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ADOPTION OF 3D PRINTING TECHNOLOGY: AN INNOVATION DIFFUSION THEORY PERSPECTIVE

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ABSTRACT

While every new technology faces multiple challenges during market penetration, some technologies could be viewed by the adopters very differently than most others. The 3D Printing also called as Additive Manufacturing (AM), has been in the market for over a decade now, and is touted to be the next revolution in the industry. Technology has found wide applications in various industries, such as consumer electronics, automotive, medical devices, manufacturing and among many others. However, less is known with regards to the adoption and diffusion of 3D Printing technology, especially from the emerging economies. Using a survey method, this study aims to examine the adoption of 3D Printing technology in select industries in India. We found Relative Advantage, Ease of Use and Trialability to be significant. Whereas, Compatibility and Observability emerged as non-significant. We also explored the challenges with respect to 3D Printing Adoption. The knowledge of the major challenges along with the significant factors affecting adoption can help the manufacturers and suppliers of 3D Printing technology to focus on for increasing the rate of adoption.

Keywords: Additive Manufacturing. 3D Printing. Innovation Diffusion Theory. Technology Adoption. Emerging Economies

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INTRODUCTION

Some of the common facets of modern industry are the rapidly changing technologies, systems and processes which influence the effectiveness, efficiency and the cost of production in some or the other combination. Additive Manufacturing which is often colloquially known as 3D Printing is considered to be a new industrial revolution (Weller, Kleer & Piller, 2015; Lipson & Kurman, 2013; Berman, 2012). It is considered to be a disruptive technology as it can fundamentally have an effect on the production processes, supply chain, product lifecycle planning and consumer behaviour, among others (Jiang, Kleer & Piller, 2017).

Currently, 3D Printing faces several constraints and challenges, such as the high cost of implementation, limited choices of materials, lack of information and knowledge penetration, among others.

However, the future of 3D Printing looks promising as factors such as expiry of related key patents, increase in the options of materials to work with, increasing knowledge globally among users, and new system manufacturers taking interest and entering into the market could propel the growth in the coming future.

3D Printing offers numerous benefits ranging from customisation to ease of designing, a flexibility of prototyping and production, reducing wastage, shortening the lead time, and enhancing efficiency in the supply chain. Due to this, it has found applications in various industries.

The 3D Printing industry has considerably grown over the last few years. In the year 2016, 3D Printing market was estimated to be around USD 7.3 billion and it is expected to grow at a CAGR of above 20% to reach USD 13 billion and USD 21 billion by 2018 and 2021 respectively (UPS, 2016). According to Wohlers (2018), there was a rise in the sale of Additive Manufacturing systems by about 80% in 2017 as compared to 2016. More companies entered into producing and selling AM systems in 2017 which makes it as 135 companies in 2017 from 97 in 2016 (“Wohlers Report 2018 Shows”, 2018; “Wohlers Report 2018 reflects”, 2018). Concerning the major markets of 3D Printing, North America dominates the market with about 40% share, followed by Europe with 28% and the Asia Pacific with around 27% of the market share (UPS, 2016).

India occupies a special place in the global supply chain. India’s trade in merchandise witnessed an average growth rate of around 8.94% from 2007 to 2017 whereas its services grew at the rate of around 8.78% during the same year. In 2017, India accounted for about 2.23% of the global trade. India’s manufacturing sector contributes to the Indian economy by offering employment to around 30 million people and 16-17% to the GDP.

India also is aiming to achieve about 25% contribution to GDP by 2022 from the manufacturing sector. India is seeking to become a global manufacturing hub. It is claimed that India is already in the phase of entering into industry 4.0 (Indian Brand Equity Foundation, 2018; “Manufacturing”, 2018). The service sector also plays an essential role in the India economy. In fact, its contribution is greater than manufacturing sectors in terms of employment and GDP (“Services Sector in India”, 2018).

It is believed that AM can play a crucial role in transforming Indian manufacturing and can make a considerable contribution to the service sector as well. With this in view, this paper aims to explore the adoption of 3D Printing in India using an Innovation Diffusion Theory framework and to identify two more key aspects – how is 3D printing seen as a new technology compared to any new technology in general and what are the key challenges to adoption.

LITERATURE REVIEW

Definition of 3D Printing

The 3D Printing is a colloquially known term of Additive Manufacturing (AM), which may be defined as, ‘processes that convert digital file or information piece by piece, surface by surface and layer by layer into physical objects

(Thompson et al., 2016; Gibson, Rosen & Stucker, 2010; Kruth, 1991). Besides, Rapid Prototyping (RP) and Rapid Manufacturing (RM) are other two widely recognised synonyms of Additive Manufacturing. In comparison to RP and RM, Additive Manufacturing is considered to be more general designation that reflects the processing strategy of this advanced manufacturing technology (Hagedorn, 2017).

Different Additive Manufacturing Technologies

There are several systems and technologies for Additive Manufacturing and over the years these technologies have evolved and improved. Some of the most widely discussed AM technologies are Stereolithography (SL), Fused Deposition Modelling (FDM), Laminated Object Manufacturing (LOM), Selective Laser Sintering (SLS), 3D Printing (3DP), Electron Beam Melting (EBM), Laser Melting (LM) and Laser Metal Deposition (LMD) among many others (Hagedorn, 2017; Gross et al., 2014; Bose, Vahabzadeh and Bandyopadhyay, 2013; Vaezi, Seitz and Yang, 2013; Murr et al., 2012; Melchels, et al., 2012; Kruth, Leu and Nakagawa, 1998; Pham and Gault, 1998).

According to Wong (2012), some technologies such as EBM, Prometal, Laminated Engineered Net Shaping (LENS) and Polyjet were non-existent.

Background of 3D Printing

Certain scholars are of the view that the foundations of the 3D Printing technology were laid as long as more than century ago with proposals to build freeform topographical maps and photo-sculptures from two-dimensional (2D) layers (Thompson et al., 2016; Pham & Dimov, 2012; Bourell, Beaman, Leu & Rossen, 2009; Beaman, 1997). During the 1960s and 70s, further research and patents of a few Additive Manufacturing processes such as photo-polymerisation, powder fusion and sheet lamination were seen (Thompson et al., 2016; Wohlers, 2014; Nakagawa, 1979; Ciraud, 1972). However, real thrust and growth in 3D printing technology was witnessed during the period of the 1980s and early 1990s. This period saw the rise in academic publications and patents, and the development of new technologies or processes like MIT's 3D Printing process, Laser Beam Melting (LBM), Stereolithography, Fused Disposition Modelling (FDM), solid ground curing and laminated object manufacturing. In this period, not only there was a development of technologies but also the successful commercialization of these technologies, such as Stereolithography, FDM, solid ground curing and laminated object manufacturing (Thompson et al., 2016; Weller et al., 2015; Gebler, Uiterkamp & Viser, 2014). New processes like Electron Beam Melting (EBM) were developed and commercialized besides improving the existing technologies in 1990s and 2000s.

The improvement in the technologies meant the processes were capable to produce patterns, tooling and final parts. By the late 2000s, the 3D Printing industry became more vibrant as the patents pertaining to some of the 3D Printing technology processes expired which opened the doors for other players to participate in the industry; the commoditisation of AM processes which were commercialized earlier took place, coupled with growing AM hobby community, and constant innovation.

In general, the evolution of AM can be categorized into three phases: Phase I- where AM processes mostly concentrated on mock-ups of new designs, prototypes and models. Phase II- In this phase, AM processes improved and have had the capability to manufacture or create finished products. 'Rapid Tooling' and 'Direct Digital Manufacturing' are other words that are sometimes used to refer to this phase. Phase III- At this phase, final consumers will have the access and be able to own the 3D Printers like that of conventional Ink Jet or Laser Desktop Printers (Thompson et al., 2016; Berman, 2012).

From the applications point of view, 3D Printing has found applications for various purposes across varied industries. Manufacturing, energy, transportation, art, architecture, education, hobbies, space exploration, military, medical, dental, and aerospace, among others are widely using the AM products and support services (Hagedorn, 2017; Thompson et al., 2016; Weller et al., 2015; Gross et al., 2014; Wohlers, 2013; Wong, 2012). It is mostly used for prototyping and even used for product development and Innovation (UPS, 2016).

In general, it can be seen that 3D Printing is mostly used in applications involving low production, small part sizes and having complex printers (Berman, 2012).

Benefits of 3D Printing

3D Printing offers a variety of benefits as compared to the traditional manufacturing. Some of the known and significant benefits are:

- ability to create customised products in small batches (Ford & Despeisse, 2016),
- as designs are in digital form, can be shared, and production can be outsourced (Ford & Despeisse, 2016; Berman, 2012),
- offers speed, ease, and flexibility in designing and modifying products (Peng, 2016; Frazier, 2014; Berman, 2012)
- It helps in reusing material and reducing waste, thus, leading to material savings (Ford & Despeisse, 2016; Weller et al., 2015)
- It can lead to less dependence on high energy consuming manufacturing activities like forging, casting, etc. (Peng, 2016)
- It can lead to an improved and shorter value chain (Niaki & Nonino, 2017; Peng, 2016; Gebler et al., 2014)

3D Printing has also attracted a lot of researches from sustainability community due to the many environmentally friendly and societal benefits it can offer (Ford & Despeisse, 2016; Gebler et al., 2014).

Constraints of 3D Printing

Despite a number of benefits, the 3D Printing can offer, there are many challenges which are acting as constraints or barriers for 3D Printing implementation in various organisations across industries. Some of these challenges are:

- The high cost is involved in 3D Printing implementation (Dwivedi, Srivastava & Srivastava, 2017; Ford & Despiesse, 2016; Berman, 2012)
- Speed of production is not yet up to the mark (Berman, 2012)
- Limited choice of materials to work with (Weller et al., 2015; Frazier, 2014; Berman, 2012)
- AM faces challenges concerning the quality of output which could be in the form of limited strength, resistance to heat and moisture, and colour stability (Thompson et al., 2016; Chia and Wu, 2015; Berman, 2012)
- AM is suitable for producing products in smaller quantities but faces a great challenge with large volumes (Niaki & Nonino, 2017)
- Difficulty in shaping the mindset and attitude of the designers (Dwivedi et al., 2017; Ford & Despeisse, 2016)
- Lack of knowledge and awareness amongst the organisations (Martinsuo & Luomaranta, 2018; Dwivedi et al., 2017)
- Status quo and resistance to change in the organisations (Martinsuo & Luomaranta, 2018; Dwivedi et al., 2017)
- Lack of management and leadership support (Dwivedi et al., 2017)
- Intellectual Property Rights issues (Dwivedi et al., 2017; Ford & Despeisse, 2016)

Managerial and organisational aspects of 3D Printing

Most of the previous academic works on 3D Printing have been on the technological aspect whereby most contributions have come from the fields of engineering, material science, and computer science. There has not been much work focusing on the managerial and organisational, and socio-economic aspects of 3D Printing.

Mellor, Hao & Zhang (2014) developed a framework for the 3D Printing implementation and further used a single case study to validate the framework. However, the use of single case study poses its own limitations. Schniederjans (2017) also studied the adoption of 3D Printing using Diffusion of Innovation (DOI) Theory and Unified Theory of Acceptance and Use of Technology (UTAUT). Their study concentrated on the manufacturing sector and larger organisations in the United States.

There are studies which focused on the challenges in the implementation of 3D Printing. Dwivedi et al. (2017) identified challenges from the literature and then used expert opinions and

Fuzzy-ISM Methodology to rank challenges in terms of criticality. Their study concentrated on the Indian automotive sector.

Niaki & Nonino (2017) used multiple case studies comprising of 16 companies from Italy and USA to explore the challenges associated with 3D Printing adoption. Martinsuo & Luomaranta (2018) concentrated their study on the challenges on the SMEs using interview method.

By focusing on both, the manufacturing and service sectors, using the survey method, this study fills up the gap and contributes to the literature on 3D Printing further. Besides, considering the importance of emerging economies like India, in the global supply chain, and the uniqueness of emerging economies from that of developed economies, regarding laws and regulations, availability of finance, labour, infrastructure, among others, adds up to the need for the study.

THEORETICAL FRAMEWORK AND HYPOTHESES

Innovation Diffusion Theory (IDT)

Innovation Diffusion Theory (IDT) proposed by Rogers (2010) has been widely applied for studying the adoption and diffusion of innovation as it is widely accepted to offer a reliable framework for examining the adoption and diffusion of a new technology. It describes the process of adoption, i.e. awareness, interest, intention and eventual adoption. It also groups the adopters into five categories, i.e. innovators, early adopter, early majority, late majority and laggards based on their degree of innovativeness and time required for acceptance. The theory also proposes five characteristics or attributes of innovation, i.e. Relative Advantage, Compatibility, Complexity, Observability and Trialability, that affects the rate of adoption. Besides, it also specifies that there will be a difference in perception between adopters and non-adopters. The adopters, in general, should have more positive perceptions of the new technology or innovation than non-adopters.

There are a few additional features unique to the diffusion of innovation within organisations, including a number of characteristics of an organisation's structure that influence how innovative an organization is (Rogers, 2010).

Some of these features could be including centralization of power, organizational complexities, bureaucracy, interpersonal links within the social system, amount of resources available, size of the organization and leadership characteristics etc. Variables most closely associated with diffusion of innovation among individuals are numerous and well defined; while the variables that extend diffusion of innovation theory to the organizational realm are fewer and not well defined (Lundblad, 2003).

Moore & Benbasat (1991) contributed to the Innovation and Diffusion Theory by working on the scales and measurements of the constructs as of the prior measurements very few had requisite levels of validity and reliability. Beyond Roger's classification of characteristics of innovation which were thought to be important for adoption, the scales and measurements were made for two more constructs, i.e. Image and Voluntariness. Even Observability was divided into 'Result Demonstrability' and 'Visibility'.

Many theories and models have been proposed to study and understand innovation adoption and diffusion. Venkatesh, Morris, Davis & Davis (2003) reviewed eight models used for studying acceptance of information technology and formulated a unified theory called 'Unified Theory of Acceptance and Use of Technology (UTAUT).

Incorporating all three models, i.e. Roger's Innovation and Diffusion Theory, Technology Acceptance Model (TAM) and UTAUT (Straub, 2009) suggested that technology adoption is a complex, inherently social, developmental process; individuals construct unique yet malleable perceptions of technology that influence their adoption decisions. Straub (2009) further explains that successfully facilitating technology adoption must address cognitive, emotional, and contextual concerns.

Innovation Diffusion Theory or Diffusion of Innovation (DOI) has been widely used for studying the adoption of varied technologies and innovation. It has been used as a single theoretical framework as well in conjunction with the other theories such as Uses & Gratification (U&G) framework (Jung, Chan-Olmsted, Park, & Kim, 2011), Technological

Organisational and Environmental (TOE) (Oliveira, Thomas & Espadanal, 2014; Ramdani, Kawalek & Lorenzo, 2009; Wang, Wang & Yang, 2010; Gutierrez, Boukrami & Visser, 2015), Organisational Theory/Behaviour Research (Ramamurthy, Sen & Sinha, 2008), Technology Acceptance Model (TAM) (Carter & Bélanger, 2005; Osei-Assibey, 2015), among others.

Table 1 provides the information of some of the papers that have used DOI to study the adoption of innovation and technology.

Table 1: Some articles using DOI for studying adoption

Authors	Techno-logy	Country	Sample Size & Response Rate	Rate of Adoption	Theory	Method of Analysis	Variables considered
Al-Jabri & Sohail (2012)	Mobile Banking	Saudi Arabia	466 & 33%	82.5%	DOI	EFA & OLS	Relative Advantage, Complexity, Compatibility, Observability, Trialability, Perceived Risk
Oliveira et al. (2014)	Cloud Computing	Portugal	369 & 18.5%	-	DOI & TOE	SEM	Security concerns, cost savings, Relative Advantage, Complexity, Compatibility, Trialability, Technology readiness, Top management support, firm size, competitive pressure, regulatory support, cloud computing adoption
Jung et al. (2011)	e-book reader	South Korea	500 & -	-	IDT and Uses & Gratification (UG)	Hierarchical regression	Self-efficacy, Novelty seeking, Relative Advantage, Compatibility, Complexity, Trialability, Observability, Tech Ownership, Gratification, Perceived needs
Teo, Tan & Wei (1995)	Financial EDI	Singapore	105 & 24%	-	DOI	EFA and OLS	Relative Advantage, Compatibility, Complexity, Observability, Trialability, Operational Risks, Strategic Risks
Ramdani, et al. (2009)	Enter-prise Systems	United Kingdom	102 & 40%	-	DOI and TOE	Logistics Regression	Relative Advantage, Complexity, Compatibility, Trialability, Observability, Top Management Support, Organisational readiness, competitive pressure, External IS Support
Wang et al. (2010)	RFID	Taiwan	133 & 26.6%	41.4%	DOI and TOE	Logistics Regression	Relative Advantage, Complexity, Compatibility, Top Management Support, Firm Size, Technology Competence, Competitive Pressure, Trading Partner Power, Information Intensity
Ramamurthy, et al. (2008)	Data Ware-house	USA	196 & 8%	55%	DOI & Organ	EFA, CFA, Logistic Regression &	Organisational Commitment, Organisation's absorptive

	Adoption				isational Theory/Behaviour Research	SEM	Capacity, Organisational Size, DW's Relative Advantage and DW's Complexity
Gutierrez et al. (2015)	Cloud Computing	United Kingdom	257 & 25.62%	90.27%	DOI and TOE	EFA, Logistics Regression	Technology readiness, Competitive Pressure, Trading Partner Pressure, Complexity; Relative Advantage, Compatibility, Firm Size

Source: Prepared by the authors

Research Model and Hypotheses

Relative Advantage

Relative Advantage is defined as the degree to which an innovation is perceived as being better than its precursor technology or idea (Rogers, 2010; Moore & Benbasat, 1991). In order for the idea or technology to have a higher chance of adoption, it should demonstrate to be better than the idea or technology it is superseding. The literature on 3D Printing shows that it has many benefits to offer as compared to the traditional manufacturing technology (Ford & Despeisse, 2016; Berman, 2012; Gebler et al., 2014; Weller et al., 2015; Peng, 2016; Niaki & Nonino, 2017).

The findings from the studies focusing on other new technologies also support that Relative Advantage is positively related to the adoption (Jung et al., 2011; Al-Jabri & Sohail, 2012; Oliveira et al., 2014). Hence,

H1: The greater the perceived Relative Advantage of 3D Printing, the more likely the will be its adoption.

Compatibility

Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters (Rogers, 2010; Moore & Benbasat, 1991). If the new technology under consideration does not fit the values, requirements, experiences and most importantly the resources and infrastructure of the potential adopters then the chances of it being adopted will be lower.

Compatibility has been found to be a significant determinant of adoption and it is found to be positively related to it (Jung et al., 2011; Wang et al., 2010; Wang, Li, Li & Zhang, 2016). Therefore,

H2: The greater the perceived Compatibility of 3D printing with the values, beliefs, resources and infrastructure, the more likely will be its adoption.

Ease of Use

Ease of Use is the degree to which the innovation and technology is easy to learn and use (Moore & Benbasat, 1991). If the potential adopter perceived that the technology is easy to learn and use, the higher will be the chances of its adoption (Carter & Belanger, 2005; Lederer, Maupin, Sena & Zhuang, 2000; Pikkarainen, Pikkarainen, Karjaluoto, & Pahnila, 2004).

On the other hand, if the firms perceive the technology to be complex and difficult, thus, requiring to expend a lot of energy and effort, then the likelihood of adoption will be lower (Oliveira et al., 2014; Teo et al., 1995; Wang et al., 2016). Hence,

H3: The higher the Ease of Use of 3D Printing, the higher will be the likelihood for adoption

Observability

Observability is the degree to which the results of an innovation are observable to others. Innovations and the impact of which are easily visible in the industry will be viewed more favourably and will have more chances of adoption.

Previous studies on the adoption of innovation and technologies have shown that Observability is positively related to adoption (Al-Jabri & Sohail, 2012; Teo et al., 1995). Therefore,

H4: The higher the perceived Observability of 3D Printing, the higher the chances of its adoption

Trialability

Trialability is the degree to which an innovation may be experimented with before adoption. In general, firms would like to be able to try out and experiment before eventually deciding for adoption. This can help in understanding the capabilities, benefits and acclimatising with the technology and will be more likely to adopt the technology (Agarwal & Prasad 1998; Rogers 2010; Al-Jabri & Sohail, 2012). Trialability is found to be positively related to adoption (Jung et al., 2011; Teo et al., 1995). Hence,

H5: The greater the ability to experiment 3D Printing, the more likely will be the adoption

Voluntariness

Moore & Benbasat (1991) defined Voluntariness as the degree to which use of the innovation is perceived as being voluntary, or of free will. It is important to consider whether the adoption the firms are free to adopt or the reject the innovation. Though companies may adopt an innovation and technology voluntarily, some will be adopting due to compulsion which may come from the competition, trading partners or regulation.

Previous studies have shown that external pressure drives the adoption and is positively related to it (Lin, 2014; Gutierrez et al., 2015). Hence,

H6: The greater the perceived Voluntariness, the less likely will be the adoption

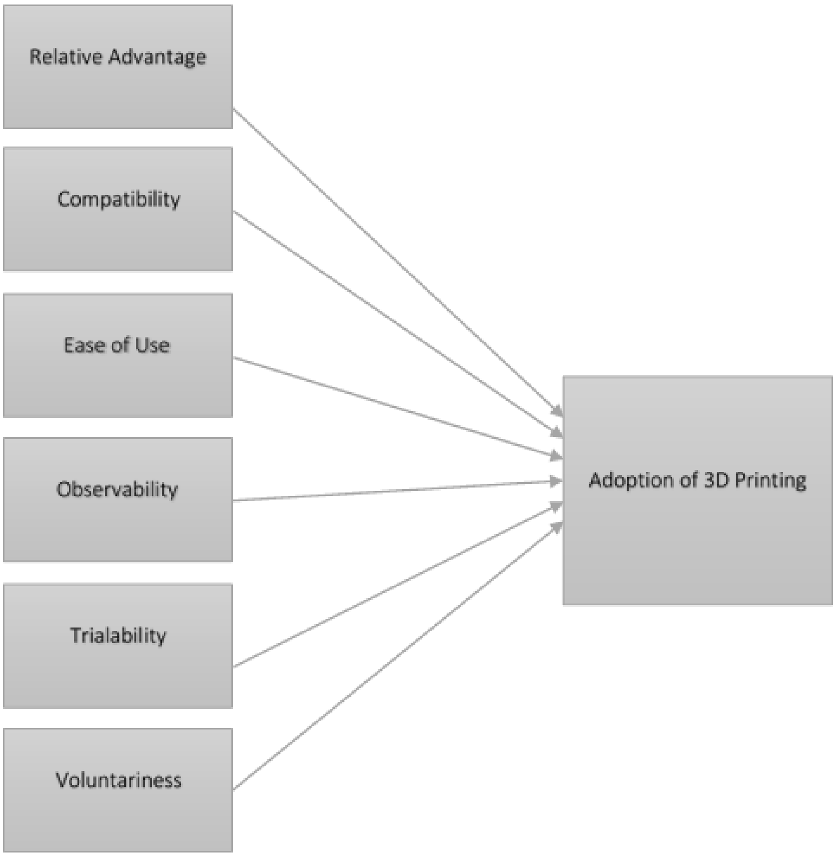

Figure 1: The Research Model
Source: Prepared by the authors

METHODOLOGY, DATA COLLECTION AND ANALYSIS

Construct Measurement

The construct scales and measurements were derived from the existing literature. However, certain modifications were done to fit the context of 3D Printing. Moore & Benbasat (1991) and Jung et al. (2011) were referred to obtain the measurement for the constructs. Voluntariness, Relative Advantage, Compatibility, Ease of Use, Observability and Trialability were measured in 5 points Likert Scale. The dichotomous dependent variable, adoption, measured whether a company was an adopter or non-adopter of 3D Printing (0: non-adopter, 1: adopter). The construct was operationalised via a "yes or no" response to the question, as "Does your firm have a 3D printing set up?".

Data Collection and Sample Profile

The survey was conducted through electronic medium and these questionnaires were sent to companies from manufacturing as well as service sectors in India. The questionnaires were sent to around 400 firms using an electronic medium and we received the responses from 92 respondents, thus, accounting a response rate of 23%. Out of which 90 responses were complete and used for analysis. Among the responses, 24 responded that they have adopted 3D Printing technology which accounts for 26.67% adoption. Table 2 provides the profile about the sample.

Table 2: Sample Profile

Category	Frequency	Percentage
Industry-wise Responses	70	77.8
Manufacturing	14	15.6
Services	6	6.7
Research	**90**	**100.0**
Total		
Profile of the Respondents		
Production	9	10
Maintenance	1	1.1
Business Management	41	45.6
Top Management	20	22.2
Others	19	21.2
Total	90	100

Construct Validation

The researchers took care that the constructs and their measure are valid and reliable. A survey using a questionnaire was conducted using the insights from the previous literature to map the factors influencing the acceptance of 3D Printing technology. Personal in-depth interview with an expert and practitioner was conducted to validate the questionnaire, thus, leading to face validity of the instrument.

The conceptual model of the 3D printing technology adoption has been validated through Exploratory Factor Analysis. The factor analysis with the initial six dimensions i.e. Voluntariness, Relative Advantage, Compatibility, Ease of Use, Observability and Trialability, was performed with Orthogonal Varimax Rotation, as the independent factors are not expected to be correlated. Besides, a criterion of Eigen-values of at least 1 was used while extracting the factors.

The Kaiser-Meyer-Olkin (KMO) test was performed to measure the sampling adequacy of the data through investigation of the correlations between individual variables. The KMO showed 0.807 indicating a 'good' level of sampling adequacy.

The Explorative Factor Analysis (EFA) initially extracted six factors with 75% variations. However, the last two factors from the six factors mentioned above did not have an adequate number of items loaded. It was felt appropriate to retain the analysis with only four factors which had significantly higher loadings. These four factors explain a cumulative variation of 64%. Similar to the issue faced by Teo et al. (1995), Compatibility and Ease of Use did not emerge as separate factors. As empirically unidimensional construct does not need to be conceptually unidimensional (Bollen & Hoyle, 1990), Compatibility and Ease of Use were treated as two separate constructs. Finally, five constructs were derived explaining 64% of the variation. Unfortunately, the construct, 'Voluntariness' had to be dropped due to poor factor loadings. The details of the items and the source from which they are derived are given in Appendix 1.

Further, in order to test the reliability of the constructs Cronbach's alpha was used. All the factors had Cronbach's alpha greater than 0.7, thus, satisfying the Nunnally & Bernstein's (1978) reliability criteria of 0.7. The descriptive statistics relating to the variables are given in Table 4.

Table 3: Exploratory Factor Analysis (EFA) and Cronbach Alpha

	Factor				Cronbach Alpha
	1	2	3	4	
RA1		.728			
RA2		.883			Relative Advantage (0.821)
RA3		.844			
CM1	.562				
CM2	.697				Compatibility (0.887)
CM3	.744				
EU1	.800				
EU2	.716				Ease of Use (0.897)
EU3	.719				
EU4	.705				
OB1				.820	
OB3				.858	Observability (0.794)
OB4				.649	
TR1			.616		

TR2			.703		Trialability (0.794)
TR3			.826		
% Variance Explained	38.209	10.780	8.281	6.900	
Cumulative % Variance Explained	38.209	48.989	57.271	64.171	

RA= Relative Advantage CM= Compatibility EU=Ease of Use
OB=Observability TR=Trialability
Source: Prepared by the authors

Table 4 Descriptive Statistics

Constructs	No. of items	Mean	Standard Deviation
RA	3	4.2852	0.625
CM	3	3.382	0.981
EU	4	3.533	0.880
OB	3	2.952	1.094
TR	3	3.315	1.025

Source: Prepared by the authors

Data analysis and findings

As the dependent variable, Adoption, is dichotomous, we performed logistics regression. Logistic regression can help in solving the major problems with using linear probability model such as heteroskedastic and non-normally distributed error terms, as well as difficulty in interpreting predicted values (Hosmer & Lemeshow, 1989). Table 5 shows the results of logistics regression. The -2LL of the regression model was 68.634. The Hosmer and Lemeshow measure of the overall fit of the model was 7.832 and was not significant at 0.05 level of significance, thereby indicating, there were no significant differences between the observed and the predicted classifications. The pseudo R square, i.e. Negelkerke R^2 was 0.48 showing a satisfactory explanatory capability of the model. Further, Table 6, shows the overall predictive power of the model, with an overall accuracy of 86.7% it corroborates that the model is good.

Three factors, i.e. Relative Advantage, Ease of Use and Trialability to be significant. Relative Advantage and Ease of Use is significant at 0.05 level of significance whereas Trialability is significant at 0.01 level of significance. Compatibility and Observability are found to be statistically insignificant.

Table 5: Logistics Regression

Predictor	β	Wald Statistics	Sig.	Exp (B)
Constant	-3.056	1.957	0.162	0.047
RA	-2.169	6.628	0.010	0.114
CM	0.234	0.175	0.675	1.263
EU	1.429	3.893	0.048	4.175
OB	-0.747	3.121	0.077	0.474
TR	2.080	11.924	0.001	8.002
-2LL	68.634			
$\chi 2$ Hosmer & Lemeshow **	7.832			
Nagelkerke R^2	0.478			

** signifies test is non-significant at 0.05% level of significance (p=0.450)
Source: Prepared by the authors

Table 6: Classification Table

		Predicted		
		Non-adopters	Adopters	Percentage
Observed				
	Non-adopters	64	2	97.0
	Adopters	10	14	58.3
Overall Percentage				86.7

Source: Prepared by the authors

Challenges to the adoption of 3D Printing in India

We also included in the survey the section to understand the challenges to the adoption of 3D Printing. Responses reveal that the key challenges faced by Indian businesses in adopting 3D Printing can be majorly grouped into Human Resource, Financial and Infrastructure related Challenges. Here 'lack of orientation and training' was regarded as the foremost challenge followed by 'huge cost', 'lack of skilled manpower to handle', 'lack of appropriate infrastructure', and 'difficulty to see the benefits as to the cost' among others have been the majorly perceived challenges. These key challenges and difficulties reflect the association with the particular mindset which is risk-averse, lacking trust and confidence in people and system while preparing for the future.

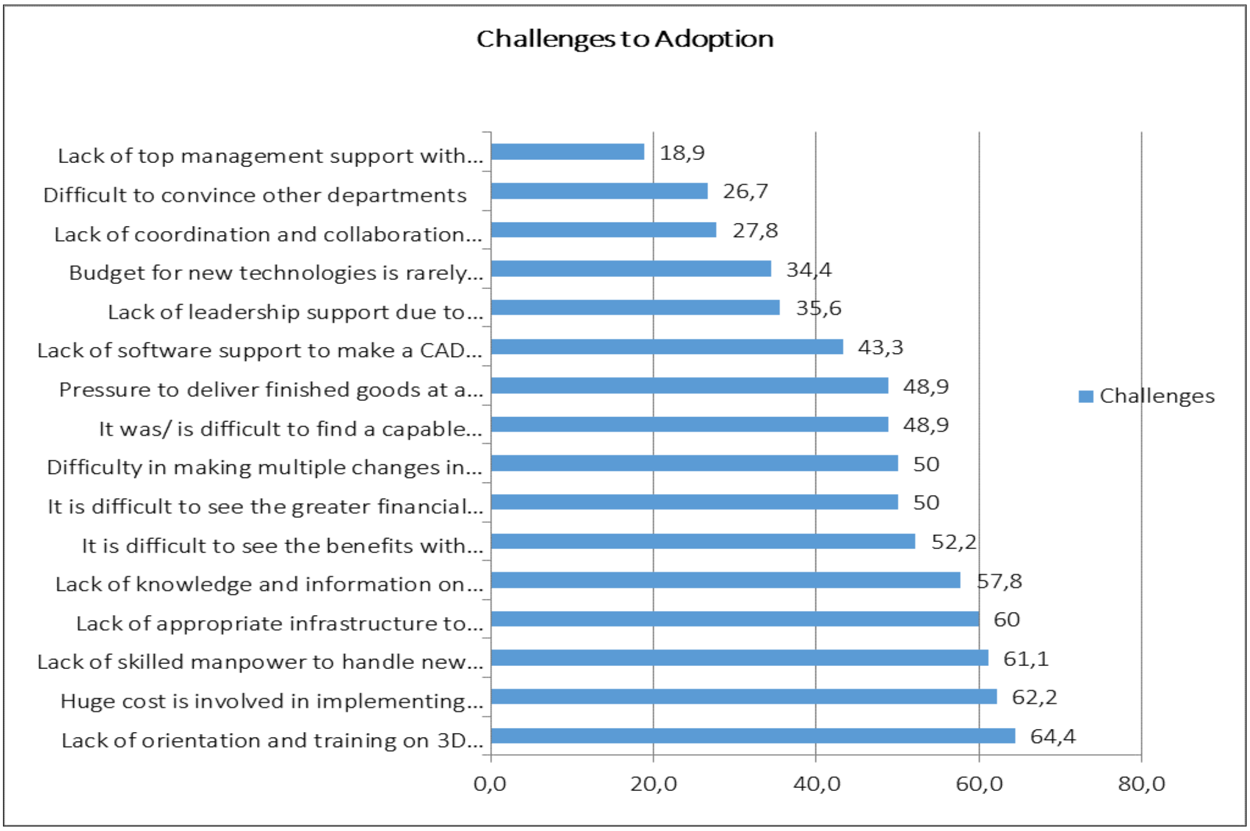

Figure 2: Challenges to the Adoption of 3D Printing
Source: Prepared by the authors

SUMMARY AND CONCLUSION

3D Printing technology is touted to be the next revolution in the industry by many and is considered to be a disruptive technology. It can have an effect not only on a single firm but the entire supply chain. Most of the previous studies on 3D Printing have focused on the technical and technological aspects of it, whereby focus on the managerial and organisational aspects was lacking. Moreover, most of the previous work has come from developed regions, with emerging economies are playing a key role in today's global value chain. It was felt necessary to study the adoption of 3D Printing from the perspective of emerging countries, and especially manufacturing focused countries.

For this analysis, the framework of Innovation and Diffusion Theory (IDT) was used.

Exploratory Factor Analysis (EFA) was performed and out of it, four independent factors were generated initially. Compatibility and Ease of Use were not generated as separate factors, however, as empirical constructs need not be unidimensional conceptually, Compatibility and Ease of Use were treated as two separate constructs. Finally, five independent factors were derived which explains 64% of the variations. As the dependent variable, Adoption was dichotomous, logistics regression was used.

The regression model revealed three variables, i.e. Relative Advantage, Ease of Use and Trialability to be significant. However, Compatibility and Ease of Use are found to be non-significant. Ease of Use and Trialability are found to be positively related to the adoption of 3D Printing. The easier and convenient the firms perceive 3D Printing to be, the higher the probabilities of adoption. On the contrary, the more the complex the firms perceive 3D Printing to be, the lower the probabilities of non-adoption. The findings also show that firms value experimentation and the ability to try out before adoption. It makes sense in the case of 3D Printing as it is a new technology and with the current state of development where the cost of 3D Printer can be quite costly, the ability to try out and understand its capabilities and benefits and costs would be essential. As such, the more the ability of trialability of 3D Printing is expected to increase the probabilities of adoption. These findings are in support of the theory and the previous findings (Oliveira et al., 2014; Jung et al., 2011; Ramamurthy et al., 2008; Gutierrez et al., 2015). Compatibility and Observability have been found to be non-significant which is not in accordance with the theory. However, there have been similar findings in the past where Compatibility and Observability emerged to be non-significant (Oliveira et al., 2014; Teo et al., 1995; Ramdani et al., 2009; Gutierrez, et al., 2015). Relative Advantage though emerged as a significant variable has a negative coefficient indicating that it is negatively related to the adoption of 3D Printing. This finding is incongruent to the previous findings. However, there were cases where other variables such as 'Trialability' were found to be negatively related to the adoption (Ramdani et al., 2009). Nevertheless, this demands more investigation as to why 'Relative Advantage' has emerged to be negatively related to the adoption of 3D Printing.

Managerial Implications

This study offers several managerial implications. The study shows 3D Printing technology adoption of around 26.67% which offers a great opportunity for penetration and increase the adoption. The manufacturers and suppliers of 3D Printing technology can focus on the factors which increase the probabilities of adoption. They should put an effort to make the use of 3D Printing easier. The marketing and communication strategies should be to focus on communicating and demonstrating the 'ease of use' of 3D Printing. They should also focus on giving more opportunities for trials and experimentations before the final adoption. This study also reveals several perceived and felt challenges to adoption. It would be beneficial if the manufacturers and suppliers can create awareness campaigns and most importantly offer orientation and training to their potential and as well as their existing customers. This will enhance the awareness as well the skill set of the potential and existing customers. For buyers implementing the same, this research may help top and senior management in knowing how executives may behave towards 3D Printing or such technologies; what will their people need in developing acceptance towards adoption.

Though 'Relative Advantage', 'Ease of Use' and 'Trialability' may be influencing the adoption of 3D Printing highly, there could be many other factors which may influence the adoption. This study could not include other potential factors. 'Relative Advantage' emerged to be negatively related to the probabilities of adoption. This study could not provide a valid answer as to why it is so. Due to the limitations of the sample size this study could not make a comparison between groups, i.e. Manufacturing and Services. These are some of the inherent limitations of this study, and future research can look into these aspects.

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