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# 3D Printing Technology and its Applications in Real-World Scenario

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**ABSTRACT:** - 3D printing is an additive manufacturing process in which the entire part of a product is constructed using layer by layer deposition of materials that based on plastic and its derivatives. There are various processes of 3D printing namely fused deposition modelling (FDM), selective laser sintering (SLS), stereolithography (SLA), digital light processing (DLP), and multi jet fusion (MJF) to name a few. Each process has its unique characteristics and applications but the fused deposition modelling process is widely used due to its simplicity. As additive manufacturing processes becoming more common coupled with rapid technological advancement in the manufacturing sector, we may see the decentralised manufacturing network in the near future. The prices of 3D printers vary depending of several factors related to the type of printing material used, and the precision and quality requirements. This paper discusses a study conducted on using low cost 3d printer for rapid prototyping a commercially ready product. It also summarises the experiences, advantages and disadvantages of the study.

**KEYWORDS:** 3D printing, FDM, rapid prototyping, design thinking, product, design, engineering.

## I. INTRODUCTION

One of the major disadvantages of traditional manufacturing techniques is their limits and huge capital investment is needed for setup of industry[1]. Unlike traditional subtractive manufacturing techniques additive manufacturing techniques have limitless possibilities. In additive manufacturing one can start from basic printers and may expand up to industrial grade more advanced 3D printers according to the need. This is also supported by many researchers, as once can always find their reports on proposing ideas to develop the habitats on other planets using 3D printing techniques [2,3,4]. The first 3D printing process invented was stereolithography technique invented by Japanese researcher Dr. Hideo Kodama in 1970's. The Fused Deposition Modelling 3D printing technique is developed by Scott Crump in 1980's who later founded Stratasys Ltd. company which is a leading 3d printer manufacturing company [5].

## II. RELATED WORK

Now a days one of the widely used manufacturing technique for plastic products is injection moulding. However, it requires a huge machine, and creation of a precise and high quality die. Therefore, a huge capital investment is needed [6]. Whereas the idea of manufacturing a commercial grade product using fused deposition modelling 3D printing technique may help one to save the huge capital investment that was anyways needed for injection moulding process. 3D printers are built using electromechanical hardware components. from its construction point of view a basic 3D printer consists of a printing bed, an extruder, filament, together integrated on a tri-axial motion stage, where everything is controlled using a specially design controller also called as the mother board [7]. Whereas from the application point of view 3D printing a product involves following procedures designing a 3D part on any 3D modelling software like AutoCAD, Fusion 360, Freecad etc. Then the 3D part is converted into standard tessellation language abbreviated as STL which is then given to the slicing software which slices the 3D part into small units enabling slicer to generate G code information acceptable by 3D printer mother board to build a part. All these steps are already summarised in a previously published paper. [8, 9] The chief objective of this paper is to discuss on a study conducted by the authors, using a low cost 3d printer to rapidly



prototype a batch of a previously patented product, for its readiness on its commercial use. This paper also summarises the experiences, advantages and disadvantages of the study.

### III. MATERIALS AND METHODS

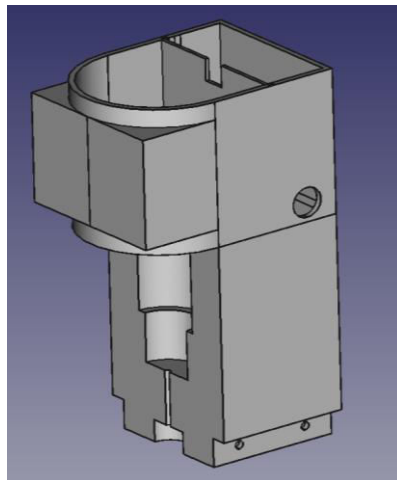
The authors in this paper learnt about the basics of fused deposition modelling 3D printing techniques at an incubation centre facility of P.V.P. Institute of Technology Budhgaon Sangli in the year 2019 [9, 10]. Later the authors (Founders of Autosustainable 3D printing and prototyping services) self purchased a desktop 3D printer to learn and exploit more advanced 3D Printing techniques. Using the user manual and after going through several online courses and through free learning resources like YouTube the printer was assembled and made ready to use it to print some actual job. One of the first implementations of 3D printing was the named key chains of themselves. Later the founders started approaching nearby businesses which were making commercial grade products by using subtractive manufacturing techniques. During meetings with prospective business subjects, knowledge and awareness was shared on the idea of potentially rapid prototyping their products and how batch production of the commercial grade products can be done using the 3D printing. Plans were also discussed on its potential for very early delivery to the hungry market, as compared to the subtractive manufacturing techniques. Finally one business subject got interested to batch produce his formerly patented commercial grade product and is discussed here after.

#### III a MEETING WITH PROSPECTIVE BUSINESS CUSTOMER

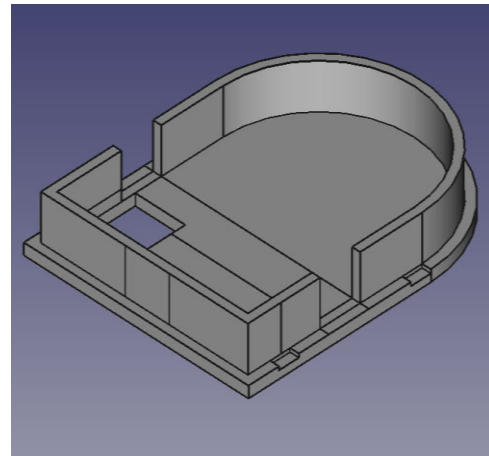
**Table 1.** Information of the first batch commercial grade product to be created using 3D Printing.

|                                                        |                                                                                                    |
|--------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| <b>Name of Invention</b>                               | 3d Printed Household Cotton Wickes Machine                                                         |
| <b>Idea Patent Applicants Name</b>                     | Abhishek Sutar.                                                                                    |
| <b>Company Name/Company Product and Services</b>       | Founder of Abhishek enterprises/ Manufacturer of SPM parts.                                        |
| <b>Designed by</b>                                     | Mr. Nitesh Raju Chavan<br>Founder, Autosustainable 3d printing and prototyping services.           |
| <b>Helping credits during managing the 3D printing</b> | Mr. Dnyaneshwar Ashok Patil. Co-Founder, Autosustainable 3d printing and prototyping services.     |
| <b>Credits on Mentorship</b>                           | Dr. Nandkishor M. Dhawale, Incharge - R&D Cell<br>P.V.P. Institute of Technology Budhgaon, Sangli, |

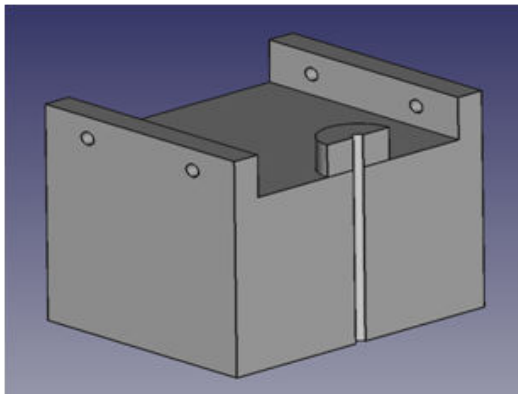
The details of the potential first batch production of the commercial grade product is summarised in table 1. This was when and where the authors approached the founder of Abhishek enterprises, Mr. Abhishek Sutar sir and gave them information of their 3D printing and prototyping services. Also all technical information was shared in regards to the potential of batch production of commercial grade products and the cost associated with the rapid prototyping techniques and what advantages this technique gives us over the traditional manufacturing techniques. Later the customer was convinced and he shared the details of the requirements of his potential product that could be tried manufacturing using 3D Printing Technology. Considering the requirements a initial sketch was drawn and then a details 3D Design/Model was created using Free CAD (an open source application software tool to create 3D Computer Aided Designs) The details of the design is shown in figure 2. From design it was clear that product to be printed was a machine and it consisted of four parts. 1) the main body, 2) top cover, 3) bottom part, and 4) slider cover.



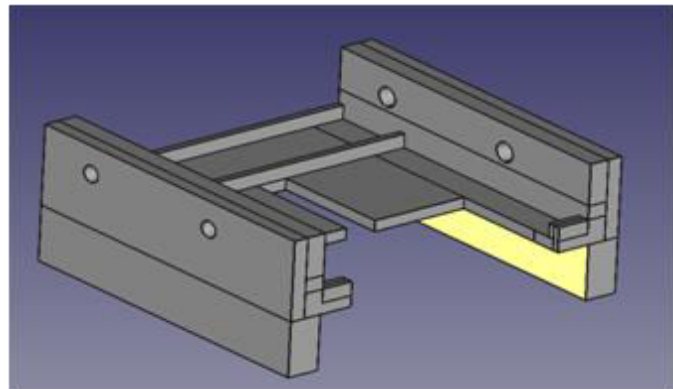
(a) Main body of Machine



(b) Top cover of Machine



(c) Bottom part of Machine



(d) Slider Cover

**Figure 1.** The designed parts of the to be 3d Printed Household Cotton Wickes Machine.

Considering the requirements and the designs the next step was to assess the cost associated with the rapid prototyping techniques and what advantages this technique gives us over the traditional manufacturing techniques. The details are specified in the next sections.

The cost consideration factors for the injection moulding process are the initial mould making cost, material cost, machining cost, labour cost etc. Also, when we opt for injection moulding process there is a certain criterion for minimum number of parts that we have to take order as per the machining and economical factors of injection moulding industry. As per findings the minimum number of parts to be injected for injection moulding process are 1000 so we have calculated the cost per unit based on following formula.

$$\text{Total Cost} = \text{Mould Making} + \text{material} + \text{labour} + \text{Machining, Maintenance} \quad (\text{EQ.1})$$



**Table 2.** Information summarizing the total cost of product using injection moulding.

| Mould Making Cost (a)                                                                                                                                                     | Material cost (b)                                                                                                                                                              | Labour cost(c)                                 | Machining, Maintenance and other (d)                                                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| 1,50,000, (Local mould maker)                                                                                                                                             | 1000 units * 200 gram = 200000 grams = 200 kg.<br>(Average cost of commonly used plastic moulding Materials like ABS, polyethylene. )<br>Overall Material cost 200* 80 =16,000 | 600 Rs per day.<br>(Local market labour cost.) | 8000 Rs per hour.<br>Total hours = 6<br>Total cost= 6* 8000= 48000<br>(Local industry information.) |
| So total cost per product using EQ.1 will be, 1,50,000 + 16,000 + 600 + 48000 = 2,14,600<br>Therefore the unit cost per product shall be 2,14,600/1000 = <b>214.6 Rs.</b> |                                                                                                                                                                                |                                                |                                                                                                     |

**III a1 COST CALCULATION FOR BATCH PRODUCTION USING FDM 3D PRINTING**

The cost consideration factors for the batch production using FDM 3D printing process are the Product design cost, Material cost, Machining cost, labour cost etc. In 3D printing process there is no any criteria for minimum number of products to get printed for a given order. So, it will be advantage over plastic moulding process that we can manufacture the product as per the customers' orders with minimum of capital investment. The formula used to calculate the cost associated using FDM 3d printing was as listed as EQ.2 as follows:

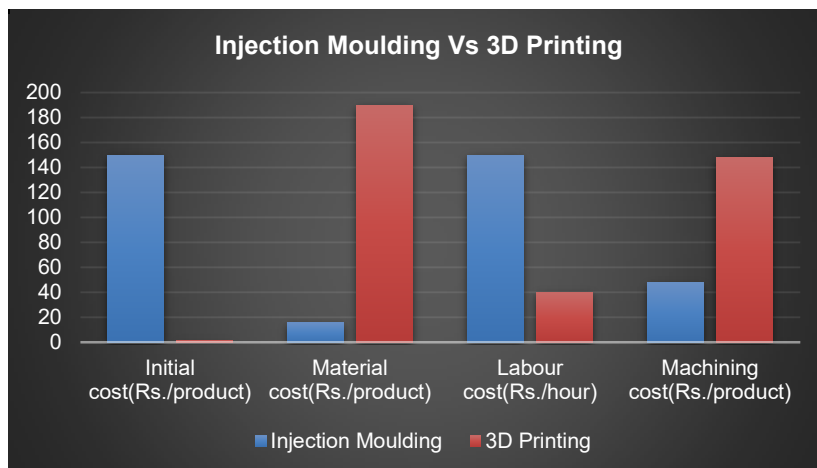
$$\text{Total cost} = \text{Product design} + \text{Material} + \text{Machining} + \text{labour} \quad (\text{EQ.2})$$

**Table 3.** Information summarizing the total cost of product using 3D Printing.

| Product design cost (a)                                                                                                                                                                                             | Material cost (b)                                                                                                                                                                                                                                                        | Machining, Maintenance and other (c)                                                                                                                                                                                                                                                                                                                                                                                                           | Labour cost(d)                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| It took 1.5 hours for the author (Founder) to design the product in Free CAD. Taking arbitrary average hourly rates charged by designers as 1000/hour. 1000*1.5 = 1500. (The product design cost is one time cost.) | Thus is easily calculated by the slicer tool. As per the tool the total material consumption per product was ~ 200 grams.<br>Generally 3d printer PLA filament cost is around 950 Rs per 1000 gram. So, the material cost per product was supposed to be 200*0.95=190 Rs | Machining cost is considered keeping in mind electricity consumption expenses and maintenance cost. 360-watt machines consumption 1 kW in roughly 2.8 hours. As per slicer tool information. The time required for whole machine for printing = 11.5 hours.<br><br>Therefore, total kW consumption = 4.11<br>electricity consumption expenses. 4.11* 8 = 33 Rs.<br><br>Maintenance cost was considered to be 10 Rs per hour. 11.5*10 = 115 Rs. | As per the slicer tool the printing time was supposed to be 11.5 hrs. Considering an average hourly labour rate as 40 Rs there for the associated labour cost was to be 11.5 *50 = 460.<br>(Labour cost is minimum as machines are automatic only requires human intervention during start of print and at end of print to remove part.) |
| So total cost per product using EQ.2 will be, 1500 + 190 + 148 + 460 = 2298 Rs. Per Product<br>However considering the designing cost as to be charged only once the unit product cost could be 798Rs.              |                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                          |

As shown in table 2 and 3 and figure 3, it was clear that 3D printing cost per product is almost 3.5 times greater than the cost associated per product by injection moulding process. However the customer was briefed on the advantages by going ahead with 3d printing. One main reason was that his product could land into the market very early. Where as the huge capital investment were also avoided, helping him to reduce the burden to sale the products as in the injection moulding process. After briefly putting such ideas in front Abhishek sir, he got impressed and gave the amber signal to go ahead. However he also gave another challenge of producing a cube with good compression strength.

This was possible by re-designing the product and 3D printed it keeping the high infill percentage therefore the product passed the test and also helped to confirm the deal.



**Figure 2.** Comparison of cost involved in injection Moulding and 3D printing.

### III b MORE CHALLENGES

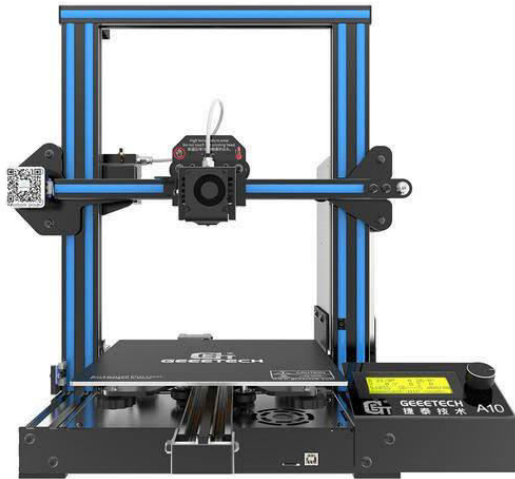
Once the customer was satisfied. He then briefed about the general idea of small handy size cotton Wick machine and its general aesthetics and insisted if it can be manufactured by 3D printing technique with a minimum cost. The customer already being experienced about his product, all necessary insights were taken from him by conducting a small meeting to discuss about the product features, parameters, about product aesthetics and general product shape and sizes. Considering all points as discussed in the meeting a design of the machine was created using Free CAD and submitted to the customer for their review. The customer was impressed with the design and aesthetics of a product and suggested few improvements as per his experience of manufacturing machines over the last few years. After re-adapting the requirements in the design the first prototype was printed using FDM 3D printing process and tested it in real world conditions. However it was realised that the product needs to have wall mounting features and easy operating sliding platform for the efficient use. Therefore all necessary changes to the final product design were made and then it was a time of selection of a printer, printing parameters, hardware changes etc. Based on readily availability reasons the choice was between Geeetech A10 3d printer and Creality's ender 3 3d printer.

### III b1 COMPARISON BETWEEN PRINTERS

**Table 4.** Comparison between low cost readily available 3D Printers

| Aspects Category | Aspects                 | Geeetech A10                    | Creality Ender 3                |
|------------------|-------------------------|---------------------------------|---------------------------------|
| Mechanical       | Drive system            | Stepper motor, Belt driven      | Stepper motor, Belt driven      |
|                  | Build volume.           | 230*230*260                     | 230*230*250                     |
|                  | Extruder system         | Bowdon system                   | Bowdon system                   |
|                  | Material compatibility. | PLA, ABS, TPU, PETG,            | PLA, ABS, PETG                  |
|                  | Dimensional accuracy    | 0.1 mm                          | 0.1 mm                          |
| Electronics      | Motherboard             | V4.2.7 32 bits motherboard      | V3.1.7 32 bits motherboard      |
|                  | End stops               | Limit switch                    | Limit switch                    |
|                  | Temperature control     | thermistor based PID control    | thermistor based PID control    |
|                  | Power supply.           | 24-volt 16 ampere Standard PSU. | 24-volt 16 ampere Standard PSU. |
|                  | Power rating.           | 360 w                           | 260 w                           |

|         |                                   |                        |                        |
|---------|-----------------------------------|------------------------|------------------------|
|         | Motors's                          | NEMA 17 stepper motors | NEMA 17 stepper motors |
| General | Max. Temperature Nozzle, Heat bed | 260, 110               | 250, 110               |
|         | Automatic Bed Levelling           | No                     | No                     |
|         | Input type                        | LCD with Knob          | LCD with Knob          |



(a) Geeetech A10



(b) Creality Ender 3 (b)

**Figures 3a and b.** Images of the low cost readily available 3D Printers.

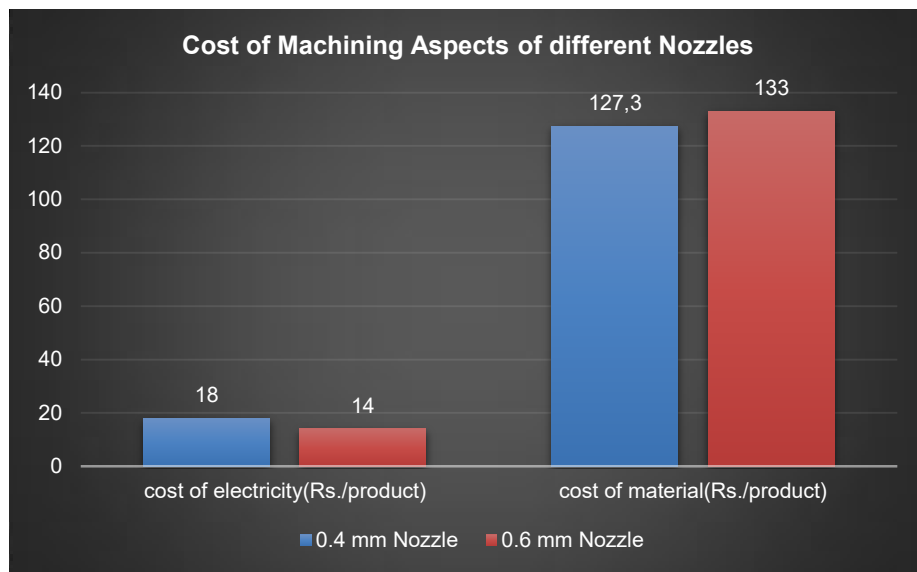
Figure 3 illustrates the two choices of the low cost readily available 3D Printers. From table 4, it is observed that there were no major differences between the printers so both printers were suitable for printing this product. The only thing which is going to vary between printers is power consumption Geeetech A10 has 360 W power rating and ender 3 has 260 W power rating so Geeetech A10 will consume somewhat more electrical power.

### III b2 MATERIAL SELECTION

As per the customers requirement on reducing the costs. The design was based on minimum Material requirements basis. Which involves keeping enough material on the specific dimensions of part which can supports the load putted on it. The printed PLA material has approximately 42 n/mm<sup>2</sup> strength (according to the temperature and printing parameters it may vary) and when considered the normal human handling it was sufficient to withstand the stresses. The PLA material is also easy to print as compared to other materials. Also, when we considered the usage aspects of product it is going to be used in indoors so there are no any significant degradation issues involved. One of the other strong contenders for material selection was ABS material but it is somewhat costly, and difficult to print as compared to PLA. So according to the mechanical principles and compatibility with 3d printing PLA material was selected for the production of part of the product.

### III b3 SELECTION OF MACHINING PARAMETERS

Selection of machining parameters are taken purely based on previous learning's and experience of printing and prototyping. For this product a 0.6 mm nozzle was selected for faster printing without compromising the strength and surface finish characteristics. Figure 4, below summarises the time and material consumption comparison for 0.4 mm nozzle vs 0.6 mm nozzle by keeping other printing parameters same. Form figure 3, it is observed that 0.6 mm nozzle increases the material consumption by 5 grams, but reduces the time consumption by 1.5 hours. In terms of cost 0.6 mm nozzle increases material cost by 6 Rs. and reduces electricity cost (dependent on time consumption) 4 Rs. Also when we considering the number of production quantities (in future) the 0.6 mm nozzle works great so we 0.6 mm nozzle was selected for the printing.



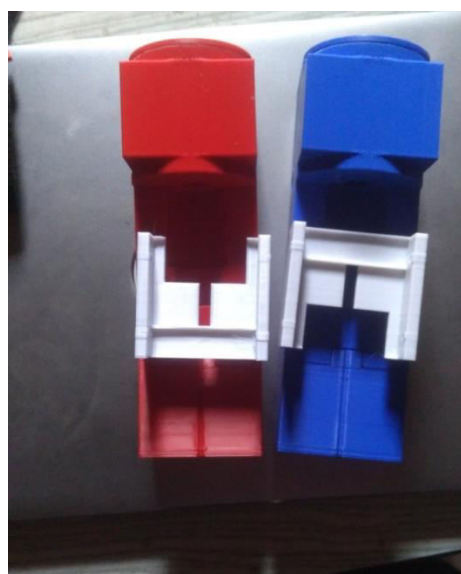
**Figure 4.** Comparison of various machining aspects of different nozzles in terms of cost.

#### IV. RESULTS AND DISCUSSIONS

Figure 5 shows the example of the real product. It was formed by assembling all four parts that were 3 printed using step discussed in previous sections. Various designs for cotton wicks machine are available in the market but those machines are industrial grade and requires somewhat more capital investment and some skill to operate it. In contrary the machine as discussed in this paper is designed and prototyped primarily considering household needs. The machine has been made small as possible as well as by satisfying all of the functional requirements. After taking a small marketing effort the customer started giving more orders for the machine. Therefore its was possible to print and assembled the machines on the order basis. As per the customer he was possible to dispatch around 120 machines to various parts of India. By doing this project from the development phase to the manufacturing phase it was possible to gain lots of experience and especially marketing knowledge.



(a) Assembled product



(b) Assembled product from back

**Fig. 5** The real product assembled after 3 printing all its four parts.





## V. CONCLUSION

The world is changing rapidly with technological development pace like never before. Everyday new technologies are emerging and making the existing technologies old. Traditional manufacturing techniques are efficient and effective for specific sector of manufacturing. Additive manufacturing techniques can adapt to the product requirement very easily without much changes in its structure. It is very easy to set up the additive manufacturing industry and manufacture the things based on the trend and customers requirement. Additive manufacturing techniques are becoming more common and individuals are accepting it as a hobby or as a small business. We may see a global network of additive machining small and medium manufacturers which will revolutionize the supply chain industry soon before that we need to achieve the technological maturity and suitable infrastructure readiness.

## ACKNOWLEDGEMENT

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