Chapter 4
Identification of Barriers in the Implementation of Additive Manufacturing in Indian Scenario

Shivam Verma, Manish Gupta, and Shivam

Abstract Additive manufacturing, also known as 3D printing is a material joining technology based on layer-by-layer deposition. AM technologies have capabilities to reduce lead time, to increase material efficiency, to deal with complexity in production, to reduce time and labor in construction, making cell-based organs in healthcare technologies and is an important part of Industry 4.0. Countries like the USA, China, South Korea, Japan are taking a leap in the adaptation and making patents in AM technology, India is being slow in the adaptation and implementation of this technology. This gap is governed by several barriers which are needed to be addressed. This study identifies the barriers prevailing in Indian scenario towards the adaptation of AM technologies using Fuzzy ISM methodology and classify them on the basis of dependence power and driving power and also level their hierarchy in Fuzzy ISM model. Some critical barriers like Compatibility, Initial Cost, Lack of talent etc. are identified and considered for analysis.

Keywords Additive manufacturing · Fuzzy ISM · Barriers · India · Implementation

4.1 Introduction

Additive Manufacturing (AM), also known as 3D Printing is a modern material joining manufacturing technology which is generally based on layer-by-layer deposition and creating a 3D object by using digital file. This technology has been used to produce prototype for years but recent technological advancements like increase in number of materials, speed, accuracy, bionics lead AM to produce whole part with the help of little or more post processing. Today, this technology is being used for functional parts, fit and finish components, mold and tooling and visual proof of concept [1] in various fields like automotive sector, health sector, Research and Development

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etc. Cost reduction, increased efficiency, innovation, prototyping, product development etc. are the main reasons which are motivating the industries to adopt this technology [1].

In 2018, AM market reached $9.1 billion with a growth rate of 18% [2] and it is expected to reach $23.79 billion by 2025 [3] with $7.65 billion in North America, $7.18 billion in European and Middle Eastern Countries, $5.56 billion in Asia Pacific Countries with 70% business share of China only and $1.11 billion by rest of the world [4]. Although Asia Pacific contributes 23.79% of Global additive manufacturing market but the contribution of India is less than 2.2% as compared to other major economies like China (13%), Japan (9.2%) [4]. India has become the 6th largest economy in the world with a phenomenal growth rate of 7.3% but somehow India is being slow in the race of adaptation of AM technologies and considered as a follower country in the categories of Leader, Challengers and Followers in a report published by AT Kearney group [5]. Interestingly growth of global AM market has not been able to make the grade as it was forecasted few years ago for e.g. Global AM market was expected to reach $13 billion in 2018 [1] but it reached $9.1 billion in 2018 [2]. Differences show that there are some challenges and barriers which are creating gap between implementing AM technologies in India and other developing and developed nations and those barriers are needed to be addressed. This paper is organized as literature review, methodology, results, discussion, conclusion, limitation and future scope.

4.2 Literature Review

Additive Manufacturing, as the name suggests it adds material to make the object. It is commonly known as 3D Printing. It uses CAD software or 3D scanner to create the 3D geometry file and then this geometry is transferred to printer to deposit or fuse the material layer by layer.

Diffusion of AM technologies in India is relatively slow as compared to other countries, it consists about 2.2% with total of 23.79% market of Asia Pacific compared to China (13%) and Japan (9%) [4]. Major contributors are electronic industry (24.1%), automotive sector (21.2%), industrial sector (13.8%), aerospace sector (10.8%), architectural sector (5.1%) and educational sector (3%), medical sector (15%) in India. Indian AM market is expected to reach at $79 million by 2022. With the arrival of new startups in AM like 3Dexter, Aha3D, Imaginarium India, AM in India is gaining some momentum but due to lack of centralized approach this technology is still in its nascent stage in India. India is being slow in the adoption of Additive Manufacturing technologies so there is a need to address the barriers which are leading to the slow adoption rate.

To identify the barriers in implementation of AM in India, literature search, published interviews of industry experts, industry reports have been used. These barriers are then discussed with experts for their relevance and they are chosen in the manner that relationship between them can be established. Barriers have been

Table 4.1 Frequency of citation

Sr. No.	Barriers	References
1	Resistance to change (a) Resistance of acquiring new skill (b) Fear of losing jobs	[6, 7]
2	Initial cost (a) High printer cost (b) Training and skill development cost (c) AM technology implementation cost (d) IT security cost	[6, 8–10]
3	Lack of talent/experience (a) Designer unavailability	[6, 11, 8, 9, 12]
4	Compatibility: dependence on other industries	[10]
5	Technical limitations (a) Speed of large-scale production (b) Surface finish (c) Hazardous chemicals used in post processing (d) Material development	[6, 8–10]
6	Intellectual property threat and security (a) AM sabotage (b) Design data theft (c) Intellectual property rights	[13, 9, 14]
7	Management support	[15, 8]
8	Status of India in R&D towards AM	[9]
9	Lack of awareness	[6, 16]
10	Lack of government support	[17, 9]
11	Technology versus expectation mismatch	[16]

identified as follows, frequency of citation of different barriers is shown by Table 4.1.

(a) Resistance to change: Workers show resistance in acquiring new skill after doing conventional work for years. AM technologies are followed by automation so fear of losing job increases resistance among worker to adopt technology [7]. These barriers among workers lead to resistance of management support to adopt AM.

(b) Initial Cost: Industrial grade 3D printers requires high cost and is too much for medium and small scale industries of India, extra 30–40% custom duty makes it more costlier [9]. Skilled labor, IT security cell also increases the initial cost of AM implementation [9].

(c) Lack of Experience/Talent: Only 3% students of India get enrolled in vocational training courses after higher secondary school. According to a report by Manpower group, employers find 58% difficulty in job filling due to lack of talent [18]. AM technologies demands high skilled worker availability in CAD based systems.

(d) Compatibility: Dependence on other industries: Successful implementation of AM technologies depends on the mutual intersection of two supply chains i.e. if there is an industry which is producing parts through AM technologies then there must be a consumer industry willing to buy it [10].
(e) Technical limitations: Chemicals used for post processing and UFP (Ultrafine particles) from printing have been observed causing some health threats [19], speed of large scale production and breakeven point have been observed at 42 for Selective Laser Sintering on comparison to high pressure die casting [20]. Strength of layer needs additional methods to restructure the required properties [8]. Intrinsic properties such as holes, degenerating facets have been observed during conversion from CAD to STL file [21].
(f) Intellectual Property threats and Security: A research published by Gartener states that there would be loss of $100 billion per year by the end of 2018 [9] because of IPR threats. Even complex parts can be scanned and printed easily without the consent of copyright holder [13]. Less efficient security system can lead to technical theft and AM sabotage [14].
(g) Management Support: Successful implementation of technology in any industries is supported by its management, it is done by adapting technology, making workers comfortable about technology and provide training to workers.
(h) Status of India in R&D towards AM: India's investment on R&D is stagnant at 0.6–0.7% of GDP for 20 years as compared to other developing and developed economies which is around 2.5–3.0% of GDP. Construction 3DP can play a vital role in Housing for All mission by Government of India, a decent amount of research publications and case studies can help industries to implement this technology [6]. Only few number of Institutions are offering master's program in additive manufacturing specialization [9].
(i) Lack of Awareness: A survey done on 186 stakeholders of construction industries states that only 72% have heard this technology from newspaper and videos and only 7% of them have researched on this topic to know more about it [6]. According to AM startups like Think3D and 3Ding, lack of awareness is main reason for slow adoption of AM technologies in India [16].
(j) Lack of Government Support: The leading countries in AM technologies like USA, China, South Korea, Russia have developed nation action plan on Additive Manufacturing, such action plans are missing in Indian context and high custom duty of around 35–40% on industrial level printer are also increasing the initial cost of implementation [9]. AM output product are kept in 28% GST slab, making these less attractive to adopt.
(k) Technology versus Expectation Mismatch: According to the lead member of 3D printing venture Think3D Prudhvi, there is a mismatch between technology and expectation of people regarding cost, quality and speed. People want their product to be really quick and do not distinguish between 2D printing and 3D printing. Gartner hype cycle put only few AM application in plateau of productivity and maximum AM application in slope of enlightenment, which signifies only few AM application have been stabilized at ground level and remaining are yet to be commercialized.

4.3 Methodology

Taking barriers from academic literature, published interviews and industrial reports, now to find relationship among these barriers Interpretive Structural Modeling (ISM) methodology will be used. ISM methodology transform poorly articulated data into visible and well defined data [22]. Some important studies have been performed using ISM methodology which includes, finding enablers for flexible manufacturing system in India [23], for the analysis of barriers in implementing solar power installations in India [24], in analyzing the interaction of criteria, sub criteria for supplier selection in supply chain environment [25], etc.

Fuzzy ISM Methodology: To make ISM model more sensitive Fuzzy based ISM methodology is used. Some important studies have been performed using Fuzzy ISM which includes, to identify and analyze the barriers in solar energy implantation in Indian rural sector [26], to analyze the barriers in green supply chain management implementation [27], to find the enablers for Indian Manufacturing Sector competitiveness [28], etc. Citation of various barriers in the literature is shown in Table 4.1. Flow chart of ISM fuzzy model is shown in Fig. 4.1 [15].

Since ISM methodology uses binary values for assigning the weights to the factor i.e. 0 or 1, it does not provide the strength of relationship to the factors. In fuzzy based ISM methodology strength to relationship is provided on the scale of 0–1. Table 4.2 will be used for providing relationship to the factors [28].

4.3.1 Fuzzy Direct Relationship Matrix

Fuzzification increases the sensitivity of conventional MICMAC. It is done by introducing fuzzy input as shown in the table. Using values in the table, fuzzy direct relationship matrix of barriers of implementation AM in Indian Scenario is shown by Table 4.3.

4.3.2 Fuzzy Indirect Relationship

The indirect relationship signifies the hidden impact of the factor which are overlooked in direct relationship. Composition operator of fuzzy relation is used to find indirect relationship between barriers. Some common compositions are max–min, max product, max average. Let us assume the fuzzy relation matrix R showing relationship between x_1, y_1, y_2 and fuzzy relation matrix S showing relationship between y_1, y_2, z_1. To find interrelationship between x_1, z_1 through variable y_1, y_2 we can use above mentioned composition.

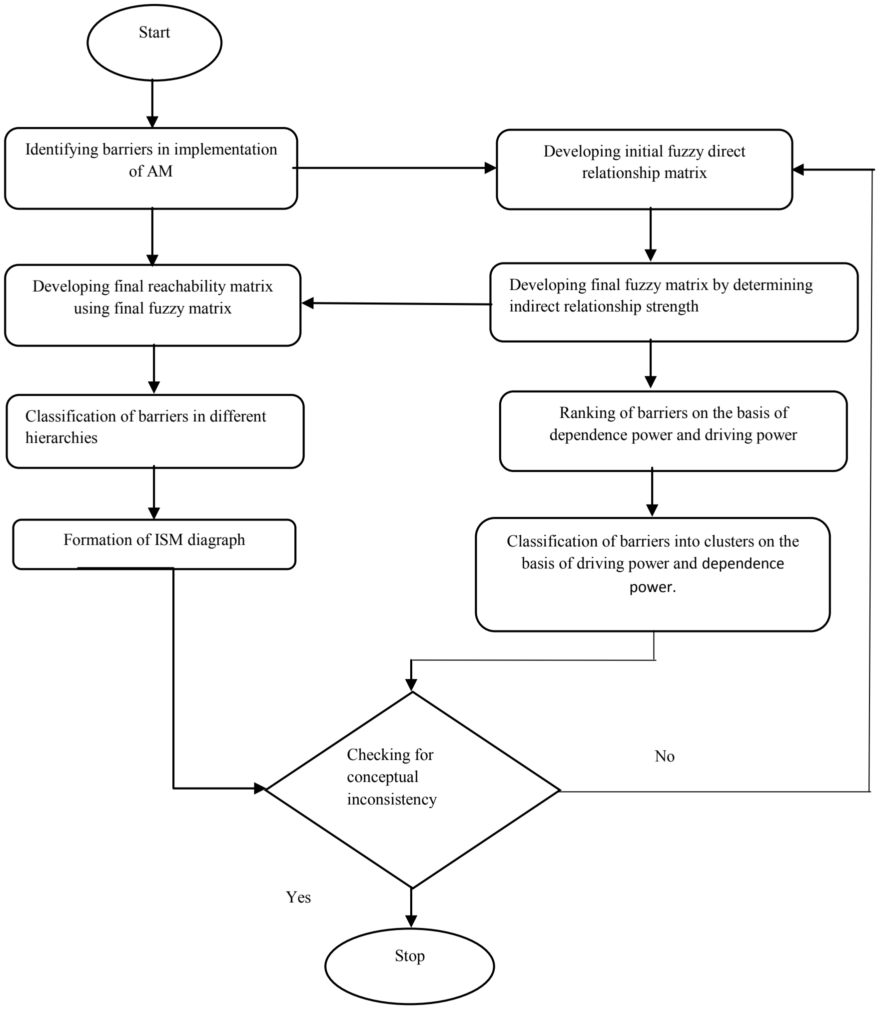

Fig. 4.1 Fuzzy ISM methodology

Table 4.2 Relationship strength values

Relative strength	No	Very low	Low	Medium	High	Very high	Full
Value	0	0.1	0.3	0.5	0.7	0.9	1

$$R = \begin{array}{c} \\ x_1 \end{array} \begin{array}{cc} y_1 & y_2 \\ \left(.7 \right. & \left. .5 \right) \end{array}$$

.5

$$S = \begin{array}{c} y_1 \\ y_2 \end{array} \overset{z_1}{\begin{pmatrix} .9 \\ .3 \end{pmatrix}}$$

Table 4.3 Fuzzy direct relationship matrix

S. No.	Barriers	1	2	3	4	5	6	7	8	9	10	11
1	Resistance to change	1	0	0.3	0	0	0	0.3	0.1	0.3	0	0.3
2	Initial cost	0.1	1	0.1	0.7	0	0.3	0.9	0	0.1	0.3	0.1
3	Lack of experience/talent	0.3	0.3	1	0.1	0	0	0.3	0.1	0.5	0.3	0.5
4	Compatibility: dependence on other industries	0	0.5	0.1	1	0	0.5	0.7	0	0.3	0	0.1
5	Technical limitations	0.1	0.9	0	0.7	1	0	0.9	0.1	0.1	0.3	0.7
6	Intellectual property issue and threats	0	0.7	0	0.5	0.1	1	0.7	0.1	0	0.7	0.1
7	Management support	0.5	0	0.5	0.1	0	0.3	1	0.3	0.1	0.3	0
8	Status of India in R&D towards AM	0	0.3	0.5	0.1	0.3	0.5	0	1	0.1	0.9	0.1
9	Lack of awareness	0.5	0	0.5	0.1	0	0.1	0.1	0.3	1	0.1	0.7
10	Lack of government support	0.1	0.5	0.5	0	0.7	0.7	0.9	0.7	0.5	1	0.3
11	Technology versus expectation mismatch	0.3	0	0	0.1	0	0	0	0	0	0	1

Matrix R is showing direct relationship between x_1, y_1, y_2 variables and matrix S is showing direct relationship between y_1, y_2, z_1. To calculate the indirect relationship between x_1, z_1, following compositions are used. Relationship strength of x_1 to y_1 is represented by $x_1\_y_1$ and same representation have been followed for other variables.

Max min composition: R.S
$x_1\_z_1 = \max(\min(x_1\_y_1, y_1\_z_1), \min(x_1\_y_2, y_2\_z_1))$
$x_1\_z_1 = \max(\min(0.7, 0.9), \min(0.5, 0.3))$
$x_1\_z_1 = \max(0.7, 0.3).$
$x_1\_z_1 = 0.7$
Max product Composition: R.S
$x_1\_z_1 = \max((x_1\_y_1 * y_1\_z_1), (x_1\_y_2 * y_2\_z_1))$
$x_1\_z_1 = \max((0.7*0.9), (0.5*0.3))$
$x_1\_z_1 = \max(0.63, 0.15)$
$x_1\_z_1 = 0.63$
Max-average composition: R.S
$x_1\_z_1 = \max((x_1\_y_1 + y_1\_z_1)/2, (x_1\_y_2 + y_2\_z_1)/2)$
$x_1\_z_1 = \max((0.7 + 0.9)/2, (0.5 + 0.3)/2)$
$x_1\_z_1 = \max(0.8, 0.4)$
$x_1\_z_1 = 0.8$

Values obtained from max–min, max-product, max-average composition for relation of x_1 to z_1 are 0.7, 0.63, 0.8 respectively. Since relation of x_1 to y_1 is high (0.7), and relation of y_1 to z_1 is very high (0.9) so indirect relationship between x_1 and z_1 should be less than high (0.7). Since max–min composition yields a relationship of 0.7, max-average composition yields a relationship of 0.8 and max-product yields a relationship of 0.63, so among mentioned, max-product composition is more prominent to calculate indirect relationship between barriers. Max product composition has also shown some promising results in the past [26, 28]. For the fuzzy direct relationship table, max product algorithm will be applied since it contains large number of iterations, a MATLAB program have been created to calculate indirect relationship. Iterations will be repeated till we get fuzzy stabilized matrix i.e., values do not change on performing repetitive max-product algorithm.

4.3.3 Fuzzy Stabilized Matrix

After repetitive iterations of max-product composition, a final stabilized fuzzy matrix is obtained which contains transitivity. Stabilized matrix will be used to make binary matrix by assigning 1 for values greater than 0.5 and 0 for the values less than 0.5. Fuzzy stabilized matrix is shown by Table 4.4.

4.3.4 Final Binary Reachability Matrix

Now with the help of fuzzy stabilized matrix, final reachability matrix is constructed with all interrelationship between barriers. Fuzzy values greater or equal to 0.5 will be considered as 1 and values less than 0.5 will be considered as 0. Final Reachability Matrix from stabilized fuzzy matrix is given by Table 4.5.

4.3.5 Level Partitioning

The final reachability matrix will be used to group factors into different levels. The antecedent set (A) and reachability set (R) are obtained for each factor from final reachability matrix. Reachability set consist of factor itself and other factors which this factor may help to achieve and Antecedent set consist of factor itself and another factor, which may help to achieve this factor. In final reachability matrix the row will represent reachability set while column will represent antecedent set. To level the factors intersection set (I) is found between Reachability set and Antecedent set and if for a certain factor $\{R\} = \{I\}$ then that factor is considered in top level. Summary of Barriers after performing all the iteration is given in Table 4.6.

Table 4.4 Final fuzzy stabilized matrix

S. No.	Barriers	1	2	3	4	5	6	7	8	9	10	11	D.P
1	Resistance to change	1.000	0.090	0.300	0.063	0.063	0.090	0.300	0.100	0.300	0.090	0.300	2.696
2	Initial cost	0.450	1.000	0.450	0.700	0.210	0.350	0.900	0.270	0.225	0.300	0.225	5.080
3	Lack of experience/talent	0.300	0.300	1.000	0.210	0.210	0.210	0.300	0.210	0.500	0.300	0.500	4.040
4	Compatibility: dependence on other industries	0.350	0.500	0.350	1.000	0.245	0.500	0.700	0.245	0.300	0.350	0.210	4.750
5	Technical limitations	0.450	0.900	0.450	0.700	1.000	0.350	0.900	0.270	0.225	0.300	0.700	6.245
6	Intellectual property issue and threats	0.350	0.700	0.350	0.500	0.490	1.000	0.700	0.490	0.350	0.700	0.343	5.973
7	Management support	0.500	0.210	0.500	0.150	0.210	0.300	1.000	0.300	0.250	0.300	0.250	3.970
8	status of India in R&D towards AM	0.405	0.567	0.500	0.441	0.630	0.630	0.810	1.000	0.450	0.900	0.441	6.774
9	Lack of awareness	0.500	0.170	0.500	0.132	0.189	0.189	0.243	0.300	1.000	0.270	0.700	4.193
10	Lack of government support	0.450	0.630	0.500	0.490	0.700	0.700	0.900	0.700	0.500	1.000	0.490	7.060
11	Technology versus expectation mismatch	0.300	0.050	0.090	0.100	0.031	0.050	0.090	0.031	0.090	0.045	1.000	1.878
Dependence power		5.055	5.117	4.990	4.486	3.978	4.369	6.843	3.916	4.190	4.555	5.159	52.659

Table 4.5 Final binary matrix using fuzzy stabilized matrix

Sr. No.	Barriers	1	2	3	4	5	6	7	8	9	10	11	D.P
1	Resistance to change	1	0	0	0	0	0	0	0	0	0	0	1
2	Initial cost	0	1	0	1	0	0	1	0	0	0	0	3
3	Lack of experience/talent	0	0	1	0	0	0	0	0	1	0	1	3
4	Compatibility: dependence on other industries	0	1	0	1	0	1	1	0	0	0	0	4
5	Technical limitations	0	1	0	1	1	0	1	0	0	0	1	5
6	Intellectual Property issue and threats	0	1	0	1	0	1	1	0	0	1	0	5
7	Management support	1	0	1	0	0	0	1	0	0	0	0	3
8	Status of India in R&D towards AM	0	1	1	0	1	1	1	1	0	1	0	7
9	Lack of awareness	1	0	1	0	0	0	0	0	1	0	1	4
10	Lack of government support	0	1	1	0	1	1	1	1	1	1	0	8
11	Technology versus expectation mismatch	0	0	0	0	0	0	0	0	0	0	1	1
Dependence power		3	5	5	4	3	4	7	3	3	3	4	44/44

Table 4.6 Level classification

Barriers	Reachability set	Antecedent set	Intersection set	Level
Resistance to change	1	1, 7, 9	1	I
Technology versus expectation mismatch	11	3, 5, 9, 11	11	I
Lack of experience/talent	3, 9	3, 7, 8, 9, 10	3, 9	II
Lack of awareness	3, 9	3, 9, 10	3, 9	II
Management support	7	2, 4, 5, 6, 7, 8, 10	7	III
Initial cost	2, 4	2, 4, 5, 6, 8, 10	2, 4	IV
Compatibility	2, 4, 6	2, 4, 5, 6	2, 4, 6	IV
IPR threats and security	4, 6	4, 6, 8, 10	4, 6	IV
Technical limitations	5	5, 8, 10	5	V
Status of R&D in AM	8, 10	8, 10	8, 10	VI
Government support	8, 10	8, 10	8, 10	VI

4.4 Results

Nine clusters have been defined on the basis of Driving Power and Dependence Power as LL, ML, HL, LM, MM, HM, LH, MH, HH, L signifies Lower, M signifies Medium, H signifies High. It is very less likely that a barrier having low dependence and low driving power as well as high dependence and high driving power hence cluster LL and HH are empty. It can be seen in Fig. 4.2: Barrier Classification that barriers are divided in four cluster as LM, MM, HM, MH where LM stands for lower driving power and Medium dependence power. As conceived in the literature Lack of Government Support, India's status in R&D are in HM cluster and last at level 6 in hierarchy level driving other barriers. Technical limitation, Initial Cost, IPR threats, Compatibility, Lack of awareness, Lack of experience are in MM cluster and ranked as level V, IV, IV, II, II level of hierarchy. Management Support is in MH cluster and at level III in hierarchy. Resistance to change and Technology versus Expectation Mismatch is in LM cluster with very little driving power and considerable dependence power and are at level I in hierarchy. Barriers summary is given by Table 4.7. Fuzzy ISM model is shown by Fig. 4.3.

4.5 Discussion

Final ISM model which is constructed with the help of Fuzzy stabilized matrix clearly shows that Lack of Government support, Status of India in R&D towards AM, Technical limitations are crucial factors in the implementation of additive manufacturing in Indian scenario and these factors are then followed by initial cost, Dependence on other industries, IPR threat, Management Support, Lack of awareness, Lack of

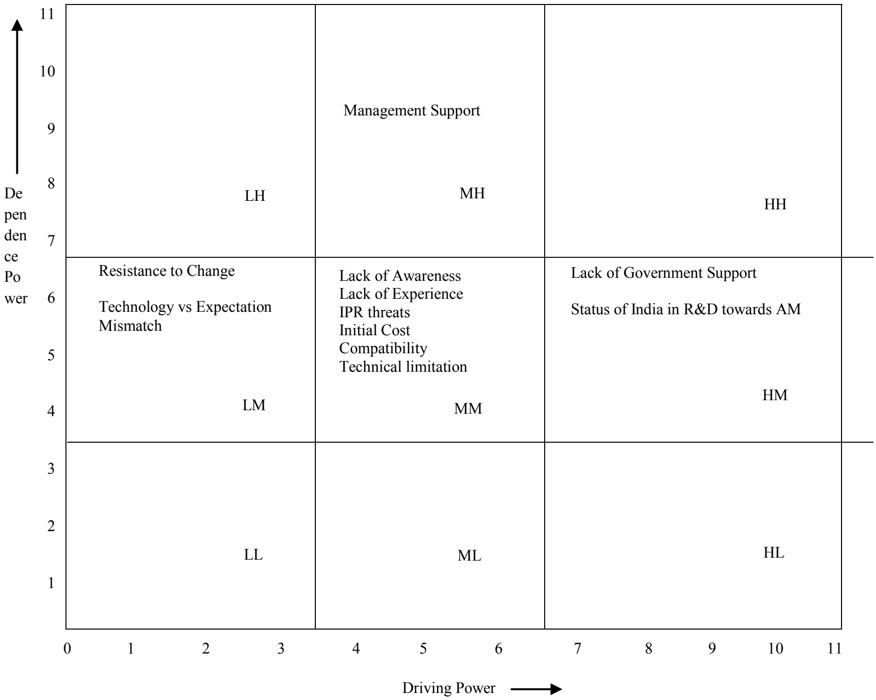

Fig. 4.2 Barrires classification (MICMAC analysis)

talent in AM technology, all these factors combined leads to resistance to change and technology versus expectation mismatch.

Government of India launched FAME (Faster Adoption and Manufacture of Hybrid Vehicle in India) scheme in two phases in order to adopt Electric and Hybrid Vehicle [29], absence of such framework in implementing Additive Manufacturing technology and subsidies provided by government on Industrial level 3D printers and its associated products are increasing its initial cost of investments. Initial cost is also affected by unavailability of experienced worker; management have to invest a large amount on training. Status of India in Research and Development towards AM technologies is also present due to gap between Industries and Institutions. There are also very lesser institutions in India which are providing specialization in AM technologies which leads to the technical limitations of AM technologies and can be minimized if there is active participation between industry and institutions. IPR threats are also needed to be tackled with high IT security system which increases the initial cost of AM implementation. Industries tends to be sceptic about new technologies in their supply chain so an industry which is seeking to adapt AM technology can not apply in its supply chain until other supply chain don't want to. These factors combined leads to less management support. In India only 3% of students who are entering in upper secondary level join vocational or technical

Table 4.7 Barriers summary

Barriers	Driving power	Dependence power	Driving power—dependence power	Rank	Level	Cluster
Resistance to change	2.696	5.055	−2.359	9	I	LM
Initial cost	5.080	5.171	−0.091	7	IV	MM
Lack of experience/talent	4.040	4.990	−0.950	8	II	MM
Compatibility	4.750	4.483	0.266	5	IV	MM
Technical limitations	6.245	3.978	2.266	3	V	MM
IPR threats	5.973	4.369	1.604	4	IV	MM
Management support	3.970	6.843	−2.873	10	III	MH
Status of R&D in AM	6.774	3.916	2.857	1	VI	HM
Lack of awareness	4.193	4.190	0.003	6	II	MM
Government support	7.060	4.555	2.505	2	VI	HM
Technology versus expectation mismatch	1.878	5.159	−3.281	11	I	LM

courses and very less vocational training courses are offered below secondary level and hence due to lack of skill availability, 58% of employers find difficulty in filling the job vacancies. A survey done in Indian Built Sector with 186 stakeholders towards AM concludes that 86.04% people thought that AM is more about prototyping and concept proofing and were not aware about the actual construction process it can carry out [6]. With advanced and cheap technological development in AM it can be vastly used in construction process like making toilets and home at very faster rate.

Departmental and Worker's resistance to change is merely a driving barrier, leads to less management support but a dependent barrier on the above-mentioned barriers. Lack of awareness and lack of experience in AM technologies leads to mismatch between actual technology and expectation.

Various national action plan by different countries like China's Additive Manufacturing Industry Promotion Plan 2015–16 and 2017–20, South Korea's 3D Printing Development Council, United States of America's National Additive Manufacturing Innovation Institute are some classic examples in which government played a key role in the development of AM related technologies, such programs are need of the hour for India. These initiatives can improve the conditions of Research and Development in AM technologies and will lead to reduce technical limitations and initial cost of implementation. Vocational courses at the pre secondary school level can

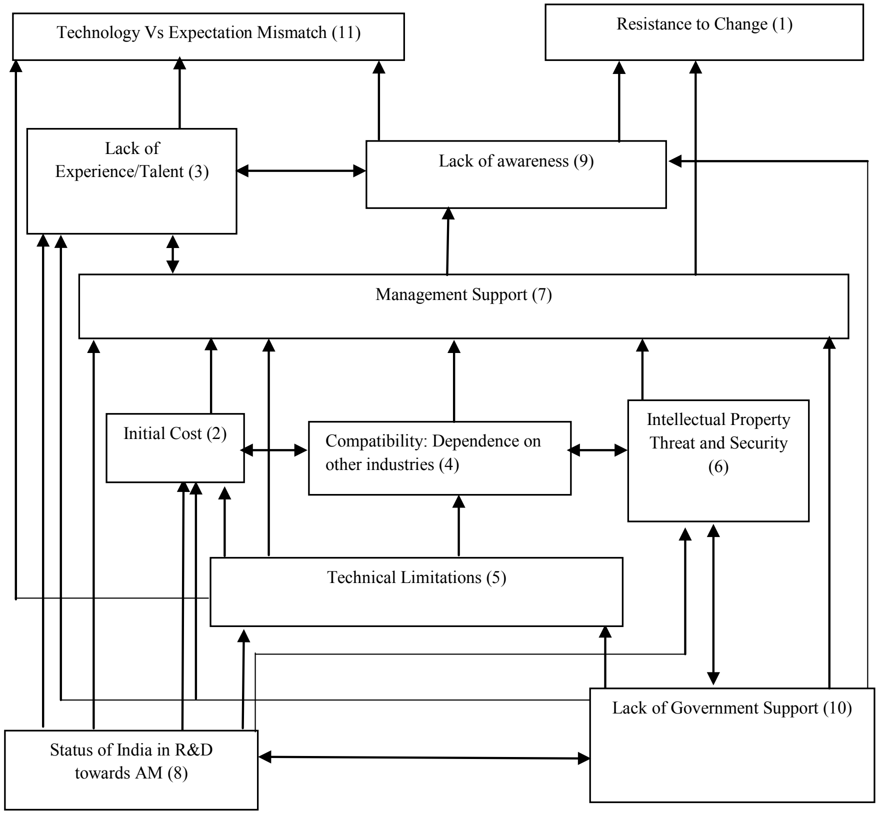

Fig. 4.3 Fuzzy ISM model

also inculcate curiosity and innovation towards technology among students. Technical workshop and short-term courses can be very helpful in industries to make people aware about the technology and filling gap between technology and expectations mismatch. More the worker and organization is aware about the technology and its implication less the resistance they will offer. Additive Manufacturing is also a major part of Industry 4.0 and can help India achieve a leap towards it, all it needs a good framework to implement.

4.6 Conclusion

This study identifies the barriers prevailing in implementation of Additive Manufacturing in India, finds their driving power and dependence power and level them using Fuzzy ISM methodology. Number of researcher and AM industry experts also agree on the point that with the arrivals of AM based startups, AM technologies adoption is gaining momentum in India but due to absence of national plan of AM implementation like USA, China, South Korea, Japan, this adaptation has not accelerated yet. Government support also leads to decrease in initial cost of implementation. Industries and Universities are needed to collaborate to reduce technical limitation, Industries can help University choose project as per their requirement. To inculcate awareness about technology some workshops can be organized with in the industries about technological changes and its effects frequently so that there will be familiarization with the technology and worker offer less resistance to adopt. Additive manufacturing is being considered as pillar for future manufacturing, we need to eradicate these barriers as fast as we can otherwise there will be loss for Indian Manufacturing sector in long run.

4.7 Limitation and Future Scope

Barriers are selected on the basis of literature, published interviews and articles from different industrial organisations, however some more barriers may exist on the ground level. In this study Fuzzy ISM methodology have been used. Results are based on expert opinions which depends on one's knowledge and expertise in AM technology, which are judgemental in nature. Barriers can also be quantified and more accurate results can be obtained. Different approaches like AHP can also be used to rank the barriers.

This study sheds little light on why these barriers are existing, a separate detailed study can be done on the root cause of these barriers prevailing. A separate study of the solutions of identified barriers can also be performed.

References

1. Johnson, D.: 3D printing the next revolution in industrial manufacturing, pp. 1–10 (2016). https://doi.org/10.1016/j.micromeso.2014.04.051
2. Sher, D.: AM global market.pdf (2018)
3. Research, G.V.: AM future forecast.pdf (2018)
4. Frost & Sullivan's Global 360° Research Team: Global Additive Manufacturing Market 2023—Forecast', Frost & Sullivan, May 2016, pp. 20–25 (2016)
5. Sean, M., et al.: 3D printing: disrupting the $12 trillion manufacturing sector, pp. 1–8. https://doi.org/10.1364/AO.23.000134(2017)
6. Anjum, T., et al.: Purview of 3DP in the Indian Built Environment Sector. Procedia Eng. **196**(June), 228–235 (2017). https://doi.org/10.1016/j.proeng.2017.07.194
7. Mellor, S., Hao, L., Zhang, D.: Additive manufacturing: a framework for implementation. Int. J. Prod. Econ. **149**, 194–201 (2014). https://doi.org/10.1016/j.ijpe.2013.07.008
8. Manda, V.R., Kampurath, V., Msrk, C.: 3D printing and its effect on outsourcing: a study of the Indian aircraft industry. J. Aerosp. Technol. Manag. **10**, 1–22 (2018). https://doi.org/10.5028/jatm.v10.862
9. Panneerselvam, P.: Additive manufacturing in aerospace and defence sector: strategy of India. J. Defence Stud. **12**(1), 39–60 (2018)

10. Rogers, H., Baricz, N., Pawar, K.S.: 3D printing services: classification, supply chain implications and research agenda. Int. J. Phys. Distr. Logist. Manag. **46**(10), 886–907 (2016). https://doi.org/10.1108/IJPDLM-07-2016-0210
11. Berman, B.: 3-D printing: the new industrial revolution. Bus. Horiz. **55**(2), 155–162 (2012). https://doi.org/10.1016/j.bushor.2011.11.003
12. Sudheer, N., et al.: Implementation of additive manufacturing in educational institutions by enrichment of technology, pp. 7–10 (2017)
13. Kietzmann, J., Pitt, L., Berthon, P.: Disruptions, decisions, and destinations: enter the age of 3-D printing and additive manufacturing. Bus. Horiz. **58**(2), 209–215 (2015). https://doi.org/10.1016/j.bushor.2014.11.005
14. Yampolskiy, M.: Security of additive manufacturing: attack taxonomy and survey. Additive Manuf. **21**, 431–457 (2017). https://doi.org/10.1016/j.addma.2018.03.015.
15. Dwivedi, G., Srivastava, S.K., Srivastava, R.K.: Analysis of barriers to implement additive manufacturing technology in the Indian automotive sector. Int. J. Phys. Distr. Logist. Manag. **47**(10), 972–991 (2017). https://doi.org/10.1108/IJPDLM-07-2017-0222
16. Ranipeta, S.S.: 3D printing lacks awareness in India, but can the few startups in this space change that? Accessed From: The News Minute (2017)
17. India: Tracking additive manufacturing industry (2019). Available at: https://www.maschinenmarkt.international/english/global/articles/839606/
18. Development, S.: SUMMARY Skill Development for Industry 4.0 (2016)
19. Wohlers, T.: 'Wohlers Report 2015: Additive Manufacturing and 3D Printing State of the Industry Annual Worldwide Progress Report. Wohlers Associates, pp. 1–34 (2014)
20. The Economist Intelligence Unit: Adding it up: the economic impact of additive manufacturing, p. 24 (2018)
21. Matta, A. K., Ranga Raju, D. and Suman, K. N. S. (2015) 'The Integration of CAD/CAM and Rapid Prototyping in Product Development: A Review', Materials Today: Proceedings, 2(4–5), pp. 3438–3445. doi: https://doi.org/10.1016/j.matpr.2015.07.319
22. Attri, R., Dev, N., Sharma, V.: Interpretive Structural Modelling (ISM) approach: an overview. Res. J. Manag. Sci. **2**(2), 3–8 (2013). https://doi.org/10.1108/01443579410062086
23. Raj, T., Shankar, R., Suhaib, M.: An ISM approach for modelling the enablers of flexible manufacturing system: the case for India. Int. J. Prod. Res. (2008). https://doi.org/10.1080/00207540701429926
24. Ansari, M.F., et al.: Analysis of barriers to implement solar power installations in India using interpretive structural modeling technique. Renew. Sustain. Energy Rev. **27**, 163–174 (2013). https://doi.org/10.1016/j.rser.2013.07.002
25. Kannan, G., Haq, A.N.: Analysis of interactions of criteria and sub-criteria for the selection of supplier in the built-in-order supply chain environment. Int. J. Prod. Res. **45**(17), 3831–3852 (2007). https://doi.org/10.1080/00207540600676676
26. Sindhu, S., Nehra, V., Luthra, S.: Identification and analysis of barriers in implementation of solar energy in Indian rural sector using integrated ISM and fuzzy MICMAC approach. Renew. Sustain. Energy Rev. **62**, 70–88 (2016). https://doi.org/10.1016/j.rser.2016.04.033
27. Govindan, K., et al.: Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. Int. J. Prod. Econ., 1–14 (2013). https://doi.org/10.1016/j.ijpe.2013.08.018
28. Kumar, D., Agrawal, R., Sharma, V.: Enablers for competitiveness of Indian manufacturing sector: an ISM-fuzzy MICMAC analysis. Procedia Soc. Behav. Sci. **189**, 416–432 (2015). https://doi.org/10.1016/j.sbspro.2015.03.200
29. What is FAME India Scheme?—Indian Economy (2019). Available at: https://pib.gov.in/newsite/PrintRelease.aspx?relid=191377. Accessed 23 Nov 2019