and features during technology adaptations
42. Change plans and procedures for technology adaptations.
43. Empowerment of employees
44. Facilitate open communication within the company
45. Provide job security to employees
46. Implement mechanism for rewards and recognitions for enhancing the effectiveness of technology adaptation.
47. Consider role of government in adaptation of new technology.
48. Take top management’s support for technology adaptation
49. Arrange sufficient funds for technology adaptation.
50. Take short term risks in order to have long term pay offs.
51. Consider availability of skilled workers.
52. Technocratization in the company.
53. Make employees willing to accept changes.
54. Develop in-house R&D.
55. Formulate well the technology adaptation policies.
56. Include procedures and practices in technology adaptation policies
57. Remain aware of role of technology in company’s competitiveness.
58. Scan or monitor external technology events and trends.
59. Define individual technological strengths and build up a unique advantage in specific area.
60. Formulate a technology strategy as a key part of the overall business strategy.
61. Gather information on range of technological options available.
62. Choose quickly among competing solutions
63. Identify the most appropriate source which fits with its needs.
64. Deploy resources to exploit the selected technological option either by creating technology through in-house R&D or by acquiring it through a joint venture / technology licensing or otherwise.
65. Implement the acquired technology which may involve various stages like its adaptation or reconfiguration.
66. Reflect upon and review technology projects and processes within the firm in order to learn from success or failures.
67. Maintain links with different kinds of external organizations which may provide them technology related services.
68. Carry out continuous improvements in all technological related activities and components.
69. Effectively utilize available technologies for transformation.
70. Utilize the relevant technologies in distributing, selling or servicing its outputs.
71. Utilize process development technologies.
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) Building technological capabilities through acquiring, transforming, vending, modifying and innovating capabilities.

b) Setting short term and long term goals

c) Planning, analysis and validation in detailed

d) Setting objectives of new technology adoption and adaptation.

e) Getting top Management support

f) Allocating funds for various technological activities.

g) Formulating technology adoption and adaptation policies

h) Retaining trained and skilled workforce

i) Creating special teams and departments

j) Involving all concerned

k) Developing human resource development through formal education and trainings.

l) Making sustained and regular efforts

m) Reviewing technology upgradation plans

n) Formulating manufacturing strategy

o) Focusing on the entire problem

p) Developing economic and viable strategies

q) Implementing system / structural changes

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

These dimensions were classified into broader categories called clusters. The principles of clustering have already been explained. Clusters 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:

i. Development of appropriate strategies
   a. Focusing on the entire problem
   b. Developing economic and viable strategies
   c. Implementing system / structural changes

ii. Continuous improvement
   a. Making sustained and regular efforts
   b. Reviewing technology upgradation plans
   c. Formulating manufacturing strategy

iii. Involvement and development of human resource
   a. Creating special teams and departments
   b. Involving all concerned
   c. Developing human resource development through formal education and trainings.

iv. Professionally managed companies
   a. Setting objectives of new technology adoption and adaptation.
   b. Getting top Management support
   c. Allocating funds for various technological activities.
   d. Formulating technology adoption and adaptation policies
   e. Retaining trained and skilled workforce

v. Strategic planning
   a. Building technological capabilities through acquiring, transforming, vending, modifying and innovating capabilities.
   b. Setting short term and long term goals
   c. Planning, analysis and validation in detailed
6.4.5 Options profile methodology

Various profiles or courses of action identified for flexible management of new technology for developing its technological capabilities are:

I. **Hard technology adoption approach**: A firm can adopt new technologies directly for its manufacturing applications, such as, CNCs, robots, FMS, AS/RS etc. These may include:

- Adoption of new technologies to match the future requirements.
- Adoption of new technologies for most of the important processes.
- Sustained and regular efforts
- Creation of facilities
- Manufacturing strategy and technology adoption policies.

II **Soft technology adoption approach**: A firm can also adopt new technologies for manufacturing support activities like design softwares or other infrastructural technologies, such as, ICT, ERP, MRP, JIT, GT etc.

III **Technology adaptation approach**: A firm may go in for localizing adopted technology (hard or soft or both) to make those appropriate for use in existing system. These may include:

- Standardization of the equipment
- Effective use and presentation of controls and instrumentations
- Measures to ensure smooth flow of material
- New methods for productivity measurements
- Joint R&D efforts

IV **System adaptation approach**: In this approach, a firm makes changes in its existing system to make it appropriate for new technology like redesign of production system or organizational structure, changes in practices and procedures etc. Activities in this approach may include:

- Re-design of existing production systems.
- Redesign of existing organizational structure
- Internal shifting of people
- Fresh recruitment of suitable manpower.
<table>
<thead>
<tr>
<th>Development of appropriate strategies</th>
<th>Continuous improvement</th>
<th>Involvement and development of human resources</th>
<th>Professionally managed companies</th>
<th>Strategic planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible management of technology adoption and adaptation for building technological capabilities.</td>
<td>Adopt new technology to match the future requirement.</td>
<td>Involve the manpower from the beginning of new technology adoption.</td>
<td>Making Increased competitiveness as first objective of new technology adoption and adaptation.</td>
<td>Awareness of role of technology.</td>
</tr>
<tr>
<td>Adopt new technology when its performance is proved.</td>
<td>Adopt new technology for most of the important processes.</td>
<td>Provide training to employees through technology adoption and adaptation policies</td>
<td>Making Improved Product Quality as second objective</td>
<td>Scan or monitor external technology events and trends.</td>
</tr>
<tr>
<td>Consider the alternate process that can be developed in house for making new technology cost effective.</td>
<td>Formal manufacturing strategies to include new technology adoption needs.</td>
<td>Active participation of in-house engineers in new technology adoption.</td>
<td>Making Improved Productivity as third objective.</td>
<td>Define individual technological strengths and build up a unique advantage in specific area.</td>
</tr>
<tr>
<td>Conduct analysis based on the trends of the past years before going for new technology.</td>
<td>Regular updating of technology adoption and adaptation policies.</td>
<td>Align the attitude of employees towards objectives of new technology.</td>
<td>Top management’s full support for new technology adoption and adaptation.</td>
<td>Formulate a technology strategy as a key part of the overall business strategy.</td>
</tr>
<tr>
<td>Study economic viability of new technology and analyze its quantitative and qualitative effects.</td>
<td>Encouragement of companies to adopt new technologies by the government through its agencies.</td>
<td>Formal education and training programmes for employees at all levels.</td>
<td>Understand the benefits of new technology.</td>
<td>Gather information on range of technological options available, choose quickly among competing solutions and identify the most appropriate source which fits with its needs.</td>
</tr>
<tr>
<td>Consider consequential changes in related products and processes.</td>
<td>Availability of new technology due to globalization.</td>
<td>Empowerment</td>
<td>Well defined and clear objectives of new technology.</td>
<td>Deploy resources to exploit the selected technological option either by creating technology via in-house R&amp;D or by acquiring it through a joint venture or technology licensing.</td>
</tr>
<tr>
<td>Adopt new cleaner technologies</td>
<td>Carry out continuous improvements in all technological related activities and components.</td>
<td>Design new methods of performance and efficiency measurement.</td>
<td>Put in efforts to make new technology acceptable to employees.</td>
<td>Implement the acquired technology which may involve various stages like its adaptation or reconfiguration.</td>
</tr>
<tr>
<td>Avail incentives for cleaner technologies adoption through Industry policies.</td>
<td></td>
<td>Availability of skilled workers.</td>
<td>Open communication within the company, Job security.</td>
<td>Reflect and review technology projects and processes within the firm in order to learn from success or failures.</td>
</tr>
<tr>
<td>Consider the opportunities or threats caused by the globalization as a justified reason to adopt new technology.</td>
<td></td>
<td>Technocentrism.</td>
<td>Availability and thorough use of well defined technology adoption policies.</td>
<td>Maintain links with different kinds of external organizations which may provide them technology related services.</td>
</tr>
<tr>
<td>Formulate, update and use the technology adoption policies.</td>
<td></td>
<td>Employees’ willingness to accept changes.</td>
<td>Existing staffing flexibility and production flexibility.</td>
<td>Effectively utilize available technologies for transformation.</td>
</tr>
<tr>
<td>Redesign the production systems to achieve ergonomics and safety layout of machines.</td>
<td></td>
<td>Rewards and recognition</td>
<td>Allocation of sufficient funds for new technology adoption and adaptation.</td>
<td>Utilize the relevant technologies in distributing, selling or servicing its outputs.</td>
</tr>
<tr>
<td>Standardization of equipment.</td>
<td></td>
<td></td>
<td>Willingness of top management for taking short term risks in order to have long term payoffs.</td>
<td></td>
</tr>
<tr>
<td>Plan effective use and presentation of controls and instrumentation.</td>
<td></td>
<td></td>
<td>Existence of well laid technology adaptation policies.</td>
<td>Utilize process development technologies.</td>
</tr>
<tr>
<td>To ensure the smooth flow of materials.</td>
<td></td>
<td></td>
<td>Develop in-house R&amp;D.</td>
<td></td>
</tr>
<tr>
<td>Redesign the organization structure, internally shift people or recruit suitable persons from outside for successful adaptation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implement changes in manufacturing, product design and features, plans and procedures during technology adaptations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alter product design, features, plans and procedures during technology adaptations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend

Hard Technology Adoption Approach

Soft Technology adoption Approach

Technology Adaptation Approach

Systeme Adaptation Approach

Figure 6.3 Options Profile Methodology
• Formal Evaluation Systems
• Effective co-ordination system
• Empowerment, job security, rewards and recognitions
• Open communication in organization
• Creation of special teams, departments
• Involvement of all concerned
• Human resource development

After identifying various profiles or approaches, the next task was 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 Fig. 6.3 (OPM).

6.4.6 Analytic hierarchy process modeling

Technological capabilities have been categorized in five following categories (Paul, 2004).

• Acquiring Capabilities
• Transforming Capabilities
• Modifying Capabilities
• Vending Capabilities
• Innovating Capabilities

Each of these capabilities has to be individually developed by the companies for building overall technological capabilities. Among these five categories of technological capabilities, the acquiring capabilities and vending capabilities can be developed by almost all organizations as these are not very critical. A company may not need capability of a higher level to acquire technology as a lot of commercial / general technologies are available, which do not require some special selection criterion. Any company can outsource its vending capabilities easily without significantly affecting its technological capabilities. So, the critical capabilities that make the difference in overall technological capabilities of a company include other three types of capabilities i.e. transforming capability, modifying capability and innovating capability. The further analysis is done considering these three capabilities.
Paired comparison method of analytical hierarchy process was applied to find out the weightage of each objective. Each objective was compared with each other, independently by three respondents. These were: technology manager of Swaraj Enterprises; General Manager, R&D, Maruti Udyog Limited and the researcher himself. The respondents compared the objectives on a qualitative scale of the difference between the importance of two criteria. They, however, wrote the response in quantitative terms by converting the qualitative response using the following scale.

<table>
<thead>
<tr>
<th></th>
<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></td>
<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 – F. These matrices also show the calculation of Eigen vector and the weights of objectives. The weightages 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 participants is given in Table 6.2.

<table>
<thead>
<tr>
<th>Participant ⊗ Objective ⊘</th>
<th>Researcher</th>
<th>Technology Manager</th>
<th>R&amp;D Manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transforming Capabilities</td>
<td>0.156</td>
<td>0.105</td>
<td>0.114</td>
</tr>
<tr>
<td>Modifying Capabilities</td>
<td>0.185</td>
<td>0.258</td>
<td>0.405</td>
</tr>
<tr>
<td>Innovating Capabilities</td>
<td>0.659</td>
<td>0.637</td>
<td>0.481</td>
</tr>
</tbody>
</table>

The role of innovating capabilities has been found to be foremost among other categories followed by modifying capabilities and then transforming capabilities for building overall technological capabilities of organizations. Relative weightages scored by transforming capability are quite less than other two types of capabilities i.e. modifying capability and innovating capabilities. This could be attributed to the fact that for building firm-level technological capabilities, the innovating capabilities and modifying capabilities have bigger roles to play. Most of the companies can adopt and use technology for transforming their raw materials into finished goods, but only a few can modify these technologies to suit their requirements, and further a very few of these companies can learn from these technologies and then innovate new technologies on their own. So the
highest level of technological capability is achieved when a firm develops innovating capability.

6.4.7 **Fuzzy set theory**

After determining the weights of the objectives, the next step was to make position matrices. In these matrices, the qualitative value of contribution of each profile or approach to each of the three capabilities was to be decided. This exercise was done by each of the three participants independently. The position matrices along with the weights determined earlier are given in Appendix – G.

From the position matrices, weighted position matrices were determined. This has also been done individually for the matrix from each respondent. The weight of the objective as determined earlier was multiplied by value of each position of the position matrix and weighted values were obtained. Appendix – H shows the weighted position matrices.

From these weighted position matrices, optimistic, average and pessimistic weighted position matrices were made using Fuzzy Set Theory. For optimistic matrix, the highest value of each position was selected, for pessimistic the lowest values and for average matrix, the average values were selected. Tables 6.3 to 6.5 show these values.

<table>
<thead>
<tr>
<th>Profile Objectives</th>
<th>Hard technology adoption approach</th>
<th>Soft technology adoption approach</th>
<th>Technology Adaptation approach</th>
<th>System Adaptation approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transforming Capabilities</td>
<td>0.1406</td>
<td>0.0781</td>
<td>0.1093</td>
<td>0.0798</td>
</tr>
<tr>
<td>Modifying Capabilities</td>
<td>0.2027</td>
<td>0.1291</td>
<td>0.2838</td>
<td>0.2027</td>
</tr>
<tr>
<td>Innovating Capabilities</td>
<td>0.3293</td>
<td>0.4459</td>
<td>0.5928</td>
<td>0.5733</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Profile Objectives</th>
<th>Hard technology adoption approach</th>
<th>Soft technology adoption approach</th>
<th>Technology Adaptation approach</th>
<th>System Adaptation approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transforming Capabilities</td>
<td>0.0733</td>
<td>0.0570</td>
<td>0.0524</td>
<td>0.0524</td>
</tr>
<tr>
<td>Modifying Capabilities</td>
<td>0.0926</td>
<td>0.0556</td>
<td>0.1296</td>
<td>0.1296</td>
</tr>
<tr>
<td>Innovating Capabilities</td>
<td>0.1442</td>
<td>0.1976</td>
<td>0.3364</td>
<td>0.3364</td>
</tr>
</tbody>
</table>
### Table 6.4 Average weighted position matrix

<table>
<thead>
<tr>
<th>Profile Objectives</th>
<th>Hard technology adoption approach</th>
<th>Soft technology adoption approach</th>
<th>Technology Adaptation approach</th>
<th>System Adaptation approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transforming Capabilities</td>
<td>0.0979</td>
<td>0.0695</td>
<td>0.0805</td>
<td>0.0701</td>
</tr>
<tr>
<td>Modifying Capabilities</td>
<td>0.1415</td>
<td>0.1021</td>
<td>0.1981</td>
<td>0.1710</td>
</tr>
<tr>
<td>Innovating Capabilities</td>
<td>0.2215</td>
<td>0.2946</td>
<td>0.4584</td>
<td>0.4569</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. Preferred strategies for building transforming capabilities, modifying capabilities and innovating capabilities under various degrees of optimism have been compiled in Table 6.5.

### Table 6.5 Preferred strategies for building various capabilities

<table>
<thead>
<tr>
<th>Optimism Objectives</th>
<th>100% Optimistic</th>
<th>80% Optimistic</th>
<th>Average</th>
<th>20% Optimistic</th>
<th>100% Pessimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transforming Capabilities</td>
<td>I-III-IV-II</td>
<td>I-III-IV-II</td>
<td>I-III-IV-II</td>
<td>I-III-IV-I</td>
<td>I-II-III-IV</td>
</tr>
<tr>
<td>Modifying Capabilities</td>
<td>III-IV-I-II</td>
<td>III-IV-I-II</td>
<td>III-IV-I-II</td>
<td>III-IV-I-II</td>
<td>I-II-III-IV</td>
</tr>
<tr>
<td>Innovating Capabilities</td>
<td>III-IV-II-I</td>
<td>III-IV-II-I</td>
<td>III-IV-II-I</td>
<td>III-IV-II-I</td>
<td>III-IV-II-I</td>
</tr>
</tbody>
</table>

I: Hard technology adoption approach  
II: Soft technology adoption approach  
III: Technology adaptation approach  
IV: System adaptation approach  

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

- Transforming capabilities of an organization represent its proficiency in effectively utilizing available plant and equipment; planning and controlling production operations; carrying out troubleshooting and maintenance; and quickly changing over to different products in shortest time. For building transforming capabilities, the hard technology adoption approaches contributes highest under all conditions of optimism. After adopting hard technologies, transforming capabilities can be further enhanced by adaptation of technology, whereby it is made suitable to localized conditions. Under conditions of higher optimism, the system adaptation and soft technologies also contribute, though a little, in building transforming capabilities.

- Duplicating acquired machinery; adapting installed technology for better efficiency and carrying out minor incremental improvements for superior quality
outputs are the key functions under modifying capabilities. Adaptation of technology primarily influences the development of modifying capabilities under almost all of the optimism conditions (except 100% pessimistic), closely followed by system adaptation approach. Further, hard technology adoption and soft technology adoption approaches moderately influence the development of modifying capabilities. However, in pessimistic conditions, due to resistance to change, hard technology adoption approach takes first place and system adaptation takes the last place for developing modifying capabilities.

- Product and process innovations along with easily reverse engineering acquired technology are the key aspects of the innovating capabilities. Technology adaptation approach has emerged as the primary and most important aspect in developing innovating capabilities under all conditions of optimism. The innovating capabilities can further be developed by system adaptation approach and then by soft technology adoption approach. However, hard technology adoption approach contributes only minimally for developing innovating capabilities.

Following this, dominance matrices were prepared considering overall technological capabilities. In these matrices, the dominance of each course of action over the others has been tabulated. In Table 6.6 to Table 6.9, cell value denotes, number of times, the domination of a profile written on the top, over a profile written on the left. The column sum depicts the number by which the profile dominates all other profiles.

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Hard technology adoption approach</th>
<th>Soft technology adoption approach</th>
<th>Technology Adaptation approach</th>
<th>System Adaptation approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard technology adoption approach</td>
<td>--</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Soft technology adoption approach</td>
<td>2</td>
<td>--</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Technology Adaptation approach</td>
<td>1</td>
<td>0</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>System Adaptation approach</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>--</td>
</tr>
<tr>
<td>Column Sum</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Rank</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
The similar dominance matrices for various degrees of optimism (80%, 60%, 40% and 20%) have been compiled in Appendix – K. The results of these dominance matrices have been summarized in Table 6.9

**Table 6.7 Dominance matrix - pessimistic**

<table>
<thead>
<tr>
<th>Profiles ⇒</th>
<th>Hard technology adoption approach</th>
<th>Soft technology adoption approach</th>
<th>Technology Adaptation approach</th>
<th>System Adaptation approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard technology adoption approach</td>
<td>--</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Soft technology adoption approach</td>
<td>2</td>
<td>--</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Technology Adaptation approach</td>
<td>1</td>
<td>1</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>System Adaptation approach</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td>Column Sum</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Rank</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 6.8 Dominance matrix - average**

<table>
<thead>
<tr>
<th>Profiles ⇒</th>
<th>Hard technology adoption approach</th>
<th>Soft technology adoption approach</th>
<th>Technology Adaptation approach</th>
<th>System Adaptation approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard technology adoption approach</td>
<td>--</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Soft technology adoption approach</td>
<td>2</td>
<td>--</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Technology Adaptation approach</td>
<td>1</td>
<td>0</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>System Adaptation approach</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>--</td>
</tr>
<tr>
<td>Column Sum</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Rank</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

The Hadley’s matrix of cautious optimism in Table 6.9 indicate that technology adaptation approach has affirmed as the most preferred strategy whereas soft technology adoption approach has occupied the last (fourth) position for building technological
capabilities under all degrees of optimism. System adaptation approach and hard technology adoption approach have occupied almost equal rank under various degrees of optimism.

The dominance matrix for average values or a high degree of optimism (80%) seems to be the most realistic strategy. In these matrices, technology adaptation approach has emerged as the most preferred strategy; system adaptation approach has got the second rank, whereas hard technology adoption approach and soft technology adoption approach have come into sight as the preferred strategies ranked as number three and four respectively.

6.5 Discussion

Results of qualitative modeling have clearly depicted that more or less, all the approaches like optimistic, average, pessimistic and Hadley’s cautious optimism have brought out the following as the preferred strategies for building technological capabilities in Indian manufacturing industry.

i) Technology adaptation approach

ii) System adaptation approach

iii) Hard technology adoption approach

Currently India is passing through a transition phase, in which globalization and liberalization have made significant impact on Indian manufacturing industry. The competition has already reached unprecedented levels. In these circumstances, a pessimistic approach in technology management is not expected to succeed. On the other hand, a pure optimistic approach may also not yield the desired results because of the government rules and regulations, (which are at present, a bit in favor of the employees), the attitude of the employees in general, and the kind of work culture existing in the country. In such a scenario, a cautious optimism approach with quite a high degree of optimism can be successful.

Technology adaptation approach is the most preferred strategy in all the dominance matrices. System adaptation approach and hard technology adoption approach occupy the second and third position respectively at 80% optimism. To sum up, the following three strategies in order of their importance have emerged to be workable ones for building technological capabilities.
1. Technology adaptation approach
2. System adaptation approach
3. Hard technology adoption approach

**Technology adaptation approach**

The qualitative modeling has clearly indicated that for building technological capabilities, the most preferred strategy is technology adaptation approach. Further, technology adaptation approach has also emerged as the most preferred strategy in developing modifying capabilities and innovating capabilities individually. At the same time for developing transforming capabilities, the technology adaptation approach has been ranked as second most preferred strategy.

Technology is important, but almost all companies can have access to these technologies and rather quickly. The competitive edge a company can keep on a long term basis is not just by buying a new machine but by learning to use that equipment in a certain application. When a new technology is adapted, deployment is more likely to succeed, in some cases with less system adaptation, but when the new technology cannot be adapted and the company faces large system adaptations that it cannot successfully make, the new technology is not successfully deployed. Technology adaptation processes include standardization of equipment, effective use and presentation of controls and instrumentation, and to ensure the smooth flow of materials etc.

Technology adaptation also cover joint R&D efforts for considering the alternate process that can be developed in house for making new technology cost effective, conducting analysis based on the trends of the past years before going for new technology, studying economic viability of new technology and analyze its quantitative and qualitative effects and considering consequential changes in related products and processes.

There is sufficient support in the literature for the mutual adaptation of the system and the technology. Mutual adaptation can be effectively described as a tradeoff. An optimal level of adaptation for technology or system cannot be determined independently. When exogenous constraints are placed upon organizations for adaptation of technologies, results in terms of deployment are less than the optimal. Taking the extreme examples, if the new technology is rigid and technology adaptation is necessary but not possible, then only system can be adapted, within the organization itself. A potential exists for the organization to need to adapt itself to a potentially harmful extent. In such a case, an organization would most likely reject the product, either before or after adoption. At the
other extreme, if system adaptation is needed but the organization cannot or will not adapt to it, the entire dependence for adaptation is on the technology. This creates the potential that the organization will want to adapt the technology to an extent that violates the basic tenets of the technology’s underlying models. Most real cases of new technology adoption (with the exception of custom-built applications) appear to be more aligned with the first example, where the organization must adapt itself. Thus, an additional factor appears to affect the success of the deployment of new technologies - the degree of system and technological adaptation required to use the new technology effectively versus the degree of system and technological adaptation that is possible.

Sometimes, adaptations may be infeasible because they are either technically impossible or too expensive to implement with current technologies.

Technology adaptation usually occurs after adoption and is initiated by the adopter. In the long run, the learning process and the adaptation of technologies ultimately depend on the communication and exchange of information between partners during technology transfer. The supplier of the technology has control over production modes and design decisions, which make their product, i.e. the technology, more or less easily adapted. A goal of the technology supplier can be to select a production process that provides the best match between the degree of technology adaptation required and the degree possible. Thus, maintaining good relations with supplier facilitates the process of technological adaptation.

The technological adaptations significantly depend upon the human factor in terms of their education, technical expertise, attitude, involvement, and training etc. It has been found that transition required for a successful technology adaptation is achieved when (a) each partner actually carries out these complementary tasks for which he is responsible according to contract, (specific competence); (b) partners share a common technical language that enables effective communication (generic competence); and (c) participants recognize and respect their partners’ distinctive work styles.

When technology adaptation takes place under extremely demanding conditions, it offers an excellent opportunity to upgrade actual or potential competencies available in the receptor company. The successful adaptation of a technology that is to be efficiently used in a new context depends on the establishment of an on the spot communication process regarding specific theoretical and practical knowledge. It is usually assumed that the ability to develop, build and properly operate production equipment is a capacity that
goes naturally together with technology. However, the key to successful adaptation does not lie in the drawings, the equipment and their description manuals or in the formality of contractual guarantee clauses. It is to be found in something not formalized or formalizable that resides in the minds of the cooperating parties: the generic aspects of their competences that allow them to communicate in order to carry out specific tasks jointly and efficiently. So the mechanism design is very important to explicitly create conditions for successful implicit adaptation.

**System adaptation approach**

The system adaptation approach has emerged as the second most preferred strategy for developing overall technological capabilities. Various strategies for system adaptation include redesign of organizational structure, products, its features, production systems, and manufacturing processes to achieve ergonomics and safety layout of machines. Employees’ empowerment, extensive training, open communication within the company, job security, and rewards and recognition make the process of system adaptation smooth.

In a highly interconnected world in which the pace of change is accelerating, organizations are forced to achieve high performance levels in the short-run, and a capacity to adapt to change in order to survive and succeed in the long-run.

After an inherently complex technology is adopted by an organization, the implementation process requires somewhat more than just communication of knowledge. The technology must be adapted to the organizational context and the relevant organizational processes within broad work culture of the organization, and routines may need to be adapted to the technology. The implementation of advanced technologies can be seen as a process of mutual adaptation of the technology and the system. That is, the system (the user, the organization and its norms, procedures, etc.) must be adjusted to accommodate the technology, and the technology must be reinvented or adapted to the environment. Inherently complex technologies, particularly those that affect the organization’s core processes, require significant organizational change.

The system must be modified to use the technology effectively. Custom-made technologies lie at one extreme of the technology spectrum, while generalized technologies lie at the other. By definition, a custom-made technology should fit all of a client’s specifications. On the one hand, a company would, therefore, not be required to modify a custom-made technology, while customers of commercial / generalized technologies usually would require both technology and system adaptations on the other.
The need for system adaptation could be related to the structure and assumptions that underlie a new technology, or to response to customers’ needs to adapt the technology in the face of constraints that make it difficult for them to do so. In such cases, the system may be adapted to compensate for the adaptations in the technology that would have been preferred by the customer. The best strategy, from a resources standpoint, is to minimize the degree of system and technological adaptation beyond optimal levels.

A major problem firms facing worldwide is the adoption of new technology and the adaptation of the firm to technological change. Therefore, firms need to formulate strategies that enable them to maximize their opportunities for benefitting from these new technologies. This approach means that more attention must be paid to the problems of system adaptation as part of the problem of managing technology within the firm. The problems of adaptation must be looked at, and a set of necessary conditions be developed for management to make a transition to a new technology in a way that would help the company in achieving its goals. These problems are difficult ones and require an interdisciplinary approach.

In a globalized economy, firms may pursue two approaches for survival and success. These involve developing a capacity to innovate continually either in products that create greater value for customers or in processes which are more resource-efficient and/or environment-friendly. The latter is related to an ability to adapt faster to a continually changing business landscape. Both the ability to innovate and the ability to adapt depend on the quality of network flows for materials, information, and human communication. The potential for environmental changes in the adopting organization may be limited by internal factors (e.g., the organization’s own norms and policies or formal structure) or by external factors (e.g., laws of governmental bodies or industry-wide competitive forces). The system adaptation also significantly depends upon the human factor in terms of their education, technical expertise, attitude, flexibility, involvement and training etc. Extensive training and formal education as an element of a human resource development enables all organizational processes to operate more efficiently in a self-reinforcing manner. Thus, raising the level of training – personal, organizational or inter-organizational – not only enhances the exploration, testing, and evaluation of new ideas but also improves coordination for performing ongoing tasks.

Changing mindsets of human resources is a difficult task. Preparing employees in advance to new technologies helps them in their acceptance of new technology.
Preparation and development of human resources not only can bring the required change in their attitudes, but also can improve their skill levels and involvement in the endeavors of the company. This introduces human flexibility in the process of adaptation. Multi-functional task forces or teams should be used when a company plans to adapt a new technology in order to avoid waste of time, effort and other resources later. Teamwork seems to be one of the preferred approaches in flexibly managing technology adoption and adaptation. Further, human resource development strategies should be aimed to inculcate some essential capabilities in the human resources, such as capabilities in:

a. improvising and diversifying their skills  
b. making decisions and solving problems  
c. communicating effectively  
d. understanding the process as a whole  
e. adapting to new situations  
f. continuous learning

It is now generally accepted that abandoning some traditional managerial concepts in order to develop a flexible workforce is necessary. One such concept is the complete separation between planning/controlling and executing tasks. These tasks are not any more the old, simple, and repetitive ones based on “scientific management” principles. The new reality demands flexibility, which requires decentralized decision making, improved skills to solve non-repetitive problems, planning and self-control skills of those who perform the job or, in other words, managerial skills beside technical excellence. The idea of teamwork is basic to create conditions for workers where they can develop improved skills and managerial ability. These conditions can be created largely by the way the workers are managed by supportive supervision rather than directive; continuous learning, not only on technical aspects but also on managerial aspects; and largely by rewarding considering group performance and skill levels of the worker rather than considering individual performance. Therefore, a flexible workforce is increasingly becoming important for a firm which intends to achieve high levels of competitiveness.

**Hard technology adoption approach**

The hard technology adoption approach has emerged as the most preferred strategy in developing transforming capabilities of an organization. However for developing complete set of technological capabilities, it ranks as the third most preferred strategy.
Because of ever-increasing competition, the companies cannot increase the prices of the products in direct proportion to increase in input costs. They can become competitive and survive in the market only by reducing cost. This can be achieved by lowering the operational costs and avoiding waste of any kind. New technologies, while ensuring higher output of products with lower expenditure on resources, economies of scale and scope are the answer to the present crisis in manufacturing sector. The industry must adopt new technologies to match with the future requirements. New technology should be adopted for most of the important processes. Firms must formulate manufacturing strategies that have the components to assess new technology adoption needs.

However, because of the reducing market share of each company due to increasing number of competitors in the market, the companies do not have the kind of funds to replace technology in all areas in a single go like in reengineering. Rather, the companies have to be very selective and should choose the area of technology improvement very carefully. That area should be selected which involves maximum gains with minimum expenditure. This will facilitate easy adoption, adaptation and assimilation of new technology. In addition, the areas should be chosen in such a way that the rule of whole-to-part and part-to-whole is satisfied, that is, the areas of technology adoption and adaptation, though independent, at one point of time, should ultimately get integrated to achieve transformation of the whole company after a specified amount of time. Indian companies should, therefore, bring in new technology in a phased manner making the process as a process of continuous improvement.

6.6 APPROACHES TO TECHNOLOGICAL CAPABILITY BUILDING – A CONCEPTUAL FRAMEWORK

Based on literature review, survey results, case studies and qualitative modeling, a conceptual framework representing linkages between technology adoption and adaptation with technological capability building has been developed. In this framework, various approaches to technological capabilities building have been presented in figures 6.4 and 6.5.

Specific elements constituting various approaches have been discussed at length in this thesis. This framework suggests preferred flexible approaches to build technological capabilities at a high degree of optimism (using Hadley matrix of cautious optimism) for
different types of technological capabilities, namely, transforming capabilities, modifying capabilities, and innovating capabilities, besides for overall technological capabilities.

Figure 6.4 represents the cyclic process of developing technological capabilities through flexible management of technology adoption and adaptation. Technological capability building process starts from technology adoption. Technology adaptation is the next stage in this cyclic process. Facilitated by technology adoption and adaptation, a company develops its technological capabilities, and this completes a cycle. By virtue of acquired technological capabilities, the company then proceeds for adoption of next level of technology, after the adaptation of which, technological capabilities of the company are further developed and the cycle continues.

In figure 6.4, factors affecting technology adoption and adaptation are also shown, with significant factors in bold letters. Types of technological capabilities are also shown in this figure with critical types in bold letters.

Further in figure 6.5, interplay of preferred flexible approaches for various types of technological capabilities is shown. This framework suggests four possible approaches for developing technological capabilities, namely (i) hard technology adoption approach, (ii) soft technology adoption approach, (iii) technology adaptation approach and (iv) system adaptation approach, represented by circular platform in figure 6.5. Vertical arrows show relative priorities of these approaches for developing various types of technological capabilities at a high degree of optimism (80%). Length of an arrow represents priority of an approach. Technological capabilities that can be developed using one or more of these approaches are shown at the top in varying intensity of green color, where darkness of color represents high importance.

6.7 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 flexible management of new technology adoption and adaptation in manufacturing industry for building technological capabilities. Although the findings—based on the survey, case studies and qualitative modeling of medium and large scale firms using new technology—are in the context of manufacturing firms of northern India, yet their 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.
Figure 6.3 Cyclic process of developing technological capabilities
Figure 6.4 Approaches to technological capability building
CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

This chapter covers the summary of the research work, its results, conclusions, and the recommendations. The chapter also lists various areas, which can be taken up for further research. The summary of the research covers the methods adopted, salient features, and tools and techniques used in the work. Further, the results of the survey and the case studies, and the inferences drawn from them along with the major learnings have been presented. Based on the results and the findings, conclusions have been drawn. The limitations along with the scope for future work are covered in the subsequent sections of the chapter.

7.2 SUMMARY OF THE RESEARCH

The study has been conducted with an objective to assess the status, need and potential of technology adoption and adaptation in Indian manufacturing industry and to evolve an approach to manage it flexibly for building technological capabilities and competitive advantages. Various phases of the study have been: clarifying the context through a detailed review of literature on flexibility, technology adoption and adaptation and technological capabilities; understanding and assessing the situation by conducting a survey of the manufacturing industry of north India to assess the status of technology adoption and adaptation, technological capability and flexibility introduced in it; analysis of the data collected through survey to establish the relationship between various independent and dependent constructs; assessing the actor’s capability by conducting case studies in some of the surveyed industrial units; synthesis of the learning issues of survey and case studies; developing a management process for flexibly managing the technology adoption and adaptation in manufacturing industry; and finally recommending an implementation plan.

The survey was conducted through a specially designed questionnaire. The review of literature provided an insight into the various facets of technology adoption and adaptation, technological capability and flexibility, which was helpful in deciding the
The questionnaire was standardized after pre-testing. The survey was then carried by mail and through personal visits. From the survey, the status of 70 manufacturing organizations in the northern region of India, with respect to technology adoption and adaptation and technological capability, was found. The association between various independent constructs and technological capability, success and flexibility has been established using canonical correlation analyses and multiple regression analyses.

The purpose of the case studies has been to validate the results achieved from descriptive and empirical analysis of data of the survey.

To carry out case studies, the basis for selection of industrial units has been discussed in section 3.3.3. Accordingly, the case studies have been conducted in Maruti Suzuki India Limited (MSIL), Gurgaon; Sona Koyo Steering Systems Limited (SKSSL), Gurgaon; Moserbaer India Limited (MIL), Noida; and Punjab Tractors Limited (PTL), Mohali. Various factors related to adoption and adaptation of technology as mentioned earlier are studied through case studies. Only those factors, which were reflected as the potential factors have been taken up for detailed study.

To build technological capabilities in manufacturing industry, a management process has been developed in consultation with the experts from the industry. For this, various techniques of qualitative modeling like option field methodology, option profile methodology, analytical hierarchy process, and fuzzy set theory have been used.

Finally, an implementation plan was worked out to achieve the strategic success in manufacturing industry. The order of implementing various strategies to successfully manage new technology in Indian context has been highlighted.

7.3 RESULTS AND MAJOR LEARNINGS

The various learning issues have been derived on the basis of descriptive and empirical analyses of the primary data collected through the questionnaire survey. The following learning issues have been synthesized in the qualitative modeling for developing the implementation plan.
7.3.1 Learnings from the survey – Descriptive analyses

Concerning technology adoption

- Most of the companies have always been adopting new technology in the past to match their requirement.
- One third of the companies adopt new technology immediately on its availability and one sixth of the companies adopt only when there is dire need of it.
- Around 80% of the companies adopt new technology for some or more of the important processes.
- Around 89% of the companies consider the alternate process that can be developed in house for making new technology cost effective.
- Almost all the companies conduct some analysis based on the trends of the past years before going for new technology.
- All the companies go for economic viability study for adopting new technology.
- Around 86% of the companies considerably look into consequential changes in related products and processes, whereas 3% companies do not take any such consideration in account.
- Around 34% of the companies involve the manpower from the very beginning.
- The government through its agencies encourages 25% companies to adopt new technologies.
- 32% of the companies adopt new technology due to govt. regulations (environment or pollution related).
- Around 33% of the companies adopt new technology due to incentive provided by the govt. for the purpose.
- Most of the companies consider the opportunities or threats caused by the globalization as a justified reason to adopt new technology.
- The availability of new technology due to globalization is a significant factor for adopting new technology.
- Top management always provides full support in all companies for new technology adoption.
• Most of the companies have written formal manufacturing strategies which helps in their technology upgradations.
• Understanding the benefits of new technology assists in adoption in 87% companies.
• Well defined objectives of new technology helps in its adoption in 87% companies.
• Most of the companies have well defined technology adoption policies, though these policies are used to varying extents in companies.
• In most of the companies the technology adoption policies include training of the employees at all levels.
• These policies are updated regularly in only 60% companies.
• Technology adoption policies help in capability building of 63% companies.
• Human factor plays a crucial role in new technology adoption in all the companies.
• In-house engineers actively participate in new technology adoption in 90% of the companies.
• Aligning the attitude of employees towards objectives of new technology smoothens its adoption process in 93% of the companies.
• For adopting new technology, all companies use formal education and training programmes for employees at all levels.

Concerning technology adaptation
• In 63% companies, there is considerable need of redesigning production systems to achieve ergonomics and safety layout of machines whereas 50% of companies need some standardization of equipment.
• There is some need of redesigning the organization structure and considerable need of internal shifting of people in 63% companies.
• Almost all companies may need to recruit suitable persons from outside for successful adaptation of new technologies.
• There is considerable need of imparting training to personnel and designing new methods of performance and efficiency measurement.
• In 44% companies, considerable efforts have to be put in to make new technology acceptable to employees.

• Considerable changes in manufacturing, product design and features, plans and procedures and have to be implemented during technology adaptations.

• The effectiveness of the technology adaptation process can be considerably enhanced by empowerment, extensive training, open communication within the company, job security to employees and rewards and recognition.

• There is negligible role of govt. in adaptation of new technology.

• The top management provides support for technology adaptation and allocates sufficient funds for the same in all companies.

• Top management is also ready for taking short term risks in order to have long term pay offs in all companies.

• Skilled workers help in easy adaptation of new technology as compared to unskilled counterparts in 93% companies.

• Technocratization is found to be a key factor response for technology adaptation in 83% companies.

• In 84% companies, employees are willing to accept changes.

• Staffing flexibilities & production flexibility of company assists in technology adaptation.

• 83% companies indicate the importance of in-house R&D for new technology adaptation.

• Technology adaptation policies exist to some extent in 71% companies

• Wherever exist, these include training of employees, procedures and practices for smooth adaptation of technology.

**Concerning technological capabilities**

• 57% companies are aware of technology issues and the need to acquire technologies to a large extent.

• 81% companies have the ability to a large extent to seek out and identify technologies to solve particular problems.
• 73% companies have built distinctive capabilities to a large extent in some area of technology.

• 67% companies can develop of a technology strategy, including a framework with priorities and an action plan.

• The ability to assess and select cost effective technology solutions is possessed to a large extent by 69% companies.

• 84% companies are carrying out the acquisition and absorption of specific technologies.

• Only 37% companies possess, to a large extent, the skills involved in making effective use of technology, whereas another 41% companies possess such skill to considerable extent.

• The ability to learn from and accumulate experience in order to continuously improve capabilities is possessed to a large extent by 73% companies.

• 60% companies possess the ability to considerable extent to form and exploit linkages with networks of technology suppliers and others involved in technology, whereas only 19% companies possess such abilities to a large extent.

Concerning technology adoption and adaptation policies

• 97.1% companies have status of technology adoption policies fair or better as compared to 79.6% companies in case of technology adaptation policies

• Technology adaptation policies have stronger impact on technological capabilities as compared to technology adoption policies.

Concerning critical barriers to new technology adoption

• The following are the critical barriers to new technology adoption (in order of importance):
  o Cost of training and education
  o Cost of new technology acquisition
  o Disruptions during implementation
  o Increased maintenance expenses
  o Workers’ resistance.
Concerning critical barriers to new technology adaptation

- The following are the critical barriers to new technology adaptation (in order of importance):
  - Lack of in-house technical support
  - Adverse effect on work flow
  - Problems with compatibility of equipment

Concerning problems faced when existing and new technology are brought into contact

- The following problems are faced when existing and new technology are brought into contact (in order of importance):
  - Fear of layoffs
  - Risk of production losses
  - Resistance to change
  - Difficulty in operating and maintaining new technology
  - Lack of co-operation and understanding

7.3.2 Learnings from the survey – Empirical analyses

Concerning correlation analyses

- Technological capabilities has a very strong and significant association with other dependent variables i.e. the success due to new technology ($r = 0.838, p = 0.000$) and flexibility ($r = 0.746, p = 0.000$).
- Further, the technological capabilities also have strong and significant association with impact of globalization ($r = 0.382, p = 0.001$); role of top management ($r = 0.353, p = 0.003$); manufacturing strategy and technology adoption policies ($r = 0.525, p = 0.000$); human factor ($r = 0.709, p = 0.000$); employees’ education ($r = 0.478, p = 0.000$) and technology adaptation policies ($r = 0.400, p = 0.001$).
- Manufacturing strategy and technology adoption policy has very strong association with human factor ($r = 0.669, p = 0.000$) and technology adaptation policies ($r = 0.700, p = 0.000$).
- Role of government in technology adaptation has strong and significant association with role of government in technology adoption ($r = 0.649, p = 0.000$).
Concerning canonical correlation analyses

- The correlation between the variates (sets of independent variables and dependent variables) is found to be very high and significant \( r = 0.812, \ p = 0.000, \ r^2 = 0.659 \) which implies that the 65.9% variation in the set of dependent variables can determined by the set of selected independent variables.

- Human factors in terms of their skill, technical expertise, training, involvement, attitude has the highest cross-loading (0.724) among the independent variate.

- Employees’ education has come out to be second most significant factor affecting technological capabilities, success of technology adoption and adaptation and flexibility with cross loading of 0.499.

Concerning multiple regression analyses

- In multiple regression analysis using stepwise method, human factor, role of government in new technology adoption, employees’ education, impact of globalization and role of top management in technology adaptation are found to be significant in the prediction of technological capability.

- Human factor, role of government in new technology adoption, employees’ education, impact of globalization and role of top management in technology adaptation are found to be the significant factors in success due to technology adoption and adaptation through multiple regression analysis (using stepwise method)

- The results of stepwise multiple regression of flexibility indicates that human factor and employees’ education are significant factors in the prediction of flexibility.

7.3.3 Learnings from the case studies

The learnings from various case studies conducted in various manufacturing units have been synthesized as follows:

Concerning technology adoption

- Adopt new technology to match the future requirement.

- Adopt new technology when its performance is proved.

- Adopt new technology for most of the important processes.
• Consider the alternate process that can be developed in house for making new technology cost effective.
• Conduct analysis based on the trends of the past years before going for new technology.
• Study economic viability of new technology and analyze its quantitative and qualitative effects.
• Consider consequential changes in related products and processes.
• Involve the manpower from the very beginning of adopting new technology.
• The government through its agencies should encourage companies to adopt new technologies.
• Government regulations (environment or pollution related) force companies to adopt new cleaner technologies.
• Industry policies should provide some incentives for cleaner technologies.
• Opportunities or threats caused by the globalization serve as a justified reason for adopting new technology.
• Availability of new technology due to globalization is a noteworthy factor for adopting new technology.
• Top management’s full support is indispensable for new technology adoption.
• Formal manufacturing strategies must address to new technology adoption needs.
• Define objectives of new technology.
• Clarify the benefits of new technology.
• There should be well defined technology adoption policies in place and these must be thoroughly used.
• Include training of the employees at all levels in technology adoption policies.
• Update these policies regularly.
• Human factor plays a crucial role in new technology adoption.
• Involve manpower in the process of new technology adoption.
• In-house engineers to actively participate in new technology adoption.
• Align the attitude of employees towards objectives of new technology adoption.
• Plan formal education and training programmes for employees at all levels.
Concerning technology adaptation:

- For adapting to new technology, consider the need of redesigning the production systems to achieve ergonomics and safety layout of machines, standardization of equipment, effective use and presentation of controls and instrumentation and to ensure the smooth flow of materials.

- Consider the need of redesigning the organization structure, internal shifting of people and recruiting suitable persons from outside for successful adaptation of new technologies.

- There is considerable need of imparting training to personnel and designing new methods of performance and efficiency measurement.

- Put in efforts to make new technology acceptable to employees.

- Some changes in manufacturing, product design and features, plans and procedures have to be implemented during technology adaptations.

- The adaptability of a company for new technology is considerably affected by its staffing flexibility and production flexibility.

- The effectiveness of the technology adaptation process can be considerably enhanced by empowerment, extensive training, open communication within the company, job security to employees and rewards and recognition.

- There is little role of government in adaptation of new technology.

- The top management support is vital for technology adaptation and it should allocate sufficient funds for the same.

- Top management must be ready for taking short term risks in order to have long term pay offs in all companies.

- Skilled workers help in easy adaptation of new technology as compared to unskilled counterparts.

- Technocratization is a key factor responsible for technology adaptation.

- Employees’ willingness to accept changes is beneficial for technology adaptation.

- There is a high importance of in-house R&D for new technology adaptation.

- There are hardly any well laid technology adaptation policies and wherever exist, these include training of employees, procedures and practices to some extent.

Concerning technological capabilities

- Be aware of role of technology in companies’ competitiveness.
• Scan or monitor external technology events and trends.
• Define individual technological strengths and build up a unique advantage in specific area.
• Formulate a technology strategy as a key part of the overall business strategy.
• Gather information on range of technological options available, choose quickly among competing solutions and identify the most appropriate source which fits with the needs.
• Deploy the resources to exploit the selected technological option either by developing technology through in-house R&D or by acquiring it through a joint venture / technology licensing or otherwise.
• Implement the acquired technology which may involve various stages like its adaptation or reconfiguration.
• Review technology projects and processes within the firm in order to learn from success or failures.
• Maintain links with different kinds of external organizations which may provide them technology related services.
• Carry out continuous improvements in all technological related activities and components.
• Effectively utilize available technologies for transformation.
• Utilize the relevant technologies in distributing, selling or servicing its outputs.
• Utilize process development technologies in form of reverse engineering the acquired technology or with product / process innovations.

7.3.4 Summary of developing a management process

To achieve the projected requirements of building technological capabilities, a management process has been developed in consultation with the experts from the industry. For developing the management process, a qualitative modeling using option field methodology, option profile methodology, analytic hierarchy process, and fuzzy set theory has been used. The modeling began with listing of various options to manage new technology in manufacturing industry for building technological capabilities. These options have been derived from the synthesized learning issues of this study. Option field methodology and option profile methodology have been used as a basis for this purpose. The options have been then put into various categories and these categories have been considered as the dimensions of the design. The dimensions have been then put into
broader categories called clusters. The clusters have been put into sequence based on the importance of an area. The sequencing of dimensions within the clusters has been then carried out. Various profiles for course of actions planned for flexibly managing technology adoption and adaptation have been finalized. These profiles are: hard technology adoption approach, soft technology adoption approach, technology adaptation approach and system adaptation approach. After deciding the profiles, various objectives of the industry have been decided. These objectives have been taken from the results of the survey conducted. These are: transforming capability, modifying capability and innovating capability. To find out their degree of importance, these objectives have been compared pair-wise using AHP. Following this, quantitative contribution of each profile to each objective has been determined, and position matrices have been made. From the position matrices, weighted position matrices have been determined by multiplying weight of criteria by the value of each position of position matrices. The weighted position matrices have been aggregated in three ways, i.e. optimistic, average and pessimistic aggregation. Dominance matrices have been also prepared to display dominance structure between all possible pairs of options. Based on these matrices, the ranks of options have been decided for manufacturing industry. Different approaches have been suggested to meet the future requirements of flexible management of technology adoption and adaptation building technological capabilities.

7.3.4 Summary of implementation plan

After developing the management process for flexibly managing technology adoption and adaptation in manufacturing industry for building technological capabilities, a plan has been developed for its effective and smooth implementation. Different strategies to be followed in this regard have been discussed in Indian context. The implications of these strategies have also been pointed out.

The results of the case studies as well as the developed management process point out that ‘technology adaptation approach’ is the key strategy to be followed for achieving technological capabilities in flexibly managing technology adoption and adaptation. Further ‘system adaptation approach’, and ‘hard technology adoption approach’, are the need of the hour in this globalized business. Just to be a part of this global technological business, the organizations have to follow these three strategies seriously.
7.4 CONCLUSIONS AND RECOMMENDATIONS

This section points out conclusions, in a digest form, on each of the issues concerning technology adoption, adaptation and technological capabilities, that were raised at the beginning of this research work. This is followed by a summary of these as a response to the objective of carrying out this research, mentioned in chapter 1.

1. Manufacturing companies adopt new technology for their important processes, to match market requirements. The companies adopt new technology after its performance is established. The companies carry out economic viability studies before adopting new technology and also consider alternate processes that can be developed in-house for making it cost effective. The companies emphasize more on technology adoption than on its adaptation.

2. Flexible management of technology adoption in manufacturing companies is affected by role of government; impact of globalization; role of top management; manufacturing strategies and technology adoption policies of the company; and human factor. Flexible management of technology adaptation is affected by role of government; role of top management; employees’ skill, education and attitude; in-house R&D; and technology adaptation policies of the company.

3. Human factor; employees’ skill, education and attitude; and impact of globalization are significant factors positively correlated to technological capabilities; whereas the role of government in technology adoption and role of top management in technology adaptation are also significant, but negatively correlated to it. Human factor and employees’ skill, education and attitude are significant factors affecting overall flexibility.

4. Technology adoption policies are well defined in manufacturing companies, whereas technology adaptation policies are rare. Similar status has been found for updation of these policies. Technological capabilities have small, positive but significant association with technology adoption and adaptation policies. However, the association of technological capabilities with technology adaptation policies is stronger and more significant as compared to their association with the technology adoption policies.

5. Retrenchment, production losses, resistance to change, operation and maintenance, and non-cooperation by staff are severe problems faced in manufacturing companies, when old and new technologies are brought into
Cost of training and education, cost of new technology acquisition, disruptions during implementation, increase in maintenance expenses, and workers’ resistance have been found to be major barriers to new technology adoption in the companies. Lack of in-house technical support, adverse effect on work flow, and incompatible equipment have been found to be major barriers to new technology adaptation. Various strategies and actions have been suggested for overcoming above-mentioned barriers.

6. Four types of flexible approaches – technology adaptation approach, system adaptations approach, hard technology adoption approach, and soft technology adoption approach – have been identified for developing technological capabilities. Their combinations are recommended for developing (a) transforming (b) modifying and (c) innovating capabilities.

7.5 LIMITATIONS OF THE STUDY

The main limitations of this study are as follows:

- The study has been limited to medium and large scale manufacturing organizations in northern region of India.

- All manufacturing organizations have been treated alike, irrespective of the specific requirements of various sectors.

- As such no mathematical model or equation has been derived to calculate the contribution of flexibility to technology adoption and adaptation, and then to technological capabilities.

7.6 SCOPE FOR FUTURE WORK

While carrying out this study and trying to list its scope, a number of areas have come to focus, where detailed research can be taken up. Such areas demanding attention, further exploration, and analysis through research work are mentioned here.

- The present study has concentrated on manufacturing industry only. The work should be extended to other categories of industry like service industry.

- All manufacturing organizations have been treated alike, irrespective of the specific requirements of various sectors. Minor changes might have to be incorporated to effectively build technological capabilities in varying situations.
Thus, sectors wise analysis can also be conducted for appropriately dealing with varying requirements of different sectors.

- The present study has suggested a management process for flexible management of new technology in manufacturing industry for building technological capabilities. Certain strategies have been proposed which call for studies at micro level e.g., type of education and training to be provided to the employee at different levels to develop their skills and capabilities to utilize the new technology to the maximum, enrichment of the job, providing motivation and encouragement to the workers, introducing flexi-timings and incentives for higher and quality production.

- The item measures identified for various constructs have been considered to be equally important in the study, however in real life situations, some item measures may be more important than the others. This study can be extended by attaching appropriate weights to these item measures through qualitative techniques.

- Similar studies may be conducted on other phases of technology management also, to see their effects on building technological capabilities.

7.7 CONCLUDING REMARKS

Based on the conclusions derived on each issue identified at the beginning of the research, the present status of technology adoption is fairly good in India. The status and pace of technology adaptation is not good enough in the Indian manufacturing industry. The new technology is generally adopted in the organizations to replace existing technologies and then adapted to suit local environment. Domain of human factor and employees’ education for overall flexibility are seriously dealt with in the manufacturing industry. Technology adaptation policies and their updation are not considered seriously by the manufacturing industry. Overall technology adoption and adaptation for building technological capabilities in the Indian manufacturing industry is satisfactory, but at the same time, it also has a lot of scope for further improvements for facing the challenge of local and global competition.

It is concluded that in this modern age, adoption and adaptation of new technologies are needed to gain competitive edge in the global market. Flexible management of the same shall lead the organizations to build their technological capabilities for not only surviving but also thriving in the technology-intensive industrial environment around the globe.