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Identification of barriers in the implementation of AMTs in the SMEs of northern India using AHP–TOPSIS approach

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Abstract

Purpose – The purpose of this paper is to find out and highlight the major influential barriers in the implementation of advanced manufacturing technologies (AMTs) in small and medium enterprises (SMEs) of Northern India. The major barriers in the implementation of AMTs in manufacturing industries of Northern India have been critically assessed in this paper.

Design/methodology/approach – An ample and reasonable number of small- and medium-scale manufacturing industries of northern India have been surveyed with an aim to find out the barriers in the implementation of AMTs. On the basis of data collected, AHP–TOPSIS method was applied in order to measure the weightage of each barrier in a simple mathematical form.

Findings – High cost of AMTs, lack of appropriate financial resources and current processes or procedures are the major barriers that cause hindrance in the path of implementation of AMTs in SMEs.

Research limitations/implications – This investigation was based on the survey followed by judgments of experts in industry and academia; other approaches such as PROMETHEE, WPM, VIKOR, etc., can be applied for investigation. Also, the study can be carried out in different region(s) and parts of the country.

Practical implications – This paper can be helpful in many ways to the management or industrialists of various nations who are on the same path or will follow soon.

Originality/value – SMEs need to address the findings of this research in order to overcome the barriers and successfully implement the AMTs. A model for successful implementation of AMTs by overcoming the barriers has been suggested.

Keywords Business improvement, Small and medium enterprises (SMEs), Advanced manufacturing technologies (AMTs), Barriers in implementation of AMTs

Paper type Research paper

1. Introduction

Small and medium enterprises (SMEs), usually stated as “engine of growth”, play a noticeable role in fulfilling the major requirements, economy, development and employment for the people. The role of manufacturing enterprises is quite inevitable due to the production of goods and satisfying our needs. Also, they are the spine of present economies due to their contribution towards the global market with respect to imports and exports.

Past few decades have seen tremendous changes throughout the globe, whether in terms of the choices and variety available or in terms of quality or availability. With the changing demands and requirements of the society, they must respond quickly in order to sustain and meet the needs. There arises a need of such technologies that can meet these types of requirements. Advanced manufacturing technologies (AMTs) provide just not a ray of hope, but a path to tackle such turbulences in the market scenes. They have indisputably proved helpful in increasing flexibility, enhancing performance, improving quality and increasing production with their implementation in SMEs.

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AMTs make use of computers to support, control and assist in various fields and dimensions. They include various technologies such as computer numerical control (CNC), flexible manufacturing system, robotics, computer-aided manufacturing (CAM), computer-aided process planning, computer-integrated manufacturing, computer-aided design (CAD) and engineering systems, production planning, routing, control and integration, scheduling, material resource management, automated guided vehicles (AGVs), etc.

AMTs have indisputably proved to be significant in improving the flexibility, green standards, productivity, quality and profit of SMEs. This research discloses the various barriers in implementation of AMTs in SMEs of north India. It also aims to help management and entrepreneurs to take a closer and detailed look at various barriers in the implementation of AMTs, so that these can be dealt or tackled in a better way.

2. Literature review

2.1 Small and medium enterprises (SMEs)

SMEs play an important role in the economic progress of a country by providing a high rate of employment at a low capital cost (Chou *et al.*, 2005; Husband and Mandal, 1999). The number of employees serves as the basis of classification of SMEs in most of the countries. But in some developing countries like India, SMEs are classified on the basis of investments in plant and machinery (Hooi, 2006). Rendering to the said criteria, the Ministry of MSME (Govt. of India) has classified the SMEs. If the investment in plant and machinery is more than 2.5m (25 lakh rupees), but does not exceed 50m (5 crore rupees), then the industries fall in the category of small enterprises. If the investment in plant and machinery is more than 50m (5 crore rupees) but does not exceed 0.1bn (10 crore rupees), then the industries fall in the category of medium enterprises. Smit and Watkins (2012) stated that SMEs stand dominant in terms of number in most of the countries. SMEs stand second in case of the largest workforce after agriculture in India. Caldera *et al.* stressed that SMEs are leading the world's economy. They have been known for their major contribution in helping sustainable and equitable social development. SMEs not only create employment but also absorb retrenched people coming from other sectors also.

Joyce *et al.*; Moore; and Rothwell (1991) recommended that SMEs can achieve goals by innovation activities. They also highlighted the contribution of SMEs towards the country for its economic progression and employment. Also, the SME sector contributes highly for export of goods and industrial production for the country. With the change in scenario, high quality at low cost is just not a solution to guarantee the success of an organization. SMEs must upgrade themselves to face these challenges.

Industries have to concentrate on flexibility to achieve goals and survive in this environment (Tahriri *et al.*, 2015). To tackle these multiple challenges simultaneously, the SMEs must concentrate on implementation of AMTs (Kirk, 1998; Power and Simon, 2004). Increased competitiveness, high rate of production, flexibility, better quality, information processing capability and innovation have pushed the SMEs to implement AMTs.

2.2 Advanced manufacturing technology (AMT)

The requirement of producing goods of better quality, lower operating cost, improved manufacturing efficiency, flexibility, higher production and higher productivity has made it necessary for a large number of manufacturing organizations to upgrade themselves and implement AMTs in order to meet these requirements. Computers being used in AMTs help in making of products (Svobodova, 2011). Both information and manufacturing AMTs collectively assist in manufacturing and the entire business operations. Thus, while assisting in manufacturing, it also comes up with a complete solution to the challenges faced by the management in meeting the requirements. Computers assist to save, manipulate and store data at several levels in manufacturing organizations (Dangayach and Deshmukh, 2005).

The progress of the industrial sector in a nation represents its strength. This progress in the industrial sector can be achieved by the development and implementation of AMTs or new technologies. AMTs have clearly proved their valuable and benefits at several levels by their implementation. Improvement in competitive position and outstanding developments at various stages are a few to enlist in organizations (Tahriri *et al.*, 2015). Finances can be managed in a better way and products can be customized on the basis of lesser cost of production and less bulk with the help of AMTs. The manufacturers and academicians accept the fact that improvement in flexibility, reduction in operating costs, lesser lead time and higher levels of output can be achieved by the implementation of AMTs, because these are more consistent and accurate than varying humans (Gunawardana, 2010). AMTs help in manufacturing of small volumes with an extensive range of varieties without extra costs (Dean and Snell, 1996; Goldhar and Jelinek, 1985; Gerwin, 1993; Kaplinsky, 1984; Kotha and Swamidass, 2000; Parthasarthy and Sethi, 1993; Swamidass and Kotha, 1998).

Alcaraz *et al.* (2012) and Hynek and Janecek (2009) enlisted several advantages of implementation of AMTs. The following are the major advantages that are found to be more significant:

(1) increased flexibility;

(2) reduced cost of products;

(3) improved plant utilization;

(4) larger market coverage;

(5) increased throughput;

(6) better quality standards;

(7) maintain level of competitiveness;

(8) higher plant capacity;

(9) faster response to the buyer's needs;

(10) better management;

(11) reduced changeover/setup times;

(12) reduced delivery time;

(13) early introduction to market; and

(14) enhanced company image.

The advantages are numerous and also include the reduction in unit and labor costs, higher profitability, strategy and agility and reduction in inventories (Klocke and Straube, 2004).

2.3 Barriers in implementation of AMTs

Barriers in implementation of AMTs symbolize the various obstacles or hurdles faced by the SMEs as they face many constraints. These can be due to various factors like lack of resources, management, employees, workers, knowledge and methods. The below-mentioned barriers were considered after a rigorous literature review in various contexts:

(1) high cost involved (Chan *et al.*, 2015; Singh *et al.*, 2013; Singla *et al.*, 2018);

(2) lack of appropriate financial resources (Singh *et al.*, 2013; Singla *et al.*, 2018; Thomas *et al.*, 2008);

(3) risk of failure to achieve financial targets (Khaparde, 2012);

(4) lack of skilled personnel (Mannan and Khurana, 2012; Singh *et al.*, 2013);
(5) lack of information on markets (Mannan and Khurana, 2012; Singh *et al.*, 2013);
(6) lack of information on new technologies (Singh and Khamba, 2011; Singh *et al.*, 2013);
(7) lack of training facilities (Chung and Swink, 2009; Singh and Khamba, 2011; Singh *et al.*, 2013);
(8) technology obsolescence (Singh *et al.*, 2013; Singla *et al.*, 2018);
(9) lack of R&D facilities (Singh *et al.*, 2013);
(10) poor organizational structure (Singh *et al.*, 2013; Thomas *et al.*, 2008);
(11) lack of supplier/vendor competencies (Hottenstein and Dean, 1992; Singh *et al.*, 2013; Sohal, 1997);
(12) poor sourcing practices (Singh *et al.*, 2013);
(13) resistance to change within the industry (Singh *et al.*, 2013);
(14) unsupportive top management (Singh *et al.*, 2013);
(15) location of the plant (Singh *et al.*, 2013);
(16) long tenure of top management/static governance (Khaparde, 2012);
(17) equipment failure or malfunction (Khaparde, 2012);
(18) reliability of new technology (Ndubisi, 2012);
(19) lack of leadership/support for innovation (Khaparde, 2012);
(20) comfort level – effect of disruption (Goulding *et al.*, 2007);
(21) time required to make changes and adjust (Mannan and Khurana, 2012);
(22) understanding of and ability to implement (Khaparde, 2012);
(23) social implications – changes in collaboration communication styles (Khaparde, 2012);
(24) current processes or procedures (Atkin *et al.*, 2017);
(25) budgetary priorities;
(26) difficulty/availability/time for training (Khaparde, 2012);
(27) resistance to learning new technology (Singh and Khamba, 2011);
(28) work stress/overload;
(29) proof of value;
(30) use acceptance (Khaparde, 2012); and
(31) performance (Khaparde, 2012).

This research emphasizes on the following research questions:

RQ1. What are the barriers to the implementation of AMTs in manufacturing SMEs in context of northern India?

RQ2. Undoubtedly, there are numerous barriers that hinder the implementation of AMTs in SMEs; however, all of them do not have the equivalent impact on implementation of AMTs. Thus, it results in the following question: which factors prove to be the major barriers in the implementation of AMTs?

To answer these research questions, the following are the objectives of this research:

(1) to identify barriers in the implementation of AMTs in the manufacturing SMEs of northern India; and

(2) to inspect and rank the barriers in a quantitative way using an AHP–TOPSIS approach.

The paper is prepared in such a way that it starts with a literature review relevant to SMEs, AMTs and various barriers in the implementation of AMTs in SMEs. In the next section, the research methodology adopted for the study is discussed, followed by an analysis of the data using AHP–TOPSIS approach. In the last section, conclusion of the study and its further scope are presented.

3. Design of study/research methodology

This work is carried out in small- and medium-scale industries located in Northern India. It aims to identify and evaluate the major barriers in the implementation of AMTs in SMEs. The research path adopted for this work is represented by the block diagram, as shown in Figure 1. After a rigorous literature review and expert's opinion, the questionnaire was designed with answers to the questions based on the five-point Likert Scale. The questionnaire was validated through the peer review from industrialists/ entrepreneurs, academicians and managers of the enterprises. Data collection followed three sequential stages. From the directories of MSMEs in Northern India, 1,008 SMEs were randomly selected and approached through telephonic call or personal interviews or emails for the intimation of the survey work being carried out in the region. Also, the owners or employees of the organizations were asked for their consent to participate in the survey for attaining the best possible results in the first stage. In the following/second stage, the questionnaire was sent by e-mail or posted to them along with the intent letter. Then, in the final or third stage, reminders were sent and phone calls were made to them

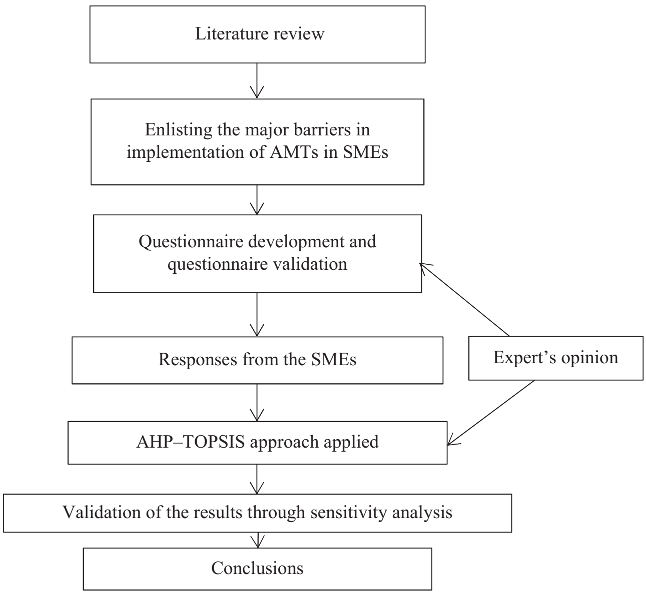

Figure 1.
Methodology for the present work

to fill up the data and mail it back. Out of all the methods adopted, personal interviews with the company owners or top officials yielded the best results. In total, 231 responses were obtained in 15 months (December 2017–February 2019). A few late responses did not significantly affect the final response percentage. Also, 11 responses were found to be partially complete because of a few missing values. After the rejection of inacceptable responses, 202 responses were left for consideration, a number sufficient for data analysis in the field of operations management (Oberoi *et al.*, 2008).

In this survey, data were collected from 140 small-scale and 62 medium-scale industries. The data are represented in the form of percentage, as shown in Figure 2.

Table I shows the distribution of responses according to the hierarchical position of the respondent, and Figure 3 shows its graphical representation.

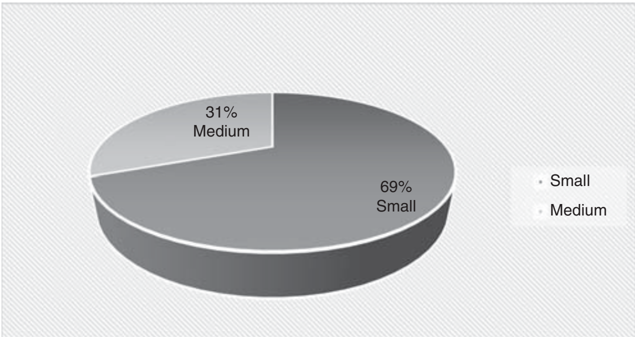

Figure 2. Type of organization

Table I. Distribution of responses according to hierarchical position

Characteristics	Number of responses	In percentage
Hierarchical position		
Proprietor	113	55.94
Director/GM/DGM/AGM	58	28.71
Engineer	21	10.39
Production head/Foreman/Quality head	7	3.46
Others	3	1.48

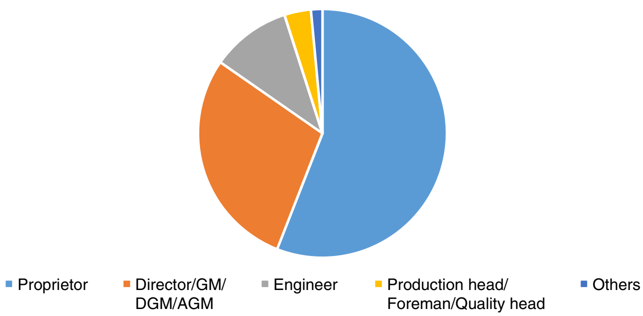

Figure 3. Respondent's hierarchy in organization

The questionnaire comprised of 31 barriers in implementation of AMTs, which were answered on Likert scale. These responses were then compiled on the basis of mean score obtained. The mean score depicts the weightage to the specific barrier in the implementation of AMTs as per the responses obtained. In context of India, the Government of India has formulated regulations and policies in order to promote the implementation of AMTs in SMEs and its impact can be seen. But practically, a lot of challenges are still being faced by the industrialists in order to implement them. The listed barriers cover a wide spectrum of different types of barriers faced by the organizations. From the mean score of the enlisted barriers, high-cost involved, budgetary priorities and lack of appropriate financial resources seem to be the most significant barriers. But the actual assessment for their contribution as hindrances or barriers in the implementation of AMTs has been done with the help of AHP–TOPSIS approach in the next section. Table II and Figure 4 show the different barriers identified and their average mean scores as per the responses received.

The barriers are then arranged according to the mean score obtained. This has to be done to obtain the most influential or significant barriers in implementation of AMTs in SMEs. Based on the mean score, only nine most significant barriers are chosen for further study and testing, as shown in Table III and Figure 5.

The major influential barriers are abbreviated for the ease of use in the next section, as shown in Table IV.

S. No.	Barriers	Mean score
H1	High-cost involved	4.24
H2	Lack of appropriate financial resources	3.29
H3	Risk of failure to achieve financial targets	2.86
H4	Lack of skilled personnel	1.68
H5	Lack of information on markets	1.09
H6	Lack of information on new technologies	1.06
H7	Lack of training facilities	2
H8	Technology obsolescence	2.99
H9	Lack of R&D facilities	1.38
H10	Poor organization structure	1.07
H11	Lack of supplier/vendor competencies	1.74
H12	Poor sourcing practices	1.07
H13	Resistance to change within the industry	2.14
H14	Unsupportive top management	1.20
H15	Location of the plant	1.11
H16	Long tenure of top management/static governance	1.08
H17	Equipment failure or malfunction	1.70
H18	Reliability of new technology	2.70
H19	Lack of leadership/support for innovation	1.56
H20	Comfort level – effect of disruption	2.49
H21	Time required to make changes and adjust	2.81
H22	Understanding of and ability to implement	2.29
H23	Social implications – changes in collaboration communication styles	1.08
H24	Current processes or procedures	3.18
H25	Budgetary priorities	3.41
H26	Difficulty/availability/time for training	2.10
H27	Resistance to learning new technology	2.55
H28	Work stress/overload	3.10
H29	Proof of value	2.5
H30	Use acceptance	1.14
H31	Performance	2.60

Table II.
Barriers in implementation of AMTs in SMEs

4. Assessing of barriers in the implementation of AMTs in SMEs using AHP–TOPSIS approach

4.1 Analytical hierarchy process approach for assessing barriers in implementation of AMTs

Analytical hierarchy process has been used as a technique to resolve complex decision-making problems and find out the best possible solution. It has been used in different fields like economics, education, healthcare, marketing, sports, finance, medicine and public policy (Saaty, 1990, 1994a, b). As compared to other approaches, AHP provides better and improved results because the primary concern or criteria weights developed by the AHP approach are based on human judgments and not arbitrary scales (Golden *et al.*, 1989). After the hierarchy is established, the other elements can be compared with each other at a time. The evaluation is converted into numerical values and the entire problem can be resolved easily. Singh *et al.* (2013) also used the AHP technique to examine the barriers to strategic flexibility in Indian manufacturing organizations. Singh and Ahuja (2012) used the AHP technique to determine the critical success factors in environmental uncertainty and evaluate TQM–TPM strategic factors.

Before proceeding for the steps of AHP, the major influential barriers were chosen after getting the scores from the experts from different organizations. Undoubtedly, variations were observed in the score received from the respondents because of their circumstances, work culture, experiences, product, etc., but these barriers have been chosen after an extensive literature review. AHP needs a proper defined problem to be broken into principal elements and its further division into pairs to be systematically analyzed. The nine major

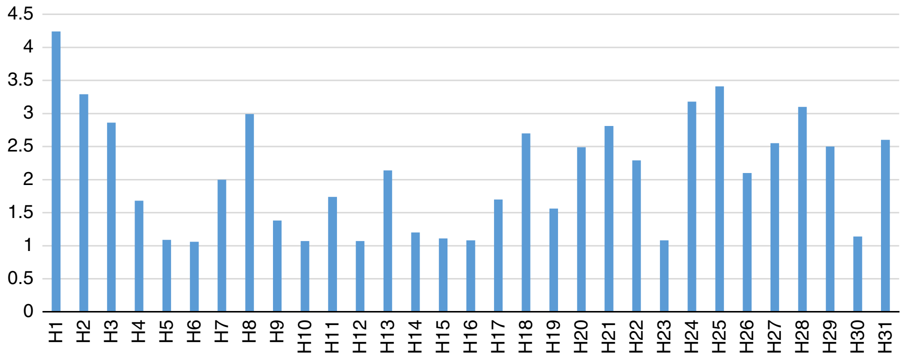

Figure 4. Depiction of barriers in implementation of AMTs according to the mean score

Table III. Major influential barriers in implementation of AMTs in SMEs

S. No.	Barriers	Mean score
J1	High-cost involved	4.24
J2	Budgetary priorities	3.41
J3	Lack of appropriate financial resources	3.29
J4	Current processes or procedures	3.18
J5	Work stress/overload	3.10
J6	Technology obsolescence	2.99
J7	Risk of failure to achieve financial targets	2.86
J8	Time required to make changes and adjust	2.81
J9	Resistance to learning new technology	2.55

influential barriers were presented before the experts from academia and industry for getting these evaluated. The brief profile of the experts is shown in Table V.

The comparisons were made and the experts were requested to fill these on the basis of scale for AHP judgment as mentioned in the below list:

- Rating = 1 if *i* and *j* are equally important.
- Rating = 3 if *i* is weakly more important than *j*.
- Rating = 5 if *i* more strongly important than *j*.
- Rating = 7 if *i* is very strongly more important than *j*.

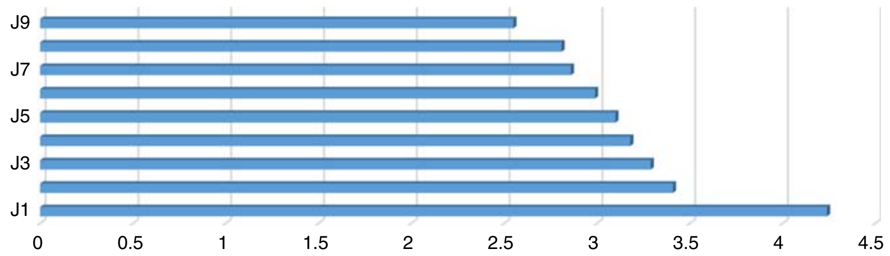

Figure 5.
Depiction of major influential barriers in implementation of AMTs in SMEs

Table IV.
Abbreviations of major influential barriers in implementation of AMTs

S. No.	Barriers	Abbreviations
1	High-cost involved	HCIN
2	Budgetary priorities	BPRI
3	Lack of appropriate financial resources	LFRS
4	Current processes or procedures	CPPS
5	Work stress/overload	WSOD
6	Technology obsolescence	TOBS
7	Risk of failure to achieve financial targets	RFTS
8	Time required to make changes and adjust	TCAT
9	Resistance to learning new technology	RNTY

Table V.
Brief profile of the experts for AHP

S. No.	Position in organization	Sector/product	Experience (years)
1	Deputy Director	Electrical goods manufacturing	18
2	Senior Engineer	Automotive parts manufacturing	13
3	Professor and AMT expert	Academia	26
4	HR Head	Manufacturing	16
5	Manager	Railway parts manufacturing	11
6	Proprietor	Rubber parts manufacturing	15
7	Senior Engineer	Manufacturing	10
8	Owner	CNC machining	16
9	Senior Engineer	CAD/CAM manufacturing	12
10	General Manager	Automotive parts manufacturing	19
11	Owner	Hand tools manufacturing	13
12	Owner	Manufacturing	16
13	Proprietor	CAD/CAM manufacturing	10
14	Senior Manager	Shoe manufacturing	11

- Rating $= 9$ if i is absolutely more important than j.
- Rating $= 2$ or 4 or 6 or 8, which are intermediate values between judgments.

In this step, we get the value of scale from the experts by the weightage of comparison of one element with another element within the scale 1–9, as mentioned in the above list. When element is compared by itself, 1 value is given to it. For comparing these pairs, 14 experts from industry and academia spared their precious time. They filled the pair wise comparison on the most influential barriers, keeping in mind their relevancy, and opinions were noted. From their valuable judgments and opinions, a pair wise comparison matrix was developed, as shown in Table VI. This matrix was of order n×n judgment matrix. From this developed matrix, a total of n (n−1)/2 judgments were considered for explaining the importance of one over the other. The pair wise comparison matrix developed is shown in Table VI.

After this, normalized matrix is obtained by dividing each entry of the matrix by the sum of entries in the column of the comparison matrix. The formula used to calculate normalized value (r_{ij}) is as follows:

$$r_{ij=}a_{ij}/\sum a_{ij}.$$

Then, the approximate priority weight (APW) of each attribute is calculated by dividing the sum of entries in a row by the total number of entries, as shown in Table VII. Then the eigenvector values and index of consistency are calculated for verification of the results. The following relation must be obeyed for the relative weights presenting eigenvalues of the criteria:

$$A \times W_i = \lambda_{\max\,.} \times W_i i = 1, 2, \ldots, n,$$

where $W_{1,}$ $W_2, \ldots, W_n$ are the APWs of each attribute and $\lambda_{\max}$ is the largest eigenvalue of the judgment matrix.

After the calculations stated above, the consistency index (CI) $=$ ($\lambda_{\max}$ $-n$)/ (n−1) is calculated, where n is the number of the elements being compared. Consistency ratio (CR) is calculated by dividing CI by the random consistency number for the same size matrix. The CR value should be either equal or less than 10 percent. If CR is not within the limits, then the problem can be rectified by revising the judgments. The average consistencies for different order matrices are shown in Table VIII (Saaty, 1990), and results of consistency test are shown in Table IX.

4.2 Technique of order preference by similarity to ideal solution (TOPSIS)

This approach is very effective and practical in finding the best possible solution to complex problems where multi-criteria decision is to be made. TOPSIS has been extensively used in

	HCIN	BPRI	LFRS	CPPS	WSOD	TOBS	RFTS	TCAT	RNTY	SUM
HCIN	1	3	2	3	5	4	5	4	7	34
BPRI	0.333333	1	2	0.333333	2	3	0.5	3	5	17.166666
LFRS	0.5	0.5	1	1	1	1	1	1	5	12
CPPS	0.333333	3	1	1	3	2	3	4	5	22.333333
WSOD	0.2	0.5	1	0.333333	1	1	0.5	1	3	8.533333
TOBS	0.25	0.333333	1	0.5	1	1	1	2	1	8.083333
RFTS	0.2	2	1	0.333333	2	1	1	3	0.5	11.033333
TCAT	0.25	0.333333	1	0.25	1	0.5	0.333333	1	1	5.666666
RNTY	0.142857	0.2	0.2	0.2	0.333333	1	2	1	1	6.07619

Table VI. Pair wise comparison matrix

Table VII. Normalized decision matrix

	HCIN	BPRI	LFRS	CPPS	WSOD	TOBS	RFTS	TCAT	RNTY	AHP Weights	Eigen Vector	AHP Ranking
HCIN	0.3115728	0.2760736	0.1960784	0.4316547	0.3061225	0.2758621	0.3488372	0.2	0.245614	0.287979485	1.081926996	1
BPRI	0.1038575	0.0920245	0.1960784	0.0479616	0.122449	0.2068966	0.0348837	0.15	0.1754386	0.12550999	0.827483847	3
LFRS	0.1557864	0.0460123	0.0980392	0.1438849	0.0612245	0.0689655	0.0697674	0.05	0.1754386	0.09656876	1.613217252	4
CPPS	0.1038575	0.2760736	0.0980392	0.1438849	0.1836735	0.137931	0.2093023	0.2	0.1754386	0.169800077	0.611645714	2
WSOD	0.0623146	0.0460123	0.0980392	0.0479616	0.0612245	0.0689655	0.0348837	0.05	0.1052632	0.063851614	0.97592766	7
TOBS	0.0778932	0.0306748	0.0980392	0.0719425	0.0612245	0.0689655	0.0697674	0.1	0.0350877	0.068177206	1.142510805	6
RFTS	0.0623146	0.1840491	0.0980392	0.0479616	0.122449	0.0689655	0.0697674	0.15	0.0175439	0.091232251	0.683032101	5
TCAT	0.0778932	0.0306748	0.0980392	0.0359712	0.0612245	0.0344828	0.0232558	0.05	0.0350877	0.049625469	1.569621347	8
RNTY	0.0445104	0.0184049	0.0196078	0.028777	0.0204081	0.0689655	0.1395349	0.05	0.0350877	0.04725515	0.941915369	9

various fields for solving complex problems of quality control, design of products, human resources management, location analysis, transport, production, etc. The basic idea behind this approach is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. It is a very useful technique to reach very close to the ideal solution (Chattopadhyay and Samanta, 2017):

- Step 1: an evaluation or decision matrix, as shown in Table X, is created, which consists of m alternatives and n criteria x_{ij}, $(x_{ij})_{m\times n}$.
- Step 2: in this step, normalized decision matrix is constructed in which various dimensional attributes are transformed into non-dimensional attributes, as shown in Table XI. The following formula is used for the same:

$$r_{ij} = x_{ij}/\left(x^2{}_{ij}\right)^{1/2} \text{for } i = 1, \ldots, m;\ j = 1, \ldots, n$$

- Step 3: in this step, weighted normalized decision matrix is constructed, as shown in Table XII. If we have a set of weights for each criteria w_j, where $j = 1, 2, 3, \ldots, n$, then each associated weight is multiplied by the column of the normalized decision matrix.
- Step 4: In this step, separation measures for each alternative are calculated, as shown in Tables XIII and XIV.

The separation from the ideal alternative is calculated as follows:

$$S_i^* = \left[\left(v_j \times -v_{ij}\right)^2\right]^{1/2},\ \text{for } i = 1, 2, \ldots, m$$

Similarly, the separation from the negative ideal alternative is calculated as follows:

$$S_i' = \left[\left(v_j' - v_{ij}\right)^2\right]^{1/2},\ \text{for } i = 1, 2, \ldots, m$$

- Step 5: In this step, the relative closeness to the ideal solution (Ci^*) is calculated, as shown in Table XV:

$$Ci^* = S'i/\left(Si^* + S'i\right),\ 0 < Ci^* < 1.$$

The option with Ci^* closest to 1 is selected.

Size of the matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.42	1.45	1.49

Table VIII. Random consistency index (RI)

Maximum eigenvalue	Consistency index	Random consistency index	Consistency ratio
9.447281091	0.055910136	1.45	0.038558715

Table IX. Consistency test results

	HCIN	BPRI	LFRS	CPPS	WSOD	TOBS	RFTS	TCAT	RNTY
HCIN	1	3	2	3	5	4	5	4	7
BPRI	0.333333	1	2	0.333333	2	3	0.5	3	5
LFRS	0.5	0.5	1	1	1	1	1	1	5
CPPS	0.333333	3	1	1	3	2	3	4	5
WSOD	0.2	0.5	1	0.333333	1	1	0.5	1	3
TOBS	0.25	0.333333	1	0.5	1	1	1	2	1
RFTS	0.2	2	1	0.333333	2	1	1	3	0.5
TCAT	0.25	0.333333	1	0.25	1	0.5	0.333333	1	1
RNTY	0.142857	0.2	0.2	0.2	0.333333	1	2	1	1
Sum $(xij)^2$	1.6976299	23.762222	14.04	11.685833	46.111111	34.25	41.611111	58	136.25
SQRT (xij)	1.3029313	4.8746509	3.7469988	3.4184547	6.7905162	5.85235	6.4506675	7.6157731	11.672618

Table X.
Decision matrix for TOPSIS

	HCIN	BPRI	LFRS	CPPS	WSOD	TOBS	RFTS	TCAT	RNTY
HCIN	0.7675002	0.6154287	0.5337605	0.8775895	0.736321	0.6834861	0.7751136	0.5252257	0.5996941
BPRI	0.2558331	0.2051429	0.5337605	0.0975098	0.2945284	0.5126146	0.0775114	0.3939193	0.4283529
LFRS	0.3837501	0.1025714	0.2668803	0.2925298	0.1472642	0.1708715	0.1550227	0.1313064	0.4283529
CPPS	0.2558331	0.6154287	0.2668803	0.2925298	0.4417926	0.3417431	0.4650682	0.5252257	0.4283529
WSOD	0.1535	0.1025714	0.2668803	0.0975098	0.1472642	0.1708715	0.0775114	0.1313064	0.2570118
TOBS	0.191875	0.0683809	0.2668803	0.1462649	0.1472642	0.1708715	0.1550227	0.2626129	0.0856706
RFTS	0.1535	0.4102858	0.2668803	0.0975098	0.2945284	0.1708715	0.1550227	0.3939193	0.0428353
TCAT	0.191875	0.0683809	0.2668803	0.0731325	0.1472642	0.0854358	0.0516742	0.1313064	0.0856706
RNTY	0.1096428	0.0410286	0.0533761	0.058506	0.049088	0.1708715	0.3100454	0.1313064	0.0856706
AHP weights	0.2879795	0.12551	0.0965688	0.1698001	0.0638516	0.0681772	0.0912323	0.0496255	0.0472552
AHP ranking	1	3	4	2	7	6	5	8	9

Table XI.
Normalized decision matrix for TOPSIS

Table XII. Weighted normalized decision matrix for TOPSIS

	HCIN	BPRI	LFRS	CPPS	WSOD	TOBS	RFTS	TCAT	RNTY
HCIN	0.2210243	0.0772424	0.0515446	0.1490148	0.0470153	0.0465982	0.0707154	0.0260646	0.0283386
BPRI	0.0736747	0.0257475	0.0515446	0.0165572	0.0188061	0.0349486	0.0070715	0.0195484	0.0202419
LFRS	0.1105122	0.0128737	0.0257723	0.0496716	0.0094031	0.0116495	0.0141431	0.0065161	0.0202419
CPPS	0.0736747	0.0772424	0.0257723	0.0496716	0.0282092	0.0232991	0.0424292	0.0260646	0.0202419
WSOD	0.0442049	0.0128737	0.0257723	0.0165572	0.0094031	0.0116495	0.0070715	0.0065161	0.0121451
TOBS	0.0552561	0.0085825	0.0257723	0.0248358	0.0094031	0.0116495	0.0141431	0.0130323	0.0040484
RFTS	0.0442049	0.051495	0.0257723	0.0165572	0.0188061	0.0116495	0.0141431	0.0195484	0.0020242
TCAT	0.0552561	0.0085825	0.0257723	0.0124179	0.0094031	0.0058248	0.0047144	0.0065161	0.0040484
RNTY	0.0315749	0.0051495	0.0051545	0.0099343	0.0031343	0.0116495	0.0282861	0.0065161	0.0040484
Minimum value of each column									
$v_j^{'}$	0.0315749	0.0051495	0.0051545	0.0099343	0.0031343	0.0058248	0.0047144	0.0065161	0.0020242
Maximum value of each column									
v_j^{*}	0.2210243	0.0772424	0.0515446	0.1490148	0.0470153	0.0465982	0.0707154	0.0260646	0.0283386

Table XIII.
Negative solutions

	HCIN	BPRI	LFRS	CPPS	WSOD	TOBS	RFTS	TCAT	RNTY	Σ (Aij − min of each column)^2	Si' SQRT(Σ(Aij − Min of each column)^2)
HCIN	0.03589109	0.00519739	0.00215204	0.01934337	0.00192554	0.00166247	0.00435613	0.00038214	0.00069245	0.07160263	0.26758668
BPRI	0.00177240	0.00042428	0.00215204	0.00004386	0.00024560	0.00084820	0.00000556	0.00016984	0.00033188	0.00599366	0.07741875
LFRS	0.00623109	0.00005966	0.00042510	0.00157905	0.00003930	0.00003393	0.00008890	0.00000000	0.00033188	0.00878891	0.09374921
CPPS	0.00177240	0.00519739	0.00042510	0.00157905	0.00062875	0.00030535	0.00142241	0.00038214	0.00033188	0.01204447	0.10974730
WSOD	0.00015952	0.00005966	0.00042510	0.00004386	0.00003930	0.00003393	0.00000556	0.00000000	0.00010243	0.00086935	0.02948479
TOBS	0.00056080	0.00001179	0.00042510	0.00022205	0.00003930	0.00003393	0.00008890	0.00004246	0.00000410	0.00142842	0.03779441
RFTS	0.00015952	0.00214790	0.00042510	0.00004386	0.00024560	0.00003393	0.00008890	0.00016984	0.00000000	0.00331465	0.05757300
TCAT	0.00240345	0.00007264	0.00064248	0.00011748	0.00008768	0.00003353	0.00002139	0.00004246	0.00001381	0.00343493	0.05860827
RNTY	0.00064231	0.00002591	0.00002237	0.00006981	0.00000958	0.00013492	0.00079508	0.00004246	0.00001381	0.00175625	0.04190763

Table XIV.
Positive solutions

	HCIN	BPRI	LFRS	CPPS	WSOD	TOBS	RFTS	TCAT	RNTY	Σ(Max of each column − $Aij)^2$	Si* SQRT(Σ(Max of each column − $Aij)^2$)
HCIN	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
BPRI	0.02171191	0.00265173	0.00000000	0.01754501	0.00079576	0.00013571	0.00405054	0.00004246	0.00006556	0.04699867	0.21679178
LFRS	0.01221294	0.00414333	0.00066421	0.00986907	0.00141468	0.00122141	0.00320042	0.00038214	0.00006556	0.03317375	0.18213663
CPPS	0.02171191	0.00000000	0.00066421	0.00986907	0.00035367	0.00054285	0.00080011	0.00000000	0.00006556	0.03400737	0.18441087
WSOD	0.03126512	0.00414333	0.00066421	0.01754501	0.00141468	0.00122141	0.00405054	0.00038214	0.00026223	0.06094866	0.24687783
TOBS	0.02747911	0.00471419	0.00066421	0.01542042	0.00141468	0.00122141	0.00320042	0.00016984	0.00059002	0.05487429	0.23425263
RFTS	0.03126512	0.00066293	0.00066421	0.01754501	0.00079576	0.00122141	0.00320042	0.00004246	0.00069245	0.05608977	0.23683279
TCAT	0.02747911	0.00471419	0.00066421	0.01865870	0.00141468	0.00166247	0.00435613	0.00038214	0.00059002	0.05992165	0.24478900
RNTY	0.03589109	0.00519739	0.00215204	0.01934337	0.00192554	0.00122141	0.00180024	0.00038214	0.00059002	0.06850324	0.26173123

4.3 Sensitivity analysis

Sensitivity analysis is necessary to check the reliability and feasibility of a method or model. It helps us to understand the way by which uncertainty in the output of a mathematical method or model (numerical or otherwise) can be divided and assigned to different causes of uncertainty in the inputs. Sensitivity analysis helps us to see the changes in results (if any) when the weights are replaced. Uncertainty analysis can also be done simultaneously, which focuses on uncertainty propagation and quantification. The motive of this analysis is to test the robustness of a model in the presence of uncertainty. Some researchers believe that it leads to a better option or response and it is just not about selecting multiple criteria (Merati and Sheikholeslami, 2015; Kasanan *et al.*, 2000). The understanding of input and output variables is significantly enhanced with the help of this analysis. This analysis leads to better model for clarification and makes recommendations due to better understanding (Bai *et al.*, 2018). Table XVI shows the new sets of weights for sensitivity analysis and Table XVII reflects the ranking of attributes after the test. Figure 6 helps in better understanding of AHP rankings after the sensitivity analysis, as reflected in Table XVII.

The results of sensitivity analysis clearly reflect the accuracy of AHP applied for the analysis of barriers in the implementation of AMTs in SMEs. Also, it seems that there is no uncertainty present; therefore, no change is required.

5. An action plan to overcome the barriers in implementation of AMTs in SMEs

The action plan or solution to overcome the barriers in implementation of AMTs in SMEs may vary according to various countries due to the difference in culture, mindset, conditions, etc. There are many dimensions that need to be considered for making an action

	Si'	Si*	Ci* = Si′/(Si* +Si′)	TOPSIS rank	AHP rank
HCIN	0.2675867	0	1	1	1
BPRI	0.0774188	0.2167918	0.2631407	4	3
LFRS	0.0937492	0.1821366	0.3398116	3	4
CPPS	0.1097473	0.1844109	0.3730894	2	2
WSOD	0.0294848	0.2468778	0.1066888	9	7
TOBS	0.0377944	0.2342526	0.138926	7	6
RFTS	0.057573	0.2368328	0.1955566	5	5
TCAT	0.0586083	0.244789	0.1931734	6	8
RNTY	0.0419076	0.2617312	0.138018	8	9

Table XV. Ranks from AHP–TOPSIS approaches

AHP weights	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	TEST 6	TEST 7	TEST 8	TEST 9	TEST 10
0.2880	0.0966	0.2880	0.2880	0.2880	0.2880	0.2880	0.2880	0.2880	0.2880	0.2880
0.1255	0.1255	0.1698	0.1255	0.1255	0.1255	0.1255	0.1255	0.1255	0.1255	0.0966
0.0966	0.2880	0.0966	0.0639	0.0966	0.0966	0.0966	0.0966	0.0966	0.0966	0.1255
0.1698	0.1698	0.1255	0.1698	0.0682	0.1698	0.1698	0.1698	0.1698	0.0639	0.1698
0.0639	0.0639	0.0639	0.0966	0.0639	0.0912	0.0639	0.0639	0.0639	0.1698	0.0639
0.0682	0.0682	0.0682	0.0682	0.1698	0.0682	0.0496	0.0682	0.0682	0.0682	0.0682
0.0912	0.0912	0.0912	0.0912	0.0912	0.0639	0.0912	0.0473	0.0912	0.0912	0.0912
0.0496	0.0496	0.0496	0.0496	0.0496	0.0496	0.0682	0.0496	0.0473	0.0496	0.0496
0.0473	0.0473	0.0473	0.0473	0.0473	0.0473	0.0473	0.0912	0.0496	0.0473	0.0473

Table XVI. New set of weights for sensitivity analysis plan to overcome these barriers. There is a need to educate SMEs, and support is required to find out the best possible way to implement AMTs by training and system integration (Mannan and Khurana, 2012). There are many approaches that can be adopted. Early adopters and achievers of AMTs can act as role model to demonstrate and advertise. Another catalyst can be that SMEs are provided with custom-made or modified AMTs as per their needs. The government policies and financial aids play an important role in overcoming financial barriers (Singla *et al.*, 2018). The solutions and action plan to overcome the major influential barriers have been formulated after a lot of literature review and discussions with experts from different fields (manufacturing industry and academia). This will surely play an important and a constructive role in providing a helping hand to SMEs to overcome these barriers and implement AMTs. The solution to overcome the barriers has been discussed in Table XVIII.

Figure 7 depicts the model for successfully implementing AMTs in SMEs. This model has been generated after an extensive literature review, survey and discussion with experts (manufacturing industry and academia). The business objective must be very clear to the management or the owner (Chen and Small, 1994; Kaur *et al.*, 2019). It is very important in evaluation of the current production processes being followed. In the next stage, analysis of structure and management, workforce skill, finance, product and technology needs to be done closely. This analysis will help in evolution of the feasibility of the technology being considered for implementation. Also, this analysis can help in improving various parameters and techniques (Thomas *et al.*, 2008). R&D helps to discover better options at more affordable prices, hence addressing the cost and finance barrier. After this step, the expert advice is very valuable in completing the work done in previous two steps with better understanding,

Attributes	AHP ranking	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	TEST 6	TEST 7	TEST 8	TEST 9	TEST 10
HCIN	1	4	1	1	1	1	1	1	1	1	1
BPRI	3	3	2	3	3	3	3	3	3	3	4
LFRS	4	1	4	7	4	4	4	4	4	4	3
CPPS	2	2	3	2	6	2	2	2	2	7	2
WSOD	7	7	7	4	7	5	7	7	7	2	7
TOBS	6	6	6	6	2	6	8	6	6	6	6
RFTS	5	5	5	5	5	7	5	9	5	5	5
TCAT	8	8	8	8	8	8	6	8	9	8	8
RNTY	9	9	9	9	9	9	9	5	8	9	9

Table XVII.
Ranking of attributes as per the tests applied

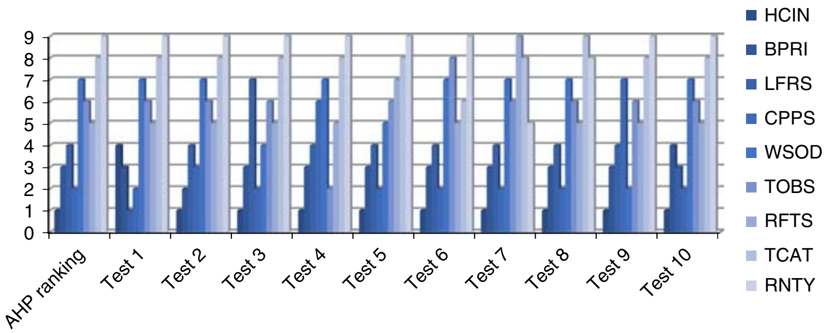

Figure 6.
Graphical representation of AHP rankings after sensitivity analysis

S. No.	Major barriers	Strategies/solutions
1.	High-cost involved	High level R&D should be focused upon so that the cost of owning AMTs gets reduced. The decrease in overall cost by research can lead to more implementation of AMTs
2.	Current processes or procedures	The achievers should lead by an example and bring forward the advantages of AMTs over current processes and procedures
3.	Lack of appropriate financial resources	The government should formulate policies to provide easy and accessible financial support to the sector for enabling the management to invest in AMTs
4.	Budgetary priorities	The management must focus on long-term gains and advantages. It can overcome these challenges by sacrificing short-term gains
5.	Risk of failure to achieve financial targets	The role of achievers again plays a very important role in building up the trust in new technology and motivating others to overcome the fear of achieving financial goals
6.	Time required to make changes and adjust	Workshops, industrial visits and proper training can help in overcoming this barrier
7.	Technology obsolescence	The flexibility and adaptability of the technology to the varying scenarios must be brought into notice to enhance the trust factor
8.	Resistance to learning new technology	Mindset of people needs to be changed by awareness camps, lectures, training, etc., at regular intervals, thereby highlighting the benefits of AMTs
9.	Work stress/overload	Motivational lectures should be conducted to overcome the daily pressure and stress of work

Table XVIII. Action plan to overcome barriers in implementation of AMTs in SMEs

Figure 7. Model for successfully implementing AMTs in SMEs

amendments (if required) and clarity. The motivation of employees, management and setting a positive mindset are very important, as human factor plays a very important role in its success (Darbanhosseiniamirkhiz and Ismail, 2012). For continuous improvement, the management should have a long-term approach. This farsightedness enables the management to adopt AMTs and overcome the fear. The achievers play an important role in changing the mindset of people and advancing to the implementation of AMTs. Training of workers and employees to make them friendly and have faith in the technology is also very important (Na-Nan, 2019; Singh *et al.*, 2007). The customer feedback plays a vital role for the improvement in product and finally the technology.

6. Conclusions

It is clear that AMTs have numerous benefits after their implementation in SMEs. AMTs can bring up the level of SMEs to compete and face the changing scenario. It is the need of time in developing nations like India to adopt and implement AMTs. SMEs face many barriers or hindrances on the way to implement AMTs. These barriers need to be analyzed in terms of weightage, and this paper addresses the same by the AHP–TOPSIS approach. Although all the barriers are important and need to be addressed with a solution, the major influential barriers need more focus in order to advance for the implementation of AMTs. High cost of AMTs, lack of appropriate financial resources and current processes or procedures are the major barriers that cause hindrance in the path of implementation of AMTs in SMEs. This paper can be helpful in many ways to the management or industrialists of various nations who are on the same path or will follow soon. The major influential barriers have been deeply analyzed, and solution to overcome them has been discussed. Also, a model for successfully implementing AMTs in SMEs has been suggested. This model seems a better version from the previously discussed models in literature, as it covers a wider area for consideration to implement the AMTs successfully and overcome the major influential barriers.

Future scope of work: this investigation was based on the survey followed by judgments of experts in industry and academia; other approaches such as PROMETHEE, WPM, VIKOR, etc., can be applied for investigation. Also, the study can be carried out in different region(s) and parts of the country.

References

Alcaraz, J.L.G., Iniesta, A.A. and Castello, M.C.J. (2012), “Benefits of advanced manufacturing technologies”, *African Journal of Business Management*, Vol. 6 No. 16, pp. 5524-5532.

Atkin, D., Chaudhry, A., Chaudry, S., Khandelwal, A.K. and Verhoogen, E. (2017), “Organizational barriers to technology adoption: evidence from soccer-ball producers in Pakistan”, *The Quarterly Journal of Economics*, Vol. 132 No. 3, pp. 1101-1164.

Bai, C., Satir, A. and Sarkis, J. (2018), “Investing in lean manufacturing practices: an environmental and operational perspective”, *International Journal of Production Research*, Vol. 57 No. 4, pp. 1037-1051.

Chan, F., Yusuff, R.M. and Zulkifli, N. (2015), “Barriers to advanced manufacturing technology in small-medium enterprises (SMEs) in Malaysia”, International Symposium on Technology Management and Emerging Technologies (ISTMET), Langkawi, pp. 412-416.

Chattopadhyay, A. and Samanta, S. (2017), “Integrating information theory and TOPSIS for mapping solar power generation potential in Indian states”, *International Journal of Advanced in Management, Technology and Engineering Sciences*, Vol. 7 No. 12, pp. 76-78.

Chen, I.J. and Small, M.H. (1994), “Implementing advanced manufacturing technology: an integrated planning model”, *Omega, International Journal of Management Science*, Vol. 22 No. 1, pp. 91-103.

Chou, T., Hsu, L., Yeh, Y. and Ho, C. (2005), "Towards a framework of the performance evaluation of SMEs' industry portals", *Industrial Management and Data Systems*, Vol. 105 No. 4, pp. 527-544.

Chung, W. and Swink, M. (2009), "Patterns of advanced manufacturing technology utilization and manufacturing capabilities", *Productions and Operations Management*, Vol. 18 No. 5, pp. 533-545.

Dangayach, G.S. and Deshmukh, S.G. (2005), "Advanced manufacturing technology implementation: evidence from Indian small and medium enterprises (SMEs)", *Journal of Manufacturing Technology Management*, Vol. 16 No. 5, pp. 483-496.

Darbanhosseiniamirkhiz, M. and Ismail, W.K.W. (2012), "Advanced manufacturing technology adoption in SMEs: an integrative model", *Journal of Technology Management and Innovation*, Vol. 7 No. 4, pp. 112-120.

Dean, J.W. Jr. and Snell, S.A. (1996), "The strategic use of integrated manufacturing: an empirical examination", *Strategic Management Journal*, Vol. 17 No. 6, pp. 459-480.

Gerwin, D. (1993), "Manufacturing flexibility: a strategic perspective", *Management Science*, Vol. 39 No. 4, pp. 395-410.

Golden, B.L., Wasil, E.A. and Harker, P.T. (1989), *The Analytic Hierarchy Process*, Springer Verlag, New York, NY, pp. 13-14.

Goldhar, J.D. and Jelinek, M. (1985), "Computer integrated flexible manufacturing: organizational, economic and strategic implications", *Interfaces*, Vol. 15 No. 3, pp. 94-105.

Goulding, J., Sexton, M., Zhang, X., Kagioglou, M., Aouad, G.F. and Barrett, P. (2007), "Technology adoption: breaking down barriers using a virtual reality design support tool for hybrid concrete", *Construction Management and Economics*, Vol. 25 No. 12, pp. 1239-1250.

Gunawardana, K.D. (2010), "Introduction of advanced manufacturing technology: a literature review", *Sabaragamuwa University Journal*, Vol. 6 No. 1, pp. 116-134.

Hooi, L.W. (2006), "Implementing e-HRM: the readiness of SME manufacturing company in Malaysia", *Asia Pacific Business Review*, Vol. 12 No. 4, pp. 465-485.

Hottenstein, M.P. and Dean, J.W. (1992), "Managing risk in advanced manufacturing technology", *California Management Review*, Vol. 34 No. 4, pp. 112-126, available at: http://msme.gov.in/know-about-msme (accessed 23 July 2019).

Husband, S. and Mandal, P. (1999), "A conceptual model for quality integrated management in small and medium size enterprises", *International Journal of Quality and Reliability Management*, Vol. 16 No. 7, pp. 699-713.

Hynek, J. and Janecek, V. (2009), "Problems of advanced manufacturing technology benefits evaluation", *Proceedings of the International Conference on Intelligent Engineering Systems, IEEE, Barbados*, pp. 107-111.

Kaplinsky, R. (1984), *Automation: The Technology and Society*, Longman, London.

Kasanan, E., Wallenius, H., Wallenius, J. and Zionts, S. (2000), "A study of high-level managerial decision processes with implication for MCDM research", *European Journal of Operational Research*, Vol. 120 No. 3, pp. 496-510.

Kaur, M., Singh, K. and Singh, D. (2019), "Synergetic success factors of total quality management (TQM) and supply chain management (SCM)", *International Journal of Quality & Reliability Management*, Vol. 36 No. 6, pp. 842-863.

Khaparde, V.M. (2012), "Barriers of ERP while implementing ERP: a literature Review", *IOSR Journal of Mechanical and Civil Engineering*, Vol. 3 No. 6, pp. 49-91.

Kirk, D. (1998), "Entrepreneurial context and behaviour in SMEs: an investigation of two contrasting manufacturing firms", *International Journal of Entrepreneurial Behaviour & Research*, Vol. 4 No. 2, pp. 88-100.

Klocke, F. and Straube, A.M. (2004), "Virtual process engineering – an approach to integrate VR, FEM and simulation tools in the manufacturing chain", *MéCanique & Industries*, Vol. 5 No. 2, pp. 199-205.

Kotha, S. and Swamidass, P.M. (2000), "Strategy, advanced manufacturing technology and performance: empirical evidence from U.S. manufacturing firms", *Journal of Operations Management*, Vol. 18 No. 3, pp. 257-277.

Mannan, B. and Khurana, S. (2012), "Enablers and barriers for introduction of robotics as an AMT in the Indian industries (Case of SME's)", *IJCA Proceedings on National Conference on Communication Technologies & its impact on Next Generation Computing 2012, CTNGC(2), New Delhi*, pp. 19-24.

Merati, H. and Sheikholeslami, A. (2015), "Sensitivity analysis decision techniques and weighting techniques in multiple attribute decision making case study (priority public transport systems in Qom)", *Science Journal (CSJ)*, Vol. 36 No. 6, pp. 601-609.

Na-Nan, K. (2019), "Employee work adjustment scale for small and medium-sized enterprises in Thailand", *International Journal of Quality & Reliability Management*, Vol. 36 No. 8, pp. 1284-1300.

Ndubisi, N.O. (2012), "Mindfulness, quality and reliability in small and large firms", *International Journal of Quality & Reliability Management*, Vol. 29 No. 6, pp. 600-606.

Oberoi, J.S., Khamba, J.S. and Sushil, K.R. (2008), "An empirical examination of advanced manufacturing technology and sourcing practices in developing manufacturing flexibilities", *International Journal of Services and Operations Management*, Vol. 4 No. 6, pp. 652-671.

Parthasarthy, R. and Sethi, S.P. (1993), "Relating strategy and structure to flexible automation: a test of fit and performance implications", *Strategic Management Journal*, Vol. 14 No. 7, pp. 529-549.

Power, D. and Simon, A. (2004), "Adoption and diffusion in technology implementation: a supply chain study", *International Journal of Operations & Production Management*, Vol. 24 No. 6, pp. 566-587.

Rothwell, R. (1991), "External networking and innovation in small and medium-sized manufacturing firms in Europe", *Technovation*, Vol. 11 No. 2, pp. 93-112.

Saaty, T.L. (1990), "How to make a decision: the analytical hierarchy process", *European Journal of Operations Research*, Vol. 48 No. 1, pp. 9-26.

Saaty, T.L. (1994a), "How to make a decision: the analytic hierarchy process", *Interfaces*, Vol. 24 No. 6, pp. 19-43.

Saaty, T.L. (1994b), "Highlights and critical points in the theory and application of the analytic hierarchy process", *European Journal of Operational Research*, Vol. 74 No. 3, pp. 426-447.

Singh, D., Oberoi, J.S. and Ahuja, I.S. (2013), "An empirical examination of barriers to strategic flexibility in Indian manufacturing industries using analytical hierarchy process", *International Journal of Technology, Policy and Management*, Vol. 13 No. 4, pp. 313-327.

Singh, H. and Khamba, J.S. (2011), "An interpretive structural modelling (ISM) approach for advanced manufacturing technologies (AMTs) utilisation barriers", *International Journal of Mechatronics and Manufacturing Systems*, Vol. 4 No. 1, pp. 35-48.

Singh, K. and Ahuja, I.S. (2012), "Justification of TQM–TPM implementations in manufacturing organisations using analytical hierarchy process: a decision-making approach under uncertainty", *International Journal of Productivity, Quality and Management*, Vol. 10 No. 2, pp. 69-84.

Singh, R.K., Garg, S.K., Deshmukh, S.G. and Kumar, M. (2007), "Modelling of critical success factors for implementation of AMTs", *Journal of Modelling in Management*, Vol. 2 No. 3, pp. 232-250.

Singla, A., Sethi, A. and Ahuja, I.S. (2018), "An empirical examination of critical barriers in transitions between technology push and demand pull strategies in manufacturing organizations", *World Journal of Science, Technology and Sustainable Development*, Vol. 15 No. 3, pp. 257-277.

Smit, Y. and Watkins, J.A. (2012), "A literature review of small and medium enterprises (SME) risk management practices in South Africa", *African Journal of Business Management*, Vol. 6 No. 21, pp. 6324-6330.

Sohal, A.S. (1997), "A longitudinal study of planning and implementation of advanced manufacturing technologies", *International Journal of Computer Integrated Manufacturing*, Vol. 10 Nos 1-4, pp. 281-295.

Svobodova, L. (2011), "Advanced manufacturing technology utilization and realized benefits", *Recent Researches in System Science, Proceedings of the 15th WSEAS International Conference on Systems*, *Corfu Island*, pp. 137-142.

Swamidass, P.M. and Kotha, S. (1998), "Explaining manufacturing technology use, firm size and performance using a multidimensional view of technology", *Journal of Operations Management*, Vol. 17 No. 1, pp. 23-37.

Tahriri, F., Dawal, S.Z.M., Jen, Y.H., Case, K., Tho, N.H., Zuhdi, A., Mousavi, M., Amindoust, A. and Sakundarini, N. (2015), "Empirical evidence of AMT practices and sustainable environmental initiatives in Malaysian automotive SMEs", *International Journal of Precision Engineering and Manufacturing*, Vol. 16 No. 6, pp. 1195-1203.

Thomas, A.J., Barton, R. and John, E.G. (2008), "Advanced manufacturing technology implementation", *International Journal of Productivity and Performance Management*, Vol. 57 No. 2, pp. 156-176.

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