MODELLING THE CRITICAL SUCCESS FACTORS FOR ADVANCED MANUFACTURING TECHNOLOGY IMPLEMENTATION IN SMALL AND MEDIUM SIZED ENTERPRISES

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ABSTRACT

In almost every part of the world, small and medium-sized businesses (SMEs) are seen as the backbone of economic expansion. Small and medium-sized enterprises (SMEs) typically have a simpler organisational structure than large corporations, which allows them to be more adaptable, provide instantaneous feedback, have shorter decision-making chains, and respond more quickly to customer needs. Even so, SMEs face enormous pressure to stay competitive in both domestic and international markets. Globalization, new technologies, and evolving consumer preferences are all contributing to a shift in the competitive landscape. These shifts are compelling small and medium-sized enterprises to adopt cutting-edge manufacturing techniques. The goal of this research is to identify the critical success factors (CSFs) that will help and guarantee that SMEs will be able to successfully implement AMTs (SMEs). Literature-based CSFs for AMT deployment are collected and fine-tuned using input from professionals in the field and scholars in the academy. The method of interpretive structural modelling (ISM) is applied to this CSF analysis. According to the ISM study, the three most important factors influencing the adoption of AMT are "Top management support and commitment," "entrepreneurial environment," and "financial availability." The desired goal of AMT implementation is found to be "performance improvement" and "sustainable AMT implementation." The identified CSFs and the structural relationship between them will help SMEs' top management create and prioritise business strategies that ease the implementation of AMT. The study's results point potential AMT financiers in the right direction by highlighting a handful of critical considerations that will improve the project's chances of success.

KEYWORDS

Small And Medium-Sized Enterprises (SMES), Advanced Manufacturing Technologies (AMTS), Success Factors, Interpretive Structural Modeling (ISM), MICMAC Analysis.

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1. INTRODUCTION

Today's businesses should be better prepared than ever to meet the challenges of a highly competitive market. Therefore, in today's world of ever-increasing competition, they must overcome the difficulty of discovering novel ways to boost their efficiency and effectiveness. Failure to rise to this challenge may prevent businesses from fortifying their position against rivals or expanding into new markets. Many factories are now using AMT to improve their competitiveness [1, 2]. It is possible that SMEs could benefit from AMT implementation if they had a better understanding of and ability to manage the drivers and barriers. They might be able to improve their efficiency as a result. There is substantial evidence in the literature that AMT implementation has helped organisations improve their operational and economic performance [3]. But in most cases, companies that have already implemented AMTs fail to see the expected benefits. This may be due to the fact that, in many cases, organisations overlook crucial aspects of AMT implementation that would improve its success. Critical success factors (CSFs) of AMT implementation refer to these actions. To succeed in a competitive environment, one must focus on a small number of critical success factors (CSFs). CSFs are the "things must go right" areas of a business that are essential to the achievement of the manager's goals. [4]. Thus, the CSFs approach is an effort to disentangle factors that are vital to project management's success [5]. When considered in the context of their significance at each stage of the implementation process, these CSFs take on a much richer meaning, helping to push the boundaries of process improvement. In this research, critical success factors (CSF) refer to anything considered important for the effective use of AMTs by Indian SMEs.

Small and medium-sized enterprises (SMEs) are the backbone of India's manufacturing sector (SMEs). Small and medium-sized enterprises (SMEs) in India are responsible for 43% of the country's industrial output and 40% of its exports. [7]. For India's economy to thrive and for new jobs and growth to be created over the long term, small and medium-sized enterprises (SMEs) must undergo a process of industrial modernization. These small and medium-sized enterprises (SMEs) face internal and external challenges as they adopt new technologies. [8].

Compared to large industries, which are more efficient at scale but slower to adapt to innovations, small and medium-sized businesses (SMEs) are more nimble when it comes to technology and niche markets. [9]. Since the decision to invest in AMT is so important, SMEs need to think through the entire implementation process before making a final decision.

Although the technical capabilities of AMTs are well established, a framework for effective implementation has not been agreed upon by practitioners or academics. The reason for this is that researchers have yet to identify all of the factors that either help or hurt when trying to implement AMT. Therefore, in order to hasten the spread of advanced manufacturing, it has been decided to study the factors that contribute to the success of implementing advanced manufacturing technology in small and medium-sized businesses. The connections between AMT factors and firm performance are of critical strategic importance. Potential investors who are thinking about investing in AMTs in the future can use the information gleaned from this study. Further, business leaders who take the time to comprehend these connections will have an easier time crafting efficient strategies for managing technology within the company.

2. RESEARCH METHODOLOGY

This study employed the following research methodology: I A comprehensive literature review of success factors for AMT implementation in SMEs. To learn more about how SMEs in India are using AMT, a questionnaire-based survey was conducted. To analyse the survey questionnaire data, the researchers used SPSS (20.0). There were two primary methods used to examine the data. The data was

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initially put to use for broad statistical purposes. Second, the proposed relationship between the business environment, competitiveness, and firm performance was tested using the standard Pearson correlation test. To model the intricate web of causality linking the most crucial factors influencing the adoption of AMT, the interpretive structural modelling (ISM) method is employed. The authors hope to determine which factors have the greatest impact on whether or not an AMT is adopted by using this method. With ISM, the chaos of such variables can be brought under control. v) Creating a framework for identifying the critical success factors for implementing AMT in SMEs. vi) The scope of each driver of the AMT implementation practise is critically examined using a Matrice d Impacts Croises - Multiplication Applique'and Classment (MICMAC) analysis. When conducting a MICMAC analysis, the significance of a variable is not determined by the strength of its direct relationships but rather by the number and types of indirect relationships it has. Understanding how different factors affect the whole system is revealed. The analysis's purpose is to categorise variables according to their driving and dependent powers.

3. ISM BASED MODELLING OF THE OF CRITICAL SUCCESS FACTORS OF AMT IMPLEMENTATION

This section included an Interpretive Structural Modeling of the important success criteria of AMT implementation in the context of Indian SMEs. The model can be employed to rank and understand the complex nature of hierarchy and explore the relationship existing among the critical success factors.

3.1. IDENTIFICATION OF CRITICAL SUCCESS FACTORS FOR AMT IMPLEMENTATION

Eighteen success factors are collected from literature survey and calibrated by industry experts and academicians are listed as follows:

Table 1: Success factors for AMT implementation.

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S. No.	CSF	Literature Relevanc
C1	Top management support and commitment	6,11,12,14,33,34,47,4
C2	Finance availability	11,12,14,33,43,47,48
C3	Entrepreneurial environment	6,35,36,37
C4	Absorptive capacity	38,39,40,41,42
C5	Organizational context	26,27,28,33,47,48
C6	Clear and long term AMT objectives	14,33,47,48
C7	Linking business and manufacturing strategy	3, 6,14,33,44,45,46,4
C8	Operations strategy	14,25,33,47,48
C9	Technology champion	12, 14,46,47,48
C10	Employee training and pilot project	12,14,45,48
C11	Sustainable AMT implementation	32,33
C12	Cross functional implementation team	6, 14,46,47,48
C13	Employee participation & empowerment	30,31,47,48
C14	High level system integration	3,12,14,33,47
C15	Technology know how	3,45,46,47,48
C16	Vendor development	2,6,14,11,29,33, 45,47,48
C17	Performance improvement	14, 33,47,48
C18	Customer involvement	11,12, 14,46,48

3.2. (SSIM) FOR CRITICAL SUCCESS FACTORS

Through the use of expert consultation and the identification of contextual relationships between the success factors included in the system, a structural self-interaction matrix for the critical success factors is developed. A 'leads to' type contextual relationship is selected to examine the interplay of the success factors. For instance, a "favourable company image" can result from "better quality." The interrelationships of the variables in their context are constructed in a similar fashion. The existence of a relation between any two variables I and j) and the direction of the relation are questioned, while taking into account the contextual relationship for each variable. There are four signs used to indicate the directional relationship between the I and j variables:

P: The stress caused by I will be reduced by j.

The two variables, I and j, will mutually alleviate one another, as shown in (A) and (X).

O: There is no connection between I and j.

The SSIM is built around the contextual relationships of the 18 variables found to be most important for the AMT implementation practises of Indian SMEs. The SSIM of critical success factors is shown in table 2.

Table 2: Structural self-interaction matrix of critical success factors.

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CSF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
C1	X	V	X	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
C2	A	X	A	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
C3	X	V	X	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
C4	A	A	A	X	A	A	A	A	A	A	V	A	A	O	A	O	V	O
C5	A	A	A	V	X	A	A	A	V	V	V	V	V	V	A	O	V	O
C6	A	A	A	V	V	X	V	V	V	V	V	V	V	V	X	V	V	V
C7	A	A	A	V	V	A	X	X	V	V	V	V	V	V	A	V	V	V
C8	A	A	A	V	V	A	X	X	V	V	V	V	V	V	A	V	V	V
C9	A	A	A	V	A	A	A	A	X	V	V	X	V	V	A	O	V	O
C10	A	A	A	V	A	A	A	A	A	X	V	A	X	V	A	O	V	O
C11	A	A	A	A	A	A	A	A	A	A	X	A	A	A	A	A	V	A
C12	A	A	A	V	A	A	A	A	X	V	V	X	V	V	A	O	V	O
C13	A	A	A	V	A	A	A	A	A	X	V	A	X	V	A	O	V	O
C14	A	A	A	O	A	A	A	A	A	A	V	A	A	X	A	O	V	O
C15	A	A	A	V	V	X	V	V	V	V	V	V	V	V	X	V	V	V
C16	A	A	A	O	O	A	A	A	O	O	V	O	O	O	A	X	V	V
C17	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	X	A
C18	A	A	A	O	O	A	A	A	O	O	V	O	O	O	A	A	V	X

3.3. DEVELOPMENT OF REACHABILITY MATRIX FOR CRITICAL SUCCESS FACTORS

If you want to create a reachability matrix using SSIM, you'll need to have a firm grasp on transitivity and reachability. These are the two main tenets of the ISM then 'k' is also related to I this is what is meant by 'transitivity. The transitive property helps maintain internal coherence in one's ideas. The ISM methodology relies on the reachability concept. Element pairs with different identifications are compared with one another in terms of their interconnection. This data is represented as a binary matrix. If the ith factor aids in achieving the jth factor, then the cell I j) of the reachability matrix is assigned a 1, otherwise it is assigned a 0. (i, j). Moreover, some of the cells in the reachability matrix can be filled inductively thanks to the transitivity property [24]. Matrix entries I j) = 1 and (j, k) = 1 imply I k) = 1 because of the identity between the two variables. By exchanging 1s and 0s for Vs, As, Xs, and Os in the SSIM, we obtain a binary matrix we refer to as the initial reachability matrix. Rules for exchanging ones and zeros are as follows:if the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.

- if the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
- if the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 1.
- if the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following these guidelines, the AMT drivers' initial reachability matrix is determined, and the final reachability matrix is obtained by incorporating the transitivities, this is shown in table 3. In this table, the driving power and dependence of each variable are also shown. The driving power of a particular variable is the total number of variables (including itself), which it may help to achieve while the dependence is the total number of variables, which may help to achieve it.

Table 3: Reachability matrix for critical success factors.

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CSF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	DP
C1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
C2	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
C3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
C4	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	3
C5	0	0	0	1	1	0	0	0	1	1	1	1	1	1	0	0	1	0	9
C6	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
C7	0	0	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	13
C8	0	0	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	13
C9	0	0	0	1	0	0	0	0	1	1	1	1	1	1	0	0	1	0	8
C10	0	0	0	1	0	0	0	0	0	1	1	0	1	1	0	0	1	0	6
C11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	2
C12	0	0	0	1	0	0	0	0	1	1	1	1	1	1	0	0	1	0	8
C13	0	0	0	1	0	0	0	0	0	1	1	0	1	1	0	0	1	0	6
C14	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	3
C15	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
C16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	4
C17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
C18	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	3
DPD	2	3	2	13	8	5	7	7	10	12	17	10	12	13	5	8	18	9	**163**

3.4. LEVEL PARTITIONS OF THE REACHABILTY MATRIX OF CRITICAL SUCCESS FACTORS

Using the final reachability matrix, we can establish the reachability and antecedent set of each factor. The antecedent set includes the element and any other elements that could be useful in achieving the goal, while the reachability set includes the element and any other elements that could be useful in reaching the goal. Next, we calculate the intersection of these sets across all variables. The root of the ISM is the element for which the reachability and intersection sets are identical. Nothing below the top-level element in the hierarchy could be achieved with the help of the top-level element. Separation from the other elements occurs after the top-level element has been identified. The same method is then used to uncover the following tier of elements. Incorporating these discovered levels into the diagraph and ultimate model is beneficial. Each critical success factor's position in the ISM-based hierarchical model was determined by first partitioning the reachability matrix into different levels. A total of 10 cycles were used to determine where each success factor stood in the system. Table 4 displays the first iteration's results, which show that the performance enhancement factor C17 is the most important variable in the underlying ISM model. In table 4, the results of iterations II through X are displayed, revealing the remaining success factors and their relative levels of rest. The ISM digraph and final model were constructed using the identified variable levels.

Table 4: Results of iteration I of the level partitions of the reachability matrix of critical success factors.

CSF	Reachability set	Antecedent set	Intersection	Level
C1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,3	1,3	
C2	2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3	2	
C3	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,3	1,3	
C4	4,11,17	1,2,3,4,5,6,7,8,9,10,12,13,15	4	
C5	4,5,9,10,11,12,13,14,17	1,2,3,5,6,7,8,15	5	
C6	4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,6,15	6,15	

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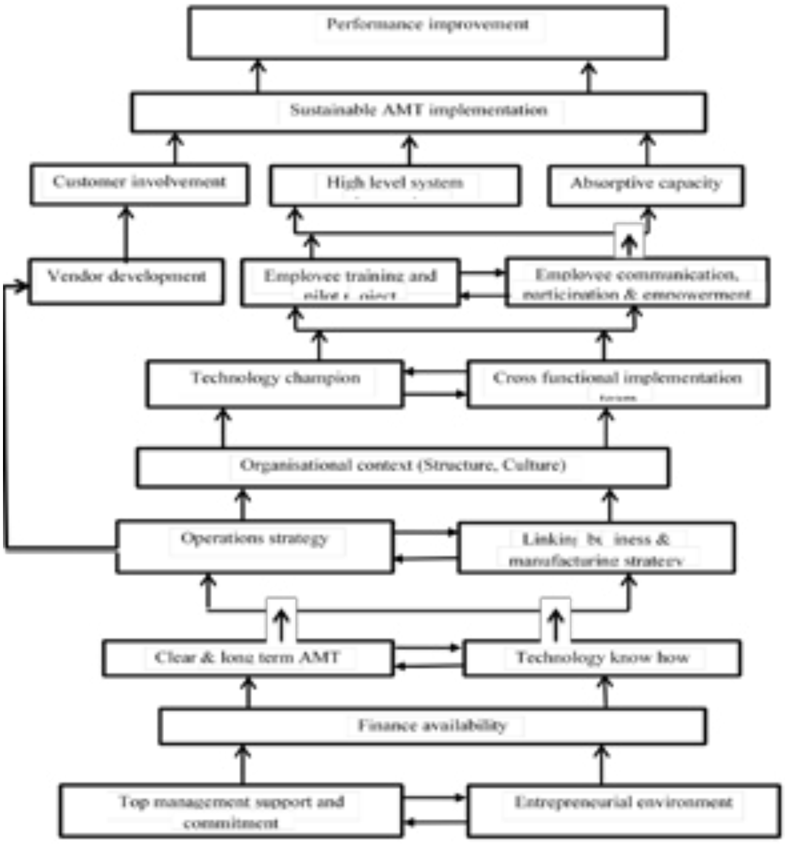
CSF	Reachability set	Antecedent set	Intersection	Level
C7	4,5,7,8,9,10,11,12,13,14,16,17,18	1,2,3,6,7,8,15	7,8	
C8	4,5,7,8,9,10,11,12,13,14,16,17,18	1,2,3,6,7,8,15	7,8	
C9	4,9,10,11,12,13,14,17	1,2,3,5,6,7,8,9,12,15	9,12	
C10	4,10,11,13,14,17	1,2,3,5,6,7,8,9,10,12,13,15	10,13	
C11	11,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18	11	
C12	4,9,10,11,12,13,14,17	1,2,3,5,6,7,8,9,12,15	9,12	
C13	4,10,11,13,14,17	1,2,3,5,6,7,8,9,10,12,13,15	10,13	
C14	11,14,17	1,2,3,5,6,7,8,9,10,12,13,14,15	14	
C15	4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,6,15	6,15	
C16	16,17,18,11	1,2,3,6,7,8,15,16	16	
C17	17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	17	I
C18	17,18,11	1,2,3,6,7,8,15,16,18	18	

Table 5: Results of iteration II-X of the level partitions of the reachability matrix of critical success factors.

CSF	Reachability set	Antecedent set	Intersection	Level
C1	1,3	1,3	1,3	X
C2	2	1,2,3	2	IX
C3	1,3	1,3	1,3	X
C4	4	1,2,3,4,5,6,7,8,9,10,12,13,15	4	III
C5	5	1,2,3,5,6,7,8,15	5	VI
C6	6,15	1,2,3,6,15	6,15	VIII
C7	7,8	1,2,3,6,7,8,15	7,8	VII
C8	7,8	1,2,3,6,7,8,15	7,8	VII
C9	9,12	1,2,3,5,6,7,8,9,12,15	9,12	V
C10	10,13	1,2,3,5,6,7,8,9,10,12,13,15	10,13	IV
C11	11	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	11	II
C12	9,12	1,2,3,5,6,7,8,9,12,15	9,12	V
C13	10,13	1,2,3,5,6,7,8,9,10,12,13,15	10,13	IV
C14	14	1,2,3,5,6,7,8,9,10,12,13,14,15	14	III
C15	6,15	1,2,3,6,15	6,15	VIII
C16	16	1,2,3,6,7,8,15,16	16	IV
C17	17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	17	I
C18	18	1,2,3,6,7,8,15,16,18	18	III

3.5 FORMATION OF HIERARCHICAL MODEL

The structural model of the critical success factors is constructed using the level partition shown in table 4 and table 5, and the final digraph is developed by removing the transitivity as discussed in the ISM methodology. The digraph is finally transformed into the ISM as shown in Figure 2. 'Top management support and commitment' (C1), 'entrepreneurial environment' (C3) lead to 'finance availability' (C2). 'Finance availability' leads to 'clear and long term AMT objectives' (variable 6), 'technical know- how' (C15), which in turn leads to 'operations strategy' (C8), 'linking business and manufacturing strategy' (C7). Put together these variables leads to 'sustainable AMT implementation' (variable 11) which ultimately leads to 'performance improvement' (variable C17).



3.5 MICMAC ANALYSIS OF THE CRITICAL SUCCESS FACTORS

The critical success factors are categorized into four groups 'autonomous variables' (Cluster-I) 'dependent variable' (cluster-II), linkage variables (cluster-III) and independent variable (cluster-IV) through MICMAC analysis. The analysis requires construction of a driving power-dependence diagram (figure 3). Horizontal axis of this diagram represents the dependence potential while the vertical axis represents the driving potential of the critical success factors. Allocation of the critical success factors into different clusters of the driving power-dependence diagram is done based upon their driving and dependence potential values represented in table 3. For example, it is found from table 3, that 'top management support and commitment' (variable 1), entrepreneurial environment (variable 3) have a driving power of 18 and a dependence of 2; therefore, the factors are placed at a position corresponding to driver power of 18 and dependency of 2, in driving-dependence power diagram (figure 3). Similarly, factor 2 (finance availability), has driving power of 16 and dependence of 3 therefore, in figure 3, the factor is positioned at a place corresponding to driver power of 16 and dependency of 3. The factors 'sustainable AMT development', 'performance improvement', 'technology champion', 'cross functional implementation team' 'employee training', 'Employee communication, participation and empowerment' 'technology know-how, 'customer involvement', 'absorptive capacity' and 'high level system integration' are positioned in cluster-II, which indicates that these have strong dependence and weak driving power. Similarly, the variables 'top management support and commitment', 'entrepreneurial environment', 'finance availability' are placed in fourth cluster, which is an indication of their strong driving potential and weak dependence.

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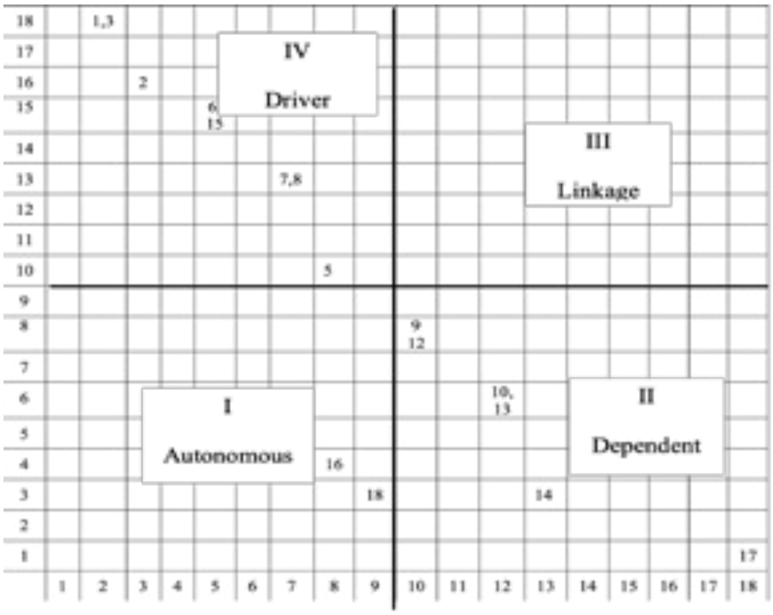

Figure 3: Driving power dependence diagram of the critical success factors.

4. DISCUSSION AND MANAGERIAL IMPLICATIONS

Implementation of AMT is a complex and difficult phenomena. Complexity of AMTs implementation is due to its dependency on several criteria. For effective AMT implementation all the relevant criteria have to be identified and the existing interrelationship between them has to be understood. This research has made an attempt to identify various success criteria for AMT implementation in Indian SMEs and used ISM approach to evaluate the critical success factors. The following managerial implications emerge from this study.

- The study explored a validated measure of 18 success factors of AMT implementation specific to Indian SMEs. Prior knowledge of these factors can be useful for the SMEs to consider a wide range of factors instead of focusing on few factors for successful AMT implementation.
- Interrelationships among the critical success factors were identified using a logical structure developed through ISM that can help managers to better prioritize their available resources while trying to bring desired changes in strategic adjustments that are necessary for improvements in AMT implementation practices.
- The driver power-dependence diagram (figure 3) indicates that ‘customer involvement’ and ‘vendor development’ are autonomous factors in this study. Autonomous variables generally appear as weak driver as well as weak dependent and are relatively disconnected from the system. These variables do not have much influence on the other variables of the system.
- Figure 3 (driver power-dependence diagram) shows factors placed in cluster II. The factors identified as dependent variables and have weak driving potential but strong dependence power.
- There is no factor positioned in the third cluster. The absence of linkage variables indicates that no identified critical success factor is unstable in nature.

Further, it can be observed from figure 3 that the variables that are positioned in fourth cluster are having strong driving power and weak dependence. These variables demand treatment of these factors as key drivers for an effective AMT implementation. Owners/managers of SMEs and practitioners should give priority while addressing these factors to achieve AMT implementation success.

The key findings of the present research are:

‘Top management support and commitment’, ‘entrepreneurial environment’ and ‘finance availability’

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are positioned at the bottom of ISM based hierarchy are the critical success factors of the AMT implementation process. The factor 'performance improvement' occupies the highest hierarchical level and 'sustainable AMT implementation' is placed below it in the hierarchy. These factors represent the desired objective of successful AMT implementation. For obtaining these objectives the bottom level variables should be improved continuously.

5. CONCLUSION

AMT implementation has been viewed by SMEs as a significant step forward in their quest to stay competitive. However, it has been said that SMEs' inadequate resources and skills prevent them from using AMTs effectively, which is why the acceptance rate of AMT in Indian SMEs is uninspiring. It has been observed that most of the companies hesitate to adopt full integration whereas others adopt it partially. This could be due to the fact that the organizations that have adopted AMTs have shown mixed results. In this regard the knowledge of the potential critical success factors and their relative importance on effectiveness of AMT implementation practices, explored in this study could be beneficial for the organizations trying to implement AMTs in their plants. This research work has identified and prioritized the critical success factors that have to be considered for successful implementation of AMTs in Indian SMEs.

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