Global Journal of Enterprise Information System

DOI: 10.18311/gjeis/2016/15652

# Modelling of the Factors Influencing the Implementation of Advance Manufacturing Technologies in MSME

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**Abstract**

Indian MSMEs constitute ninety percent of total number of industrial enterprises and thus fostering the employability in India. The major advantage of this sector is it's contribution in industrial production and export. However in spite of their positive outlook towards industrial growth, these enterprises are facing technological obsolescence. The imminent need of these enterprises is technological innovations to make them competitive and survive in the global market. The solution for technological innovation aspects is use of latest automated manufacturing technologies that efficiently utilizes the resources and hence the entire chain of production. The decision of opting Advance Manufacturing Technologies (AMTs) in enterprises with limited capital resources is rather difficult as it is the question of not only the nation's economy but employability expectations of people. The objective of this paper is to assist the mangers on a systematic framework that will answer how to perform the decision making process of adopting the AMTs in their enterprises. The key factors that one should considers while making this crucial decision are: Strategic aspects, organization structure, hands on training, implementation practices etc. A total 14 factors are considered in this study and these are modelled based on their level of priorities using Total Interpretive Structural Modelling (TISM). The model derived in this research will be helpful for manufacturing practitioners for making decisions on adopting AMTs.

**Keywords:** Advance Manufacturing Technologies (AMTs), Critical Factors, Micro, Small and Medium Enterprises (MSMEs), TISM (Total Interpretive Structural Modeling)

**Manuscript Accepted:** 15-July-2016; **Originality Check:** 28-July-2016; **Peer Reviewers Comment:** 30-July-2016; **Double Blind Reviewers Comment:** 03-Aug-2016; **Author Revert:** 28-Aug-2016; **Camera-Ready-Copy:** 20-Sep-2016)

## 1. Introduction

Micro Small and Medium Enterprises are the kernel of any economy and these have been worldwide accepted as the engine of economic growth and equitable development. These enterprises are the backbone of industrialization in developing countries like India. These enterprises under the manufacturing categories are classified on the level of investments in plant and machinery. According to Government of India the manufacturing enterprises are micro, if the investment is less than 25 Lakhs, for small it should be more than 25 Lakhs but less than 5 crores, and medium will have investments in plant and machinery not more than 10 Crores. Within the last decades the level of flexibility and efficiency has escalated the uncertainty in customer preferences through cost reductions and cosmic competitive environment. With the globalization and free Trade agreement, MSMEs are pressurized to adopt Advance Manufacturing Technologies (AMTs) to thrive in the global market. Advance manufacturing systems have emanated as an important area of research in Indian context. The requirement of these systems in MSME has increased due to lower quality and productivity of the products. Since the budget is limited for MSMEs, the decision to adopt AMTs is pivotal for top management of these enterprises (Pratihar & Swain, 2013)[28.]

Automated Manufacturing Technologies are defined as computer controlled equipment integrated with micro -electronics circuitry for designing, handing and manufacturing of products (Thomas & Barton, 2012)42. Raymond and Croteau (2006)29 have broadly classified AMTs into: 1. Product Design Technologies 2. Process Technologies and 3. Logistics Applications. However, Uwizeyemungu (2015)45, further categorized these Logistics Application AMTs into AMTs for integration and AMTs for Logistics and monitoring. A wide range of AMTs available for industry are: Computer Aided Design, Computer Aided Manufacturing, Flexible Manufacturing Systems, Programmable Logic Controller, Computer Numerically Controlled machines, bar codes, computer based inventory management, quality control system etc.

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MSMEs face technological and expertise related challenges that hinder the implementation procedure of AMTs. A firm needs to make a targeted model that must meet the requirements of external market (Cardoso, Pinheiro de Lima, &Gouvea da Costa, 2012)4. However, implementation of AMTs should justify their utilization because these enterprises have limited resources in terms of capital and expertise (Mechling et.al,1995)24. It is also observed that the decision on adoption of AMTs doesn't always prove beneficial for an enterprise with limited capital resources (Koc&Bozdag, 2009)17. Thus the top management always feels a pressure while making such decisions. A decision on whether to opt AMT or not depends on core factors that need to be considered by the expert committee. These factors should also be prioritized while making the decision.

A sound decision making process involves evaluation of tangible factors that play a vital role in the effective utilization of AMTs in an organization (Singh &Khamba, 2011)14. In this paper through the detailed literature survey, the authors have identified fourteen factors that need to be addressed while making an important decision: ''whether to implement AMT in MSMEs or not".

Many researches have been undertaken in the field of advance manufacturing technologies (Sethi et.al., 201033; Mora-Monge et.al.,20073). Many techniques have been employed like Financial evaluation techniques (Orr,2002)27, cone -ratio DEA (Talluri et.al., 2000)40, AHP (Yusuff et.al., 200147; Tansel&Yurdakul, 2013)41. After reviewing an extensive literature on adoption of AMTs , we have identified 14 factors that may influence the decision of implementing AMTs in MSMEs.

***1. Strategic Issues (ST)***

Strategic Issues deal with how the dynamic nature of market demands the evaluation of current process technology. The continuous changing market conditions force the management to simultaneously update their business and strategic objectives that cover both business and technology issues. These issues should be addressed before the adoption of AMTs and include operational strategies, technological strategies, long term goals and automation strategies , government policies and planning of human resource development (Efstathiades,et.al. 200211;Kreng et.al., 2011;Saberia&Yusuff, 2011).

## 2. Organizational Changes and External Consultants (OR)

The decision of adopting AMTs also considers the possibility of redesigning organizational structure and processes. It has been argued that a hierarchical structure of organization that involves multiple level of authority often proved to be obstacle to the effective implementation of AMTs. A fewer level of authority which streamlines an organization structure is necessary for adoptions of automated technologies (Saberia &Yusuff, 201132; Darbanhosseiniamirkhiz & Ismail, 20126**).**

It has been observed from previous studies that employee involvement positively relates to technology whereas organizational structure negatively relates to technology. The available literature truly supports that maximum administrative decentralization improves company performance and thus is in favor of advanced technologies.

## 3. Continuous Management and Manufacturing Support (CM)

The top management support is vital in every stage starting from pre -preparation to post adoption of advance technologies in manufacturing sector. Their commitment is required in each and every activity of production system. The successful implementation of these technologies seeks support from all departments of the organization (Singh et.al., 2007; Raymond,2005)30.

## 4. Human Factors (HF)

Human resource has a significant impact on strategic decisions and is an asset for any organization. It is the human resource department that provides a competitive advantage with respect to its rivals. The researchers have emphasized on management of people in distinctive way, their support in implementation of AMTs is highly desirable and it can be achieved via inherent motivation and job satisfaction. It is recommended that the organization seeking support for adoption of automated technologies should organize workshops that enhance knowledge, skills, responsibilities and attitude of workers. If an organization prepares workers for adoption of AMTs then the system benefits from these new technologies (Bidanda& Cleland, 19955; Bayo-Moriones&Cerio, 20042).

## 5. Vendor Selection (VS)

Another critical factor in AMT adoption is appropriate selection of vendors (Lefebvre, Lefebvre & Harvey, 1996; Spanos&Voudouris, 2009)37. Generally India is considered as an outsourcing capital that offers services like software development to engineering. So, within such a competitive environment, selection of right vendor becomes more crucial. This enforces an organization to form a vendor selection team, where the team evaluates a vendor based on following criteria:

1. Whether the vendor meets the technical and business requirements of the organization

**Table 1.** Interpretive Logic-Knowledge Base

| S.NO | Element no | Y/N | In what way a change force may influence /enhance other change force. Provide reasons in brief. |
|---|---|---|---|
| **Strategic Issues** | | | |
| 1 | E1-E2 | Y | New strategy enforces changes in organizational structure |
| 2 | E2-E1 | N | |
| 3 | E1-E3 | N | |
| 4 | E3-E1 | Y | Top management makes a new strategy. |
| 5 | E1-E4 | Y | Cooperation from workers/human factors depends on strategy planned. |
| 6 | E4-E1 | N | |
| 7 | E1-E5 | Y | Selection of vendors depends on planned strategy. |
| 8 | E5-E1 | N | |
| 9 | E1-E6 | Y | Depending upon strategy, implementation of AMTs will be done. |
| 10 | E6-E1 | N | |
| 11 | E1-E7 | Y | Depending upon the objectives of organization, Level of Hands on training to employees will be decided. |
| 12 | E7-E1 | N | |
| 13 | E1-E8 | N | |
| 14 | E8-E1 | Y | Individual departments plan their strategy. |
| 15 | E1-E9 | Y | Transitive |
| 16 | E9-E1 | N | |
| 17 | E1-E10 | Y | Transitive |
| 18 | E10-E1 | N | |
| 19 | E1-E11 | Y | Transitive |
| 20 | E11-E1 | N | |
| 21 | E1-E12 | Y | Transitive |
| 22 | E12-E1 | N | |
| 23 | E1-E13 | N | |
| 24 | E13-E1 | Y | New strategies are developed based on existing market conditions. |
| 25 | E1-E14 | N | |
| 26 | E14-E1 | Y | Capital is required for planning |
| **Organizational structure** | | | |
| 27 | E2-E3 | N | |
| 28 | E3-E2 | Y | Top management enforces changes in organizational structure and external consultants |
| 29 | E2-E4 | Y | Workers selection will be done for individual departments in an organization. |
| 30 | E4-E2 | N | |
| 31 | E2-E5 | N | |
| 32 | E5-E2 | N | |
| 33 | E2-E6 | Y | Different departments will have their unique implementation practice |
| 34 | E6-E2 | N | |
| 35 | E2-E7 | Y | External consultants suggest hands on training |
| 36 | E7-E2 | N | |
| 37 | E2-E8 | Y | Collaboration or integration of different departments depends on structure. |

| | | | |
|---|---|---|---|
| 38 | E8-E2 | N | |
| 39 | E2-E9 | Y | Transitive |
| 40 | E9-E2 | N | |
| 41 | E2-E10 | Y | Transitive |
| 42 | E10-E2 | N | |
| 43 | E2-E11 | Y | Transitive |
| 44 | E11-E2 | N | |
| 45 | E2-E12 | Y | Transitive |
| 46 | E12-E2 | N | |
| 47 | E2-E13 | N | |
| 48 | E13-E2 | Y | External competition demands changes in the internal structure of organization |
| 49 | E2-E14 | N | |
| 50 | E14-E2 | N | |
| **Continuous management and support** | | | |
| 51 | E3-E4 | Y | Top management decides incentives of workers |
| 52 | E4-E3 | N | |
| 53 | E3-E5 | Y | Vendor selection will be based on judgment of management |
| 54 | E5-E3 | N | |
| 55 | E3-E6 | Y | Transitive |
| 56 | E6-E3 | N | |
| 57 | E3-E7 | Y | Management decides the level of training provided to employees |
| 58 | E7-E3 | N | |
| 59 | E3-E8 | Y | Transitive |
| 60 | E8-E3 | N | |
| 61 | E3-E9 | Y | Transitive |
| 62 | E9-E3 | N | |
| 63 | E3-E10 | Y | Transitive |
| 64 | E10-E3 | N | |
| 65 | E3-E11 | Y | Transitive |
| 66 | E11-E3 | N | |
| 67 | E3-E12 | Y | Transitive |
| 68 | E12-E3 | N | |
| 6 | E3-E13 | Y | management support helps in striving in the global market |
| 70 | E13-E3 | N | |
| 71 | E3-E14 | N | |
| E72 | E14-E3 | N | |
| **Human Factor** | | | |
| 73 | E4-E5 | N | |
| 74 | E5-E4 | N | |
| 75 | E4-E6 | Y | Cooperation of employees is needed to implement any practice |
| 76 | E6-E4 | N | |
| 77 | E4-E7 | Y | Enthusiasm of employees is needed to actively participate in training |
| 78 | E7-E4 | N | |
| 79 | E4-E8 | Y | Integration of department requires cooperation from teams. |

| | | | |
|---|---|---|---|
| 80 | E8-E4 | N | |
| 81 | E4-E9 | Y | Workers productivity influence the lead time |
| 82 | E9-E4 | N | |
| 82 | E4-E10 | Y | Workers productivity influence the delivery time |
| 84 | E10-E4 | N | |
| 85 | E4-E11 | Y | Increase in worker's productivity contributes in overall productivity of the system |
| 86 | E11-E4 | N | |
| 87 | E4-E12 | Y | Quality largely depends on programming skills of programmer |
| 88 | E12-E4 | N | |
| 89 | E4-E13 | N | |
| 90 | E13-E4 | N | |
| 91 | E4-E14 | N | |
| 92 | E14-E4 | Y | Capital Incentives are the source of motivation for any industry |
| **vendor development and selection** | | | |
| 92 | E5-E6 | Y | Implementation practices must be suggested by selected vendor |
| 93 | E6-E5 | N | |
| 94 | E5-E7 | N | |
| 95 | E7-E5 | N | |
| 96 | E5-E8 | Y | Departments select vendors as per their need and their integration will help in selecting suitable vendor that meets demand of all the departments. |
| 97 | E8-E5 | N | |
| 98 | E5-E9 | Y | Transitive |
| 99 | E9-E5 | N | |
| 100 | E5-E10 | Y | Transitive |
| 101 | E10-E5 | N | |
| 102 | E5-E11 | Y | Transitive |
| 103 | E11-E5 | N | |
| 104 | E5-E12 | Y | Largely depends on product/services provided by vendors |
| 105 | E12-E5 | N | |
| 106 | E5-E13 | N | |
| 107 | E13-E5 | Y | Current conditions of the market drives the selection criteria of vendors |
| 108 | E5-E14 | N | |
| 109 | E14-E5 | Y | FR will be needed to invest in available technology |
| **Implementation Practice** | | | |
| 110 | E6-E7 | N | |
| 111 | E7-E6 | Y | Depending upon Hands on training, implementation practices will be utilized |
| 112 | E6-E8 | N | |
| 113 | E8-E6 | Y | Depending upon the decision of teams from different department, implementation practices will be proposed |
| 114 | E6-E9 | Y | Better the IP, more will be reduction in LT |
| 115 | E9-E6 | N | |
| 116 | E6-E10 | Y | Transitive |
| 117 | E10-E6 | N | |
| 118 | E6-E11 | Y | Best IP are those that maximizes the utilization of the system |
| 119 | E11-E6 | N | |

| | | | |
|---|---|---|---|
| 120 | E6-E12 | Y | Better the IP, less will be the defects in the product |
| 121 | E12-E6 | N | |
| 122 | E6-E13 | N | |
| 123 | E13-E6 | Y | Existing competition drives the IP |
| 124 | E6-E14 | N | |
| 125 | E14-E6 | Y | Organization must have FR to implement the best practices |
| **Hands on Training** | | | |
| 126 | E7-E8 | Y | Depending on the level and type of hands on training, teams will be formed in a department |
| 127 | E8-E7 | N | |
| 128 | E7-E9 | Y | Transitive |
| 129 | E9-E7 | N | |
| 130 | E7-E10 | Y | Transitive |
| 131 | E10-E7 | N | |
| 132 | E7-E11 | Y | Transitive |
| 133 | E11-E7 | N | |
| 134 | E7-E12 | Y | Quality depends on machine and workers capability |
| 135 | E12-E7 | N | |
| 136 | E7-E13 | N | |
| 137 | E13-E7 | Y | Depending upon the existing competition, level of training will be decided |
| 138 | E7-E14 | N | |
| 139 | E14-E7 | Y | Higher the FR better will be the HT |
| **Integration of Departments** | | | |
| 140 | E8-E9 | Y | Transitive |
| 141 | E9-E8 | N | |
| 142 | E8-E10 | Y | Transitive |
| 143 | E10-E8 | N | |
| 144 | E8-E11 | Y | Transitive |
| 145 | E11-E8 | N | |
| 146 | E8-E12 | Y | Transitive |
| 147 | E12-E8 | N | |
| 148 | E8-E13 | N | |
| 149 | E13-E8 | N | |
| 150 | E8-E14 | N | |
| 151 | E14-E8 | Y | Financial resources are required for any changes in departments |
| **Reduction in Lead Time** | | | |
| 152 | E9-E10 | Y | Reduction in lead time will slightly reduce the delivery time |
| 153 | E10-E9 | N | |
| 154 | E9-E11 | Y | Reduction in LT will improve overall productivity of the system |
| 155 | E11-E9 | N | |
| 156 | E9-E12 | N | |
| 157 | E12-E9 | N | |
| 158 | E9-E13 | N | |
| 159 | E13-E9 | Y | Competitive Environment demands reduction in Lead time |

| | | | |
|---|---|---|---|
| 160 | E9-E14 | Y | |
| 161 | E14-E9 | N | Transitive |
| **Reduction in Delivery Time** | | | |
| 162 | E10-E11 | N | |
| 163 | E11-E10 | N | |
| 164 | E10-E12 | N | |
| 165 | E12-E10 | N | |
| 166 | E10-E13 | N | |
| 167 | E13-E10 | Y | To survive in CE, products should reach to the customer on /before time. |
| 168 | E10-E14 | N | |
| 169 | E14-E10 | Y | Transitive |
| **Productivity** | | | |
| 170 | E11-E12 | N | |
| 171 | E12-E11 | N | |
| 172 | E11-E13 | N | |
| 173 | E13-E11 | Y | Transitive |
| 174 | E11-E14 | N | |
| 175 | E14-E11 | Y | Transitive |
| **Quality** | | | |
| 176 | E12-E13 | N | |
| 177 | E13-E12 | N | Best quality should be deliver to customers for survival in competitive environment |
| 178 | E12-E14 | N | |
| 179 | E14-E12 | Y | To get best quality of products, one needs to invest in advance technologies. |
| **Competitive Environment** | | | |
| 180 | E13-E14 | N | |
| 181 | E14-E13 | Y | Sound financial conditions influence survival in competitive environment. |

**Table 2.** Reachability Matrix

| | | OR | CM | HF | VS | IP | HT | ITD | LT | DT | PD | QA | CE | FR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| ST 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| OR 2 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| CM 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| HF 4 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| VS 5 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| IP 6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| HT 7 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| ITD 8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| LT9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| DT 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| PD 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| QA 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| CE 13 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| FR | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

2. Vendor's background based on information provided in request for information (RFI) form.
3. Selection based on information provided in request for quotation (RFQ) form.

## 6. Implementation Practice (IP)

The successful implementation of AMTs lies in how well an organization has adopted the technology. It is not only the hardware and software, but the working practices, planning and control procedures, inter-functional relationships, skills deposition etc that make these technologies useful. Better implementation practices ultimately deliver good quality products in shorter time-span and affordable prices (Weill et.al.,199144; Dangayach& Deshmukh,20037).

## 7. Hands on Training (HT)

It is important to provide training to people if any new technology is being introduced in the organization. It is also advisable to organizations that during the planning stage of AMT implementation, around 25 to 40% of the total cost of automation project should be kept aside for education and training of workers. If there is any change in production activities, it has to start from shop floor workers and their trust and cooperation can only be gained by making them comfortable with the change. Thus effective hands on training can actually overcome their fear to new technology (Efstathiades, 2002; Singh & Kumar, 2013).

## 8. Integration of Departments

Every organization either large or small has some internal and external factors that influence the revenues (Spathis, 200638; Singh et.al. 2007). Integration of Departments enhances these internal factors. A successful implementation of technology largely depends on coordination among different departments of an organization because AMTs require a large number of information handled by different departments. The team work and cooperation will be of utmost importance for best results of technology.

## 9. Reduction in Lead Time

In MSMEs, it is not always a good decision to keep inventory, so the lead time becomes a competitive advantage for these enterprises. The lead time in any manufacturing unit is the function of queue time, batching of products and batching in time. The reduction in lead time ultimately increases the market share and brings customer satisfaction. Automation technologies not only lower the production time, they also reduce work in process inventory and thus bring down the manufacturing lead time. (Dyson et al., 19979; Marri et al., 2000)

## 10. Reduction in Delivery Time

AMTs are the integration of hardware with information technology, which strengthen not only the manufacturing processes but also the supply chain. With the help of integrated informa-

**Table 3.** Level portioned Iteration 1

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 1 ST | 1,2,4,5,6,7,9,10,11,12 | 1,3 | 1 | |
| 2 OR | 2,4,6,7,8,9,10,11,12 | 1,2,3 | 2 | |
| 3 CM | 1,2,3,4,5,6,7,8,9,10,11,12,13 | 3 | 3 | |
| 4 HF | 4,6,7,8,9,10,11,12 | 2,3,4,14 | 4 | |
| 5 VS | 5,6,8,9,10,11,12 | 3,5,14 | 5 | |
| 6 IP | 6,9,10,11,12 | 1,2,3,4,5,6,7,8,14 | 6 | |
| 7 HT | 6,7,8,9,10,11,12 | 2,3,4,7,14 | 7 | |
| 8 ITD | 6,8,9,10,11,12 | 2,3,4,5,7,8,14 | 8 | |
| 9 LT | 9,10,11 | 1,2,3,4,5,6,7,8,9,13,14 | 9 | |
| 10 DT | 10 | 1,2,3,4,5,6,7,8,9,10,13,14 | 10 | LEVEL 1 |
| 11 PD | 11 | 1,2,3,4,5,6,7,8,9,11,13,14 | 11 | |
| 12 QA | 12 | 1,2,3,4,5,6,7,8,12,14 | 12 | |
| 13 CE | 1,2,5,6,7,9,10,11,13 | 3,13 | 13 | |
| 14 FR | 1,4,5,6,7,8,9,10,11,12,13,14 | 14 | 14 | |

tion technology, an organization can meet the customer agreed deadlines. AMTs smoothen the supply chain by eliminating bottlenecks and thereby reduce inefficient or time consuming processes. The supply chain monitors the delivery of products to customers. By increasing the efficiency of supply chain, a huge reduction in delivery time is obtained. (Singh et.al., 2007; Alcaraz.et.al., 20121)

## 11. Productivity

Productivity is a function of input and output resources. The appropriate use of AMTs in manufacturing units improves the utilization of resources. The appropriate utilization of resources such as capital, raw material, machines, technology etc ultimately

**Table 4.** Level portioned Iteration 2

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 1 ST | 1,2,4,5,6,7,9 | 1,3 | 1 | |
| 2 OR | 2,4,6,7,8,9 | 2,3 | 2 | |
| 3 CM | 1,2,3,4,5,6,7,8,9,13 | 3 | 3 | |
| 4 HF | 4,6,7,8,9 | 2,3,4,14 | 4 | |
| 5 VS | 5,6,8,9 | 3,5,14 | 5 | |
| 6 IP | 6,9 | 1,2,3,4,5,6,7,8,13,14 | 6 | |
| 7 HT | 6,7,8,9 | 2,3,4,7,14 | 7 | |
| 8 ITD | 6,8,9 | 2,3,4,5,7,8,14 | 8 | |
| 9 LT | 9 | 1,2,3,4,5,6,7,8,9,13,14 | 9 | LEVEL 2 |
| 13 CE | 1,2,5,6,7,9,13 | 3,13 | 13 | |
| 14 FR | 1,4,5,6,7,8,9,13,14 | 14 | 14 | |

**Table 5.** Level portioned Iteration 3

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 1 ST | 1,2,4,5,6,7, | 1,3 | 1 | |
| 2 OR | 2,4,6,7,8, | 2,3 | 2 | |
| 3 CM | 1,2,3,4,5,6,7,8,13 | 3 | 3 | |
| 4 HF | 4,6,7,8 | 2,4,14 | 4 | |
| 5 VS | 5,6,8 | 3,5,14 | 5 | |
| 6 IP | 6 | 1,2,3,4,5,6,7,8,13,14 | 6 | LEVEL 3 |
| 7 HT | 6,7,8 | 2,3,4,7,14 | 7 | |
| 8 ITD | 6,8 | 2,3,4,5,7,8,14 | 8 | |
| 13 CE | 1,2,5,6,7,13 | 3,13 | 13 | |
| 14 FR | 1,4,5,6,7,8,13,14 | 14 | 14 | |

**Table 6.** Level portioned Iteration 4

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 1 ST | 1,2,4,5,7, | 1,3 | 1 | |
| 2 OR | 2,4,7,8, | 2,3 | 2 | |
| 3 CM | 1,2,3,4,5,7,8,13 | 3 | 3 | |
| 4 HF | 4,7,8 | 2,3,4,14 | 4 | |
| 5 VS | 5,8 | 3,5,14 | 5 | |
| 7 HT | 7,8 | 2,3,4,7,14 | 7 | |
| 8 ITD | 8 | 2,3,4,5,7,8,14 | 8 | LEVEL 4 |
| 13 CE | 1,2,5,7,13 | 3,13 | 13 | |
| 14 FR | 1,4,5,7,8,13,14 | 14 | 14 | |

increases the productivity of the unit. (Scheer, 199435; Mechling et al., 1995; Sohal, 1996)36

## 12. Quality

Automation technologies bring better quality products in the market by eliminating human error, improving accuracy and precision, strict tolerances and are best known for their error detection capabilities through automated inspection. If the company is launching good quality of products in the market, then ultimately the life cycle of the product will be high(Kreng et.al.2011; Marri et al., 2000)21

## 13. Competitive Environment

Competitive environment is a source of inducement to perform better in comparison to other competitors. Introduction of AMTs results in better flexibility and improved product design that ultimately increases the local market share (Efstathiades et al. 199910; Narula, 200426; Mosey, 2005)25. An organization can compete with its rivals only through its upgraded research and development department that often implements novel simpler technologies for modification of their products.

## 14. Financial Resources

Installation of AMTs seeks a huge investment in capital resources. High initial investments are required to install AMTs in manufacturing units (Singh et. al , 200734; Larsen & Lewis, 2006)20.

The remainder of this article is organized as follows: the next section will briefly cover the Total interpretive structural modeling (TISM) technique. The third section will cover the methodology of this paper. The last section concludes the entire article with directions for further research in the area.

**Table 7.** Level portioned Iteration 5

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 1 ST | 1,2,4,5,7, | 1,3 | 1 | |
| 2 OR | 2,4,7 | 1,2,3 | 2 | |
| 3 CM | 1,2,3,4,5,7,13 | 3 | 3 | |
| 4 HF | 4,7 | 1,2,3,4,14 | 4 | |
| 5 VS | 5 | 1,3,5,14 | 5 | LEVEL 5 |
| 7 HT | 7 | 1,2,3,4,7,14 | 7 | |
| 13 CE | 1,2,5,7,13 | 3,13 | 13 | |
| 14 FR | 1,4,5,7,13,14 | 14 | 14 | |

**Table 8.** Level portioned Iteration 6

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 1 ST | 1,2,4 | 1,3 | 1 | |
| 2 OR | 2,4 | 1,2,3 | 2 | |
| 3 CM | 1,2,3,4,13 | 3 | 3 | |
| 4 HF | 4 | 1,2,3,4,14 | 4 | LEVEL 6 |
| 13 CE | 1,2,13 | 3,13 | 13 | |
| 14 FR | 1,4,13,14 | 14 | 14 | |

**Table 9.** Level portioned Iteration 7

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 1 ST | 1,2 | 1,3,13 | 1 | |
| 2 OR | 2 | 1,2,3,13 | 2 | LEVEL 7 |
| 3 CM | 1,2,3,13 | 3 | 3 | |
| 13 CE | 1,2,13 | 3,13 | 13 | |
| 14 FR | 1,13,14 | 14 | 14 | |

## 15. TISM

In 1973, Interpretive Structural Modeling was proposed by Warfield. The contribution of Farris and Sage (1975)12 is immense in decision analysis and worth assessment of large scale systems. ISM helps in arranging a set of related variables into a systematic hierarchical model called structural model. ISM utilizes the expert's practical experience and knowledge to construct this multilevel model. The basis of ISM lies in the expert's opinion about the relationships between the decision variables. ISM has been implemented to analyze factors contributing to world class manufacturing (Haleem et.al., 2012)15. ISM has also been used to establish a systematic model that take into account the factors affecting the growth of electric vehicle market in India (Digalwar&Giridhar, 20158). ISM approach has been implemented in various fields: To analyze the barriers while implementing green supply chain management in auto components manufacturing industry in south India (Mathiyazhagan, 2013)23; for sustainable lean manufacturing in organization (Jadhav et.al., 2014)16, establishing model for implementing lean practices in automobile industry (kumar et.al., 2013]18. ISM can be used for any system that can be technical, social or medical. ISM helps in presenting a complex system into a concrete model which answers what and how in theory building, however it fails to answer causality of links and thus "why" in theory building.

An ISM model can be upgraded to TISM (Sushil, 2012)39 by answering why the relationships exist in between two elements and thus it interprets both the links and nodes. Several researchers have implemented this advanced version of ISM in various fields: strategy technology management in automobile industry (Kedia& Sushil, 2013)19, model for construction labor productivity (Sandbhor&Botre, 2014)31, factors affecting implementation of ERP in SMEs (Gandhi, 2015)13 and for predicting the performance of R&D cell (Sushantaet.al., 2013). The basic process of TISM is explained in step by step manner:

### 15.1 Identify and Define Elements

The first step is to identify and define elements whose relationships are to be modelled for a specific problem. This involves brain storming exercise among a panel of experts. The elements can be identified after going through a detailed review of the available literature.

### 15.2 Define Contextual Relationships

Like ISM, state the contextual relationships between the elements i.e State whether element E1 will influence or enhance E2.

### 15.3 Interpretation of Relationships

This step upgrades the ISM into TISM by answering how the element E1 will influence or enhance E2.

16. Interpretive logic of pair wise comparison

In ISM, Self Structural Interaction Matrix (SSIM) is developed by pair wise comparisons among the elements that provide the direction of relationships. The upgraded model of ISM i.e. TISM involves a different exercise for pair wise comparisons. In TISM, each $i^{th}$ element is individually compared with all the ele-

**Table 10.** Level portioned Iteration 8

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 1 ST | 1 | 1,3,13,14 | 1 | LEVEL 8 |
| 3 CM | 1,3,13 | 3 | 3 | |
| 13 CE | 1,13 | 3,13,14 | 13 | |
| 14 FR | 1,13,14 | 14 | 14 | |

**Table 11.** Level portioned Iteration 9

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 3 CM | 3,13 | 3 | 3 | |
| 13 CE | 13 | 3,13,14 | 13 | LEVEL 9 |
| 14 FR | 13,14 | 14 | 14 | |

**Table 12.** Level portioned Iteration 10

| Factors | Reachability Set | Antecedent Set | Intersection Set | Level |
|---|---|---|---|---|
| 3 CM | 3 | 3 | 3 | LEVEL 10 |
| 14 FR | 14 | 14 | 14 | |

ments, starting from (i+1)th to nth element. For each link the entry in comparative table could be Y (Yes) or N (No) and for each yes, the brief reason is to be mentioned. The above paired wise comparison is called interpretive logic-knowledge base in TISM. This knowledge base is upgraded if transitivity is observed for a link and the entry in comparative table is then changed to transitive. If the reason for transitivity can be meaningfully explained then it is mentioned otherwise left blank.

### 15.4 Reachability Matrix

To form reachability matrix, if the entry in interpretive logic knowledge base is Y, or transitive, it is 1 in the reachability matrix. Otherwise, it is 0 for N entry in the knowledge base.

### 15.5 Level Partitions on Reachability Matrix

The level partitions in reachability matrix are carried out in same way as in ISM. The reachability set for an element is consisting of that element itself and the other elements that may help in achieving them. The antecedents and intersection sets were formed. The variables for which reachability and intersection sets are same is given the top level in TISM hierarchy which would not help achieve any other factor above their own level. After the identification of top level factor, it is removed from other performance factors and the iterative procedure continues till all the factors are associated with a level.

### 15.6 Developing Diagraph

The diagraph is obtained by linking the relationship among the elements as per the reachability matrix. A simpler version of diagraph is first obtained by eliminating the transitive relationships, which is then upgraded to diagraph, which may retain some transitive relationships which are crucial for interpretation.

## 16. Methodology

To derive a model using TISM, the enablers for advance manufacturing technologies in MSME were identified after an extensive review of available literature, which was then followed by expert's opinion. In this study, we have outlined 14 factors (Refer Table 1). These factors were identified from research available in reputed journals which are indexed in SSCI/SCI/Scopus. These factors were then reviewed by some senior members of companies currently using AMTs in their organizations. We have changed some factors as per the expert's opinion. In our study we have identified 84 small and medium level industries in Delhi –NCR region. Out of these, 73 were already using AMTs, while 11 were in a dilemma whether to opt it or not?

After the identification of enablers of AMTs, the contextual relationships were then discerned by domain experts. The discussion among experts lead to answering the question - in what way relationship exists among enablers of AMTs. Table 1 shows the Interpretive Logic-Knowledge Base formed during discussion phase.

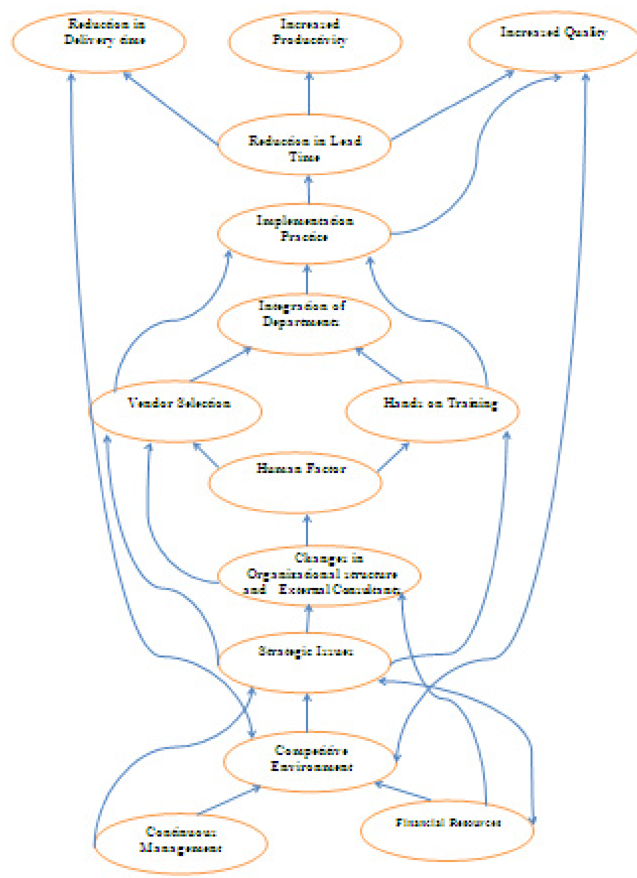


**Figure 1.** Diagraph of TISM model proposed.

Once the knowledge base was assembled, the reachability matrix was formed by marking 1 against Y and 0 against N entries in the knowledge base (see Table 2). From The reachability matrix, levels were partitioned during series of iterations (Refer Table 3-12]. The diagraph is then prepared based on the levels and the directive relationships among the enablers. Once the directive relationships were indicated, some meaningful transitive relationships were also added to make it a more precise and conceptualizing better articulated model.

## 17. Results and Conclusions

The main objective of this research is to create a practical model that will offers guidance to management and manufacturing practitioners of small and medium scale enterprises in Indian context. With this research, an attempt has made to identify the relevant enablers for adopting advance manufacturing technologies in MSME. Although a large amount of literature is available in this regard, but none has established interactions among these enablers using TISM. A systematic framework has been presented in this paper that has recognized the contextual relationships among enablers of AMTs (Refer Figure 1).

The present study expounds that reduction in delivery time, increase in quality and productivity are at the top level of articulated model. This indicates these three enablers will not help in achieving other enablers above themselves and thus have an immense dependency on others. These three enablers are the foremost objectives the organization can achieve.

Another important finding of this study is the bottom two factors i.e. continuous management support and financial resources, having strong driving and less dependency over other factors. The top management needs to focus on these variables in order to embrace AMTs in MSME. The TISM model has enlightened the decision making process while adopting an advanced technology in an enterprise. Enablers like strategic issues and competitive environment enforces the management to achieve their targets.

The TISM model gives a clear picture on direct and indirect relationship among enablers e.g. Implementation practices" directly influencing "quality "and "reduction in Lead time". But "reduction in lead time" is indirectly influenced by "hands on training". Implementation practices are governed by hands on training and these practices have direct influence on reduction in lead time.

This model can be used by manufacturing practitioners in decision making and policy formulation process. The model equally benefits academicians for better understanding in this research domain. The TISM model in this paper can be further scaled up by adding more enablers in decision making process. Since a limited number of experts were approached for reviewing the reachability matrix hence it can be overcome by carrying out an extensive questionnaire survey and through illustrative case studies in the area. The authors believe that the knowledge base can be updated further to a great extent. The TISM model of this paper can lay out the foundation for a detailed theory building in the area of advance manufacturing technologies.

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**Citation:**
Nisha Bhatt
"Modelling of the Factors Influencing the Implementation of Advance Manufacturing Technologies in MSME"
Global Journal of Enterprise Information System. Volume-8, Issue-3, July-September, 2016. (http://informaticsjournals.com/index.php/gjeis)
**Conflict of Interest:**
Author of a Paper had no conflict neither financially nor academically.