Impact of Advanced Manufacturing Technologies on Productivity of Indian Small & Medium Manufacturing Enterprises

[1]Divanshu Gupta, [2]Surjit Kumar Gandhi, [3]Harmesh Lal
[1]Assistant Professor, [2]Professor, [3]Professor
Mechanical Engineering Department
PCTE Institute of Engineering and Technology, Ludhiana, India

Abstract : Advanced manufacturing technology (AMT) has brought significant changes in manufacturing operations in overall industrial manufacturing scenario. Waste due to motion and transportation are effectively eliminated by implementing AMTs. Hard and soft technologies are capable to enhance the operations. Right time delivery of product is enhanced by these strategies. Research is still lacking to check the performance of such strategies in manufacturing organizations. Reliability analysis including measuring of reliability coefficient, testing of mean difference using ANOVA, descriptive testing and student *t* test have been employed for the analysis of filled questionnaire. Results of investigation recommended that clarity in goals of AMTs should be there for every employee in the organization. Moreover, robotics and computer-aided design/computer-aided manufacturing are highly utilized in manufacturing industry of Punjab.

Key words: AMTs(advanced manufacturing technologies); manufacturing; CAD/CAM.

I. INTRODUCTION

Advanced manufacturing technology (AMT) has brought significant changes in manufacturing operations in overall industrial manufacturing scenario. It is the main technique that is useful improving competitiveness and efficiency of an organization. It includes computer-aided design/computer-aided manufacturing (CAD/CAM), computer numerical controlled (CNC) equipment, robotics, flexible manufacturing systems (FMS), rapid prototyping, environmentally sustainable technologies, etc. (Rao, 2007). Advanced strategies involves implementation of new technologies and organizational structural changes and strategies like total quality management and just-in-time manufacturing that result in significant changes that are required in manufacturing operations. The adoption of AMT includes adoption of advanced technologies and application of computer system in production planning and control activities (Young and Selto, 1991). AMT include software and hardware based technologies that were properly controlled and implemented to improve the effectiveness and efficiency of manufacturing operations of the organization. Mize (1987) argued that AMT is a strategy of setting objectives and goals of the organization by all round development of the organization by solving problems and integration of computers and process planning. Hofmann and Orr (2005) claimed that as a manufacturing strategy framework that affects the manufacturing strategy in the "manufacturing process technology" decision area. The decision control not only includes manufacturing decision area but also production control area, and human resources and management and organizational processes revision

(organization). AMTs are used for manufacturing and design activities. Investment in implementing AMTs is associated with investment in supportive mechanisms such as preventive maintenance policies.

In global manufacturing scenario, manufacturing organizations are focused on narrow type of product and efficient mass production manufacturing operations through programs of productivity improvement (Huber, 1984). In order to anticipate markets and develop production systems quickly that is required to produce product that delivers the product that meet customer requirement, AMTs implementation is necessary (Hall, 1992). Continuous refineness of manufacturing processes is necessary in this high competitive environment. AMTs programs are useful tools to work continuously with suppliers in order to improve the performance of manufacturing operations (Hernandez-Matias et al., 2008). This type of environment is characterized by rapid changes in market and short product life cycles. Dramatic changes in customer demanding situations have led to adoption of such types of technologies (Singh and Khamba, 2010).

The changes in the manufacturing environment are characterized by competitive environment on supply side and increased volatility in customer requirement in the demand part. Such changes have remarkable marks on different aspects of organizations.

(Gomes et al., 2006). In order to pose the competitive environment, manufacturing organizations must apply AMT initiative in all aspects of their operations for improving the competitiveness (Pintelon and Gelders, 1992). In the era of globalization phase, fuelling of production manufacturing techniques has raised the need of new technologies in manufacturing organizations. Decrease in the life cycles of products, flexibility of manufacturing operations has become necessary (Mechling et al., 1995). AMTs help to provide foster changes in management organization both through its application to operations of the firm and managerial work. These changes results in production of smaller and more comprehensive management structures on the basis of control and integration offered by new technology. Research is still lacking to check the performance of strategies of AMTs in manufacturing organizations. So an attempt has been made to assess such technologies and impact of these technologies.

II. LITERATURE REVIEW

Kotha and Swamidass (2000) investigated the relationship among strategy, AMT and performance by conducting survey in 160 US manufacturing organizations. Multidimensional view of AMT has been studied by stressing the information processing capability in AMT. The survey confirms the fit between certain strategy-dimensions of AMT that will be associated with superior performance.

Laosirihongthong and Paul (2004) explained the role on management practices in implementing AMTs on 149 organizations in Thai automotive industry. Results of investigation demonstrated that investment in these technologies and adoption of quality management practices shows better performance that do not use these management practices including leadership, continuous improvement, improved vendor relationship and customer focus.

Dangayach and Deshmukh (2005) examined the competitive priorities of AMTs, implementation criteria of AMTs and degree of investment in AMTs fo achieving the flexibility. Results indicated that SMEs of India are prioritizing quality and are giving less priority to flexibility. Post-implementation requirement and evaluation crtiteria implementation steps have got least attention from SMEs of India.

Small (2006) presented the investigation on investment justification in manufacturing unit of USA. The study adopted the complex technology portfolio using economic and strategic justification supported by ratio and discounted cash flow justification technique. Results indicated that functional level integration at different stages of AMT project has been reported.

Zhang et al. (2006) used additive, mediating and moderating models to conduct survey in 173 manufacturing organizations. It has been observed that from the three alternative models, best supportive model is moderating model. The results conclude that advanced technologies shows highly positive impact on operations improvement practices and flexible manufacturing competence that are needed to be implemented effectively in the organization.

Narain et al. (2007) provided the comprehensive perspective of the issues surrounding the problem of investment justification of AMTs and provides future research suc as development and design of hardware elements of AMTs, popularize the use of activity based costing system and information from pooling from different users of AMT.

Liao and Tu (2008) determined responses of manufacturing strategy to different levels of uncertainty in environment, either integration o manufacturing strategy o automation strategy for manufacturing system plays the important role for a manufacturing organizations to achieve performance level under uncertainty The study aimed at determining the impact of integration and automation on manufacturing performance. Survey of 303 companies indicated that under uncertainty environment, manufacturing automation system has positive impact on manufacturing performance, while in uncertainty environment integrated manufacturing system as significant positive impact on manufacturing performance.

Thomas (2008) conducted a survey in 300 manufacturing SMEs from different manufactory industry sector. The survey investigated, for a period of three year period how many benefits these organizations have occurred after AMTs implementation. The purpose of survey is to educate academicians and industrialists for its significance. The capabilities of these companies to implement AMTs have been ascertained. SMEs attributes for development of AMTs have been explained. Finally strategic model for effective implementation of AMTs has been explained.

Chuu (2009) developed decision making model using fuzzy attributes to evaluate the suitability of AMTs. Different attributes have been considered in evaluating the suitability of new technologies. The approach involves development of fuzzy information for fusion method. The flexible manufacturing system utilized in the Taiwan bicycle industry is used in this study to illustrate the computational method of the proposed method.

Gouvea da Costa and Pinheiro de Lima (2009) presented the organizational design development rationality for adoption of AMT. The theoretical synthesis developed integrates two refined and tested framework. This paper

is a theoretical construction that organizes and synthesizes the issues that are being studied in the main theme: "The adoption of the automated systems," focusing the discussion on the manufacturing strategy and organizational design domains..

Small et al. (2009) explained the results of investigation of implementation of AMTs strategies at 82 parts durable goods manufacturing plants in the USA. The results of investigation indicated that plants that are desirable of implementing integrated technologies must prepare of preplanning activities and justification stages of implementing AMTs in their manufacturing organizations.

Singh and Khamba(2010) assessed different success factors affecting utilization level of AMTs. Various difficulties faced by organizations have been assessed. Factor loading approach has been applied to determine the relationship among success factors. It has been observed that effective utilization of AMTs is not an easy task. To overcome the problems some enablers are employed in order to compete.

Goyal and Grover (2013) developed a model for the evaluation of AMT using fuzzy graph theoretic approach. Effectiveness of AMTs is evaluated by quantifying the intangible factors based on single numerical index which is useful to managers. The survey has been performed to rank the attributes which provides quality and reliability. The survey data is converted into crisp score by using 11-point fuzzy scale that is done by defuzzification.

Singh et al. (2015) utilized AMTs, Analytic Hierarchy Process and Quality Function Deployment to develop framework for AMT implementation. An industrial example of an aerospace supplier company that is trying to make a selection between three groups of AMTs. Moreover multiple requirements are identified and suggest the selection between three technologies.

Bhandari et al. (2018) gave the justification of AMTs in SMEs in auto sector. From literature survey and expert opinion the benefits identified includes flexibility improvement, production cost reduction, reduction in inventory, improvement in productivity and time delivery of product. Global desirable index of SMEs in connection with AMTs and traditional manufacturing is compared and calculated with AHP. The findings suggest that judicious application of AMTs can improve their performance in their processes.

Singh et al. (2019) determined the impact of AMTs in Indian organizations. The relationship of AMT and strategic factors has been ascertained. The organization success has been achieved by strategy formation. Finally the model for development of Indian Organization has been culminated for strategic success. The study is useful to academicians and professionals for better comprehension of relationship between AMTs and success attributes.

III. RESEARCH METHODOLOGY

The research methodology has been discussed below:

- Literature survey has been performed
- Questionnaire Preparation
- Testing of Questionnaire

- Testing of filled Questionnaire
- Conclusions and limitations

The purpose of the study is to assess level of utilization of AMTs, to determine the role of determinants of AMTs towards performance improvement, to assess the barriers in implementing AMTs and to assess the benefits accrued after implementing AMTs

For this survey questionnaire has been designed, containing 4 sections as shown in Table 1.

General Organizational Information	
Level of utilization of AMTs	1. Mature 2. Developing 3. Immature 4. Not Applicable
View points regarding determinants	1. Disagree 2. Neutral 3. Agree 4. Highly Agree
Benefits	1. To a some Extent 2. To moderate Extent 3. To a Large Extent 4. To Extremely Large Extent

Table 1. Different Sections of AMT Questionnaire

A total of 20 organizations have been surveyed including pharmaceutical, chemicals, steel products, bicycle parts, spring makers, clothes, towel, engineering goods, chairs and tables, fasteners, iron forging, iron tools, auto parts, manufacturing .of wire drawing.

IV. RESULTS AND DISCUSSIONS

4.1 Reliability Analysis

The reliability analysis has been performed using SPSS 16.0v. Cronbach alpha has been calculated and value as been calculated at the output sheet of SPSS software. The results of reliability shows high reliability i.e above 0.7 as shown in table 2.

Self Interest Factors	
Employees morale enhancement is effective towards organization	**Case Processing Summary**
Employees's satisfaction with projects is compulsory	
Appropriate reward system is effective in enhancing employee morale	**Reliability Statistics**

		N	%
Cases	Valid	20	95.2
	Excluded[a]	1	4.8
	Total	21	100.0

a. Listwise deletion based on all variables in the procedure.

Cronbach's Alpha	N of Items
.936	3

Housekeeping factors

Quality plan of actions are effective

Quality technical support from technical team contributes towards planning

Integration of business function is essential for housekeeping

Case Processing Summary

		N	%
Cases	Valid	20	95.2
	Excluded[a]	1	4.8
	Total	21	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.872	3

Literacy Factors

Understanding of AMT capabilities is effective to the organization

Clear understanding of business principles is essential to every employee

Clarity of AMT goals and objective plays an effective role in performance improvement

Case Processing Summary

		N	%
Cases	Valid	20	95.2
	Excluded[a]	1	4.8
	Total	21	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.890	3

Cost

Reduction in inventory level

Effective utilization of capacity

Case Processing Summary

		N	%
Cases	Valid	20	95.2
	Excluded[a]	1	4.8
	Total	21	100.0

reduction in production costs	a. Listwise deletion based on all variables in the procedure.
Increase in labor productivity	**Reliability Statistics** Cronbach's Alpha: .757; N of Items: 4
Quality	
Offering high performance products	**Case Processing Summary** Cases – Valid: N = 20, % = 95.2 Excluded[a]: N = 1, % = 4.8 Total: N = 21, % = 100.0 a. Listwise deletion based on all variables in the procedure.
Offering reliable product	**Reliability Statistics** Cronbach's Alpha: .891; N of Items: 3
Low defective products	
Flexibility	
Fast change in design	**Case Processing Summary** Cases – Valid: N = 20, % = 95.2 Excluded[a]: N = 1, % = 4.8 Total: N = 21, % = 100.0 a. Listwise deletion based on all variables in the procedure.
Adjustment of capacity quickly	
Fast volume changes	
Changes in product mix	**Reliability Statistics** Cronbach's Alpha: .825; N of Items: 4

Table 2. Reliability of determinants and benefits

4.2 Testing of mean difference

The testing of mean difference for various determinants has been done using ANOVA test applied on Excel 2007.

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	20	64	3.2	0.168421		
Column 2	20	64	3.2	0.168421		
Column 3	20	66	3.3	0.221053		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.133333	2	0.066667	0.358491	0.700294	3.158843
Within Groups	10.6	57	0.185965			
Total	10.73333	59				

Table 3: ANOVA for significance testing self interest factors

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	20	66	3.3	0.221053		
Column 2	20	66	3.3	0.221053		
Column 3	20	67	3.35	0.239474		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.033333	2	0.016667	0.073359	0.929355	3.158843
Within Groups	12.95	57	0.227193			
Total	12.98333	59				

Table 4 ANOVA for significance testing of housekeeping factor

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	20	66	3.3	0.221053		
Column 2	20	66	3.3	0.221053		
Column 3	20	67	3.35	0.239474		

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.033333	2	0.016667	0.073359	0.929355	3.158843
Within Groups	12.95	57	0.227193			
Total	12.98333	59				

Table 5 ANOVA for significance testing of Literacy Factors

4.2.1 Results Discussion of the findings

In this test, a null hypothesis is that there is no significant difference between the different determinants in terms of main determinant. Results indicated that since F value calculated for all the main determinants is less than F critical and p values are more than 0.05, which shows that null hypothesis is accepted which further indicated that no significant difference is there means the different determinants.

4.3 Student's t test on importance of each area

Student's t test has been performed to ascertain the significance of various factors. The *t* statistics and degree of freedom for each factor has been calculated using SPSS Software. The results of various factors are sown in Table 6.

Factor	***t* value**	**Degree of freedom**
Self interest factors		
Employees morale enhancement is effective towards organization	3.508846	19
Employees's satisfaction with projects is compulsory	12.86577	19
Appropriate reward system is effective in enhancing employee morale	12.16601	19
Housekeeping factor		
Quality plan of actions are effective	12.16601	19
Quality technical support from technical team contributes towards planning	12.16601	19
Integration of business function is essential for housekeeping	12.13829	19
Literacy Factors		
Understanding of AMT capabilities is effective to the organization	8.404085	19
Clear understanding of business principles is essential to every employee	9.295783	19
Clarity of AMT goals and objective plays an effective role in performance	9.936871	19

improvement		
Cost		
Reduction in inventory level	10.60821	19
Effective utilization of capacity	7.16734	19
reduction in production costs	7.642628	19
Increase in labor productivity	6.180515	19
Quality		
Offering high performance products	8.760082	19
Offering reliable product	8.760082	19
Low defective products	6.180515	19
Reliability		
Fast change in design	5.391774	19
Adjustment of capacity quickly	5.844362	19
Fast volume changes	4.871045	19
Changes in product mix	4.871045	19
Tcitical=2.093(table value)		

Table 6 Student's *t* test

4.3.1Results of t test

Results indicated that since calculated value of t is more than table value at 19 degree of freedom, all the factors are significant.

4.4 Importance of determinants and benefits achieved

Factor	**mean**	**Standard deviation**
Self interest factors		
Employees morale enhancement is effective towards organization	3.2	0.410391
Employees's satisfaction with projects is compulsory	3.2	0.410391
Appropriate reward system is effective in enhancing employee morale	3.3	0.470162
Housekeeping factor		
Quality plan of actions are effective	3.3	0.470162
Quality technical support from technical team contributes towards	3.3	0.470162

planning		
Integration of business function is essential for housekeeping	3.35	0.48936
Literacy Factors		
Understanding of AMT capabilities is effective to the organization	3.45	0.759155
Clear understanding of business principles is essential to every employee	3.45	0.686333
Clarity of AMT goals and objective plays an effective role in performance improvement	3.55	0.686333
Cost		
Reduction in inventory level	2.95	0.394034
Effective utilization of capacity	2.9	0.552506
reduction in production costs	2.85	0.48936
Increase in labor productivity	2.9	0.640723
Quality		
Offering high performance products	3.1	0.552506
Offering reliable product	3.1	0.552506
Low defective products	2.9	0.640723
Reliability		
Fast change in design	2.7	0.571241
Adjustment of capacity quickly	2.65	0.48936
Fast volume changes	2.65	0.587143
Changes in product mix	2.65	0.587143

Table 7 shows the mean and standard deviation

4.4.1 Result discussion of the important determinants

Appropriate reward system is effective in enhancing employee morale is rated most important followed by Employee morale and Employee satisfaction among self interest factors; Integration of business function is most essential followed by Quality plan of actions and quality technical support from technical team in terms of housekeeping; clarity of AMT goals is rated most important followed by understanding of AMT capabilities and clarity of business principles in terms of Literary factors; Reduction is inventory is rated most important followed by effective utilization of capacity and increase in labor capacity, and reduction in production cost in

terms of cost; offering high performance product and reliability product are rated most important followed by low defective products in terms of quality; and fast changes in design is rated most important followed by adjustment of capacity, and fast volume changes and changes in product mix in terms of reliability.

4.5 Extent of utilization of AMTs

AMT	Mature	Developing	Immature	Not Applicable
computer numerical controlled (CNC) equipment	4%	25%	55%	16%
computer-aided design/computer-aided manufacturing(CAD/CAM)	4%	40%	11%	45%
flexible manufacturing systems(FMS)	4%	35%	55%	6%
robotics	6%	4%	15%	75%
rapid prototyping	5%	30%	50%	15%
environmentally sustainable technologies	15%	55%	30%	0%
Just-in time manufacturing	10%	60%	20%	10%
Kaizen	40%	40%	20%	0%
Total productive maintenance	75%	25%	0%	0%
Six sigma	0%	55%	45%	0%

Table 8 shows the extent of utilization of AMTs

4.5.1 Result Discussion of the findings

Results demonstrated that utilization of CNC equipments is in immature state in 55% of organizations surveyed; CAD/CAM is not applied by 45% of the organizations surveyed; FMS is in immature use in 55% of the organizations surveyed; Robotics is not utilized by 75% of the manufacturing organizations; rapid prototyping is in immature state in 505% of these organizations; environmentally sustainable technologies are in developing stage in 55% of these organizations; JIT manufacturing is in developing state in 60% of these organizations; Kaizen is in mature and developing state in 40% of these organizations; TPM is in mature in their use in 75% of these organization; and Six Sigma is in developing state in 55% of the manufacturing organizations surveyed.

V. CONCLUSION, PRACTICAL IMPLICATION and LIMITATIONS

From the results, it is concluded that AMTs helps in improving cost, quality and reliability that is helpful in overall growth and developm4nt of the organization for enhanced competition. The study investigates the demonstration of AMTs towards performance improvement by achieving benefits in terms of cost, quality and reliability of manufacturing system processes.

- Organizations are applying robotics technology to a very less extent; total productive maintenance to a very high extent.
- Providing rewards to the employees helps to create self interest of employees; Business function integration is very essential for housekeeping; clarity of AM goals plays an important role.
- Inventory level reduction is reduced; high performance and reliable product is achieved and fast change in design is achieved by implementing AMTs in the organization.

The study will help the practitioners, engineers and industry consultants to know the significance of AMT implementation towards improving the performance of operations in manufacturing. The limitations of the study include:

- The study is limited to only Punjab based industry only.
- Sample size is small.
- There can be changes of method variance and little content validity as there is one respondent from each organization.

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