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Advanced Manufacturing Technology Implementation Process in SME: Critical Success Factors

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Abstract: The aim of this paper is to present critical factors that constitute a successful implementation of the *Advanced Manufacturing Technologies* (AMT) in Small Medium Enterprise (SME). Many large companies have applied AMT and the applications have shown significant results in this global market era. Conveniently, these phenomenons are also engaged to Small Medium Enterprises (SME) that of high demands on performing high quality product, fast delivery, reliable and more flexible. The implementation of AMT follows several processes namely pre installation, installation, improvement and mature. In order to guarantee the succesfull of running these processes, one should consider the Critical Success Factors (CSF). We conducted a survey to 125 SMEs that have implemented AMT, and found that the CSF for each process is moderately different. Good leadership is the main critical success factor for preparing and installation of the AMT. Once the AMT started or installed and arrived at growth stage, the financial availability factor turns into a critical success factor in the AMT implementation. In, mature stage, the support and commitment of top management becomes an important factor for gaining successful implementation. By means of factor analysis, we could point out that strategic factor is the main factor in pre-installation and installation stage. Finally, in the growth stage and mature stage, both tactical and strategic factors are the important factors in the successful of AMT implementation.

Keywords: AMT, SME, CSF.

Introduction

In this globalization era, industries face tense competition in attracting both domestic and international customers. On the other hand, customers increase their expectation on quality and service delivered. Customers demand high quality products, shorter delivery and more flexible services. Unavoidably, industries need to improve their manufacturing technology. One of the choices is applying Advanced Manufacturing Technology (AMT). Potential advantages of adopting AMT are enabling penetrate market earlier, prompt response to market needs, high quality and reliability of products. The companies which have adopted the technology have increased domestic and global market shares. Nowadays, the basis of product competition is shifted from emphasizing the lower costs production to the time-to-market, flexibility, quality and reliability production.

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Many small and large companies have adopted the AMT to improve their performance and achieving competitiveness success. However, results of several empirical studies indicate that the implementation of AMT has often not been either successful or can be implemented straightforward as it was expected. Many AMT projects fail to meet the expectation of their implementer (Lewis and Boyer [11]). Some factors that cause the implementation of AMT fail are the inability of companies to integrate advanced technology with existing conventional technologies, financial problems, infrastructure problems such as inadequate planning of the organization in preparing AMT implementation, worker training, top management commitment, and also the lack of long term planning in the beginning of the process of implementing AMT pre-installation, installation, development of technology to optimization and preparation for the use of more advanced technology. Although there are some problems in the implementation of AMT in large companies, but generally they have no significant obstacles and have shown significant improvement. Only a few of them did not succeed. It is not because they are short in the investment or finance, but they failed due to some other factors, such as infrastructure, culture, or external factors.

Small Medium Companies or Small Medium Enterprises (SMEs) also want to patronize those

large companies in implementing the AMT, so they can race in the same competition especially for providing better quality, fast delivery, flexible and reliable products. Since, nowadays customers only consider the desired products regardless big companies or SME which produce those ones. However, SMEs get more struggles in implementing the AMT than the big companies. Frequently, SMEs have limitation in financial condition or other factors that obstruct them in implementing the AMT successfully. Therefore, this study explores the critical success factors which have big impacts in the implementataion of AMT for SME.

Methods

AMT Taxonomy

Advanced Manufacturing Technologies refers to a family of technologies used in all facets of manufacture including design, control, fabrication and assembly (Monge [9]). Narain *et al.* [10], Raymond [12] and Salaheldin [14] defined the AMT usage: Computer aided design (CAD), Computer aided manufacturing (CAM), Materials requirements planning (MRP), Manufacturing resources planning (MRPII), Enterprise resources planning (ERP), Electronic data interchange (EDI), Optimized production technology (OPT), Quality control software (QCS), Statistical Process Control (SPC), Expert systems, Manufacturing automation protocol (MAP), Management Information System (MIS), Mainframe, Minis, Local Area Network and Wireless Area Network (LAN/WAN), Online process instrumentation, Shop floor data capture, Graphics hardware, Automatic assembly, Flexible assembly systems, Manufacturing cells, Automated warehousing/order picking, Automatic testing equipment, Equipment controlled by programmable automation, Robot-based operations, Numerical control machines (NC), Automated handling of materials, Flexible manufacturing systems (FMS) Implementations, Computer-based inventory management, Computer-based bar-coding, Computer-based maintenance management, Computer-based production scheduling, ISO, Total Quality Management (TQM), Just in Time (JIT).

From the AMT usage, Beaumont *et al.* [2], classified AMT in three dimensions such as, Direct: Technology used on the factory floor to cut, join, reshape, transport, store or otherwise modify materials. Examples include numerically controlled machinery and production line robots (CNC, DNC, Robotics, FMS, AMHS, AGV, etc). Indirect: Technology used to design products and schedule production. Examples include computer-aided design and drafting and scheduling system such as manufacturing resources planning (MRP II) and production monitoring systems. (CAD, MRP, SPC, BC, MRP II, JIT, etc). Administrative: Technology used to give administrative support to the factory and integrate its operations with the rest of the organization. Examples include job-costing system, ordering and inventory systems, accounting and cost control systems and communication systems supporting electronic data interchange and other forms of electronic business.

Sun *et al.* [18] classify AMT as follows: Planning and Control include ERP, Information resource management include Technology databases/product data management (PDM), Product design and development, LAN-WAN/Intranet/shared database/internet, CAD, CAE., Factory automation: Integrated design processing systems (CAD, CAE, CAM, CAPP), Numerical control machines, CNC, DNC, Computer aided inspection/trial/tail, FMS, FMC, automated tool change parts loading/unloading robots, automated storage-retrieval system (AR/RS) and Automated guided vehicles (AGVs).

Summarizing from the definitions above, it appears that AMT varies from simple method to very advance and it application not only to advance manufacturing system but also can be applied to simple SME operations. It can also be categorized into soft and hard technology and the technique application depend on the stages of operations system from input, transformation system, output and environment.

AMT Implementation Process

Implementation of AMT is a strategic issue; therefore it requires strategic planning, not only at the business level but also at the manufacturing level. AMT implementation involves more than technical challenge. It is also an organizational challenge. It requires that organizations involve redefine traditionnal roles and responsibilities, organization structure, work content, reward system, and its approach to education and training. Because of the complexities of all the issues involve in implementing AMT, many companies are ending up with disappointing results, as their attempts to implement AMT fail to yield quick and dramatic benefits, and may even cause problems that are more complex and serious than those they were intended to solve. Many factors determine the success of AMT implementation. The factors that have to consider are not only technological issues, but also involve cultural and organizational, problems of integrating the new system and the old, defining new human roles and many others. Some researcher found the factors can influence to the

success of AMT implementation such as: Degree of investment, context of organization (organization culture, organization structure), Strategic Orientation, Entrepre-neurial Environment (type of ownership, experience, education), external factors (government, supplier, customer, technology trend), manufacturing strategy, role of management information system department, justifying, planning and installing (Raymond and Pierre [13]; Raymond [12]; Swamidass and Kotha [19]; Small and Yasin [17]; Beaumont *et al.* [1]; D´ıaz *et al.* [6]; Castrillon and Cantorna [4]; Small [15,16]). The initial stage of AMT investment decisions is the recognition of need or opportunity (Chan *et al.* [5]). The investment in AMT requires long periods of planning and the resulting impact on the firm is not immediate. Since variety of environmental, structural, technological, individual and task-related factors in a firm's operating environment can facilitate or inhibit adoption, implementation and successful management of AMT, the success or failure of AMT projects in linked to be the implementation process of AMT.

One model of AMT implementation starts from the institutionalization/initiation, acceptance, routinization and infusion (Beatty [1]). In the initiation stage, Yussuf *et al.* [20], considered six success factors such as committed sponsor, operating sponsor, think-tank linkage, alignment of organization and business, integration with existing system, natural organizational interfaces to new system and commitment of users and stake holders. Besides that factor, companies should be considered in the organization issue such as the vision, commitment top management, and employee participation, size of organization, type of ownership, organization strategic and company growth such as R&D expenditure, asset and sales. Lack of resources, lack of customer requirement, changing the environment, increased technological availability, degree of AMT adoption by competition, labor cost consideration are some factor in the initiation stage of AMT implementation too. In the planning stage involve two stages; adoption stage and adaptation stage. Frohlich [7] has adopted a Kwon and Zmud's model six stage for technology implement-tation. The six stages are initiation, adoption, adaptation, acceptance, use and incorporation. That model can be combined with the theory.

In the Implementation stage includes adoption and adaptation as a change in the theory of organizational change. Top management plays a key role in the initiation stage to the next step of implementtation project team. The chain of AMT implementtation gives an effect to each stage. The successful of the next stage is depended on the previous stage.

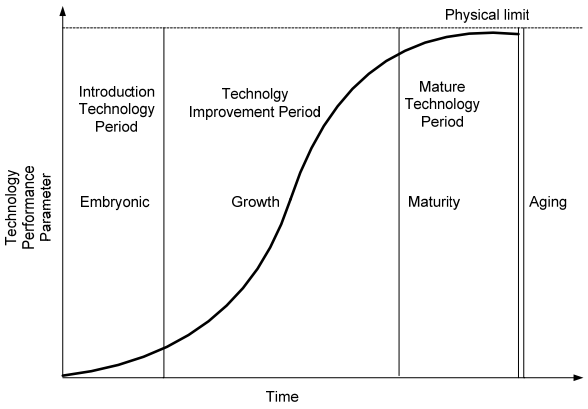

Figure 1. The S-curve of Technological Progress

The other model is from Brache and Bodley-Scott S [3]. Their model is quite same with Frohlich's model start from Initiation phase, definition phase, planning phase, execution phase and closure phase. The other model of AMT implementation is as follows S-curve in technology life cycle start from pre or initial, introduction or installation, growth and mature as in Figure 1. (Khalil [8]).

Research Methodology

This study utilized the question survey technique to solicit the data from 125 SMEs in Malaysia. The questionnaires were distributed at an SME convention held in Malaysia. This event attracted many SMEs that showcased their products. The target respondents were managerial-level employees of SMEs in the food and beverage industry, herbal industry and craft industry. The questionnaire is divided into four sections including profile of organization, techniques in AMT implementation, Critical Success Factors of AMT Implementation and lastly, investigation of the performance of SMEs. A total of one hundred and twenty five (125) sets of usable questionnaires were successfully collected and analyzed. Data is first analyzed using descriptive analysis and later using factors analysis to reduce the factor and one way analysis of variance to identify the differences between two factors.

Result and Discussion

AMT Techniques

The used of AMT in input stages of operations system is presented in Figure 2. The techniques are Computer Equipment, LAN, WAN, Automation and loading and unloading as a Hard Technology and MIS, Auto-mated Drafting Technologies, CAD, CAE, Auto-mated Statistical Process Control, Quality Function Deployment, CRM, and Forecasting software as a soft technology.

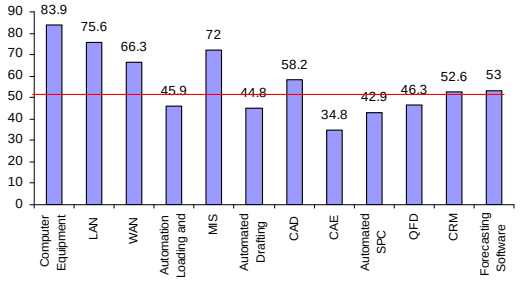

Figure 2. The Use of AMT in Input stage

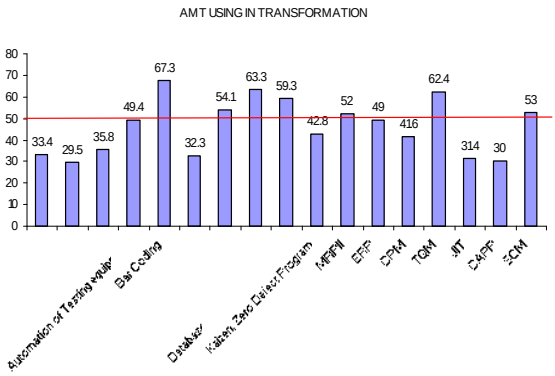

Figure 3. The Use of AMT in Transformation Process

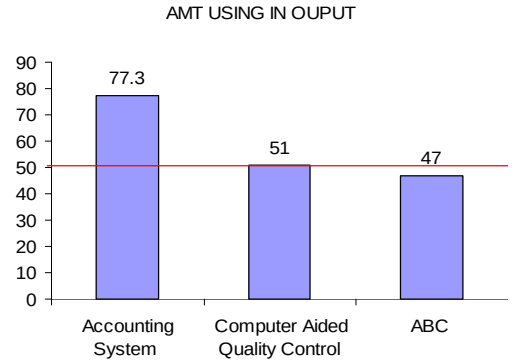

Figure 4. The Use of AMT in Output stage

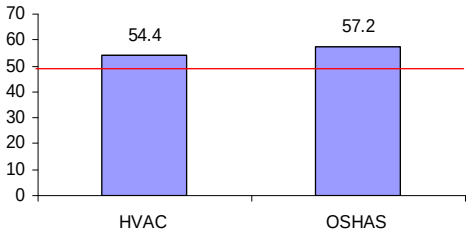

Figure 5. The Use of AMT in Environment

From the total of hard technologies surveyed only three techniques have percentage of usage more than 50%, they are, Computer Equipment, LAN and WAN. The soft technology, such as MIS, CAD, CRM and Forecasting software have percentage of usage also more than 50 %.

In transformation stages the hard technologies applied are CAM, CNC, CIM, Automation of Testing equipment, Bar Coding and RFID. While, the soft technologies applied are ISO, HACCP-GMP, Database Management System, Kaizen, Zero, Defect Program, MRPII, ERP, CPM TQM, JIT, CAPP, and SCM (Figure 3). The technique that has more than 50% usage in hard technology is Bar Coding. In soft technology there are 6 techniques which have more than 50% usage (Figure 3). The appliances of more soft technology compares to hard technology in the transformation process indicate that SMEs are in the right direction of optimizing their productivity and performances.

In output stage, the hard technology applied is Computer Aided Quality Control, while Accounting System and ABS asa control of finance systems are occupied in the soft technology (Figure 4).

In environment stage, Heating, Ventilation, and Air Conditioning System (HVAC) are used in hard technology part, mean while Occupational Safety and Health Administration System (OSHAS) is applied in the soft technology part (Figure 5). Moreover, the occupancy of hard and soft technology in the enviromentment stage is high. This indicates that the impact of environment stage among SME in Malaysia is very dominant.

Table 1 summarizes the total usage of soft and hard technology. It can be seen that 54.5% of the production process apply soft technology while 50% of that process apply hard technology. Trivially, it can be deduced that the use of soft technology is higher than the hard one in overall. However, if we stare at the technologies used at each process, the use of soft and hard technology tends to be the same. The similar analysis can also be concluded for the input and output and transformation processes.

Table 1. Percentage of use of AMT in production process

Process	% of AMT Used
Input	58.3 (7/12)
- Soft technology	50.0 (4/8)
- Hard Technology	75.0 (3/4)
Transformation	41.2 (7/17)
- Soft Technology	54.5 (6/11)
- Hard Technology	16.7 (1/6)
Output	66.7 (2/3)
- Soft Technology	50.0 (1/2)
- Hard Technology	100 (1/1)
Environment	100 (2/2)
- Soft Technology	100 (1/1)
- Hard Technology	100 (1/1)
Overall	
- Soft Technology	54.5 (12/22)
- Hard Technology	50.0 (6/12)

Table 2. Five rank critical success factors at each stages

Rank	Pre-intallation	Installation	Growth	Mature
1	Good Leadership	Good Leadership	Financial Availability	Suppor and involvement of top managemet
2	Support and Involvement of top management	Financial Availability	Teamwork	Inter-departmental coordination and cooperation
3	Financial availability	Teamwork	Expertise availability	Advance Communication technology
4	Firm Culture	Support & involvement of top management	Perceived control over the process of AMT	Communication with supplier
5	Training and education on AMT	Interdeparmental coordination and cooperation	Good Leadership	Collection and Analysis of AMT's data

Critical Success Factors.

Of the 15 Critical Success Factors (CSF) can be sorted based on its average value and taken five highest ranking on every stage. Results of the five rankings can be seen at Table 2.

At the stage of pre installation, the most important factor is the leadership factor besides the availability of financial factors. At this stage the company also requested support from top management commitment. In addition to the above three factors, Firm Culture is an important factor in which this factor must have been formed so that it can affect the successful implementation of AMT. Also with the factor of staff training and education is an important factor in preparation for the implementation of AMT so that they can easily implement. Castrilon and Cartona [4] also mention that policy of worker training can effect to the successful of AMT implementation. Meanwhile in the next stages, Good leadership is as important factor as same with in pre installation stage. The Financial Availability and top management support, team work building and interdepartmental coordination are also as a critical success factor. At the stage of growth, the availability financial factor is the most important in development because after the company introduced a new technology with good leadership approach and supported by top management, the financial factor is of course a major factor when this factor is ranked third in the pre-installation stage and ranked second on the stage of installation. At the mature stage factor support and involvement of top management becomes a critical success factor for ranking one. Interdepartmental factor is a second ranked, this factor has already been considered on installation stage. New factors that existed at the mature stage are the factor of advanced communication technology, advanced communication with suppliers and collecting and analyze data to maximize the existing system or to monitor existing systems that keep it running optimally.

A total of 15 CSF was collected from the survey. It can be classified into two factors: Tacticalal Factors and Strategic Factors. Tacticalal factor is the operational factor of the company when doing pre-installation, installation, development of AMT. While the strategic factor is the factor that considerable factor by top management in managing, planning to make the AMT can be run, developed and managed in its implementation. According to the factor analysis of 15 CSF, the results of grouping the two factors are the development of corporate culture, training and worker education, collection and data analysis AMT's, Participation Consultant, Communication with suppliers, availability of experts, Perceived control over the process of AMT, Advanced communication technology, the availability of finance as a tactical factor. Strategic factors can be described as a factor of top management support and involvement, Good Leadership, Interdepartmental coordination and cooperation, Reward and recognition. All the results of factor analysis can be seen in Table 3.

In Table 4 shows the value of each factor for tactical and strategic factors. At the Pre-installation stage value of tactical factor as 3.699 is lower than the value of strategic factor as 3.819. Also at the installation stage the average value of strategic factor 3.973 is also greater than the average tacticalal value 3.778. But on the growth stage average value of tactical factor 3.974 is greater than the average of the strategic value of 3889. Similarly, on average mature stage tactical factor value for 2916 is greater than the average of the strategic value of 2889.

To assure that each factor is significantly diffirent, we apply statistical inferences to test it. Results from tests on the Table 5 shows that there is a significant difference between the tactical and strategic factor in several stages. In the pre-installation stage value of the P-value is 0.040. It is under 5% level of significant so we can deduce that there is a significant difference between the tactical factor with

Table 3. Factor Analysis result for CSF Variables

CSF Variables	Factors	
	F1	F2
CSF on Firm Culture	.683	
CSF on Support and involvement of top management		.730
CSF on Interdeparmental co-ordination and co operation		.875
CSF on Good Leadership		.680
CSF on Training and education on AMT	.664	
CSF on teamwork		.691
CSF on empowerment		.782
CSF on Reward and recognition		.825
CSF on Collection and analysis of AMT's data	.733	
CSF on Consultant participation	.925	
CSF on Communication with supplier	.899	
CSF on Expertise availability	.904	
CSF on perceived control over the process of AMT	.799	
CSF on Advances Communication technology	.793	
CSF on Financial availability	.676	

F 1: Tactical Factors. F2: Strategic Factors

Table 4. Data summaries of tactical factors and strategic factors

Stage of AMT implementation		Mean	N	Std. Deviation	Std. Error Mean
Pre Installation	tactical	3.6991	27	1.13713	0.2188
	strategic	3.8194	27	1.10981	0.2136
Introduction/ Installation	tactical	3.7788	56	.96833	0.1294
	strategic	3.9732	56	.92702	0.1239
Growth	tactical	3.9748	24	1.15074	0.2349
	strategic	3.8889	24	1.11612	0.2278
Mature	tactical	2.9167	3	.72169	0.4167
	strategic	2.8889	3	.58531	0.3379

Table 5. Test of tactical factors and strategic factors

Stage of AMT implementation		t	df	Sig. (2 tailed)
Pre Installation	tactical-strategic	-3.133	26	.040
Introduction/ Installation	tactical-strategic	-3.582	55	.001
Growth	tactical-strategic	.910	23	.371
Mature	tactical-strategic	0.592	2	.122

the strategic factor. This also may imply that in pre-installation stage more strategic factors considered in the implementation of AMT.

In the installation stage value of p-value is 0.001, i.e. less than the 5% level of significant. We can say there is a significant difference between tactical factors with strategic factors. In the other word, at the installation stage strategic factor is more important factor to be considered in AMT implementation. However, if we look at results test of growth and mature stages for tactical and strategic factors, both of them have p-values greater than 5% of significant level. This implies that on those stages, tactical and strategic factors are similary important.

Conclusion

In production process started from input, transformation process, output and environment, the percentage of technology usage between soft technology and hard technology is almost the same. However, the implementation of soft technology has not been optimum yet. It seems that hard technology is crucial in manufacturing at all stages. On the other hand, soft technology such as expert knowledge and skills in the AMT area is an important element to optimize the use of the hard technologies. To seek for the quality of production improves at a greater degree, soft technologies must be included.

Successfully of AMT implementation process following the S curve that starts from the stage of pre installation, installation, development and mature. At every stage of the implementation process there are several critical factors that must be considered in order to succeed in the implementation process. In the pre installation and installation stages, the strategic factor is the critical factor to be considered where the Good Leadership and support from top Management will determine the successful implementation of AMT. With the basic strategic factor in both pre-installation and installation stages, the strategic factor in the development stage is still an important factor in addition to factor tacticals. In the development stage should be noted that tactical factors are as important factor as well, especially on financial availability factor. Availability of finance is required for the process of technological development. Besides this factor, the establishment of corporate culture is also an important factor in the growth stage in which emphasize on the continual improvement as a corporate culture.

Another tactical factor that needs attention in order to gain successful implementation of AMT is the availability of experts and also perceived control over the process of the implementation. As with the mature stage at which is a chain of the previous stages. The success of the previous stages will greatly affect the mature stage. In the optimization process in the mature stage, both tactical and strategic factors are needed to be considered in achieving the successof implementation of AMT. Support from top management is necessary in the maintenance of the application of AMT in addition to other operational factors such as factors of communication and coordination between departments and suppliers, advanced communications technology, and data analysis AMT.

Finally, suppliers might play an important role in improving company performance by sharing knowledge about optimization system or providing information of new technology.

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