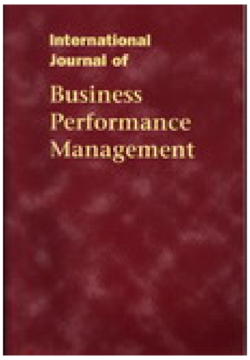

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Modelling of critical success factors of AMT implementation using TISM and SEM

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Abstract: With globalisation, competition has become fierce for manufacturing companies. Product life has become short and the customer is appreciating more variety at a lower price. To keep pace with the global market, a manufacturing firm has to become more flexible while producing products at lower prices. The success of AMT adoption should be critically analysed in view of other critical factors. Through an extensive review of literature, this study identified 19 critical success factors (CSFs) accountable for the implementation of AMT. Data was collected with the help of a structured questionnaire, and a structural model involving 19 factors was developed using total interpretive structural modelling (TISM). Using SPSS 20 software, exploratory factor analysis (EFA) was applied to extract the latent constructs for AMT implementation and to validate these constructs confirmatory factor analysis (CFA) technique of structural equation modelling (SEM) was applied through AMOS 20 software.

Keywords: modelling; AMT implementation; manufacturing; critical factors; total interpretive structural modelling; TISM; structural equation modelling; SEM.

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1 Introduction

Competition for manufacturers in developing countries has increased due to globalisation. Today's customer demands more variety with improved quality at lower prices. To keep thriving in the competitive market and meeting customer's demands, managers are looking for advanced and new manufacturing technologies. AMT touches every sphere of manufacturing, i.e., design fabrication, material handling, inspection, integration, and manufacturing resource planning I and II (Badiru, 1990). AMT is seen as the ultimate solution for achieving a competitive edge worldwide. The managers are taking heedless decisions for implementation without understanding the intertwining of AMT with so many tangible and intangible factors which are required to be identified and considered thereof. Though, the AMT help in gaining a competitive edge but at the same time poses challenges for its successful implementation (Udo et al., 1995). Only 50% of the companies implementing AMT can achieve their intended targets (Chen and Small, 1996). Therefore, before going for the implementation process, it becomes imperative to understand the critical factors affecting the AMT (Baldwin and Lin, 2002). Many researchers have identified these critical factors and developed AMT implementation models (Badiru, 1990; Thomas et al., 2008). However, the authors of this study have not come across such researches involving a comprehensive list of factors critical for the successful implementation of AMT. Moreover, there is a lack of a statistically validated structural model, which clearly states the intervening effects of various factors on AMT implementation. In developing countries like India, it becomes very important to have a validated and structured implementation model that could enhance the confidence of the managers to buy this technology. Therefore, this study applied total interpretive structural modelling (TISM) modelling which was further validated by contemporary techniques like SEM. The TISM technique has been applied by various researchers to build structural models based upon the driving and dependence power of factors along with interpretations of every relation (Ajmera and Jain, 2019c; Jain and Soni, 2019). Researchers have widely applied SEM to validate and construct the relationship between latent and identified variables. In the above-stated background, this study achieves the following specific objectives:

1 identification of critical success factors (CSFs) for AMT implementation through literature survey

2 application of TISM modelling depending upon driving and dependence power of the identified factors

3 identification of the latent construct of AMT implementation by exploratory factor analysis (EFA)

4 validation and establishing the relationship of a latent construct with the identified factors through SEM.

The remainder of this paper is organised as follows: review of literature is discussed in Section 2. The methodology adopted to carry out this study is explained in Section 3. Section 4 depicts the TISM model of AMT implementation based upon 19 CSFs. Reliability and construct validity check through SEM with the application of AMOS20 is described in Section 5 that is followed by findings and conclusion in Section 6.

2 Literature review

Through an extensive review of existing literature and, interviewing industry experts and academicians, the present study identified 19 factors critical for the successful implementation of AMT (shown in Table 1).

AMT plants that customise their *organisational structure* according to the AMT show better performance (Boyer et al., 1997; Goyal and Grover, 2012). Regardless of differences in experts' opinions, there is a high level of consent that *organisational culture* can be a CSF for implementing various improvement programs such as AMT (Mannan et al., 2016). Organisation culture can be of two types in nature, i.e., flexible or control. Flexible culture facilitates decentralised decision making wherein employees can contribute by sharing their ideas which in turn helps in successful AMT implementation (Mannan et al., 2016). In addition, *location* also plays a major role in AMT implementation, as it is associated with logistics, demand supply, customer and supplier base, etc. (Goyal and Grover, 2013a). Further, *the supplier support* to the buyer is an important factor for the successful implementation of AMT (Udo and Ehie, 1996). The main focus of the organisation is to enhance business performance through *customer satisfaction* which is also the driving factor behind the need for AMT (Thomas et al., 2008; Wilcox et al., 1994). AMTs should be adopted strategically to gain an advantage on global competition (Shah and Goldstein, 2006). To achieve sustainability, an organisation should have alignment between strategy and operations (Goyal and Grover, 2013b; Porter, 1996). AMT adoption is not the end, but managers should always be taking feedback from stakeholders for technology improvement (Thomas and Grabot, 2006). Various technologies like computer-aided design (CAD), computer numerical control (CNC), and computer-assisted process planning (CAPP) are integrated through computer-integrated transactions between functions (Netland, 2016). Additional implementation of AMTs leads to thicker incorporation among processes (Chen and Small, 1996). In addition to above-stated factors, *top management* is also a critical factor, as the success of the project is directly linked with top management's support and philosophy (Udo and Ehie, 1996). Further, *worker motivation and job design* were found to be key factors behind successful AMT implementation (Blumberg and Alber, 1982; Nemetz and Fry, 1988). Job design should bring flexibility to organisations and better utilisation of resources (Thomas and Grabot, 2006). *Multi-skilled workers* can handle multiple operations and machines. AMT requires multi-skilled workers (Monge et al., 2006; Saraph and Sebastian, 1992) and teamwork in place (King and Majchrzak, 1996). Its implementation fails in the absence of multi-skilled workers (King and Majchrzak, 1996). Also, there should be consistent worker *training programs* to fulfil the need for skilled workers (Mital et al., 1999). *Government financial plans* should be taken care of while adopting AMT, since financial planning is largely associated with it (Yeung, 2008). *The level of technology* investment indicates the level of manufacturing processes to be automated. This factor becomes important because excessively wrong automation of a given process without considering the line balancing may lead to in-process inventory which may even bring losses to the firm. *Financial planning* should be made with the future projection and keeping in mind the competitive advantage to be achieved (Singh et al., 2007).

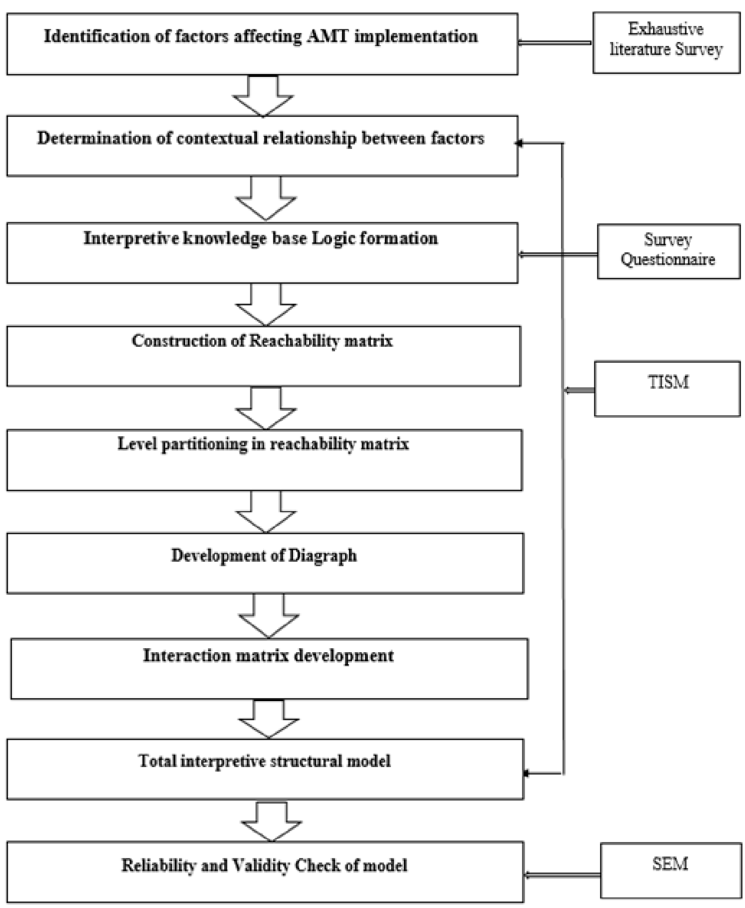
Table 1 Critical factors affecting AMT implementation

S. no.	*Critical factors*	*Authors*
1	Technology champion (TGC)	Chen and Small (1996)
2	Financial position (FLP)	Darbanhosseiniamirkhiz and Ismail (2012)
3	Level of technology investment (LTI)	Dangayach and Deshmukh (2004)
4	Government financial program (GFP)	Mannan et al. (2016)
5	Buyer supplier relationship (BSR)	Singh et al. (2007)
6	Location (LTN)	Thomas et al. (2008)
7	Organisational structure (OST)	Netland (2016) and Darbanhosseiniamirkhiz and Ismail (2012)
8	AMT implementation strategy (AIS)	Darbanhosseiniamirkhiz and Ismail (2012) and Porter (1996)
9	Multi-skilled workers (MSW)	Saraph and Sebastian (1992)
10	Integration (ITR)	Boyer et al. (1997)
11	Flexibility (FLX)	Dangayach and Deshmukh (2004), Jain and Chand (2021) and Jain and Ajmera (2021a)
12	Quality (QLT)	Dangayach and Deshmukh (2004), Jain (2018) and Jain and Raj (2019)
13	Delivery (DLR)	Dangayach and Deshmukh (2004)
14	Workers' training (WRT)	Netland (2016), King and Majchrzak (1996) and Mital et al. (1999)
15	Job design and worker's motivation (JWM)	Blumberg and Alber (1982) and Nemetz and Fry (1988)
16	Top management support (TMS)	Udo and Ehie (1996) and Thomas et al. (2008)
17	Customer satisfaction and business performance (CSP)	Mannan et al. (2016) and Jain and Raj (2018)
18	Organisation Culture (OCL)	Mannan and Haleem (2019), Darbanhosseiniamirkhiz and Ismail (2012) and Mannan et al. (2016)
19	Sustainable AMT implementation (SAI)	Thomas and Grabot (2006) and Singh et al. (2007)

3 Methodology

From the review of existing literature, 19 factors critical for the success of AMT implementation were identified and a structured questionnaire was designed to collect the data on various factors under study. A five-point Likert scale, i.e., *very less dependent*, *less dependent*, *dependent*, *highly dependent*, *very highly dependent*, was used to solicit responses. In total, 500 Indian companies belonging to five industries namely, automobile, engineering, fast moving consumer goods, pharmaceuticals, and agriculture machinery were randomly selected for data collection. The questionnaire was administered through the electronic and self-survey methods. These 500 companies were approached to fill the questionnaires; however, 121 were received after various follow-ups. After careful review of these questionnaires, 13 were found unfilled and therefore rejected for analysis. Finally, 108 were found to be valid and processed for further analysis, obtaining a 21.6% response rate which is considerable (Malhotra and Grover, 1998). Related to organisational profile, out of 108 companies, 13% had less than 100 employees, 39% had employees in the range of 100 to 500, 31% of companies fell in the range of 500 to 1,000 employees and 17% organisations were employing more than 1,000 people. The majority of employees who responded on behalf of their respective organisations held managerial or above positions. Cronbach's coefficient (α) was calculated to check the reliability and internal consistency and that was found to be 0.929. This confirms the reliability and internal consistency of the survey.

Figure 1 Implemented methodology



For analysing the data, the TISM model for AMT implementation was applied. Then, EFA through SPSS20 and confirmatory factor analysis (CFA) through AMOS20 were applied for factor analysis and establishing a relationship between latent construct and identified CSFs. The implemented methodology is shown in Figure 1 as a flowchart.

TISM takes forward the well-known ISM process (Nasim, 2011; Sage, 1977). ISM process converts the ambiguous, poorly structured models into clearly visible models, useful in many management related problems (Warfield, 1973). Warfield conceptualised the Interpretive Structural Modelling process (Warfield, 1973, 1974, 1999). ISM is applied in many other areas as assessment of government measures in combating COVID-19 (Priya et al., 2021b), barriers of TB controlling (Mittal et al., 2021), global economy during COVID-19 (Priya et al., 2021a), corporate social responsibility (Dixit and Priya, 2021), lean manufacturing (Ajmera and Jain, 2019a), knowledge management (Singh et al., 2003), supply chain management (Agarwal et al., 2007), flexible manufacturing systems (Raj et al., 2008), and medical tourism (Jain and Ajmera, 2018), etc. TISM was implemented in many kinds of research like Lean variables in healthcare (Jain and Ajmera, 2021b), barriers of Industry 4.0 (Jain and Ajmera, 2021d), constraints in FMS (Jain and Raj, 2021), Industry 4.0 barriers (Jain and Ajmera, 2021c), industry 4.0 enablers (Jain and Ajmera, 2020), healthcare barriers (Ajmera and Jain, 2019c), performance factors of FMS (Jain and Soni, 2019), life quality of Indian diabetic patients (Ajmera and Jain, 2019b), analysis of FMS flexibility factors (Jain and Raj, 2015b) and performance measurement of telecom services (Yadav, 2014), etc.

TISM inherits all the tools and techniques from ISM and extends it further by interpreting every relationship between factors. Having identified factors under study, the ISM model is developed based upon the interrelations, driving, and dependence power of the factors. Driving and dependence power is calculated through MICMAC analysis. Subsequently, TISM takes this model to one step ahead and interprets the links established in the ISM model through an interpretive matrix from the knowledge base. In ISM, pairwise comparison is done and filled in structural self-interaction matrix (SSIM). The direction of the relationship is also conceptualised. In this pairwise comparison, every i^{th} member is compared with $(i + 1)^{th}$ to the nth member. 'Y' for yes and 'N' for no can be entered for comparison between two elements. Now to construct the reachability matrix, 'Y' is replaced by '1' and 'N' by '0'. In the next step, levels of the factors are found out using iteration (Sage, 1977). In the final matrix, transitivity of only those factors is retained which are crucial as per expert opinion. In TISM, the final digraph is constructed by assigning interpretation whichever cell has '1' entry. This fully interpreted digraph is a TISM model for AMT implementation.

The linear relationships among the group of observed critical factors are specified, estimated, and evaluated by the structural equation modelling (SEM). SEM model (Jain and Ajmera, 2019; Jain et al., 2021; Jain and Raj, 2013) is an a priori hypothesis that consists of observed variables and unobserved variables. Observed variables are called measured variables (MVs) whereas unobserved variables are called latent variables (LVs). In SEM, LVs cannot be directly measured and these are the hypothetical constructs while the MVs are underlying constructs. The two special cases of SEM which is path analysis and CFA were used for the analysis of the model. Path analysis analysed the relationship of MVs and errors in LVs (Hair et al., 2010). In CFA, before analysing the data LVs must be associated with their MVs.

4 Data analysis

This section explains step-by-step TISM modelling of CSFs of AMT implementation.

4.1 Establishing relative relationship among factors

In this step, a relationship between two factors was developed as shown in Table 1 with the help of a knowledge base and, inputs involving experts from industry and academia.

4.2 Interpreting the relations

In this, every link/relation was evaluated to explain why/how one factor is affecting the other. This has been explained in Exhibit 1 in the Appendix, where 'technology champion' is assessed by comparing the remaining 18 factors from the discussion with experts.

4.3 Reachability matrix

To construct the reachability matrix, as per step 2, wherever we get 'Y', it is replaced by '1' otherwise '0'. The transitivity rule must be checked in this so that full transitivity can be achieved (as shown in Table 2).

4.4 Assigning levels to the factors in the reachability matrix

In this step, reachability and antecedent sets are found out through iterations. For example, the factors remaining at the top would be the ones that have reachability to itself. Similarly, other levels are identified through iterations as shown in Table 3.

4.5 Developing TISM model

As shown in Figure 2, a graphical representation of the levels of factors identified in the reachability matrix was obtained. This graphical representation also explains the interpretive links between factors. Transitive links are represented by dotted arrows and only transitivity having important interpretation (as per experts' advice) were retained.

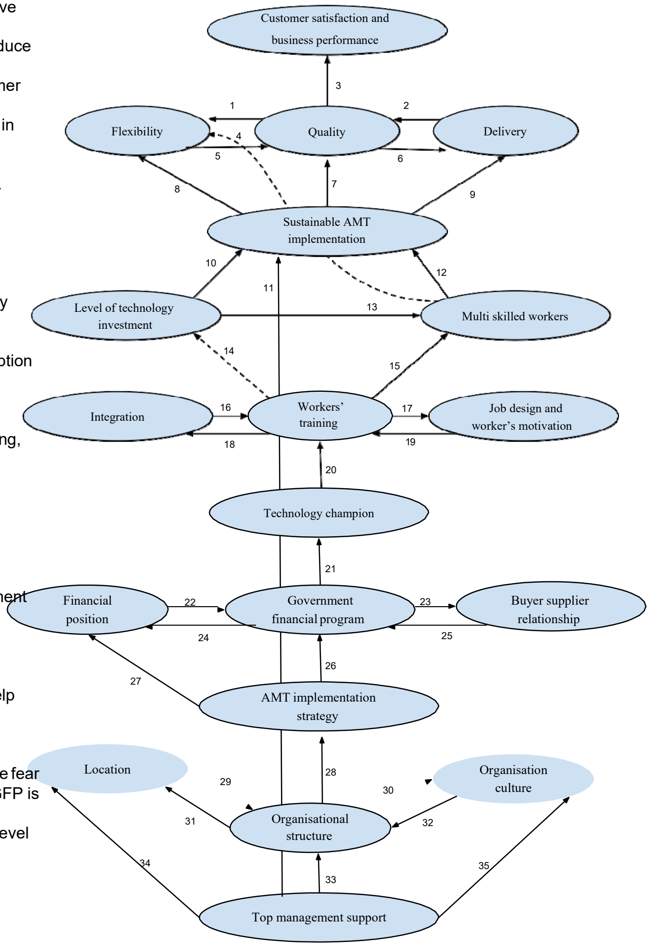
4.6 Interaction matrix

This matrix is crucial and differentiating element between ISM and TISM. Here, whichever cell has '1' entry was interpreted along with crucial transitivity links as shown in Exhibit 2.

Table 2 Reachability matrix

	TGC	*FLP*	*LTI*	*GFP*	*BSR*	*LTN*	*OST*	*AIS*	*MSW*	*ITR*	*FLX*	*QLT*	*DLR*	*WRT*	*JWM*	*TMS*	*CSP*	*OCL*	*SAI*	*Deriving power*
TGC	1	0	1*	0	0	0	0	0	1	1	1*	1*	1*	1	1	0	0	0	1	10
FLP	1*	1	1*	1	1*	0	0	0	1*	0	0	0	0	0	0	0	0	0	0	6
LTI	0	0	1	0	0	0	0	0	1	0	1*	1*	1*	0	0	0	0	0	1	6
GFP	1*	1	1*	1	1	0	0	0	1*	0	0	0	0	0	0	0	0	0	0	6
BSR	1*	1	1*	1	1	0	0	0	1*	0	0	0	0	1	1*	0	0	0	0	8
LTN	1*	1*	1*	0	1	1	1	1	1*	0	0	0	0	0	0	0	0	1*	0	9
OST	1*	1*	1*	0	0	1	1	1	1*	0	0	0	0	0	0	0	0	1	0	8
AIS	1	1	1	1*	0	0	0	1	1	1*	0	0	0	1*	1*	0	0	0	1*	10
MSW	0	0	1	0	0	0	0	0	1	0	1*	1*	1*	0	0	0	0	0	1	6
ITR	0	0	0	0	0	0	0	0	1	1	1*	1*	1*	1	1	0	0	0	1	8
FLX	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	4
QLT	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	4
DLR	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	4
WRT	0	0	1*	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	1*	6
JWM	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	1*	5
TMS	1	1	0	1*	1	1*	1*	1*	1*	1*	0	0	0	1	1	1	0	1	1*	14
CSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
OCL	1*	1*	1*	0	0	1*	1	1	1*	0	0	0	0	0	0	0	0	1	0	8
SAI	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	4
Dependence power	9	8	11	5	5	4	4	5	14	6	8	8	8	7	7	1	4	4	9	

Figure 2 TISM Model showing the levels of CSFs of AMT implementation (see online version for colours)



1) Quality improvement programs achieve higher levels of manufacturing flexibility.
2) On time deliveries put pressure to reduce defects and to improve quality.
3) Quality brings improvement in customer satisfaction and business performance.
4) transitivity (availability of MSW helps in achieving flexibility).
5) flexibility of a production system independently affects its product quality.
6) Quality reduces rejection which subsequently improves delivery.
7) Sustainability requires quality of the products.
8) Sustainability requires flexible work
9) Sustainability requires always delivery on time
10) LTI model customer demand, drive efficiencies and reduce energy consumption for sustainability.
11) transitivity (support from top management drives sustainability)
12) A multi skilled workforce for the strong, sustainable and balanced growth
13) Influences level and no. of MSW
14) transitivity(Availability of trained workforce is the key factor in deciding the level of technology investment)
15) Will help in achieving multi skills.
16) Technology integration creates job integration, thereby generating requirement for worker training.
17) Trained workers will give flexibility for job design and work motivation.
18) Availability of trained workers will help for technology integration.
19) Job design requires new skills, so worker training is needed.
20) Organizes worker training to remove fear of advance technology.21) transitivity(GFP is the key indicator for technology adoption which eventually decides the level of skills required in technology champion).
22) Basis for Government to introduce financial plans for sustainability .
23) Drives Buyer Supplier investment decisions.
24) Influences financial planning.
25) Basis for Government to introduce financial plans for sustainability.
26) transitivity(Strategy will allow the government to better plan the financial plans)
27) Financial situation, goals, evaluative alternatives and plan.
28) Geographic division structure influences the choice of location.
29) geographical divisions, differing cultures, rules, languages and customer preferences between areas make establishing organizational structure.
30) structure is a framework for the culture to be implemented.
31) Geographic division structure influences the choice of location.
32) culture dictates how the company should be structured.
33) transitivity (Top Management choose the kind of organisation structure needed to achieve AMT implementation success).
34) transitivity (location is decided with the support from top management).
35) Involvement of Top management decides how motivated the employees are, which eventually decides the organisation culture

Table 3 Partitioning the reachability matrix into different levels

Variables	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
TGC	1	1, 2, 4, 5, 6, 7, 8, 16, 18	1	VI
FLP	2, 4, 5	2, 4, 5, 6, 7, 8, 16, 18	2, 4, 5	VII
LTI	3, 9	1, 2, 3, 4, 5, 6, 7, 8, 9, 14, 18	3, 9	IV
GFP	2, 4, 5	2, 4, 5, 8, 16	2, 4, 5	VII
BSR	2, 4, 5	2, 5, 6, 16	2, 4, 5	VII
LTN	6, 7, 18	6, 7, 16, 18	6, 7, 18	IX
OST	6, 7, 18	6, 7, 16, 18	6, 7, 18	IX
AIS	8	6, 7, 8, 16, 18	8	VIII
MSW	3, 9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15, 16, 18	3, 9	IV
ITR	10, 14, 15	1, 8, 10, 14, 15, 16	10, 14, 15	V
FLX	11, 12, 13	1, 3, 9, 10, 11, 12, 13, 19	11, 12, 13	II
QLT	11, 12, 13	1, 3, 9, 10, 11, 12, 13, 19	11, 12, 13	II
DLR	11, 12, 13	1, 3, 9, 10, 11, 12, 13, 19	11, 12, 13	II
WRT	10, 14, 15	1, 5, 8, 10, 14, 15, 16	10, 14, 15	V
JWM	10, 14, 15	1, 5, 8, 10, 14, 15, 16	10, 14, 15	V
TMS	16	16	16	X
CSP	17	11, 12, 13, 17	17	I
OCL	6, 7, 18	6, 7, 16, 18	6, 7, 18	IX
SAI	19	1, 3, 8, 9, 10, 14, 15, 16, 19	19	III

4.7 MICMAC analysis

MICMAC analysis (Jain and Raj, 2015a; Mannan et al., 2016) was performed to know the drive and dependence power of the factors. The factors were segregated into four groups namely (Raj et al., 2012): 'autonomous factors having low driving and dependability', 'dependent factors – low driven but strong dependability', 'linkage factors – strong driven and dependence power' and 'independent factors – strong driven and less dependence power'. The factors with drive and dependency power are shown in Table 2 and Figure 3. Just for an illustration purpose, from Table 2, the factor 'top management support' (drive power = '14' and dependency = '1') found a place in 4th group, i.e., independent group; other factors are also placed similarly in groups.

4.8 Construct and validity check by SEM

SEM is a method used for model representation, specification, evaluation, and estimation among the linear relationships (Shah and Goldstein, 2006). Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) are two commonly used techniques for SEM.

Figure 3 MICMAC analysis

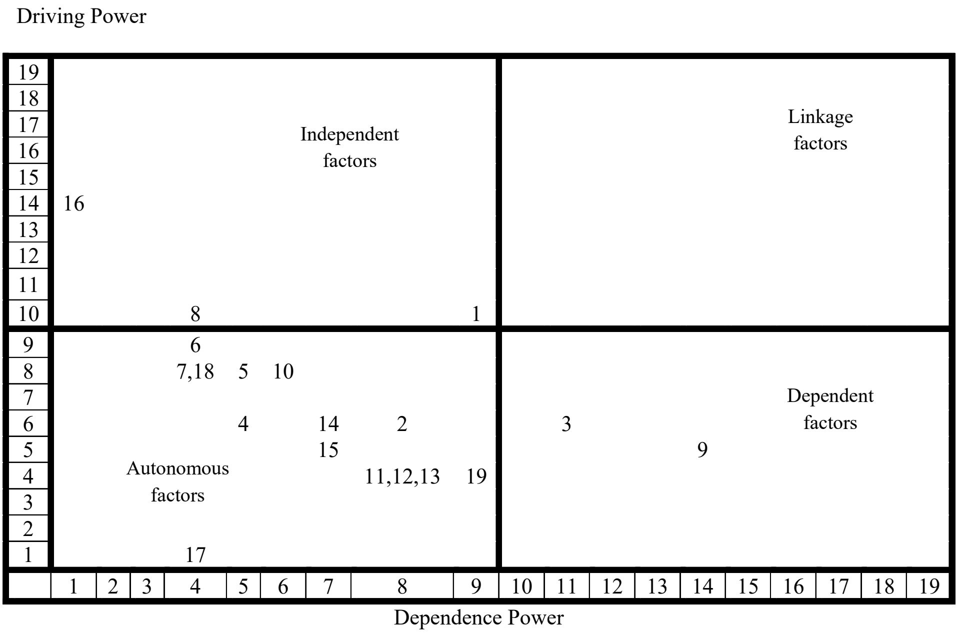


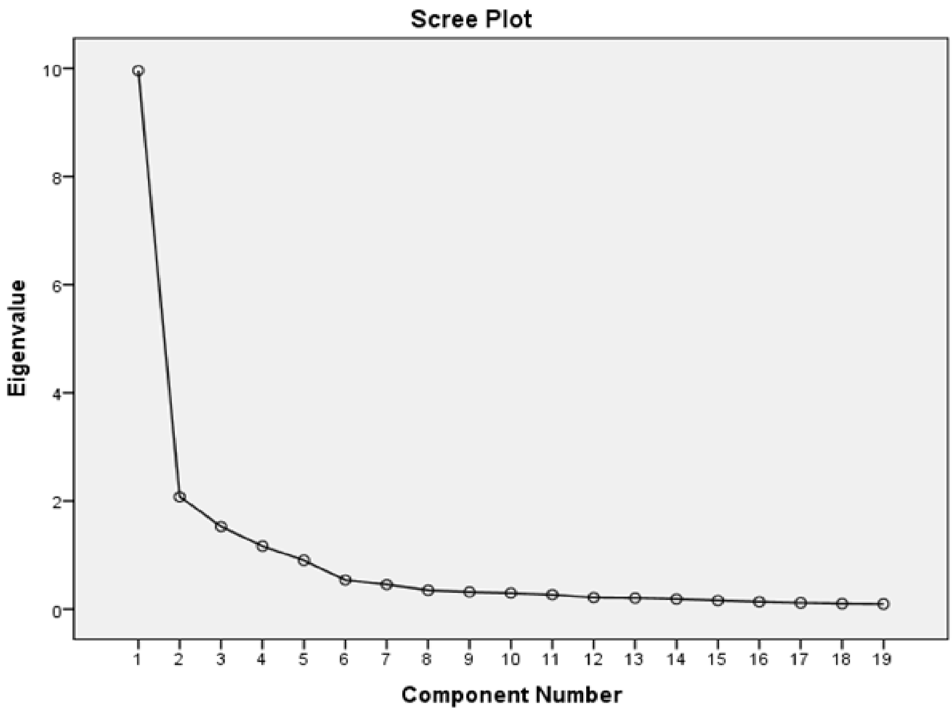
Table 4 Exploratory factor analysis result

Sr. no.	*Dimensions*	*Variables/items*	*Factor loading*	*Cronbach's alpha*
1	Operational characteristics	Flexibility (FLX)	.821	.943
		AMT implementation strategy (AIS)	.864	
		Integration (ITR)	.832	
		Quality (QLT)	.796	
		Delivery (DLR)	.781	
		Sustainable AMT implementation (SAI)	.663	
2	Human resource and management practices	Technology champion (TGC)	.827	.950
		Top management support (TMS)	.862	
		Multi-skilled worker (MSW)	.786	
		Worker training (WRT)	.822	
		Job design and worker motivation (JWM)	.796	
3	Organisational characteristics	Buyer supplier relationship (BSR)	.620	.873
		Customer satisfaction and business performance (CSP)	.576	
		Organisational structure (OST)	.782	
		Location (LTN)	.794	
		Organisational culture (OCL)	.823	
4	Financial resource	Financial planning (FLP)	.563	.764
		Level of technology investment (LTI)	.744	
		Government financial program (GFP)	.794	

4.9 Exploratory factor analysis

Using 19 critical factors affecting the implementation of AMT, firstly the exploratory factor analysis was applied. Nineteen variables were identified through PCA with varimax rotation (Nunnally, 1978). Then, the factors were extracted based upon the following criteria, i.e., variance should be more than 50% and eigenvalue should be one. Factor having loading more than 0.30 and up to elbow of the scree plot as shown in Figure 4 should be retained. The outcomes obtained from exploratory factor analysis (EFA) are shown in Table 4. According to the criteria, the selected four factors have eigenvalue one, total variance is 77.476%, and are as per the elbow of scree plot.

Figure 4 Screen plot



Factors having a loading of more than 0.5 were reserved and considered for analysis. Since Cronbach's alpha value of 0.7 or more is considered reliable (Jain and Raj, 2013), hence, was used for the estimation of factors reliability.

4.10 Confirmatory factor analysis

CFA was performed by applying SEM through AMOS 20 which confirms the consistency in items loading as per EFA. Latent constructs were significantly loaded with all indicators that show the measurement model (Jain and Raj, 2014). Briefly, the four-factor structure for the implementation of AMT was confirmed by the measurement model (shown in Figure 5) and model fit data is represented in Table 5 which indicates an acceptable model (Jain and Raj, 2013).

Figure 5 SEM output (see online version for colours)

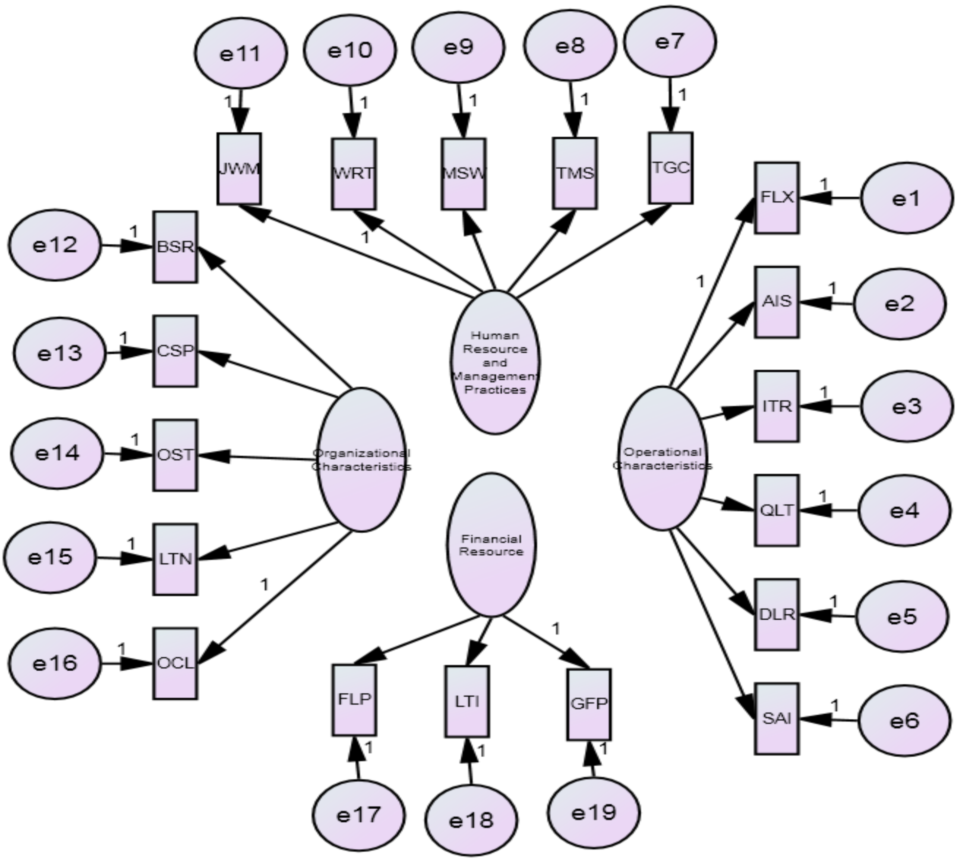


Table 5 Model fit indices values

Absolute fit indices	
Model chi-square (χ^2)	186.18
DF	81
P	0.000
χ^2/DF	2.298 (<5)
Goodness-of-fit statistic (GFI)	0.913
Root mean square residual (RMR)	0.042
Root mean square error of approximation (RMSEA)	0.068
Adjusted goodness-of-fit statistic (AGFI)	0.901
Incremental fit indices	
Normed-fit index (NFI)	0.928
Non-normed fit index (NNFI)	0.919
Comparative fit index (CFI)	0.932
Incremental fit index (IFI)	0.924

4.10.1 Reliability check for the critical factors of AMT

The composite reliability (CR) and average variance extracted (AVE) scores of all the critical factors affecting the implementation of the AMT are shown in Table 6 as evidence of the reliability of these critical factors (Jain and Ajmera, 2019). The Cronbach's alpha value for the critical factors of AMT was found to be 0.929 which shows the reliability of the factors. CR of all the latent factors has more than 0.80 which is more than the acceptable limit (Carmines and Zeller, 1988). Similarly, all the factors have more than 0.5 AVE values that show internal consistency and reliability (Jain and Raj, 2016).

Table 6 CFA result

Sr. no.	*Dimensions*	*Variables/items*	*Standardised estimate*	*p-value*	*AVE*	*CR*
1	Operational characteristics	Flexibility (FLX)	.834	*	0.70	0.93
		AMT implementation strategy (AIS)	.912	*		
		Integration (ITR)	.854	*		
		Quality (QT)	.821	*		
		Delivery (DLR)	.810	*		
		Sustainable AMT implementation (SAI)	.795	*		
2	Human resource and management practices	Technology champion (TGC)	.847	*	0.72	0.93
		Top management support (TMS)	.923	*		
		Multi-skilled worker (MSW)	.812	*		
		Worker training (WRT)	.855	*		
		Job design and worker motivation (JWM)	.801	*		
3	Organisational characteristics	Buyer supplier relationship (BSR)	.735	*	0.62	0.89
		Customer satisfaction and business performance (CSP)	.699	*		
		Organisational structure (OST)	.804	*		
		Location (LTN)	.824	*		
		Organisational culture (OCL)	.857	*		
4	Financial Resource	Financial planning (FLP)	.689	*	0.60	0.82
		Level of technology investment (LTI)	.803	*		
		Government financial program (GFP)	.824	*		

4.10.2 Construct validity

Construct validity (CV) is to check whether the observed variables have enough correlation leading to convergence to measure the given latent variable (Byrne, 2010). Face validity is to adopt the different items from literature to the present study. Convergent validity on the other hand checks how two latent constructs are interrelated

(Fornell and Larcker, 1981). Observed factors show convincing loadings concerning the latent constructs ($p < 0.001$) with values ranging from 0.689 to 0.923 (Table 6). Further, AVE for each construct was calculated and found to be more than or equal to 0.50 which is a sufficient condition for the validity of constructs.

Discriminant validity is performed to test the sufficient proof for variability in latent constructs (Fornell and Larcker, 1981). As displayed in Table 7, square roots of AVE values of four latent constructs, i.e., operational characteristics, human resource and management practices, organisational characteristics, and financial resource are higher than the inter correlations among constructs which prove discriminant validity of the constructs.

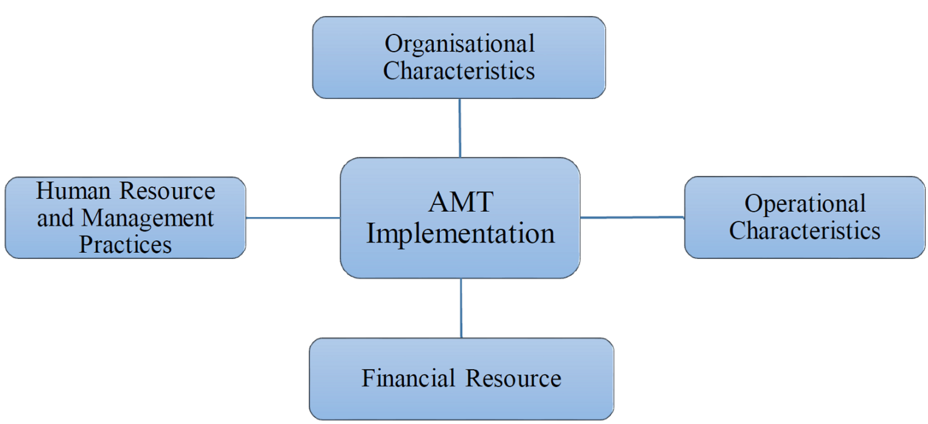
Table 7 Discriminant validity

	Operational characteristics	*Human resource and management practices*	*Organisational characteristics*	*Financial resources*
Operational characteristics	0.70			
Human resource and management practices	0.489	0.72		
Organisational characteristics	0.329	0.484	0.62	
Financial resources	0.392	0.462	0.57	0.60

Note: Diagonal elements in the correlation matrix of constructs are the AVE values and off diagonal are the Squared inter construct correlations; for discriminant validity to be present the diagonal elements should be greater than the off diagonal.

From the above construct validity values, it can be inferred that the measurement model has all intended characteristics. Finally, 'four validated constructs affecting AMT implementation are shown in Figure 6.

Figure 6 Critical factors of AMT implementation (see online version for colours)



Based on 19 factors, four factors namely operational characteristics, organisational characteristics, human resource and management practice, and financial resources were extracted. Organisational characteristics like organisational structure, organisational culture, location, buyer-supplier relationship, customer satisfaction, and business performance are likely to influence the success of the AMT implementation. Operational characteristics are considered to be the backbone of AMT implementation, as, adoption of AMT enhances flexibility, quality and reduces the delivery time (Dangayach and Deshmukh, 2004; Mannan and Haleem, 2019). Human resource and Management practices include multi-skilled workers, job design and motivation, worker training, top management support, and technology champion. The financial resource consists of financial planning, level of technology investment, and govt. financial programs.

5 Findings and conclusions

The findings of the research paper are as follow:

- 19 factors critical for the success of AMT implementation have been identified
- grouped as four factors like operational characteristics, organisational characteristics, human resource and management practice, and financial resources which affect the AMT implementation
- a logical study consisting of TISM and SEM for AMT implementation has been suggested
- using SEM analysis through CFA, the relationship among factors was found and estimated.

In this study, the TISM model proposed to achieve AMT implementation provides more clarity since users have the interpretation of every relationship which was missing in ISM. Having attached knowledge base to every link and involved subject experts, the TISM model developed in this paper provides an insight to the managers for knowing the driving and dependence power of the factors (Figure 3). Following managerial implications can be drawn from this paper:

Two dependent factors – level of technology investment (3) and multi-skilled worker (9) are weak drivers and depend strongly on one another. Therefore, management should handle these factors carefully and understand their dependence on the other factors at different levels. The independent variables, i.e., top management support (16), technology champion (1), and AMT implementation strategy (8) are mainly driving factors and show less dependability. Hence, they may be considered driving factors for all other factors. These factors may be considered as the key critical factors for AMT implementation. Financial position (2), government financial program (4), buyer-supplier relationship (5), location (6), organisational structure (7), integration (8), flexibility (9), quality (10), delivery (11), workers' training (14), job design and worker motivation (15), customer satisfaction and business performance (17), organisational culture (18) and sustainable AMT implementation (19) are the autonomous factors.

6 Limitations and future research directions

This research paper applies EFA and CFA to 19 CSFs for AMT implementation. SEM could have been deployed to intricate models involving more intervening factors. Also, the application of TISM could be extended to other ambiguous models. As a future direction, the study could be extended to other industrial sectors as well. TISM also has some limitations as the interpretation of the contextual relationship depends upon the knowledge of the responder and his/her familiarity with the organisation.

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Appendix

Exhibit 1: Interpretive logic – knowledge base

Please indicate your response to the relationship between the pair of 'technology champion' affecting AMT implementation in general, as given below, by writing 'Y' for 'yes' and 'N' for 'no' and also cite the reason for the same, in brief.

S. no.	*Element no.*	*Paired comparison of factors*	*Y/N*	*In what way a factor will influence/enhance other? Give reason in brief*
		A1 – technology champion		
1	A1-A2	Technology champion will influence or enhance financial position	N	
2	A2-A1	Financial position will influence or enhance technology champion	N	
3	A1-A3	Technology champion will influence or enhance level of technology investment	Y	*With the right set of knowledge helps in technology adoption/level of technology investment*
4	A3-A1	Level of technology investment will influence or enhance technology champion	N	
5	A1-A4	Technology champion will influence or enhance govt. policies	N	
6	A4-A1	Govt. financial plan will influence or enhance technology champion	N	GFP is the key indicator for technology adoption which eventually decides the level of skills required in technology champion
7	A1-A5	Technology champion will influence or enhance supplier buyer relationship	N	
8	A5-A1	Supplier buyer relationship will influence or enhance technology champion	N	
9	A1-A6	Technology champion will influence or enhance location	N	
10	A6-A1	Location will influence or enhance technology champion	N	
11	A1-A7	Technology champion will influence or enhance size and structure	N	
12	A7-A1	Size and structure will influence or enhance technology champion	N	
13	A1-A8	Technology champion will influence or enhance feasibility analysis	N	

Exhibit 1: interpretive logic – knowledge base (continued)

S. no.	*Element no.*	*Paired comparison of factors*	*Y/N*	*In what way a factor will influence/enhance other? Give reason in brief*
14	A8-A1	AMT implementation strategy will influence or enhance technology champion	Y	Decides level and skill of Technology Champion
15	A1-A9	Technology champion will influence or enhance multi-skilled worker	Y	*Recombination of tasks into multi-skill jobs*
16	A9-A1	Multi-skilled worker will influence or enhance technology champion	N	
17	A1-A10	Technology champion will influence or enhance technology integration	Y	*Stake holder in decision making for technology integration*
18	A10-A1	Technology integration will influence or enhance technology champion	N	
19	A1-A11	Technology champion will influence or enhance flexibility	N	
20	A11-A1	Flexibility will influence or enhance technology champion	N	
21	A1-A12	Technology champion will influence or enhance quality	N	
22	A12-A1	Quality will influence or enhance technology champion	N	
23	A1-A13	Technology champion will influence or enhance delivery time	N	
24	A13-A1	Delivery time will influence or enhance technology champion	N	
25	A1-A14	Technology champion will influence or enhance workers' training	Y	*Organises worker training to remove fear of advance technology*
26	A14-A1	Workers' training will influence or enhance technology champion	N	
27	A1-A15	Technology champion will influence or enhance motivation to workers	Y	Facilitates job design as per advanced technology to keep the motivation of the workers high
28	A15-A1	Motivation to workers will influence or enhance technology champion	N	
29	A1-A16	Technology champion will influence or enhance management support	N	
30	A16-A1	Management support will influence or enhance technology champion	Y	Assignment of technology champion & supporting in decision making

Exhibit 1: interpretive logic – knowledge base (continued)

S. no.	*Element no.*	*Paired comparison of factors*	*Y/N*	*In what way a factor will influence/enhance other? Give reason in brief*
31	A1-A17	Technology champion will influence or enhance customer satisfaction	N	
32	A17-A1	Customer satisfaction will influence or enhance technology champion	N	
33	A1-A18	Technology champion will influence or enhance organisational culture	N	
34	A18-A1	Organisational culture will influence or enhance technology champion	N	
35	A1-A19	Technology champion will influence or enhance sustainable AMT implementation	Y	*Identifies performance predictors for sustainability*
36	A19-A1	Sustainable AMT implementation will influence or enhance technology champion	N	

Exhibit 2: Interaction matrix (interpretive matrix)

	LTI	*MSW*	*ITR*	*WRT*	*JWM*	*SAI*
TGC	Right set of knowledge helps in technology adoption/level of technology investment	Redesigning of tasks into multi-skill jobs	Stake holder in decision making for technology integration	Organises training programs to remove fear of advance technology	Facilitates job design as per advanced technology to keep the motivation of the workers high	Identifies performance predictors for sustainability

	LTI	*GFP*
FLP	Transitivity (financial planning decides the level of investment in technology	Basis for government to introduce financial plans for sustainability

	MSW	*SAI*
LTI	Influences level and no. of MSW	LTI models customer demand, drives efficiencies and reduces energy consumption for sustainability

	TGC	*FLP*	*BSR*
GFP	Transitivity (GFP is the key indicator for technology adoption which eventually decides the level of skills required in technology champion)	Influences financial planning	Drives buyer supplier investment decisions

Exhibit 2: Interaction matrix (interpretive matrix) (continued)

	FLP	*GFP*	*WRT*
BSR	Drives investment decisions	Basis for government to introduce financial plans for sustainability	Training Programs are designed mutually

	FLP	*BSR*	*OST*	*AIS*	*OCL*
LTN	Transitivity (Location derives the land cost which eventually is the key factor for financial planning)	Influences logistics and availability of Buyer and Supplier	Geographical divisions, differing cultures, rules, languages and customer preferences between areas make establishing organisational structure	Drives needs and objectives for strategy	Community depends upon the location which is the major reason to decide the organisational culture

	LTN	*AIS*	*OCL*
OST	Geographic division structure influences the choice of location	Number of employees, improved communication and decision making to drive the AMT implementation strategy	Structure is a framework for the culture to be implemented

	TGC	*FLP*	*LTI*	*GFP*	*MSW*
AIS	Decides level and skill of Technology Champion	Financial situation, goals, evaluative alternatives and plan	Decision making for level of investment	Transitivity (upward feedback)	Level and number of Multi-skilled workers

	LTI	*FLX*	*SAI*
MSW	Availability of multi-skilled work force helps to decide the level of technology investment	Transitivity (availability of MSW helps in achieving flexibility	A multi-skilled workforce for the strong, sustainable and balanced growth

	MSW	*WRT*	*JWM*	*SAI*
ITR	Technology integration generates the requirement for MSW	Technology integration creates job integration, thereby generating requirement for worker training	Technology integration brings redesigning of jobs	Technology integration brings flexibility and faster deliveries thereby making the system sustainable

	QLT	*DLR*	*CSP*
FLX	Flexibility of a production system independently affects its product quality	Flexibility saves time and improves delivery	Flexibility brings improvement in quality and delivery, main factors for customer satisfaction and business performance

Exhibit 2: Interaction matrix (interpretive matrix) (continued)

	FLX	*DLR*	*CSP*
QLT	Quality improvement programs achieve higher levels of manufacturing flexibility	Quality reduces rejection which subsequently improves delivery	Quality brings improvement in customer satisfaction and business performance

	FLX	*QLT*	*CSP*
DLR	Faster deliveries put pressure for flexibility to their existing logistics network	On time deliveries put pressure to reduce defects and to improve quality	Faster deliveries bring improvement in customer satisfaction and business performance

	LTI	*MSW*	*ITR*	*JWM*	*SAI*
WRT	Transitivity (availability of trained workforce is the key factor in deciding the level of technology investment)	Will help in achieving multi skills	Availability of trained workers will help for technology integration	Trained workers will give flexibility for job design and work motivation	Transitivity (trained workers will give flexibility and faster deliveries, which leads to sustainability)

	MSW	*ITR*	*WRT*
JWM	Job redesign will create requirement of skills and number of MSW	Job design assigns new job roles, new business operations which require technology integration	Job design requires new skills, so worker training is needed

	TGC	*FLP*	*BSR*	*LTN*	*OST*	*WRT*	*JWM*
TMS	Assignmen t of technology champion and supporting in decision making	Will decide the financial support, which leads to financial planning	Top management commitment and willingness to establish a long-term relationship will build trust between buyer and supplier	Transitivity (location is decided with the support from top management)	Transitivity (top management choose the kind of organisation structure needed to achieve AMT implementation success)	Drives and provide financial support for worker training	Building trust and aligning employee with the goals and vision of the company

	OST	*AIS*
OCL	Culture dictates how the company should be structured	Derives strategic vision, goals and objectives depending upon the culture

	FLX	*QLT*	*DLR*
SAI	Sustainability requires flexible work	Sustainability requires quality of the products	Sustainability requires always delivery on time