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Assimilation of advanced manufacturing technologies in small and medium sized enterprises: An empirical analysis

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Abstract Small and medium-sized businesses are embarking on an ambitious journey of adopting advanced manufacturing technologies due to increased competition and the desire to remain competitive (AMTs). Global competition is measured in terms of improved quality, lower costs, value for money items, quick service, and variety, all supplied concurrently. Due to resource constraints, implementing advanced manufacturing technology has become a lengthy and complex process for small and medium-sized businesses. As the success or failure of a technology is determined by the implementation methods rather than the technology itself, it is worthwhile to study the practices used by small and medium enterprises while implementing advanced manufacturing technologies. A structured questionnaire was administered to 300 Indian SMEs out of which 126 valid responses were obtained. The data obtained was empirically analysed with SPSS 20.0 to explore the following: AMT enablers, current level of AMT assimilation in SMEs, assimilation pattern differences and key factors for improving AMT implementation effectiveness. Findings of this study shows that there is a very strong correlation (0.896) between two direct advanced manufacturing technologies – Flexible Manufacturing Systems and Computer Integrated Manufacturing. Other significant correlation (0.704) is observed between Robotics and Automated Storage/Retrieval Systems. Also, amongst indirect AMTs our results establish a strong correlation (0.814) between Material Requirement Planning and Computer Aided Design. The result of the hypotheses testing indicates that 43.1 % of the performance of the SMEs is explained by AMTs. The findings of this study will help SMEs in the effective assimilation of AMTs.

Keywords: small and medium sized enterprises, advanced manufacturing technology, implementation, enablers

1. Introduction

Small and medium enterprises (SMEs) play a vital role in India's economic development and span across a wide range of industrial sectors. Indian SME sector is growing in the face of a challenging global climate, with multiple highs and lows in recent years. Impetus is being given to strengthen this sector in light of its contribution to Indian GDP and its ability to generate employment. SMEs are vital to the country's economy. As the value of these enterprises is becoming more widely acknowledged, the sector's productivity and innovation capability must be promoted (Idris et al 2022; Bhalla et al 2022). SMEs are compelled to adopt advanced manufacturing technologies (AMTs) as a result of global competition, short shelf life, demanding customers, rising labour costs, and variable input prices. In order to adapt swiftly to market opportunities and dangers, firms must compete on a variety of competitive priorities at the same time (Prause 2019). SMEs represent the backbone of modern economics and are frequently suppliers of goods and services to larger enterprises. To meet national employment needs, they must remain competitive and provide high-quality output. To be competitive, SMEs are incorporating emerging technologies into their goods, manufacturing processes, and operational control.

The AMT has been implemented by number of small and large businesses in an effort to boost productivity and succeed in the competitive market. 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. Due to resource constraints, SMEs planning to implement AMT face internal and external hurdles and may not reap the potential benefits of AMT implementation. An organization's technology selection and execution must be in accordance with organisational design and external market requirements. SMEs are unable to embrace technologies that need highly trained labour and are capital heavy due to capital and human resource constraints. Three categories of AMT widely used in SMEs: LAN (Local Area Network), CAD, and CAM, but

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automated storage, robotics, and WAN (Wide Area Network) are not commonly used by SMEs. LAN is popular in SMEs due to its capacity to connect all of their tasks under a computer network in order to get superior performance outcomes (Thomas and Barton 2011; Cardoso et al 2012; Uwizeyemungu et al 2015).

Many industries, both in developed and emerging nations have benefited from advanced manufacturing technologies. With the incorporation of Industry 4.0, AMTs have already been used in the vast majority of developed nations. The successful application of AMT in developed nations has both benefits and drawbacks; developing nations can take use of this knowledge and use it to improve manufacturing production processes in their own nations (Sukathong et al 2021).

AMT offers several benefits, yet 50–75 percent of implementations face failure (Goyal and Grover 2012). A project's lifecycle must be properly planned out and managed in order to utilize automation. Additionally, researchers are of the opinion that a large number of AMT implementation failures are caused by organizations' inability to integrate advanced technologies with currently available technologies, infrastructure issues, inadequate planning, substandard operator training, low managerial resolve, and inadequate strategy (Rahardjo and Yahya 2010). AMT implementation failure is also attributed to a lack of technological initiative and ongoing support from senior management, a lack of commitment to shop floor staff, and insufficient managerial training for AMT initiatives (Bhise and Sunnapwar 2019; Bhise et al 2023). Inappropriate and insufficient planning during the pre-implementation stage negatively affects the outcome of the actual implementation.

Organizational issues, particularly those pertaining to technology, the economy, and manpower, are the main causes of AMT failures. The most crucial step in integrating new technology into an organization's old operations and reaping its benefits is planning, which entails the decision-making process of whether or not to adopt new technologies (Sukathong et al 2021; Simoes et al 2018; Saliba et al 2017; Rajesh and Gurtu 2022). Difficulties in both the pre-installation and installation phases of AMT implementations are significant and have a direct impact on the AMT projects. It can be observed from the literature that full potential of the AMTs can be realized by SMEs if the management pays attention to various factors in pre-installation and installation phases of the AMT implementation process. Therefore, this study explores the influential factors that impact the AMT implementation process of SMEs.

The study intends to explore the following:

1. What are the unique motivations for SMEs to invest in AMT?
2. What are the specific technologies that SMEs commonly employ, and how extensively have these technologies been used by SMEs?
3. Does the size of the organization influence AMT investment?
4. Is there a correlation between various types of AMTs used by SMEs?
5. What strategies do SMEs use to improve their performance?

1.1. Advanced Manufacturing Technologies (AMTs): an overview

AMT refers to the usage of computer technologies in the process of design, manufacturing, testing, transportation and controlling. AMT is defined as automation technologies that arose as a result of advancements in information technology and are classified based on the function or type of activity performed by the technology (Bhise and Sunnapwar 2019). These technologies are classified as:

Direct AMT - (technology used on the shop floor)- These technologies are used by the industries to convert and reshape the raw material into the desired product as well as for material handling purpose, for example: Computer Numerical Control (CNC), Direct Numerical Control (DNC), Robotics (RO), Flexible Manufacturing System (FMS), Computer integrated manufacturing (CIM), Automated storage and retrieval systems (AS/RS), Automated material handling systems (AMHS), automated guided vehicles (AGV) and Automated inspection and testing technologies (AITE).

Indirect AMT - These are the technologies that are used to design products, to prepare process plans and to control the production, for example: Computer Aided Design (CAD), Material Resource Planning (MRP), Statistical Process Control (SPC), Bar Coding (BC), Manufacturing Resource Planning (MRP- II), Computer-aided process planning (CAPP), Just-in-time technology (JIT).

Administrative AMT - These are the technologies that provide administrative support in industries and standardize the factory operations for example: Enterprise Resource Planning (ERP), Activity Based Costing (ABC), and Office Automation (OA). This classification has been empirically validated by Beaumont et al (2002) and is used as a basis for this study.

SMEs can maintain competitiveness by implementing AMTs and AMTs can assist SMEs in competing with larger competitors by introducing innovative products. Adoption of AMTs could benefit cash-strapped SMEs by shifting cost structures through the development of more efficient and adaptable processes, allowing for higher product quality and shorter lead times. Computer integrated manufacturing assists SMEs in shortening lead times, increasing flexibility and dependability, and improves customer service. Review of the available literature shows that AMTs can accelerate the growth of SMEs if applied in a structured manner; thus, the study aims to explore the extent to which AMTs are used by SMEs in India (Rajesh et al 2008; Lin and Chen 2012).

2. Methodology

The study is structured as follows: First, the study reviews the literature on AMT implementation practices adopted by SMEs to identify the theoretical concepts. From the literature review a structured questionnaire is designed to gather the data taking into consideration various factors that affect the AMT implementation process. Next, to complement and confront the literature review with empirical insights, data collected through SMEs from NCR of India was empirically analysed using Statistical Package for Social Sciences (SPSS) 20.0. The results of this analysis are provided and discussed.

2.1. Development of Questionnaire and Data Collection

The structured questionnaire gives a list of nineteen advanced technologies with brief descriptions. The questionnaire is developed on five-point Likert scale, for instance, 1 represents strongly disagree/no investment and 5 strongly agree/ highest investments. Most items on the questionnaire are closed-ended with definitive responses. All the questions in the questionnaire require only appropriate check marks or circles. This helped to obtain comparable statistics in the data analysis stage

The questionnaire consists of six main sections (Part I to Part VI) with a total of 109 questions. Part I of the questionnaire is related to general information of the firm like: type of industry, ownership, year of establishment, number of employees, nature of investment in plant and machinery and job title of the person answering the survey. Part II of the questionnaire consists of current status of investment in direct, indirect and administrative AMTs. Part III consist of organizational strategies used by firms for successful AMT implementation, whereas Part IV consists of source of barriers in AMT implementation. Part V and VI consist of driving forces and AMT performance measures respectively. The questionnaire is developed on five-point Likert scale, for instance, 1 represents strongly disagree/no investment and 5 strongly agree/ highest investment paralleling the scales used in (Dangayach and Deshmukh 2005). Like in other studies, most items on questionnaire are closed-ended with definitive responses. All the questions in the questionnaire require only appropriate check marks or circles. This helped to obtain comparable statistics in the data analysis stage.

A database of three hundred Indian SMEs was created based on different industrial sectors. The sample of the firms was drawn from the listing of the companies in the government agencies and Indian Industries association (IIA) directory. To assess content validity a 'dry run' was carried out and questionnaires were administered to top management, owners of SMEs. Based on their feedback the present form was evolved and final version of the questionnaire along with a cover letter offering a brief outline of the study and ensuring confidentiality was sent through an e-mail to the respondents of 300 SMEs. Despite the maintenance of confidentiality of all the company information, the difficulty of getting data in a developing country like India was quite obvious. To overcome difficulty of low response rate, computer assisted face to face interviews with company executives were conducted. A total of hundred and twenty-six valid responses in the form of filled questionnaire were received. The response rate is 42.00 percent, which seems good in Indian context.

2.2. Target sectors for questionnaire administration

For this study, following major sectors of Indian SMEs were selected for questionnaire administration:

- Automotive and transportation.
- Metal and mechanical type.
- Industrial equipment.
- Plastic moulding and rubber products.
- Sheet metal fabrication.
- Electrical and electronic.

Among the companies that are surveyed, most are metal and mechanical engineering and automotive-transportation type, whereas rest are sheet metal fabrication, industrial equipment, plastic moulding and electrical. The companies produce products that are sold in domestic market as well as outside India. Some of the small enterprises are also supplier of products to larger industries. The characteristics of sampled firms like, type of industry, profile of the respondents and number of employees are shown in Figures 1.1, 1.2, and 1.3 respectively, indicating a wide variety of industries and sizes. Out of the 126 valid responses, majority, 33% are from automotive and transportation sector whereas 24% are from metal and mechanical industries as shown in Figure 1.1.

Out of the surveyed industries 38% respondents were owners of the small firms, 26% were plant head, General Managers, Managers or CEO of the companies whereas 22% were either project in charge or team leaders of AMT projects as shown in Figure 1.2.

As shown in Figure 1.3, 57% of the firms were having less than 50 employees whereas rests of the 43% were having less than 250 employees.

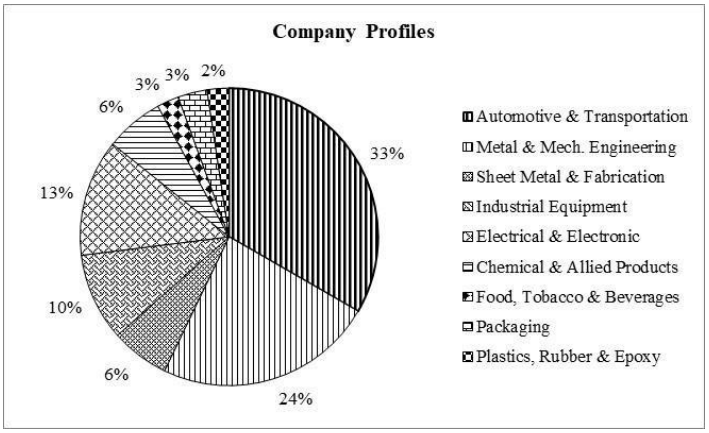

Figure 1.1 Company Profiles.

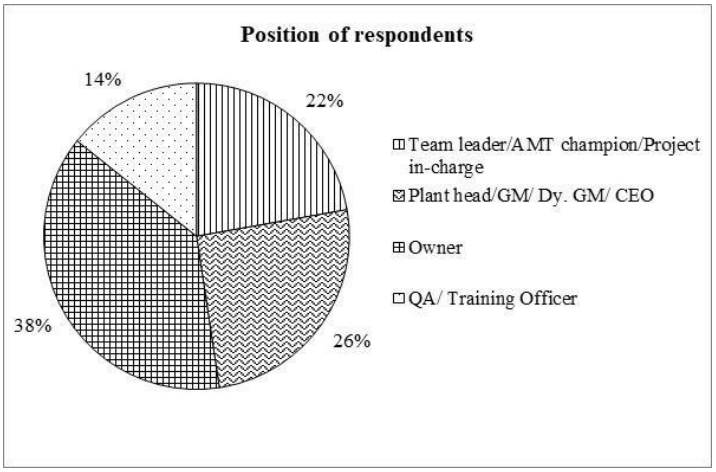

Figure 1.2 Percent of respondents of the survey based on their designation.

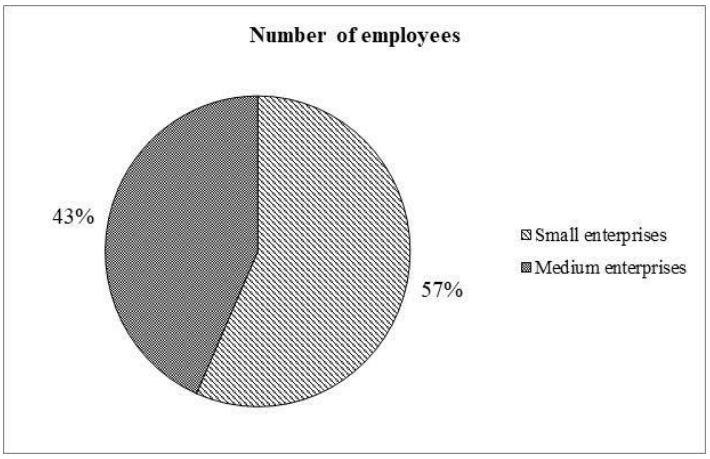

Figure 1.3. Percent of industry surveyed based on the number of employees.

2.3. Hypotheses Formulation

There are considerable disparities in the extent of AMT investment across small, medium, and big enterprises, with larger organisations investing more in AMT (1). Previous studies examined the association between firm size (number of employees) and AMT investment and found that there are variances in the level of investment by firm size and type of industry (Cheng et al 2018). Small and medium-sized businesses place varying degrees of importance on different types of technology while adopting them. As a result, this study seeks to support the data that large firms invest more in technology and that adoptions are more widespread in larger plants than in smaller ones. Thus, hypothesis one is formulated as follows;

Hypothesis 1: The investment in AMT varies across technology and industry size.

As discussed earlier, this study has considered three types of AMTs: direct, indirect, and administrative. According to the literature, the technologies in each of these categories are related and dependent on one another. CNC, for example, is most often utilised in conjunction with FMS and CIM rather than as a standalone solution. So, it is worthwhile to know the link between various types of AMTs. Is there a beneficial link between various types of AMTs used by SMEs? The present study aims to determine the degree of correlation between the technologies; hence hypothesis two is constructed as follows:

Hypothesis 2: There is a positive correlation between items of direct, indirect and administrative AMTs

AMT adoption in small and medium-sized businesses is influenced by certain factors. The greater the strength of these factors, the more likely businesses are to adopt AMTs. Operational and business objectives have long been seen as major drivers of AMT adoption. Operational flexibility is crucial for SMEs to quickly and easily implement changes in response to internal and external circumstances. Regression analysis was used to determine the dominance of operational objectives over business objectives, with AMT adoption as the dependent variable and operational and business objectives as independent variables. Hypothesis three is formulated as:

Hypothesis 3: Operational goals outweigh business goals in the AMT implementation process.

AMT investment alone does not result in significant improvements in a firm's performance if innovation does not extend to organizational and strategic issue. It would therefore be necessary to determine which other activities and factors influence the performance of previously made investments, such as infrastructure investments. The factors that allow the greatest benefits to be obtained from AMT investments and contribute to maintaining and improving the competitive position of investing companies are unanswered questions (Faisal 2013). Against this backdrop, hypothesis four is formed as:

Hypothesis 4: There are certain strategic factors that influence AMT investment performance

Organisational factors impacting AMT implementation have been discussed in a number of studies that have attempted to address issues implementing AMTs. The exact benefits of AMT adoption in manufacturing companies can be achieved and materialized only if the current organizational design is compatible with the alterations to be faced (Islam et al 2015).

Several authors discuss human resource preparation and adjustment, organisational culture aspects and the role of change management within the context of organisations. Adopting AMTs requires manufacturing companies to redesign their organizational structures and organizational processes (Bellantuono et al 2021). In view of the above, hypothesis five is formulated as:

Hypothesis 5: AMT implementation effectiveness in SMEs is enhanced by the activities (i) Organizational culture and structure (ii) Top management commitment (iii) Human factors (iv) AMT champion (v) Multi-functional team

2.4 Measurements and Data Analysis

To check the reliability of the scales used, Cronbach's coefficient alpha is calculated for each scale, as recommended for empirical research in operations management (Ko et al 2020). Table 1 shows Cronbach's alpha values calculated for scales used. Cronbach's alpha value for each scale is more than 0.5, which is considered adequate for exploratory research (Nunnally 1978; Taber 2018).

Table 1 Cronbach's Coefficient Alpha for Three Major Categories of AMTs.

	Medium Enterprises	Small enterprises
Direct AMTs	0.572	0.802
Indirect AMT	0.788	0.850
Administrative AMTs	0.731	0.581

3. Results

The various issues that covered in the questionnaire include issues related to the AMT enablers, existing challenges of AMT adoption, critical factors that enhance effectiveness of AMT implementation, AMT performance measures and perceived benefits of AMT. The results of the exploratory research with key observations on these issues are discussed in the following section:

3.1. Observations related to AMT enablers

Respondents were requested to judge the importance of the causes of the AMT adoption in their respective industries and assign numerical values on a Likert scale with five important levels. Important reasons behind AMT adoption in SMEs in the decreasing order of their weight were identified as 'increased profits' (4.65), 'increased product flexibility' (4.60), 'increased responsiveness to changing market demands' (4.56), buyer pressure (4.46), order qualifier (4.45), 'increased productivity' (4.37), 'improved product quality' (4.34), improved on-time delivery (4.33), 'reduced lead time' (4.28) and 'reducing manufacturing cost' (4.27). It was also observed from the results that 'improved information flow' (2.94) and 'tax incentives' (3.34) have less motivation towards AMT adoption. Figure 2 shows the Observations related to AMT enablers.

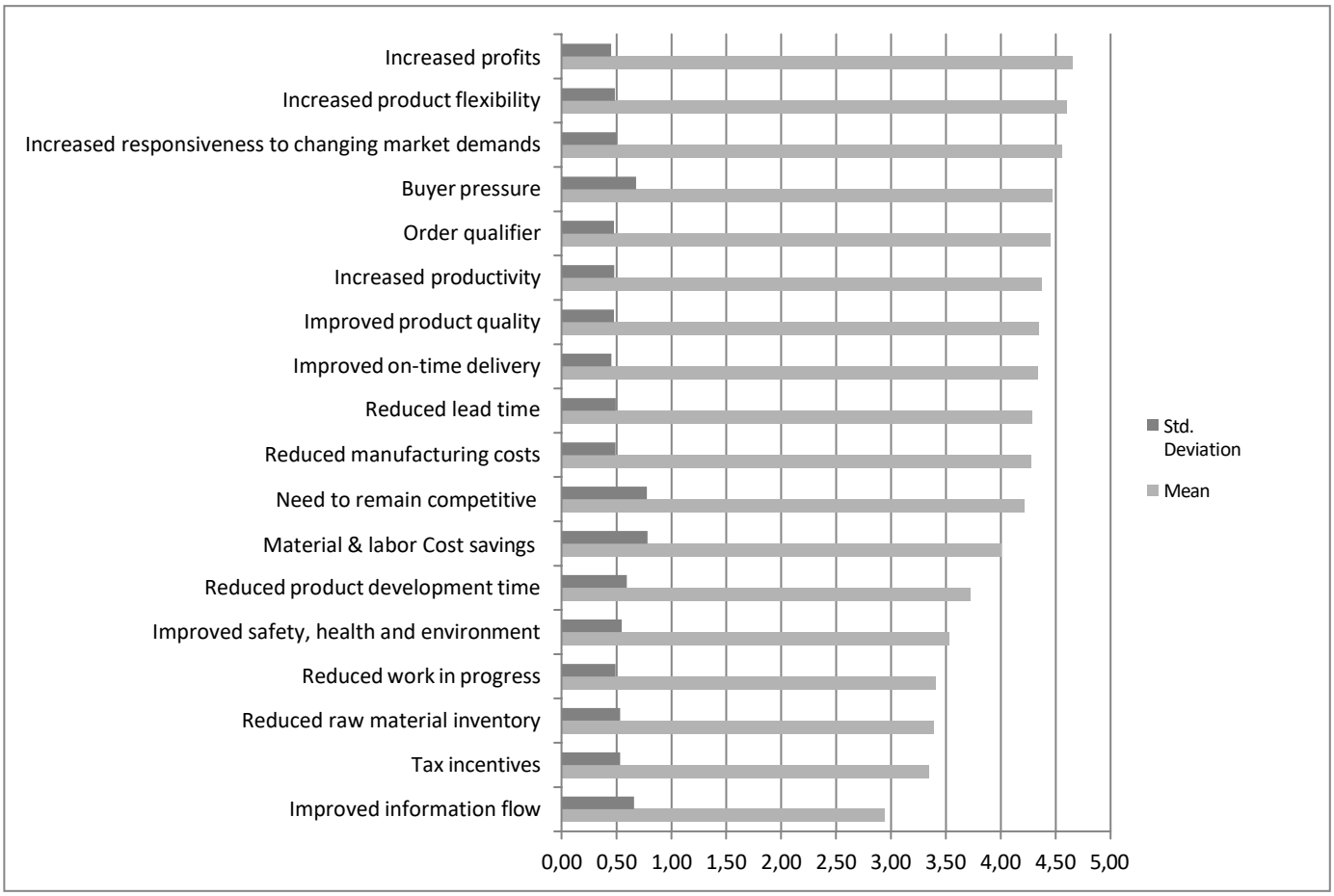

Figure 2 Observations related to AMT enablers.

3.2. Observations related to the factors that hinder AMT adoption

Existence of a large number of barriers and the existing interdependencies among them makes the structure of the system complicated. Investigation of the AMT barriers in this study is based upon the judgment of the respondents regarding importance of the barriers on a five point Likert scale. Barriers with higher inhibiting strength were recognized from the survey results as: 'financial constraints' (4.51), 'inclination towards short term gains' (4.44), 'lack of confidence in in-house capabilities' (4.38), 'level of education, training and workforce skills' (4.37) and 'lack of organic structure' (4.34), 'alignment of AMT philosophy with the organization's overall business strategy' (4.33) and "technology mapping with firm's competitive strategy' (4.31). Figure 3 shows various factors that hinders AMT implementation and adoption in Indian SMEs.

3.3. Observations related to the benefits of AMT adoption

The benefits of advanced manufacturing technologies have been realized and listed as reduced inventory, more return on equity, less cost per unit, flexibility, competitive advantage, enhanced quality and improved delivery (Ordoobadi 2013). It can be seen from Figure 4 that 'enhanced product quality (4.39), 'improved return on investment' (4.35) were rated as the two significant benefits of AMT implementation by the respondents.

3.4. Observation related to competitive priorities adopted by SMEs for AMT implementation

Competitive priorities are the critical operational dimensions a process must possess to satisfy its internal or external customers. The concept of competitive priorities is very important to organizations because it helps them set up achievable goals and it has long been known to be associated with organizational performance (Ko et al 2020). It also helps organizations to set up achievable goals when implementing corporate plans into operational plans. The competitive priorities help organizations set the right course of actions for process selection. From five common groups of competitive priorities as identified from the literature, the respondents rated 'cost' (3.95) as the top most, 'quality' (3.86) as second one, 'delivery' (3.56), 'flexibility' (3.69) and 'innovation' (3.39) as least priority. Figure 5 shows observations related to the competitive priorities adopted by SMEs during AMT implementation.

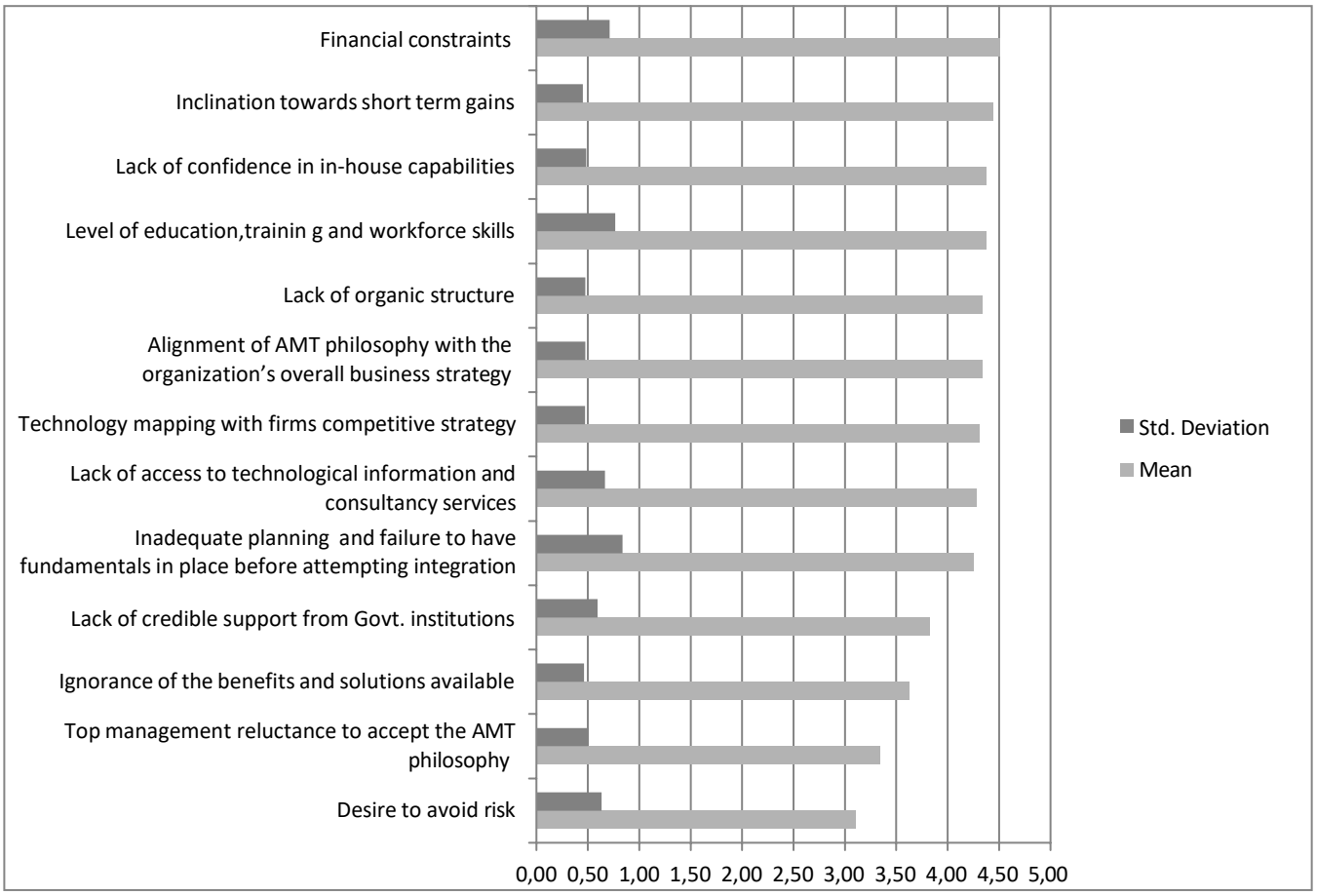

Figure 3 Observations related to factors that hinder AMT adoption.

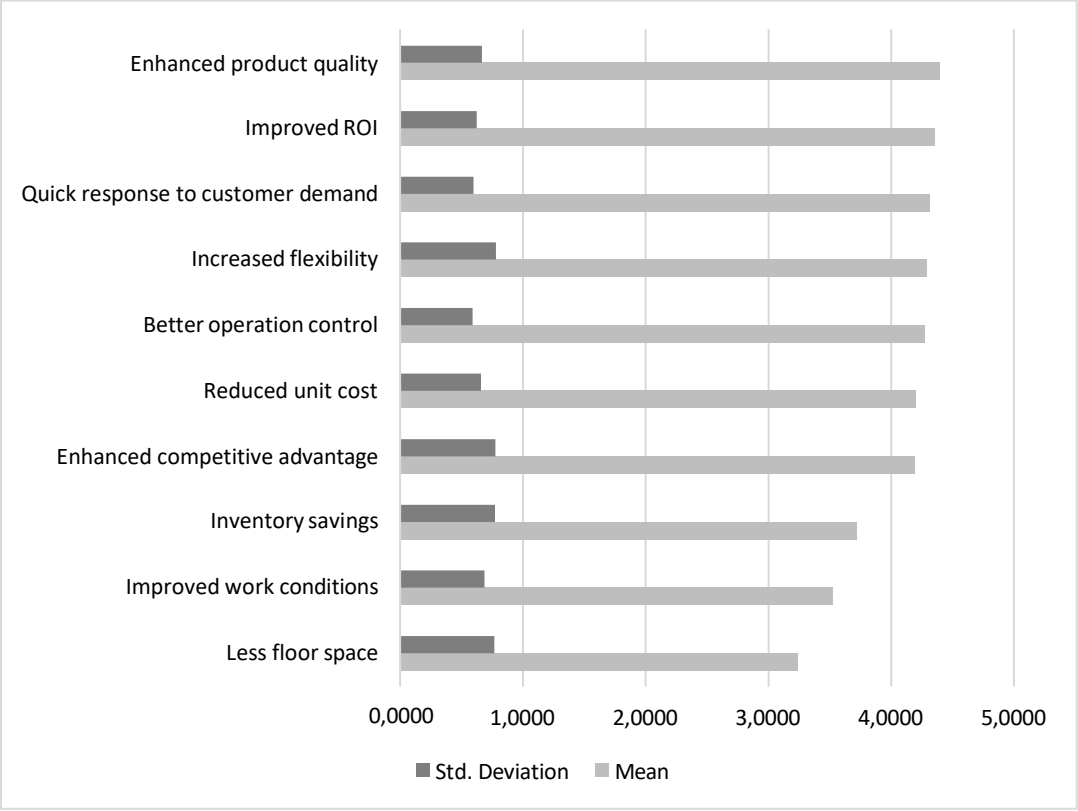

Figure 4 Observations related to the benefits of AMT adoption.

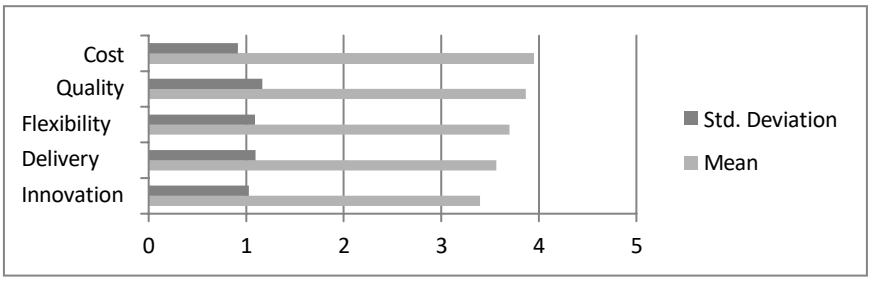

Figure 5 Observations related to the competitive priorities adopted by SMEs during AMT implementation.

4. Hypothesis testing

4.1. Hypothesis one

H1: The investment in AMT varies across technology and industry size.

We used SPSS 20.0 to analyse the data for descriptive statistics in order to test the hypothesis. The data show that (Table 2) CNC is the most often used technology by medium-sized businesses. This appears to be true due to its precision production qualities and the fact that CNC is a stand-alone technology that does not require further integration to produce superior goods. As a result, even small businesses (mean: 3.369) appear to favour the usage of CNC machines in their operations. Manufacturing businesses in India are using CNC machines to minimise waste, lower costs, and improve production rate and productivity. The deployment of CNC machines is justified by a higher return on investment, better quality, and more precise goods generated at a faster rate. CNC investment is followed by AITE and CIM. It can also be seen from the results that medium-sized businesses place less emphasis on investment in automated guided vehicles (mean: 2.22) and direct numerical control technology (mean:2.32). From the Table 2 it can be observed that small enterprises are more inclined towards use of CNC machines (mean:3.23) whereas, Robots are not that much preferred (mean: 1.23). Study of the available literature also shows that small businesses are less likely to use integrated technologies like Computer Integrated Manufacturing (CIM) and automated material handling systems (AMHS) due to their resource constraints as these technologies are capital intensive (Cheng et al 2018; Sethi et al 2010; Sukathong et al 2021; Dubey et al 2017).

Table 2 Type of Direct AMT Used by Industries.

AMT	N	Mean	Std. Deviation	N	Mean	Std. Deviation
CNC	53 (Medium enterprises)	4.5094	.66860	73 (Small enterprises)	3.3699	.93552
DNC		2.3208	.91512		1.8356	1.09308
RO		3.3962	1.08024		1.2329	.58974
FMS		3.6792	.72784		1.9041	1.06932
CIM		3.8302	.67185		1.7671	.96495
AMHS		3.6415	.76194		1.6301	.85808
AGV		2.2264	.80004		1.5479	.85051
ASRS		3.0943	.92537		1.6712	.81743
AITE		4.1698	.54547		2.2603	1.20217
Valid N (list wise)						

From the family of indirect AMTs Computer Aided Design (CAD) is most used by medium as well as small enterprises (Table 3). As CAD allows product designs to be created swiftly and so saves valuable time in design development stage of the product. These findings are supported (Oppong et al 2013)(Palčič and Prester 2020)(Marjudi et al 2011)(Sagar et al 2020) that reveals CAD usage has a positive impact on product development and cost performance. Overall, it reflects that Indian SMEs are investing more in administrative and indirect AMT in place of direct AMT. The reason for more inclination of SMEs towards indirect and administrative AMTs may be due to easy integration of these technologies with the existing set up of the plant and also the less complex nature of these technologies. In view of the above hypothesis, one is accepted.

Table 3 Type of Indirect AMT Used by Industries.

AMT	N	Mean	Std. Deviation	N	Mean	Std. Deviation
CAD	53 (Medium)	4.7736	.57651	73 (Small)	3.3699	1.07376
MRP		4.5472	.74849		2.9589	.90429
MRPII		4.4717	.84589		3.0274	.95703
BC		3.9811	.88775		2.9726	1.16634
SPC		3.9245	.61548		2.9452	.62116
CAPP		4.3962	.63062		2.8356	1.11820
JIT		3.9245	.47430		3.1507	.84445
Valid N (listwise)						

Table 4 Type of Administrative AMT Used by Industries.

AMT	N	Mean	Std. Deviation	N	Mean	Std. Deviation
ABC	53	4.0000	.96077	73	3.3836	.92241
ERP		4.3019	.72284		3.2877	.92014
OA		3.4528	.84503		3.1096	.84264
Valid N (list wise)						

4.2. Hypothesis two

H2: There is a positive correlation between items of direct, indirect and administrative AMTs

To test the hypothesis two, Pearson's correlation analysis is carried out. The correlation between various direct AMTs is found to be positive (Table 5). A very strong correlation (0.896) is found between FMS and CIM which seems to be true as FMS is always supported by CIM infrastructure. By connecting isolated automation into a distributed processing system, computer integrated manufacturing (CIM) aims to provide computer assistance, control, and high-level integrated automation at all levels of the manufacturing industries, including the business data processing system, CAD, CAM, and FMS. FMS assumes the role of a production facility that is extremely effective and "prepared to react to random orders" in this notion.

Other significant correlation is observed between RO and ASRS. The ASRS is an important module of the rapid logistic system due to consideration of limited space; high labour cost; requirement of flexibility; quality and reliability. The performance of the ASRS system is enhanced by using PLC integration where it coordinates the operation and control the AS/RS. The results contribute to the work (Radhakrishnan et al 2008) that shows a correlation between RO and ASRS as well as between AMHS and FMS but contradicts in case of AMHS and RO. Table 5-7 shows correlation values between the items of Direct, Indirect and Administrative AMT.

Table 5 Correlation between Direct AMTs.

		CNC	DNC	RO	FMS	CIM	AMHS	AGV	ASRS	AITE
CNC	Pearson Correlation	1	.245**	.517**	.481**	.475**	.447**	.314**	.405**	.483**
	Sig. (2-tailed)		.005	.000	.000	.000	.000	.000	.000	.000
DNC	Pearson Correlation	.245**	1	.444**	.421**	.358**	.223*	.470**	.321**	.086
	Sig. (2-tailed)	.005		.000	.000	.000	.012	.000	.000	.335
RO	Pearson Correlation	.517**	.444**	1	.621**	.641**	.706**	.547**	.708**	.604**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000
FMS	Pearson Correlation	.481**	.421**	.621**	1	.896**	.742**	.388**	.659**	.550**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000
CIM	Pearson Correlation	.475**	.358**	.641**	.896**	1	.740**	.360**	.714**	.610**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000
AMHS	Pearson Correlation	.447**	.223*	.706**	.742**	.740**	1	.456**	.624**	.819**
	Sig. (2-tailed)	.000	.012	.000	.000	.000		.000	.000	.000
AGV	Pearson Correlation	.314**	.470**	.547**	.388**	.360**	.456**	1	.591**	.603**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000
ASRS	Pearson Correlation	.405**	.321**	.708**	.659**	.714**	.624**	.591**	1	.676**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000
AITE	Pearson Correlation	.483**	.086	.604**	.550**	.610**	.819**	.603**	.676**	1
	Sig. (2-tailed)	.000	.335	.000	.000	.000	.000	.000	.000	
	N	126	126	126	126	126	126	126	126	126

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

In indirect AMT (Table 6), correlation between CAD and BC, and SPC and BC is insignificant. It is observed from Table 7 that correlation between activity-based costing (ABC) and enterprise resource planning (ERP) is only significant at the 0.01 level. To generate the bill of material CAD is necessary as all parts and products identification files are generated through CAD only and so there is a strong correlation between material requirement planning (MRP) and CAD. Our result responds to the call that a lot of data sharing takes place between the design and the planning department.

Table 6 Correlation between Indirect AMTs.

		CAD	MRP	MRPII	BC	SPC	CAPP	JIT
CAD	Pearson Correlation	1	.814**	.799**	.616**	.674**	.671**	.522**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000
MRP	Pearson Correlation	.814**	1	.841**	.716**	.740**	.584**	.564**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000
MRPII	Pearson Correlation	.799**	.841**	1	.694**	.726**	.775**	.705**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000
BC	Pearson Correlation	.616**	.716**	.694**	1	.565**	.302**	.375**
	Sig. (2-tailed)	.000	.000	.000		.000	.001	.000
SPC	Pearson Correlation	.674**	.740**	.726**	.565**	1	.648**	.454**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000
CAPP	Pearson Correlation	.671**	.584**	.775**	.302**	.648**	1	.718**
	Sig. (2-tailed)	.000	.000	.000	.001	.000		.000
JIT	Pearson Correlation	.522**	.564**	.705**	.375**	.454**	.718**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	
	N	126	126	126	126	126	126	126

**. Correlation is significant at the 0.01 level (2-tailed).

Table 7 Correlation between Administrative AMTs.

		OBC	ERP	OA	ISO
OBC	Pearson Correlation	1	.608**	.279**	.219*
	Sig. (2-tailed)		.000	.002	.014
ERP	Pearson Correlation	.608**	1	.364**	-.157
	Sig. (2-tailed)	.000		.000	.078
OA	Pearson Correlation	.279**	.364**	1	.045
	Sig. (2-tailed)	.002	.000		.619
	N	126	126	126	126

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

4.3. Hypothesis three

H3: Operational goals outweigh business goals in the AMT implementation process.

To test the hypothesis three, multiple regression analysis was carried out; degree of AMT investment is used as an indicator to AMT adoption (AMTAD) and is selected as the dependent variable. Need to achieve operational objectives (OPEOB) and business objectives (BUSOB) are identified as independent variables.

$$Y = b0 + b1X1 + b2X2 + ... + bnXn$$

where Y is the predicted or expected value of the dependent variable, X_1 through X_n are n distinct independent or predictor variables, b_0 is the value of Y when all of the independent variables (X_1 through X_n) are equal to zero, and b_1 through bn are the estimated regression coefficients.

The result of the multiple linear regression analysis shown in Table 8 portrays that the coefficient of determination 'R square' and correlation coefficient 'R' shows the degree of association between AMT investment and operational need to achieve objectives (OPEOB), business need to achieve objectives (BUSOB). The model summary shown in Table 9 indicates that the R square is 0.431, suggesting that 43.1% of the SMEs performance was explained by advanced manufacturing technology. AMT investment is explained by independent variables The R-square value indicates how well the model fits the data and it normally varies from 0.0 to 1.0. An R- square value close to 1.0 indicates that the dependent variable entirely depends on the independent variables while a value close to 0.0 indicates no correlation between the explanatory variables and the dependent variable. Table 8 also shows the standardized beta coefficient that compares the strength of the effect of individual independent variable to the dependent variable. It is observed that the standardized beta coefficient for operational goals is higher than the business goals and hence it explains the stronger effect of operational goals on the AMT investment and its adoption. This confirms our hypothesis that operational goals outweigh business objectives in the AMT implementation process. The hypothesis is also in line with previous studies by (Beaumont et al 2002). Table 8 also shows the Analysis of Variance (ANOVA) values, the p-values are 0.000 and all are less than 0.05 thus the result provides confirmation that AMT adoption is initiated by the need to achieve operational objectives. These findings are in line with (Awwad et al 2013).

From the Table 9, we can obtain the two regression models showing the relationship between Operational objectives and AMT adoption are expressed as;

$$Y=0.419+ 0.942\ X1 \text{ and } Y=0.297 + 0.942\ X1.$$

T- Test values also shows that there was significant relationship between AMT adoption and operational and business objectives of the firm since the p-values were 0.000 < 0.05 for model 1 and 2. The results indicate that all the independent variables influence the dependent variable at a high significance level (p<=0.001). Therefore, hypothesis 3 was accepted.

Table 8 Result of Multiple Regression Analysis of AMT Enablers.

Multiple R	0.656			
R- square	0.430			
Adjusted R Square	0.421			
Standard error	0.88			
F	46.38, p<=0.000			
Variables	Un-standardized coefficients	Standardized Beta	t	sig
Constant	.942		3.449	.001
Operational objectives	.419	.422	4.725	.000
Business objectives	.297	.298	3.336	.001

4.4. Hypothesis four

H4: There are certain strategic factors that influence AMT investment performance

A multiple linear regression analysis was carried out to test hypothesis 6. Here the key strategic factors are taken as independent variables whereas 'perceived AMT implementation outcome' is taken as the dependent variable.

The test results are shown in Table 9. The results of the analysis indicate existence of a positive relationship between the key strategic factors and AMT implementation performance. Hence hypothesis 4 is accepted.

Table 9 Results of multiple regression analysis of key strategic factors of AMT.

Multiple R	0.770			
R- square	0.593			
Adjusted R Square	0.572			
F	28.843, p<=0.000			
Variables	Un-standardized coefficients	Standardized Beta	t	sig
Constant	-2.906			
Establishment of organizational goals	.441	.314	4.821	.000
Linking business and manufacturing strategies	.301	.291	4.733	.000
Need to access market position	.348	.334	4.306	.000
Need to access technology position	.222	.237	3.363	.001
Technology capability matching with the Operations strategy of the firm	.188	.271	4.261	.000
Selecting the right type of AMT	.154	.158	2.246	.027

4.5. Hypothesis five

H5: AMT implementation effectiveness in SMEs is enhanced by the activities (i) Organizational culture and structure (ii) Top management commitment (iii) Human factors (iv) AMT champion (v) Multi-functional team

To test hypothesis 5, a multiple linear regression analysis was carried out. Here the behavioural factors are taken as independent variables whereas 'perceived AMT implementation outcome' is taken as the dependent variable.

The test results are shown in Table 10. The results of the analysis indicate existence of a positive relationship between the behavioural factors and perceived AMT implementation outcome. Hence hypothesis 5 is accepted.

Table 10 Results of multiple regression analysis of behavioural factors.

Multiple R	0.713			
R- square	0.509			
Adjusted R Square	0.489			
F	24.881, p<=0.000			
Variables	Unstandardized coefficients	Standardized Beta	t	sig
Constant	.787			
Changing the organizational design and structure	.278	.343	2.252	.026
Top management support	.169	.225	4.732	.000
Human factors	.204	.316	3.448	.001
AMT champion	.086	.140	4.390	.000
Multi-functional project team	.161	.225	2.084	.039

5. Conclusions

1) SMEs occupy an important and strategic place in economic growth and equitable development in all countries. SMEs can tide-over the problems of technological backwardness by strategically selecting a suitable technology and crafting the implementation process carefully.
2) Results of this study highlights the unique motivations behind AMT adoption in SMEs along with their weights as 'increased profits' (4.65), 'increased product flexibility' (4.60), 'increased responsiveness to changing market demands' (4.56). Also, result of the multiple linear regression analysis shows that the standardized beta coefficient for operational goals is higher than the business goals and hence it explains the stronger effect of operational goals on the AMT investment and its adoption. Analysis of Variance (ANOVA) values, the p-values are 0.000 and all are less than 0.05 thus the result provides confirmation that AMT adoption is initiated by the need to achieve operational objectives. Our observation from the analysis of the data also highlights barriers to the AMT implementation. SME owner-managers must pay attention to the barriers to reap full benefits of the AMT implementation.
3) It can also be seen from the results that medium-sized businesses place less emphasis on investment in automated guided vehicles and direct numerical control technology. Whereas, small enterprises are more inclined towards use of CNC machines as compared to Robots. Study of the available literature also shows that small businesses are less likely to use integrated technologies like Computer Integrated Manufacturing (CIM) and automated material handling systems (AMHS) due to their resource constraints as these technologies are capital intensive
4) Results of the multiple regression analysis shows that from the family of direct AMTs there is a very strong correlation (0.896) between Flexible Manufacturing Systems and Computer Integrated Manufacturing. Other significant correlation (0.704) is observed between Robotics and Automated Storage/Retrieval Systems. Also, amongst indirect AMTs our results establish a strong correlation (0.814) between Material Requirement Planning and Computer Aided Design. This responds to the call that a lot of data sharing takes place between the design and the planning department.
5) The study also establishes the effect of key strategic factors on the AMT investment performance. The results of the hypotheses test indicate the existence of a positive relationship between the key strategic, behavioural actors and AMT implementation performance. SME managers must pay attention to these strategic and behavioural factors to improve the effectiveness of AMT implementation in their organisations. Results of the study provides significant clues to enable decision makers to focus on key strategic and behavioural factors for making the AMT implementation a success.
6) A framework for the implementation of AMTs in SMEs is proposed in Figure 6. Activities in the planning and justification phase, pre-implementation phase and post-implementation phase are considered to be important for realising the full benefits of the implementation process.

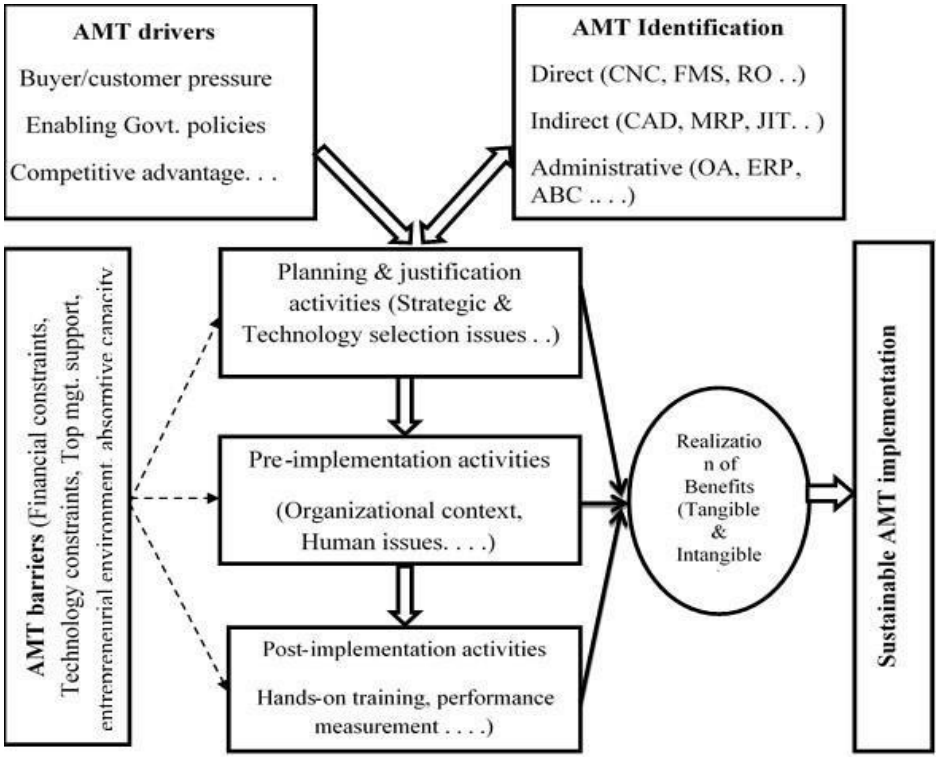

Figure 6 Proposed framework for the implementation of AMTs in SMEs.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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