Empirical Study

Advanced Manufacturing Technology: A Way of Improving Technological Competitiveness

G. S. Dangayach, S. C. Pathak and A. D. Sharma
Department of Mechanical Engineering
Malaviya National Institute of Technology,
Jaipur, India

Abstract
Survival and success in present turbulent times increasingly depends on competitiveness. Competitiveness comes through an integrated effort across different functions and deployment of advanced manufacturing technologies. Advanced manufacturing technology (AMT) plays a major role in quality and flexibility improvements in manufacturing organizations. The automated “factory of the future” is seen as the essential ingredient for increasing the competitive advantages in the global market. The concept of technology as a competitive weapon is also gaining momentum because of the rapid introduction of new products with the high complexity and accuracy, new manufacturing process, changing in customer needs and expectations, including varying extents of product support. AMT provides benefits and advantages in areas that would enable manufacturers to maintain quality, operational, organizational, financial performances to improve technological competitiveness. This research reports findings of an empirical study of process sector companies through questionnaire survey. Responses from 58 manufacturing managers are analyzed and presented.

Keywords: Advanced Manufacturing Technology, Process Sector Companies, Technological Competitiveness, Direct AMT, Indirect AMT, Administrative AMT

Introduction
Role of technology for competitiveness is increasing in emerging context. While the role was always been well understood in the developed countries, it is increasingly being touched by progressive firms in developing countries also. The importance of technology for business success and competitiveness has been confirmed empirically in several contexts. Competitiveness is a multidimensional concept. It includes core technology competence, human resource processes, operations management processes, and technology management processes (Banwet et al., 2003; Ambastha and Momaya, 2004). Competitiveness of a firm can be derived through these four factors (Figure 1). Technology plays a key role in creating and maintaining competitiveness in the global arena. Technology may be defined as all the knowledge, products, processes, tools, methods and systems employed in the creation of goods or in providing services. It consists of three important interdependent, co-determining and dynamic components (Momaya and Ajitabh, 2005):

- Hardware – the physical and logical equipment that is used to carry out the required tasks
- Software – the knowledge of how to use the hardware in order to carry out the required tasks
- Brainware – the reasons for using the technology in a particular way.

Core technology competence can be assessed by importance given to advanced manufacturing technology (AMT) and its deployment. AMT is an enabler of popular manufacturing objectives such as quality, delivery, flexibility, and cost. The quest for lower operating costs and improved manufacturing efficiency has forced a large number of manufacturing firms to embark on advanced manufacturing technology (AMT)

Figure 1. A Conceptual Framework for Competitiveness in Context of Manufacturing

projects of various types. Advanced manufacturing technologies have been heralded as new way for manufacturing companies to gain a competitive advantage (Pagell et al., 2000; Dangayach & Deshmukh, 2004). The dramatic developments in AMT at various organizational levels can be attributed to numerous benefits that improve the competitive position of the adopting companies. AMT can impact not just manufacturing, but the whole business operations, giving new challenges to a firm’s ability to manage both manufacturing and information technologies.
The benefits of AMT have been widely reported in the literature and can help classified as tangible and intangible (Kaplan, 1986). The tangible benefits, which are easily quantifiable, include: inventory savings, less floor space, improved return on equity (ROE) and reduced unit cost of production. The intangible benefits, which are difficult to quantify, include: an enhanced competitive advantage, increased flexibility, improved product quality and quick response to customer demand. The potential benefits which can accrue from investments in advanced manufacturing technologies, have become increasingly evident with growing global competition (Swamidass and Waller, 1991; Primrose 1991; Small and Chen, 1995). Advanced Manufacturing Technology plays a major role in quality and flexibility improvements in process sector companies.

Evaluating capital investments for the installation of advanced manufacturing technologies is a critical task faced by manufacturing management due to the high capital investment and the high degree of uncertainty involved in these investments.

Indian manufacturing industry is made up of many different sectors, each of which is influenced by the overall-manufacturing climate. From the Indian perspective, the major manufacturing sectors are automobile, electronics, machinery, and process industries. Process sector is the largest sector and includes companies manufacturing cement, steel, petrochemicals, fertilizers, drugs and medicine. Therefore this sector is considered in our research.

The objective of this research is to assess the status of advanced manufacturing technologies in process sector companies, to identify advanced manufacturing technologies relevant to Indian process companies, assess the degree of investment in advanced manufacturing technologies, and identify AMT implementation steps.

**Advanced Manufacturing Technologies**

AMT appeared to represent a perfect marriage between technological potential and the manufacturing challenges. AMT refers to manufacturing process technologies that use computers to store and manipulate data (Dean et al., 1992, Zammuto and O’Connor, 1992, Sanchez, 1996; Saleh and Randhawa, 2001). Advanced manufacturing technologies (AMT) is a term that covers a broad spectrum of computer-controlled automated process technologies. AMT is an umbrella term used to describe a wide range of automation and related technologies, which have emerged during the past two decades as a consequence of developments in information technology (Bessant, 1991). More specifically, AMT can be described as a group of computer-based technologies, including computer-aided design (CAD), computer numerical control (CNC) machines, direct numerical control (DNC) machines, robotics (RO), flexible manufacturing systems (FMS), automated storage and retrieval system (AS/RS), automated material handling systems (AMHS), automated guided vehicles (AGV), barcode (BC), rapid prototyping (RP), material requirement planning (MRP), statistical process control (SPC), manufacturing resource planning (MRP II), enterprise resource planning (ERP), activity based costing (ABC), and office automation (OA).

Numerous studies have been reported in the literature on advanced manufacturing technologies (Swamidass and Waller, 1991; Putterill et. al., 1996; Chan et. al., 2001; Chen and Small, 1994; Small and Yasin, 1997; Dean et al., 2000). All these studies were in context to developed economies. It seems that no study has been reported in context of developing country like India.

These advanced manufacturing technologies are classified into Direct AMT, Indirect AMT, and Administrative AMT. These terms correspond to the hardware (Direct AMT), software (Indirect AMT), and brainware (Administrative AMT) as used by Momaya and Ajitabh (2005). It must be mentioned that this set is by no means an exhaustive set of activities. However, it captures the essence of improvement activities as practiced by Indian companies. Hardware base technologies termed as Direct AMT. Software based technologies used for product design and scheduling are termed as Indirect AMT; however Administrative AMT are used for integration and simplification of business processes.

- Direct AMT: Technology used on the factory floor to cut, join, reshape, transport, store or modify materials e.g. CNC, DMC, robotics, FMS, S/R, AMHS, AGV, RP etc.
- Indirect AMT: Technology used to design products and schedule production e.g. CAD, MRP, SPC, BC, MRP II etc.
- Administrative AMT: Technology used to give administrative support to the factory and integrate its operations with the rest of the organization e.g. ERP, ABC, OA etc.

**Manufacturing Objectives**

Manufacturing objectives have been referred as measures of competitiveness (Vickery et al., 1993). Manufacturing objectives capture how capabilities-based competition will evolve. Manufacturing objectives represent a holistic set of tasks, which should be performed by the manufacturing function in order to support the business strategy (Roth, 1996).

**Role of technology for competitiveness is increasing in emerging context. While the role was always been well understood in the developed countries, it is increasingly being touched by progressive firms in developing countries also. The importance of technology for business success and competitiveness has been confirmed empirically in several contexts.**
Quality

Quality refers to all physical aspects of the process and product or service delivered. He suggested a list of dimensions of quality: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. Quality has been cited as an issue of strategic importance (Garvin 1993).

Delivery

Delivery refers to faster delivery of product in correct time. Two dimensions of delivery i.e. dependable delivery, and delivery speed have been identified in the literature.

Flexibility

Flexibility is “the ability to change or react with little penalty in time, effort, cost or performance”. Flexibility has long been recognized as a manufacturing capability that has the potential to impact the competitive position and the business performance of an organization. Upton (1995) acknowledged the important role of flexibility in today’s competitive environment. Browne et al. (1984) defined eight types of flexibility, which are machine flexibility, process flexibility, product flexibility, routing flexibility, volume flexibility, expansion flexibility, operation flexibility, and production flexibility.

Cost

The task of the manufacturing function is to provide low cost product and to support the business (Hill, 1989). Low cost is a well-established manufacturing objective.

Research Methodology

The research methodology is based on empirical data collected through a questionnaire survey. The survey methodology is used for study and focus of study is cross-sectional. The objective of this survey is to examine the status of AMT in Indian process sector companies.

A structured questionnaire has been developed on five point Likert scale. Annexure was given in the end of questionnaire, which contained key for responses and explained in brief the terminology used in the questionnaire to avoid unknown bias. Likert scale is well-established interval scale in management research (Malhotra and Grover, 1998). Explanation of five points is as under:

1 – Least important
2 – Important
3 – Not decided
4 – Very important
5 – Most important

To assess content validity a “dry run” was made and few questionnaires were administered to leading practitioners, consultant and academicians. Based on their feedback the present form has been evolved and final version of the questionnaire was sent to the CEOs of 120 companies of process sector. A random sample of 120 companies was drawn from the CII Industrial directory (2004). The questionnaire was administered in first quarter of 2004. 58 valid responses in the form of filled questionnaire have been received. The response rate is 48.3%. Table 1 shows average statistics of the respondents.

Table 1. Average Statistics of the Respondents

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of respondents</td>
<td>40.4 years</td>
<td>[27, 52]</td>
</tr>
<tr>
<td>Experience</td>
<td>18.3 years</td>
<td>[5, 30]</td>
</tr>
<tr>
<td>Number of employees</td>
<td>1350</td>
<td>[100, 5000]</td>
</tr>
<tr>
<td>Annual sales</td>
<td>&gt; 14 million US $</td>
<td>[0.25, &gt;25]</td>
</tr>
<tr>
<td>Exports</td>
<td>&lt; 9% of total sales</td>
<td>[0, &gt;30]</td>
</tr>
<tr>
<td>Products manufactured</td>
<td>Tyres, paint, cement, fertilizers, Fabric and textiles, paper, and medicine</td>
<td></td>
</tr>
</tbody>
</table>

Inter-item analysis is used to check the scales for internal consistency or reliability. Chronbach’s coefficient alpha is calculated for each scale, as recommended for empirical research in operations management (Flynn et al. 1990, Malhotra and Grover 1998, Forza, 2002). Table 2 shows Chronbach’s Alpha values calculated (through SPSS 10 for windows) for scales used. Chronbach’s alpha values for each scale is more than 0.5, which is considered adequate for exploratory research (Nunally 1978).

Table 2. Chronbach’s Alpha for Scales Used

<table>
<thead>
<tr>
<th>Scales Used</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMT implementation Steps</td>
<td>0.95</td>
</tr>
<tr>
<td>Direct AMT</td>
<td>0.85</td>
</tr>
<tr>
<td>Indirect AMT</td>
<td>0.87</td>
</tr>
<tr>
<td>Administrative AMT</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Measures

AMT Implementation Steps (AIS)

Based on literature (Badiru,1990; Schroder and Sohal,1999) eight steps are identified for effective AMT implementation. Respondents were asked to give importance to these eight implementation steps on five point Likert scale. Table 3 gives mean and standard deviation values. These eight steps are planning (AIS 1), concept development (AIS 2),
requirement analysis (AIS 3), cost/benefit analysis (AIS 4), technology assessment (AIS 5), development & implementation (AIS 6), training (AIS 7), post-implementation evaluation (AIS 8). It is observed from Table 3, that cost/benefit analysis (AIS 4) and technology assessment (AIS 5) are the more important AMT implementation steps and requirement analysis (AIS 3) is the least important AMT implementation step for process industry.

*These advanced manufacturing technologies are classified into Direct AMT, Indirect AMT, and Administrative AMT.*

Respondents were asked to indicate degree of investment in direct AMT (eight items), indirect AMT (five items), and administrative AMT (three items) in their companies on five point Likert scale (where 1- No investment and 5 – Heavy investment). Table 5 shows mean and standard deviation values of all three AMT. It is observed from Table 5 that, process sector companies are investing more in administrative AMT (Overall mean = 2.98). It reflects that companies are investing more in administrative and Indirect AMT in place of direct AMT.

**Table 3. AMT Implementation Steps (AIS)**

<table>
<thead>
<tr>
<th>AIS</th>
<th>Description</th>
<th>(N = 58)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 1</td>
<td>Planning</td>
<td>3.36</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td>AIS 2</td>
<td>Concept development</td>
<td>3.31</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>AIS 3</td>
<td>Requirement analysis</td>
<td>3.17</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>AIS 4</td>
<td>Cost/benefit analysis</td>
<td>3.53</td>
<td>1.04</td>
<td></td>
</tr>
<tr>
<td>AIS 5</td>
<td>Technology assessment</td>
<td>3.46</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>AIS 6</td>
<td>Development &amp; implementation</td>
<td>3.43</td>
<td>1.03</td>
<td></td>
</tr>
<tr>
<td>AIS 7</td>
<td>Training</td>
<td>3.27</td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td>AIS 8</td>
<td>Post-implementation evaluation</td>
<td>3.38</td>
<td>1.03</td>
<td></td>
</tr>
</tbody>
</table>

On five point Likert scale (Interval scale 1-5: 1 - least important and 5 - most important)

Bold: Highest Mean, Italic: Lowest Mean

Correlation between eight AMT implementation steps is given in Table 4. It is observed that all AMT implementation steps are positively correlated. Correlation between planning (AIS 1) and concept development (AIS 2) is the highest (0.74), however correlation between requirement analysis (AIS 3) and training (AIS 7) is the lowest (0.34). It seems true because concept development is not possible without proper planning.

**Table 4. Pearson Correlation Between AMT Implementation Steps**

<table>
<thead>
<tr>
<th>AIS</th>
<th>AIS 1</th>
<th>AIS 2</th>
<th>AIS 3</th>
<th>AIS 4</th>
<th>AIS 5</th>
<th>AIS 6</th>
<th>AIS 7</th>
<th>AIS 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 1</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS 2</td>
<td>0.74*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS 3</td>
<td>0.45*</td>
<td>0.54*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS 4</td>
<td>0.53*</td>
<td>0.46*</td>
<td>0.58*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS 5</td>
<td>0.44*</td>
<td>0.47*</td>
<td>0.52*</td>
<td>0.66*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS 6</td>
<td>0.50*</td>
<td>0.52*</td>
<td>0.46*</td>
<td>0.62*</td>
<td>0.72*</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS 7</td>
<td>0.39*</td>
<td>0.35*</td>
<td>0.34*</td>
<td>0.38*</td>
<td>0.59*</td>
<td>0.61*</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>AIS 8</td>
<td>0.56*</td>
<td>0.62*</td>
<td>0.49*</td>
<td>0.48*</td>
<td>0.65*</td>
<td>0.65*</td>
<td>0.63*</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* Significant at the 0.01 Level (2 – Tailed)

On five point Likert scale (Interval scale 1-5: 1 – No investment and 5 – Heavy investment)

Bold: Highest Mean, Italic: Lowest Mean

Table 6 to 8 gives the correlation values between the items of direct, indirect and administrative AMT. Correlation between eight items of direct AMT is found positive and significant (at the level 0.01) except correlation between robotics (RO) and automated material hand made systems (AMHS). In indirect AMT (Table 7), correlations between computer aided design (CAD) and bar coding (BC), and Statistical process control (SPC) and bar coding (BC) is insignificant. It is observed from Table 8 that correlation between activity based costing (ABC) and Enterprise resource planning (ERP) is only significant at 0.01 level.
Advantages by adopting direct, indirect, and administrative AMT. It is important for the management to understand the usage and applicability of these systems to their companies. The result of data analysis (Table 5) indicates that automated material handling systems and stand-alone technologies such as CNC have attracted more to the Indian process industry to invest in direct AMT. It seems that there are three main AMT implementation steps (AIS) i.e. cost benefit analysis, technology assessment, and development & implementation has attracted practitioner’s attention, because appropriateness of AMT should be based on their ability to meet the manufacturing strategies and organizational objectives (Table 3). This is achieved through a systematic technological justification analysis. However requirement analysis, training, and concept development factors have treated less important AMT implementation steps by Indian process industry, which are rather more important to get more yield from AMT investment.

Requirement analysis gives more in-depth justification to invest in a AMT, however post implementation evaluation tells about proper implementation and use of a AMT. It can be observed from Table 5 that Indian process companies are investing more in ‘indirect AMT’ and ‘administrative AMT’ as compared to ‘direct AMT’. Investment in the ‘direct AMT’ is the least as its mean value is 2.11 on a five point Likert scale. However it is the direct AMT, which provide maximum flexibility to the manufacturing system.

Implications of the Study
The implications of the findings of this study are several. First, Managers may adopt best practices to achieve manufacturing performance objectives of company. Second, the adoption of AMT will improve competitiveness to win the competition. This study gives parameters to evaluate their competitiveness. Managers may use the framework given in figure 1 to assess their competitiveness.

Limitations and Future Research Scope
The study was administered only in process sector companies. Similar study may be carried out in other industrial sectors viz. automotive, machinery, and electronics. The proposed framework for competitiveness (Figure 1) may be tested in other industrial environments like developed economies.

References

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### Appendix

**Survey on Advanced Manufacturing Technology (AMT)**

1. Please write the **mission** of your company.

2. Please indicate your company’s annual sales
   - (A) 0.25 - 1.25 million US $ 
   - (B) 1.25 - 2.5 million US $ 
   - (C) 2.5 - 12.5 million US $ 
   - (D) 12.5 - 25 million US $ 
   - (E) > 25 million US $ 

3. Please indicate approximate what percentage of sales turnover comes from exports
   - (A) Nil 
   - (B) 10 - 20% 
   - (C) 20 - 30% 
   - (D) > 30% 

4. Please indicate your main types of products/services
   - (A) Finished Product 
   - (B) Consumer Goods 
   - (C) Raw Material 
   - (D) Other, please specify 
   - (E) Service Industry 
   - (F) Government 

5. Please indicate who are your main customer groups?
   - (A) Consumer 
   - (B) Manufacturing Industry 
   - (C) Service Industry 
   - (D) Government 
   - (E) Others, please specify 

6. Please indicate the approximate number of employees
   - (A) 100 
   - (B) 101 - 500 
   - (C) 501 - 1000 
   - (D) 1001 - 3000 
   - (E) 3001 - 5000 
   - (F) > 5000 

7. Which AMT implementation steps are important for your company
   - **AIS 1- Planning**
   - **AIS 2- Concept development**
   - **AIS 3- Requirement analysis**
   - **AIS 4- Cost/benefit analysis**
   - **AIS 5- Technology assessment**
   - **AIS 6- Development & implementation**
   - **AIS 7- Training**
   - **AIS 8- Post-implementation evaluation**

8. Please indicate the degree of investment in following direct AMT
   - **CNC- Computer numerical control machines**
   - **DNC- Direct numerical control machines**
   - **RO- Robotics**
   - **FMS- Flexible manufacturing system**
   - **AMHS- Automated material handling systems**
   - **AGV- Automated guided vehicles**
   - **ASRS- Automated storage and retrieval system**
   - **RP- Rapid prototyping**

9. We are investing in the following indirect AMT
   - **CAD- Computer aided design**
   - **MRP- Material requirement planning**
   - **SPC- Statistical process control**
   - **BC- Bar coding**
   - **MRP II- Manufacturing resource planning**

10. Please indicate the degree of investment in following administrative AMT
    - **ERP- Enterprise resource planning**
    - **ABC- Activity based accounting systems**
    - **OA- Office automation**

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Your Name and Position: ____________________________
Phone ______________________ Fax __________ E-mail ______________
Qualification & Experience: __________________________________________
Company Name and Address: __________________________________________

Would you like to receive a copy of executive summary report based on the findings of this survey? Yes/No

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**G. S. Dangayach** is an Associate Professor in Department of Mechanical Engineering in Malaviya National Institute of Technology (MNIT), Jaipur. He has 17 years of academic and 3 years of industrial experience. He has published 60 research papers in various National and International Journals. He is Guest Editor of “International Journal of Manufacturing Technology & Management (IJMTM)” and “International Journal of Business Performance Management”. He is also a reviewer of seven reputed International Journals. He is actively involved in sponsored projects and consultancies. He was a Visiting Professor at School of Management, Asian Institute of Technology (AIT) Bangkok.

He can be reached at dangayachgs@yahoo.com

**S. C. Pathak** is presently working as Professor in Department of Mechanical Engineering in Malaviya National Institute of Technology (MNIT), Jaipur. He has published several research papers in National and International Journals. His present area of research interest are, Total productive maintenance & quality management.

**A. D. Sharma** is a senior Faculty in Apex College of Engineering and Technology, Jaipur and pursuing Ph. D. at Department of Mechanical Engineering in Malaviya National Institute of Technology (MNIT), Jaipur.