3D Printing: A Revolutionary Transformation in Manufacturing

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ABSTRACT

In current time the traditional ways of making objects are decreasing in many areas of the industry. Research has shown that the modern technologies have been taken the place of traditional manufacturing in many fields. One of the technologies is the additive manufacturing or the 3D printing. A metal joining process is more including in industrial practices than metal removing process. This study aims to analyze how 3D printing is going to transform traditional manufacturing not only in terms of making objects but also the entire industrial process that we are using now. Based on the review of the literature on applications of 3D printing in different fields of industry, an analytical study was conducted to take the idea of the influence of 3D printing technology in the industry. The data is analyzed and represented by graphical, statistical, charts, figures and in tabulation form. Analysis of the literature reviews demonstrated that a variety of industrial factors are being influenced by 3D printing technology. The results indicate that the 3D printing technology will not only change the way we make objects but it is capable of transforming the industrial supply chain, the business models and also play a significant role in the global economy. On the basis of results, it is recommended that further improvement should carry out to simplify this process so the scope of personalize printing can be increased. Further studies are needed to evaluate how much user's friendly this technology can become for the customers like mobile, and computers.

Keyword: - *Transformation, 3D printing, Rapid prototyping, and Additive manufacturing.*

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1. INTRODUCTION

The title of this research study is "3D printing: A Revolutionary Transformation in the Industry".

This topic is considered because we are facing a big change in not only industry but in science, technology and in many fields. So this topic is considered to pay your attention to what is the change happening in industry and technology and how it will influence our life.

At present time modern science is developing rapidly in every field where it's science, engineering, biology or any field. Modern science is exploring many technological accessories and application that have changed the human life in many ways. Today a lot of work is done by machine and it became possible of the technology. There's a whole technology of making objects. In ancient time the objects are used to prepare by subtractive manufacturing process. In this you take a piece of marble and break it by chisel and hammer in subtractive way.

But today the technology has changed and making objects has become easier than any other time in history. This result the traditional manufacturing has almost minimized in many field of industry. So this research study has also considered the current time and situations. As we are moving into a technological era, it is necessary to embrace the technological inventions and applications. 3D printing is also among one of the most technological applications.

In this technological era it is necessary to move your traditional way of manufacturing to the new digital automatic manufacturing process. Because the first time in the history this type of technological advancement has achieved. In this research study we'll discuss in details about current technological advancements in manufacturing that will not only change the particular process but the whole industrial process also. It is my humble request to the readers to patiently read this paper and give your review about it.

Hope you'll find answers of most of your questions related to this topic.

1.1 Brief Background

3D printing is a rapid prototyping mode without mold making. It is also known as the material additive manufacturing. Based on the 3D digital model file, it constructs the object through printing the materials layer by layer [1]. This technology has been substantially improved and has evolved into a useful tool for many fields like researchers, manufacturers, designers, engineers and scientists[2]. 3D printing is sometimes known as additive manufacturing. The term additive refers to the construction of a final part through the addition of consecutive layers of material on a build plate [3]. 3DP presents several novel opportunities, the most ubiquitous of which is prototyping. 3DP allows for decentralizing manufacturing by making parts close to consumption. Previously difficult-to make designs can be easily 3D-printed[4]. 3D printers are being used to economically create custom, improved, as well as design of components that could not be manufactured before and right there where they will be used [5].

There are several studies have conducted like "Progressive 3D Printing Technology Its Application in Medical Materials"[6], "Extrusion-based 3D food printing Materials and machines" [7], "3D printing processes for photo curable polymeric materials: technologies, materials, and future trends" [8], "Production and 3D printing processing of bio-based thermoplastic filament" [9], "Research Progress of the Modified Wood Powder for 3D printing" [10] previously to explain different applications of 3D printing (3DP) technology in various fields of industry. Similarly, "FDM 3D Printing Technology in Manufacturing Composite Elements" [11], "A brief review of the 3D printers of 2012" [12], "Evaluation of 3D Printing and Its Potential Impact on Biotechnology and the Chemical Sciences" [13] are also conducted to explain the types of 3D printing technologies and the types of 3D printers.

Nobody has conducted a research on the scope and future possibilities of 3DP technologies. They only found about the types and applications of 3D printer technology. This study will take it to the next level. It means this study will explore all the possibilities of the 3DP technology. Because this technology is not just limited to making stuffs only but it has the capability to transform the whole industry. In this study I'll explore all the aspects and the possibilities that 3DP technology has. This study will show you how 3DP technology will not only change the way we make objects but the way we live, the way we work will also get changed fundamentally.

In this technology a concept is transformed into prototype by taking help from 3D computer-aided design (CAD) files, hence digitally controlled and customized product can be fabricated. This technology utilizes a bottom-up approach in which layers of materials like living cells, wood, alloy, thermoplastic, metals etc. are placed on top of each other in order to make the required 3D object. Therefore, 3D printing is also known by other terminologies such as layered manufacturing, additive manufacturing, computer automated manufacturing, rapid prototyping, or solid freeform technology (SFF).

3D printing, otherwise known as "additive manufacturing", has been capturing the imagination of everyone from entrepreneurs to at-home hobbyists in recent years. Today, thanks to widespread media coverage of 3D printing, there is a growing surge in mainstream interest, with exciting new breakthroughs and applications being announced virtually every day [14].

Scientists and engineers impress us daily with revolutionary technologies that turned what was recently considered as science fiction or inconceivable futuristic into reality, making our lives much easier and more interesting. For example have you ever imagined being able to make your own designed glasses frame, kid's toys, or any other prototypes at your home using raw materials and a single machine? The 3D printing technology enables you to do this and it has much more complicated applications in science and industry [15].

1.2 Research Question

It's my pleasure to work on this study and find out answers related to the question of this study. Whenever we find a problem, there are many questions to solve out to get off that problem.

"How 3D printing technology will transform the industry?"

1.3 Objective

In brief my objective to meet the expectations of this study is to:

"Conduct literature review of previous papers, articles and books."

Next let me introduce the objective of the study. As every study needs an objective to conduct the research I also followed my objective to meet the expectations of research. As I earlier mentioned that my study is about qualitative and comparative analysis. So the best approach to meet expectations is literature review. So the methods of data collection and analysis are based on literature review. I have takes some previous studies in consideration to use it as a ladder in my study.

1.4: Overview

This study is structured in five chapters that are described below:

1) Introduction
2) Literature Review
3) Methodology
4) Results and Discussion
5) Conclusion

In the **Introduction** the importance and relevance of the study have been taken into consideration. At the beginning the very important work is do determine the title of the study. It took almost a week to give this title in this study. Further I justified my study over previous studies that how it can contribute to solve previous problems.

In **Literature Review** I have taken various previous papers into consideration that have been talking about the applications of 3D printing in such a way that in how many ways we can make new objects by this 3DP technology. Further I have justified my study over the previous studies that how my study is successful to solve out the problems associated with them.

In **Methodology** section I have described what methodological approaches have been taken. In this study both the qualitative and the empirical methods used to process and analysis the data and observations. Somewhere I have used statistical method to show the data in graphical and in tabulation form.

In **Results and Discussion** I have shown the significance of the study and also about the relevance of what the results have been founded. The results of the study clearly states that 3DP technology is not only limited to making objects but it has the capability to transform the entire industrial process.

In **Conclusion** chapter I have described how this study gives pertinent answers to the expected questions. I have also described that how this study is significant in finding the solution of expected questions is good enough to challenge previous studies and theories.

2. LITERATURE REVIEW

3D printing, also known as additive manufacturing is an additive technology used for making three dimensional solid objects up in layers from a digital file without the need for a mould or cutting tool. 3D printing uses a computer aided design (CAD) to translate the design into a three dimensional object. The design is then sliced into several two dimensional plans, which instruct the 3D printer where to deposit the layers of material. Then printer prepares the object by layer by layer addition of these slices. A wide variety of materials can be utilized like plastics, glass, metal, polymers, wax, sand and glue mixes, nylon, ceramic, edible material, and even human tissue.

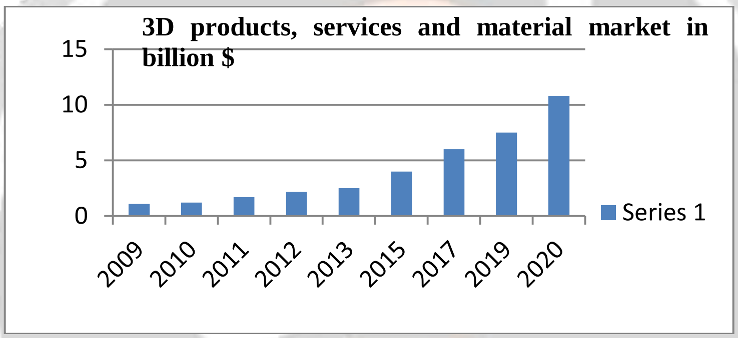


Chart -1: Additive Manufacturing Market

Printing has long been confined to the realm of the second dimension, printing out reports, essays and the like on paper, metal, and other flat objects. Printing has now vaulted into the third dimension, as new 3D printers are producing items that can be used to create a plethora of useful items. Now the 3D printing also known as additive manufacturing is growing due to the development of customized parts, prototyping, product designing, and concept modeling. By this the technology is capable of doing much more things. At present it is set to disrupt entire industries including consumer products, medical, automotive, construction, and aerospace.

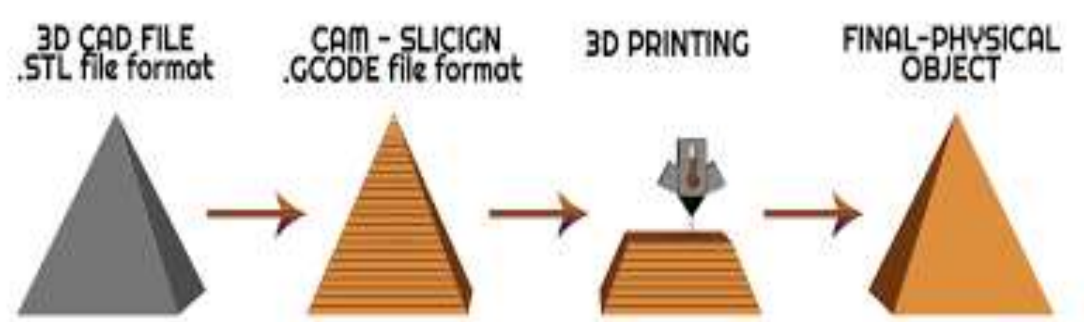


Fig -1: Steps of 3D printing process

2.1 Background

Let's Go For a Chronological Approach to Identify the Study Gap

Charles W. (Chuck) Hull is generally credited with developing the first working robotic 3D printer in 1984, 3D printing has been changing the manufacturing and prototyping industries since the late 1980's, but it wasn't until 2009 that "desktop" 3D printers were readily available to the public.. A desktop 3D printer is industry jargon for a smaller, less expensive 3D printer that a typical consumer can buy. S. Scott and Lisa Crump patented fused deposition modeling (FDM) in 1989 and co-founded the printer manufacturer Stratasys, Ltd. This technology (more generically called FFF, for fused filament fabrication) feeds a plastic filament into a heated extruder and then precisely lays down the material [2].

Bowyer published the designs for the parts for his 3D printers and encouraged others to improve them and in-turn post to improve versions. He called this source concept, the RepRep project and obtained some initial funding from the UK's Engineering and Physical Sciences Research Council (EPSRC). Bowyer's team called their first printer as Darwin (released in March 2007) and the next as Mendel (released in 2009). Since 2010, 3D printer technology has shown explosive growth with the help of the open source and DIY communities. It was superseded by the Maker Bot Thing-O-Matic in 2010. These were mostly made of laser cut wooden parts with some 3D-printed parts (plus, of course, motors and electronics). Eventually, MakerBot became one of the earlier commercial consumer printer companies and was purchased by Stratasys in 2013. The Fused Deposition Manufacturing Technology is the mostly available and comparably less expensive.

The evolution and development of 3D printing can be described in span of three times. The primary spanning time from 1980 to 2010 shows the evolution of 3DP technology, its industrial use and the beginning of the consumer 3D printing movement. In the time span of 2010 to 2015, the 3D printing market continued to expand, despite signs of weakening in 2014. Since 2015, prices for consumer 3D printers have fallen, while sales of consumer and industrial 3D printers have continued to rise as the technology has matured[16].

Establishing the Foundations of 3D Printing Technology (1980-2010)

The first major patents for 3D printing methods were filed in the 1980s, creating a nascent 3D printing market for industrial clients. In the 1990s, 3D printers using plastic, metal, paper, ceramic, and wax became available at prices from thousands of dollars to hundreds of thousands of dollars. In the early 2000s, the 3D printer market expanded into specialized industries, including medicine, dentistry, and jewelry. At the same time, new plastic printing materials were developed [3].

3D Printing was only an idea in the 1980s. In 1981, Hideo Kodama of the Nagoya Municipal Industrial Research Institute in Japan discovered a way to print layers of material to create a 3D product. Unfortunately, Kodama was unable to get his patent for the technology approved.

In 1986, an American engineer named Charles Hull created a prototype for a process called stereo lithography (SLA). Hull used photopolymers, also known as acrylic-based materials, to evolve from liquid to solid using ultraviolet lights. Hull patented the SLA printer and other companies followed suit. Hull is commonly referred to as "the father" of 3D printing.

Major developments in this span of time are the formation of the open-source 3D printer community; the 2007 release of the first website for print-on-demand custom 3D prints (Shapeways); and the 2008 creation of the popular 3D printing file-sharing website Thingiverse.18 In 2009, MakerBot, one of the first consumer 3D printing companies, released a $750 3D printer that incorporated some of the off-patent technologies from the 1980s.

A professor in England named Dr. Adrian Bowyer made it his mission to create a low-cost 3D printer. By 2008, his "Darwin" printer had successfully 3D printed over 18% of its own components, and the device cost less than $650.

Exploration of 3DP Technology (2010-2015)

As the cost of 3D printers continued to decline, the demand for the technology began to soar, and they became more commonplace in the home and in businesses. On the shop floor, manufacturers began leveraging 3D printing in a variety of ways. Machine parts could be repaired quickly, and inventory shortages could be combated with ease. By 2014, the industry generated more than $1 billion revenue. But along with the impressive financial impact of the technology, 3D printing also made an impact on how people work.

The consumer market for 3D printers expanded in the 2010s, fueled in part by the continued expiration of 20th-century patents. Innovations in 3D design software and improvements in printer reliability contributed to the spread of consumer and industrial 3D printers in shared maker spaces, commercial establishments, libraries, and universities. 3D file sharing also became widespread, both for paid and free models. One 3D file website, Thingiverse, had more than 2 million active users in 2015[3].

The 3D printing industry began to show signs of weakening in 2014 after a period of growth and consolidation. In June 2015, Time magazine reported that the stocks of four leading 3D printing companies had "lost between 71% and 80% of their market value in the past 17 months."26 Between January and October 2015, the 3D printing company Stratasys laid off 36% of staff in its MakerBot division.

Exponential Growth of 3D Printing (2015 & Further)

The period from 2015 to 2019 has seen renewed 3D printing investment, in terms of both research and development and investment in growing companies. Corporations (such as General Electric, Google Ventures, Alcoa, and Norsk Titanium AS) and federal departments and agencies—such as the Department of Defense (DOD) and the National Institutes of Health have invested a combined total of hundreds of millions of dollars in 3D printing initiatives over this period.

The first family to move into a 3D printed house actually did in 2018. The house is 1022 square feet, is perfectly habitable and took two days to print.

We take some incidents in sequential order to explain the evolution of 3DP Technology

[16]

- 1980: First patent by Japanese Dr Kodama Rapid prototyping.
- 1984: Stereo lithography by French engineers then abandoned.
- 1986: Stereo lithography taken up by Charles Hull.
- 1988: First SLA-1 machine.
- 1988: First SLS machine by DTM Inc then buy by 3D system.
- 1990: First EOS Stereos system.
- 1992: FDM patent to Stratasys.
- 1993: Solid scape was founded.
- 1995: Z Corporation obtained an exclusive license from the MIT.
- 1999: Engineered organs bring new advances to medicine.
- 2000: a 3D printed working kidney is created.
- 2000: MCP Technologies (an established vacuum casting OEM) introduced the SLM technology.

- 2005: Z Corp. Launched Spectrum Z510. It was the first high-definition color 3D Printer on the market.
- 2006: An open source project is initiated (Reprap).
- 2008: The first 3D printed prosthetic leg.
- 2009: FDM patents in the public domain.
- 2009: Sculpteo is created.
- 2010: Urbee is the first 3D printed prototype car presented.
- 2011: Cornell University began to build 3D food printer.
- 2012: The first prosthetic jaw is printed and implanted.
- 2013: "3D printing" in Obama's State of the Union speech.
- 2015: Carbon 3D issues their revolutionary ultra-fast CLIP 3D printing machine.
- 2016: Daniel Kelly's lab announces being able to 3D print bone.
- 2018: The first family moves into a 3D printed house.

2.2 Review of Previous Studies

Walters, P.; Huson, D.; Parraman, C.; Stanić, M. et al. (2009) had studied about 3D printing in colour. They used the Z-Corp powder-binder 3D printing process for the design and production of colour test blocks. This study of color reproduction in 3D printing has shown that the reproduction of colors is depending on the position and orientation of the surface, finishing method and type of printer used. Finally they found that like all technologies, the Z-Corp powder-binder 3D printing process has certain capabilities and limitations [17].

Peter Walters and Katie Davies et al. (2010) had conducted a research and creative practice to know about the scope of 3D printing for artists. Authors described the Study of the academic research into new 3D technologies which is taking place within the art and design sector, including the work of the 3D Printing Laboratory [18]. It is concluded that this is a practical case study in which 3D printing was employed by the authors in the creative realization of an artwork. Extending beyond prototyping applications in engineering and industrial design, where the technologies are most commonly employed, practitioners in the creative arts have exploited 3D printing as a means to fabricate one-off and limited edition artworks and design artifacts.

Ehud Kroll, Dror Artzi et al. (2011) studied the enhancing aerospace engineering students learning with 3D printing wind-tunnel models Polymer-based RP was used to fabricate two-aircraft models, which included stiffening metallic inserts. Testing in a subsonic-wind tunnel was carried out and the results compared to analytic performance predictions [19]. Low-cost rapid prototypes of wind-tunnel models yielded satisfactory aerodynamic performance. The savings in acquisition cost and time allowed incorporating actual testing in the aircraft design process within the framework of a tight academic budget and schedule. In contrast, RP facilitates an enhanced and more realistic learning experience by offering a quick and affordable means of model manufacturing.

Martin Hedges, Aaron Borras Marin et al. (2012) studied 3D Aerosol Jet Printing - Adding Electronics Functionality to RP/RM The authors conducted a study of aerosol jet printing is a unique CAD driven, digital manufacturing technique for creating miniaturized electronic circuits and components [20]. Study was successful to prove that the aerosol jet process is capable of handling the entire range of materials classes required for Printed Electronic manufacturing. This process works with a wide range of functional materials and can print the main building blocks of electronic systems on both 2D and 3D surfaces.

Ben T. Wittbrodt, A. G. Glover, J. Lauret, G. C. Anzalone, D. Oppliger, L. Irwin, and Joshua M. Pearce et al. (2013): Life-Cycle Economic Analysis of Distributed Manufacturing with Open-Source 3-D Printers [21].The authors conducted an experimental study on this topic. This study reports on the life-cycle economic analysis (LCEA) of RepRap technology for an average U.S. household. The results show that even making the extremely conservative assumption that the household would only use the printer to make the selected twenty products a year the avoided purchase cost savings would range from about $300 to $2000/year. It appears clear that as RepRaps improve in reliability continues to drop in cost and the number and assumed utility of open-source designs.

Thierry Rayna and Ludmila Striukova et al. (2014): The Impact of 3D Printing Technologies on Business Model Innovation [22] This study shows that in addition to enabling business model innovation, 3D printing technologies have the potential to change the way business model innovation is done. Various impacts of 3D Printing technologies on business model innovation have been studied successfully. This article has provided an integrated framework which combines both the 'inside' and 'outside' views present in the literature.

Thomas J. Hinton, Quentin Jallerat, Rachelle N. Palchesko, Joon Hyung Park, Martin S. Grodzicki, Hao-Jan Shue, Mohamed H. Ramadan, Andrew R. Hudson, Adam W. Feinberg et al. (2015): Three-Dimensional Printing of Complex Biological Structures by Freeform Reversible Embedding of Suspended Hydro gels. 3D biological structures are built by embedding the printed hydro gel within a secondary hydro gel that serves as a temporary, thermo reversible and biocompatible support. Study of 3D printing of complex biological structures by freeform reversible embedding of suspended hydro gels (FRESH) was successful. The FRESH method is significant to print 3D biological structures [23].

Abhishek Saxena and Medhavi Kamran et al. (2016): A Comprehensive Study on 3D Printing Technology. A comprehensive study has been carried out for comparing it with traditional manufacturing method for production of components, complex objects for hundreds of different applications. Types of 3D printing technologies, materials, applications and procedures are successfully studied in this paper. One can conclude that the 3D printing technology revolutionize and reshape the world as it is very exciting technology with huge potential also comprising the different technologies at one place, taking into account their economic benefits and social impact [24].

Chui Ki Venus Ma et al. (2017): "3D Printing and the Law" This study is to explore the intersection between 3D printing, Intellectual Property, Gun Laws, and Product Safety and Privacy, before concluding with a proposal to amend the Law. This study has explored the Law in relation to the 3D printing revolution, namely Intellectual Property, Gun Control, Product Liability, and Data Protection. The advent of 3D printing brilliantly demonstrates the multifaceted nature of the law [25].

Gabriele Taormina, Corrado Sciancalepore, Massimo Messori and Federica Bondioli et al. (2018): 3D printing processes for photo curable polymeric materials: technologies, materials, and future trends. A general overview on additive manufacturing and on the different technologies available for polymers is given. The materials are explored, starting from base matrix materials to composites and nano composites, with attention to examples of applications and explanations of the main factors involved. This review article explored the different solutions available for the fabrication of polymeric materials and nano composites using VP processes [8].

Caroline Freund, Alen Mulabdic, Michele Ruta et al. (2019): "Is 3D Printing a Treat to Global Trade? The Trade Effects You Didn't Hear About" study is about the impact of 3DP technology on international trade using a difference-in-difference technique and synthetic control methods (SCM). Differently from the hearing aids example, we find that the technology decreased trade for countries that used to have a comparative advantage in 3D printable products. We focus on hearing aids, a product that since the mid-2000s has almost exclusively been produced employing the 3D printing technology [26].

Azarmidokht Gholamipour-Shirazi, Michael-Alex Kamlow, Ian T. Norton and Tom Mills et al. (2020): How to Formulate For Structure and Texture via Medium of Additive Manufacturing-A Review The authors conducted a study of the methods and materials for 3D printing and also the future of 3D printing **One** step, before full transition to 3D food printing, could be adopting hybrid technologies i.e., 3D printing methods adapted to current food manufacturing processes. There still exist many questions about the safety and capabilities of 3D food printing and how to address them [27].

Finding Study Gap from Previous Studies

After review of previous studies I found that 3DP Technology not only can change the product manufacturing but it's able to transform many industries and sectors.

"3D printing is about more than products – it has potential to transform businesses, geographical challenges and entire supply chains" [28].

Some of the future possibilities that can fill the technological gap from previous studies are described below

- There is the potential for 3D printing to revolutionize the way we make almost anything. This year, I expect it will become faster and cheaper, with new materials that enhance commercial possibilities.
- It's able to eliminate the geographical boundaries. The technology is connecting the world more tightly. The digital age is global by nature.
- 3D printing is turning manufacturing and distribution upside down, with huge tax implications. Make sure your business is prepared.
- It'll transform our space missions as most of the tools and gadgets can fabricate at instant to use in space.
- If consumers have 3D printers at home, much of the taxable value may migrate there, where the supply chain ends, greatly reducing the potential for supply chain taxes.
- It's too early to answer the countless questions the 3D printing will raise. But it is certainly not too early to start defining these questions and influencing the policy surrounding the answers.

3. METHODOLOGY

3.1 Selection of Methodological Approach

I have selected the qualitative method with partially quantitative method to conduct my study. This method includes both descriptive and experimental analysis in the research. Quantitative data presents 3DP market evolution, which has been obtained by studying industry-specific market reports. At the other hand the qualitative data was included through non-structured interviews with industry technology users and academics who have worked in 3DP application research for many years.

Basic introduction of 3D printing

3D printing is an additive manufacturing process that builds objects by adding layer upon layer of a material. It is different from injection molding and subtractive manufacturing processes. The areas of application are primarily rapid prototyping and small production industries. The economic and scientific potential of this technology, as well as certain regulatory concerns recently increased congressional interest.

3D printers are used in a variety of industries such as aerospace, medicine, and education as well as in nonspecific custom prototyping. Both private industry and the federal government have supported these applications of 3D printing. 3D printing basically uses a different process than most traditional methods for manufacturing. Much of modern manufacturing uses subtractive manufacturing processes, beginning with a block of material and using a variety of tools to remove parts of the initial material to achieve a final design. 3D printers are additive, stacking up and fusing thin layer upon thin layer of a material onto a blank platform to achieve a final design.

3D Printing Process: The process of 3D printing where a digital file is transformed into solid object is a quite long and complicated one. To develop a project via 3D printing, you need to perform the following steps (AZEVEDO, 2013; OLIVEIRA, 2016):

- Develop a project of the desired object in 3D CAD software, such as SolidWorks, Inventor, AutoCAD, among others.
- Convert the project to STL (Standard Tessellation Language) format. This format describes surfaces of an object through a set of triangles of different dimensions. The more triangles there are, the greater the project accuracy.
- The next step is to choose a reference plane from the STL file, and so the object will be divided into layers parallel to the chosen reference plane. The smaller the size of the layer, the more accurate the print will be.
- Each of these layers is described by a file called GCODE. This code has the numerical commands for the manufacture of each of the layers, possessing information of temperature, trajectory, speed, positioning, among others.
- Final printing is done using the GCODE code, which directs the printer to obtain the desired object.

A flow chart is shown further to describe steps for 3D printing

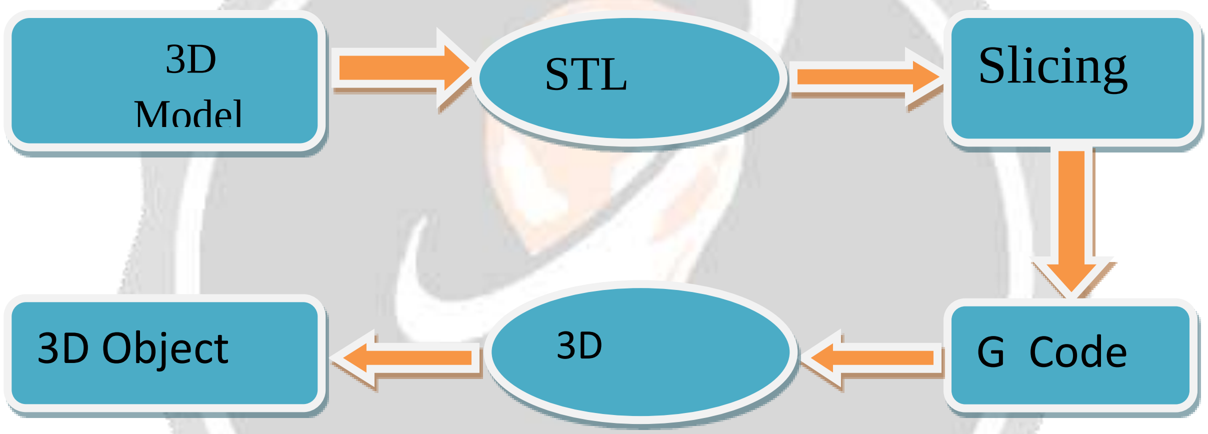


Fig -2: Flow chart of 3D printing process

3.3 Types of 3D printing

These are the several applications of 3D printing also considered as additive manufacturing

Stereo lithography (SLA): Stereo lithography (SLA) is the original industrial 3D printing process. SLA printers excel at producing parts with high levels of detail, smooth surface finishes, and tight tolerances.

Selective Laser Sintering (SLS) Selective laser sintering (SLS) melts together nylon-based powders into solid plastic. Since SLS parts are made from real thermoplastic material, they are durable, suitable for functional testing, and can support living hinges and snap-fits. In comparison to SL, parts are stronger, but have rougher surface finishes.

Poly Jet: Poly Jet is another plastic 3D printing process, but there's a twist. It can fabricate parts with multiple properties such as colors and materials. Designers can leverage the technology for prototyping elastomeric or over molded parts.

Digital Light Processing (DLP): Digital light processing is similar to SLA in that it cures liquid resin using light. The primary difference between the two technologies is that DLP uses a digital light projector screen whereas SLA uses a UV laser. This means DLP 3D printers can image an entire layer of the build all at once, resulting in faster build speeds. While frequently used for rapid prototyping, the higher throughput of DLP printing makes it suitable for low-volume production runs of plastic parts.

Multi Jet Fusion (MJF): Similar to SLS, Multi Jet Fusion also builds functional parts from nylon powder. Rather than using a laser to sinter the powder, MJF uses an inkjet array to apply fusing agents to the bed of nylon powder. Then a heating element passes over the bed to fuse each layer. This result in more consistent mechanical properties compared to SLS as well as improved surface finish.

Direct Metal Laser Sintering (DMLS): Metal 3D printing opens up new possibilities for metal part design. The process we use at Proto labs to 3D print metal parts is direct metal laser sintering (DMLS). It's often used to reduce metal, multi-part assemblies into a single component or lightweight parts with internal channels or hollowed out features.

Electron Beam Melting (EBM): Electron beam melting is another metal 3D printing technology that uses an electron beam that's controlled by electromagnetic coils to melt the metal powder. The printing bed is heated up and in vacuum conditions during the build. The temperature that the material is heated to is determined by the material in use.

Fused deposition modeling (FDM): The process involves the selection of the desired polymer, which is melted and forced through a movable heated nozzle. Along the entire 3 axis (i.e., x-y-z), the polymer is laid down layer by layer, which on solidification gives the exact shape as was designed by computer aided design models.

Thermal inkjet (TIJ) printing: It involves the heating of ink fluid by the help of micro-resistor, thereby creating a bubble of vapor that nucleates and upon expansion forces the ink to drop out of the nozzle. Dispensing of extemporaneous preparation/solution of drug onto 3D scaffolds is an area where this technique can be employed.

3D printing is sometimes known as additive manufacturing. The term additive refers to the construction of a final part through the addition of consecutive layers of material on a build plate. In contrast, subtractive manufacturing processes carve out a final part from an initial block by removing unwanted material. Computer controlled additive and subtractive manufacturing originated in the 1980s and 1970s, respectively. Yet, the basic techniques underlying these manufacturing methods that is, addition or removal of material to create a product have existed for millennia.

Aerospace	Turbine blades, fuel nozzles, structural members
Medicine	Implants, instruments, prostheses
Defense	Field replacement parts, inventory reduction
Custom manufacturing	Razor handles, sneaker soles
Prototyping	Structural electronics, fit/function validation

Education	Conceptual modeling, problem-solving, career readiness
Hobbies	Geometric designs, figurines, toys
Art	Jewelry, costume design, footwear

Table-1: Selected Applications of 3D Printing

3.4: Method of data Collection

I took both analytical and empirical approach to collect my study data. Some of the resources of data are described below:

1. Books
2. Journal Article
3. Review
4. Digital Library

3.5: Method of Data Analysis: I have taken both descriptive and empirical approach to analyze the study data. The theme and the pattern of study is comparative analysis of the research data. The data is presented in figures, descriptive, graphical, and in tabulation form.

Why 3D Printing Will Transform Industrial Manufacturing:

Whatever you want, wherever you are, whenever you need it: 3D printing is driving a revolution in the way products are made. As the technology improves, more and more industries are taking advantage of this innovative process and exploring its potential to transform the future of manufacturing.

Industrial 3-D printing is at a tipping point, about to go main stream in a big way. Most executives and many engineers don't realize it, but this technology has moved well beyond prototyping, rapid tooling, trinkets, and toys. "Additive manufacturing" is creating durable and safe products for sale to real customers in moderate to large quantities.

This obsession with scale has been at the heart of manufacturing for decades, but now a new technology is aiming to change manufacturing forever: 3D printing. This revolutionary process has the potential to enable manufacturers to make whatever they want, whenever they want it, at a location much closer to the final customer. This would shrink the cost of storage and transport, while also opening up complete freedom to customize designs right down to the smallest detail – from sneakers that are made to fit the unique measurements of your feet, through to a fully personalized interior for your car.

For traditional manufacturing, bigger has always been better: Huge numbers of products are made on massive production lines in big factories, before being put into large containers, stacked onto giant ships and carried to customers around the world. This keeps the cost of a single product low, but also involves high costs related to storing large amounts of stock and major problems when shipping gets delayed.

The beginnings of the revolution show up in a 2014 PwC survey of more than 100 manufacturing companies. At the time of the survey, 11% had already switched to volume production of 3-D-printed parts or products. According to Gartner analysts, a technology is "main stream" when it reaches an adoption level of 20%.

Among the numerous companies using 3-D printing to ramp up production are GE (jet engines, medical devices, and home appliance parts), Lockheed Martin and Boeing (aerospace and defense), Aurora Flight Sciences (unmanned aerial vehicles), Invisalign (dental devices), Google (consumer electronics), and the Dutch company LUXeXcel (lenses for light-emitting diodes, or LEDs). Watching these developments, McKinsey recently reported that 3-D printing is “ready to emerge from its niche status and become a viable alternative to conventional manufacturing processes in an increasing number of applications.” In 2014 sales of industrial-grade 3-D printers in the United States were already one-third the volume of industrial automation and robotic sales. Some projections have that figure rising to 42% by 2020.

How 3D printing is going to transform the industry:

3D printing has changed our manufacturing process in many ways. At present time we can make stuffs at very fast speed with a very low of processing time. In upcoming time 3D printing will not be limited to making stuffs but it will able to change the whole manufacturing and industrial process.

In order to understand how manufacturing with 3D Printing is different from traditional manufacturing, you need to understand the whole supply chain. Supply chain refers to all steps that occur from sourcing of raw materials to manufacturing and then delivery to the customer.

Supply Chain Models: A traditional supply chain for a consumer product that is sold in a large retail chain can look like this. An order is placed with a factory, the order is manufactured, it is shipped via ocean and/or truck/rail and delivered to your distribution center (DC). When a customer places an order, the items are picked and shipped from the DC to the customer’s DC. When quantities get low, a reorder is placed and the process starts over again. For large retailers, an additional step occurs where the items are shipped firs to their DC and then they break it down into smaller shipments, which they send to each of their retail stores. Large consumer products companies can sometimes bypass their own DC step by getting orders from their larger customers before manufacturing and then ship directly to the customer’s DC.

Supply Chain Models new: If you were to simply use 3D printing as your manufacturing process and still produce overseas, then the supply chain above stays the same. However, the features of 3D printing lend it to looking at manufacturing in a new way and the supply chain can be greatly simplified. Because you can make-to-order in small quantities (as low as 1), the process starts with a customer order, the item is printed and assembled and then shipped. Note that this can only be done at small volumes and is not a feasible method for anything that will be sold at mass retail.

Now let’s look at the three key factors that are in play when deciding how to manufacture something are cost, time and quality.

Cost: Let’s first look at how traditional manufacturing works. In traditional manufacturing, a physical model is made of the desired item. Then a tool is made for the process from that physical model. This may be a mold for injection molding or pouring processes or a die for stamping. This tool can be expensive (e.g., for injection molding, molds can cost from $10K to $50K). While the cost to make each part may be low, the cost of the tool is amortized across the number of parts being made. So at low volumes, the cost is prohibitive, but at high volumes it’s very competitive. For example, let’s assume we are using injection molding to make an item that uses 3in3 of material in one-shot (a single part). The mold costs $10K and each piece costs $0.10. If you make 100, then the final per part price is $100.10. But if you make 100K, then each part costs $0.20. **Note that this is a bit of a simplification, because the variable cost per piece will decrease with increased volume, but it gives you an idea of the concept.

For 3D printing, you start by creating a 3D model. The final STL file is fed into the printer and the part is printed. If you print the part yourself with a desktop printer, then the cost is simply the cost of the materials, which runs about $0.85/in3 for PLA or ABS. So, a part requiring 3in3 of material will cost $2.55. If you outsource the printing to a bureau, the print can cost about $1.75/cm3 ($28.68/in3), so $86.07 for the same part. This cost is generally the same whether you make 1 or 100.

cost comparison If you look at the entire supply chain as shown above, the product costs must also include the cost of inbound shipping (i.e., shipping that occurs prior to receipt at your DC – it excludes shipping to the customer). The graph below shows an example product cost at different volumes. You'll note that 3D printing stays the same price, but cuts off at fairly low levels, because it is unfeasible at higher quantities.

Lead Time: With traditional manufacturing, lead times depend on the time it takes to make the tooling, the manufacturing process and the volume of the order. Injection molding tooling can take about 8 weeks to make and perfect. The production time can be a day (if you were to make 100) or up to a couple weeks to make 100K.

The production time will also include any assembly and decoration steps. Finally, there is the time to transport the items from the factory to their destination. If you are producing nearby (uncommon) transport may take only a day or two. Across the country will take a week. Ocean shipping from Asia will take 3 weeks on the water, a few days in customs and then the time for land transport to your final destination.

Timeline comparison: For 3D printing, once you have your model, it takes about an hour to print a 1.5" round container (like a pill box) and up to a day for large more complex items. Multiply that by the quantity you want to produce. For some 3d printing processes, you can make multiple copies of the same item in one print, reducing the total time slightly. One of the missing pieces of 3D printing currently is having access to traditional finishing services (assembly and decoration) plus pack out into packaging. If an item needs these, then the time will be the same as traditional manufacturing. The time for transport for 3D printing is the same if you produce outside your local area. However, one of the advantages of this method is that it would be done in the US and most likely locally. So, shipping time is drastically reduced.

Quality: The quality of products made using traditional manufacturing all depends on the process being used and the diligence of the factory. The same goes for 3D printing although using low-priced desktop 3D printers is generally going to give you a lower quality product. So, as long as the right equipment is used with a good quality control process, quality is not a differentiating factor. For more information about the different 3D printing processes, see my earlier post.

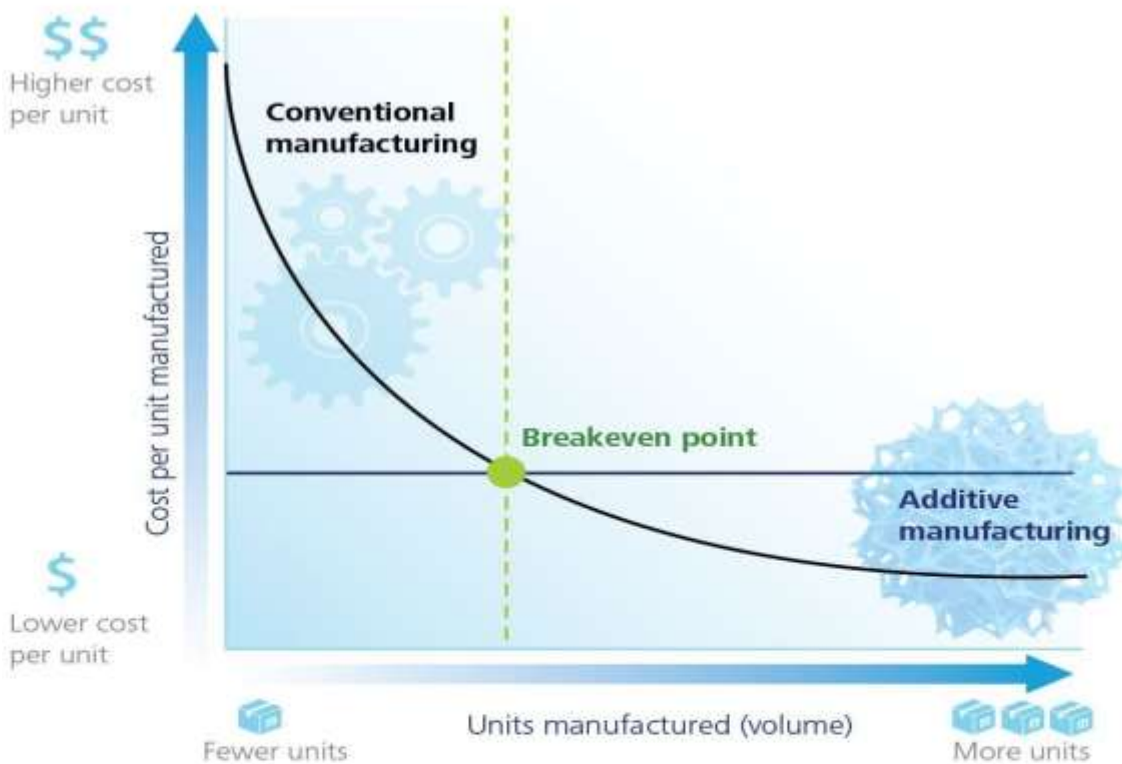


Fig-3: Brake even analysis for comparing conventional and additive manufacturing

3D printing has changed our manufacturing process in many ways. At present time we can make stuffs at very fast speed with a very low of processing time. In upcoming time 3D printing will not be limited to making stuffs but it will able to change the whole manufacturing and industrial process.

Improved access to printable digital models will be a key enabler in the adoption of 3D printing technology to support spare parts and aftermarket services [29]. CAD modeling is now ubiquitous within product design and engineering environments, meaning that digital files for spare part components are increasingly available.

These libraries of digital components will enable manufacturers and consumers to produce spare parts much more quickly and accurately. As adoption of the technology grows, engineers are also beginning to follow the principals of “Design for 3D Printing”, in which components are designed specifically to be manufactured using 3D printing technologies. Again, this will contribute to reduced lead-times and costs for 3D printed spare parts [29].

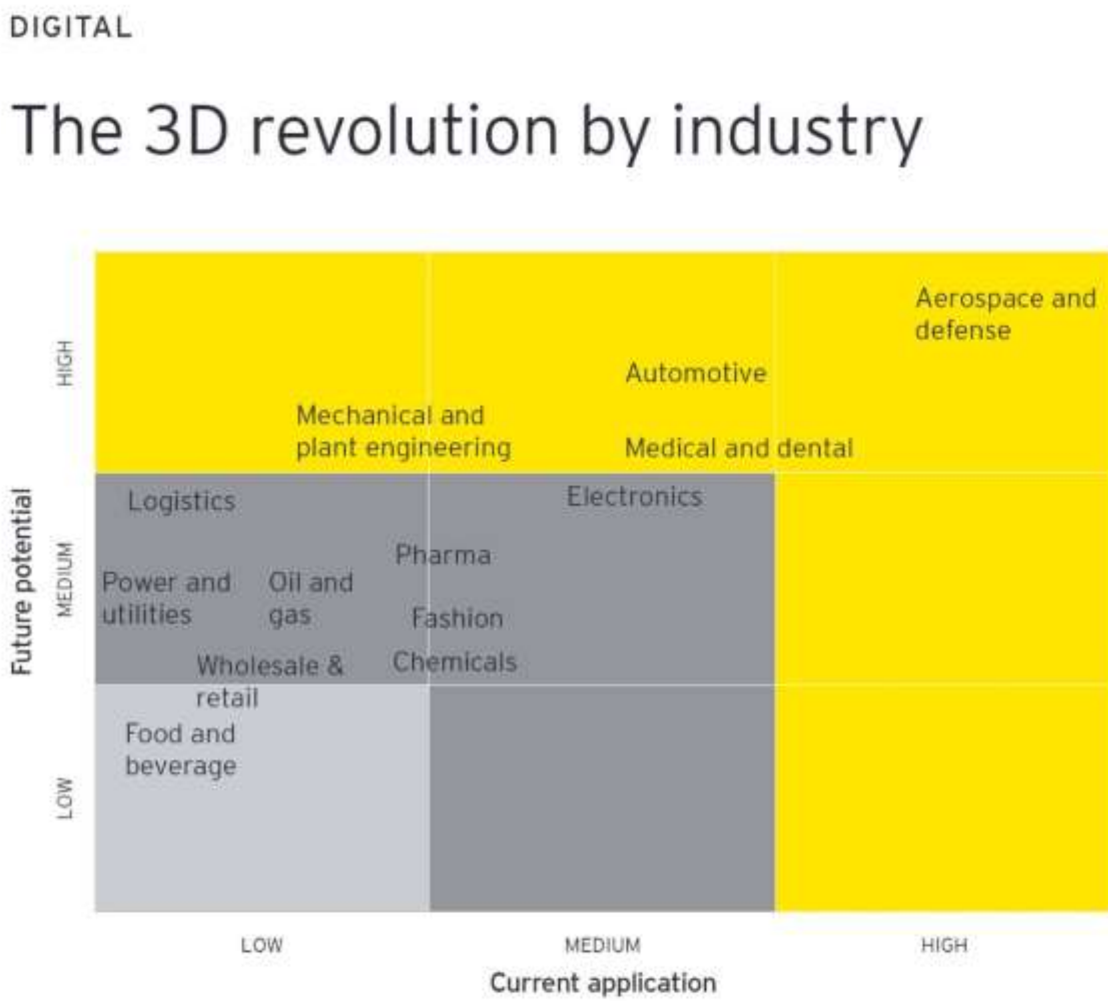


Fig-4: Field of industry that are mostly influenced by 3Dprinting

Graphical distribution of areas influenced by 3D printing:

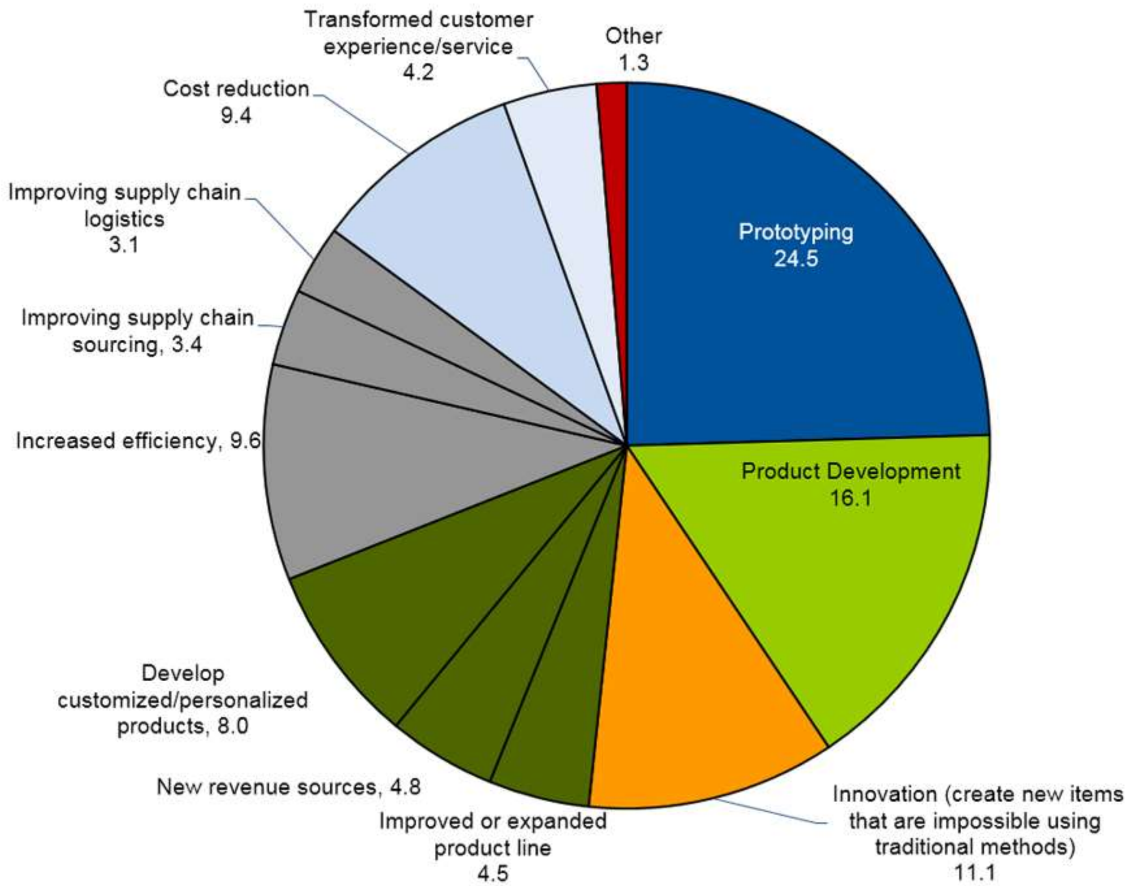


Fig-5: Graphical representation of 3D printing impacts

3.6: Major Impacts That 3D Printing Made In the Industry

1) Supply Chain

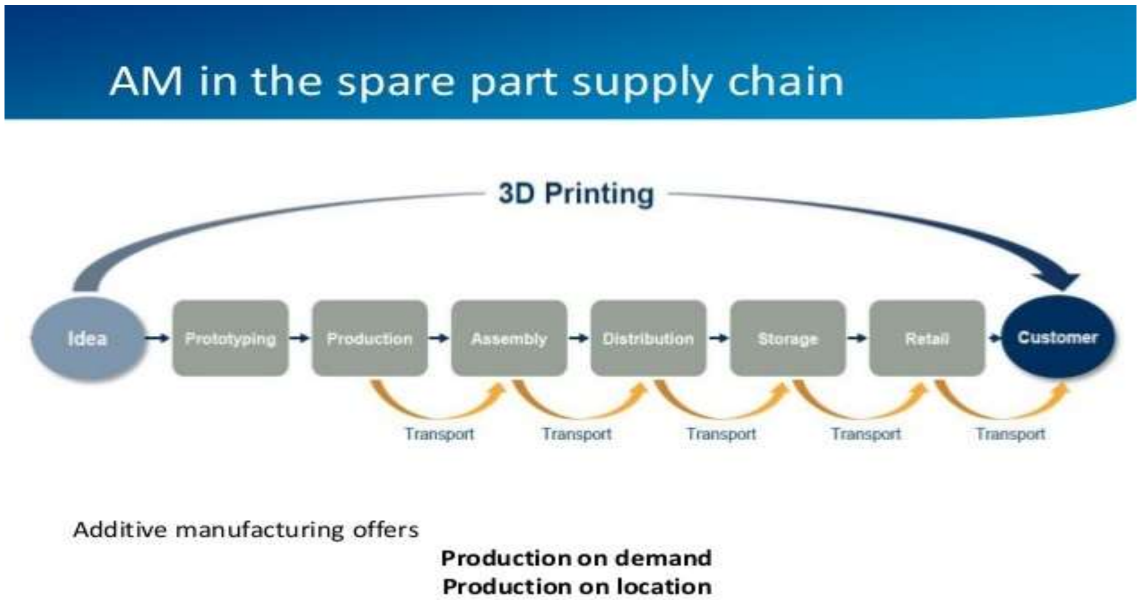
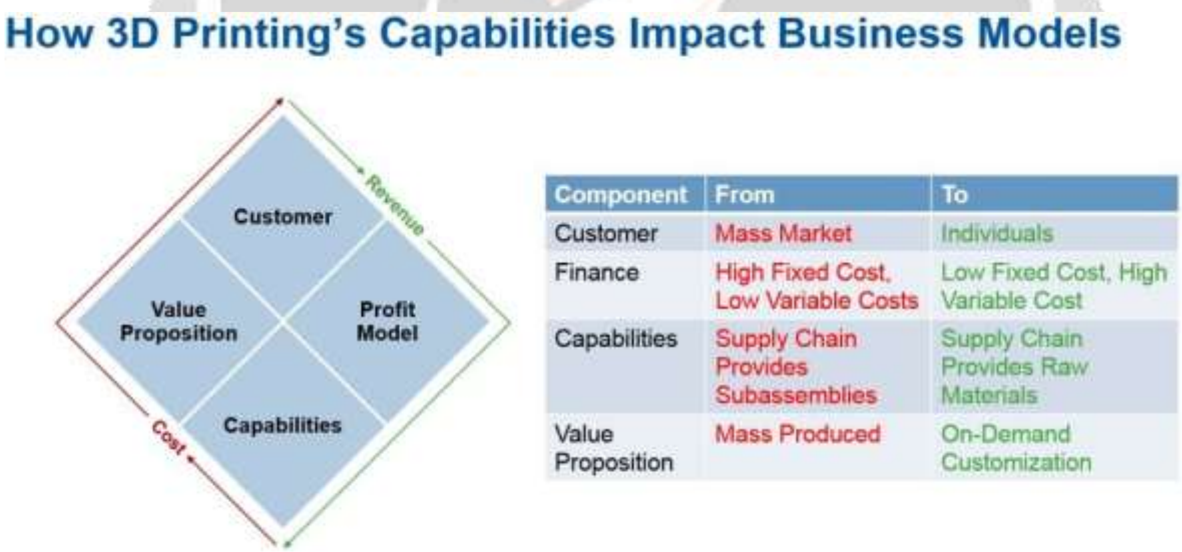


Fig-6: Impact of 3D printing on supply chain

2) Business Models



Component	From	To
Customer	Mass Market	Individuals
Finance	High Fixed Cost, Low Variable Costs	Low Fixed Cost, High Variable Cost
Capabilities	Supply Chain Provides Subassemblies	Supply Chain Provides Raw Materials
Value Proposition	Mass Produced	On-Demand Customization

Fig-7: Impact of 3D printing on business model

3) World Economy

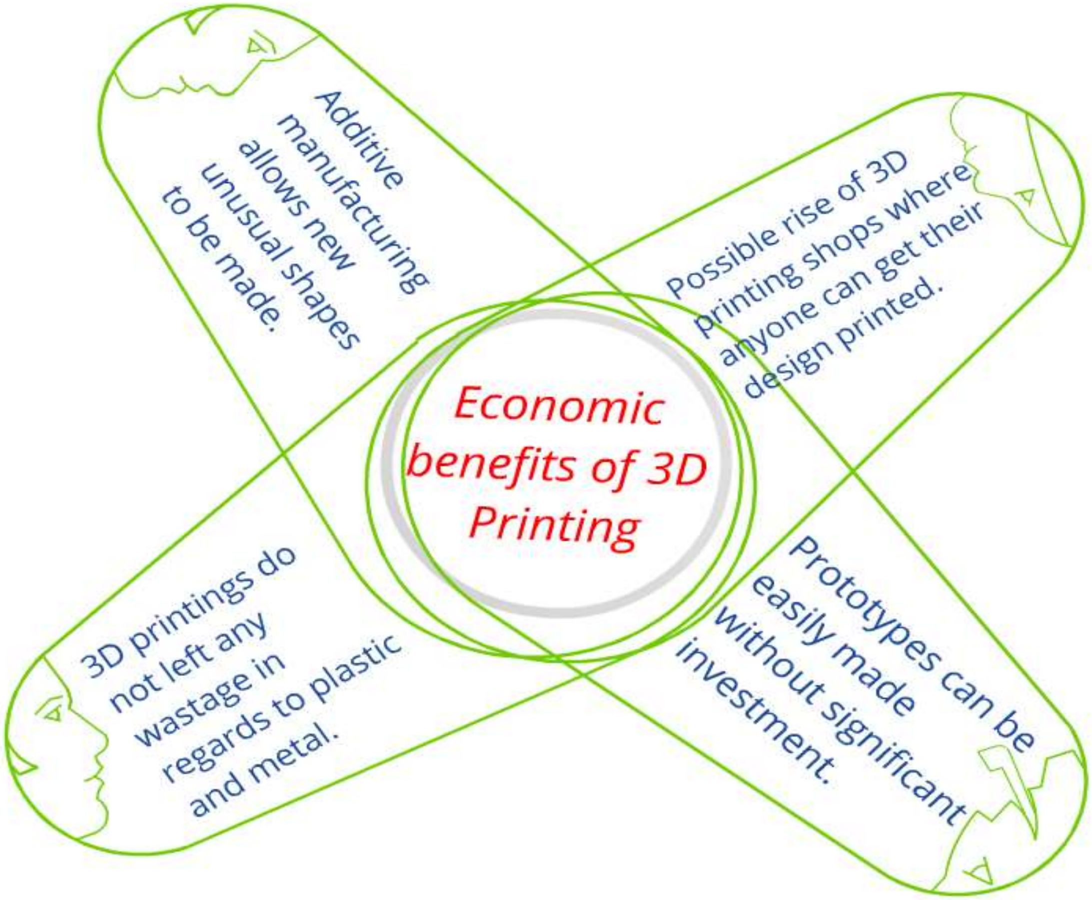


Fig-8: Impact of 3D printing on economy

3.7: Justification of Methodological Choices: I had selected both analytical and empirical methods to conduct my research study because this research is based on comparative review. The other numerical and quantitative methods would not work to analyze this study because this study is not related to numerical experiments. The graphical representation, tabulation, charts and figures have described this study very well so there's no need to use any other method. This method worked well to analyze and to describe the study data.

4. RESULTS AND DISCUSSION

4.1: Results

From the below results we can see that the 3D printing market the 3D printing market have almost doubled from 2014 to 2020. It proves that 3D printing or additive manufacturing is going to play major role in world economy.

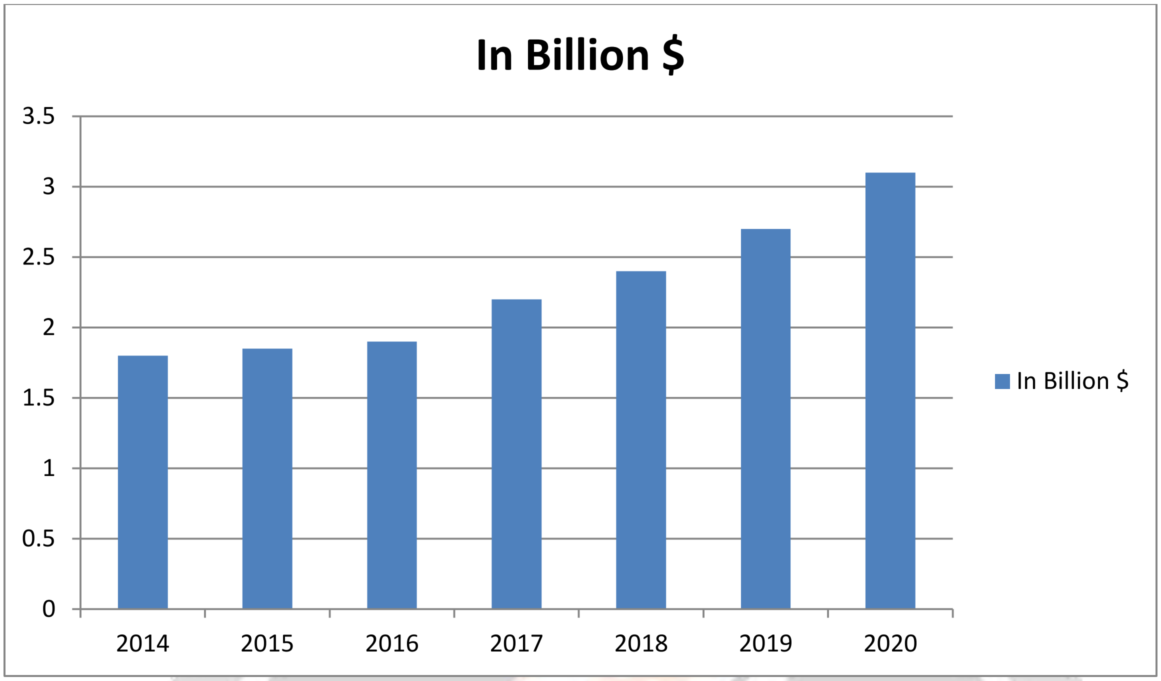


Chart-2: Graphical Representation of 3D printing Market Growth in 20th Decade

(Global 3D printing revenues from large public companies, U S $ billion, 2014-2020)

In this study I have clearly identified that 3D printing is not limited to making stuffs. It means it will not just change the way we make objects but it will change the entire industrial process like supply chain.

4.2: Discussion

As I have mentioned earlier that this study will find answer of how 3D printing will transform the industry. My study has been successful at many points to find the answers of the research question.

"In line with the hypothesis my results have proved that 3D printing technology will not only change the way we make stuffs but it will change the whole industrial process in many ways. These are the main aspect in that 3D printing will make a big difference".

- Production process
- Manufacturing process
- Supply chain
- Business modals
- Global economy

Contribution to the study

My Contribution to this research study is that it gave a broad idea of how a small technological change can make a big impact on the industry. These results challenge the previous studies to think again about this problem.

Practical Implication

In this chapter I explore how my findings are good enough to answer my research question is that how 3D printing will not only change the way we make objects but it will change the whole industrial process. "The experiment provides a new insight into the relation between 3D printing and additive manufacturing as the 3D printing is a part of additive manufacturing".

Research Limitations

Although I have used best methods to conduct my research study yet it has some limitations that the research design could be better. The methods and samples I have taken in this study are unable to give quick surety of what the results I have found. It will take years to prove the finding results as the 3D printing technology will come in trend.

Unanticipated Obstacle

It is beyond the scope of the study to address the questions of:

In how many times the 3DP technology will cover all areas of industry?, how this technology is safe in terms of intellectual property? And how long this technology will go till next evolution?

Recommendation:

There are some aspects where the current study is limited so there may be further scope to overcome the limitations of previous studies. Some of the points to be carried out further are given below:

I. Will 3D printing completely take the place of traditional manufacturing process?
II. Will this technology become as user friendly as the other technologies like mobiles and computers are?

5. CONCLUSION

As my whole research study is about finding the answer of the question that how 3D printing will transform the industry. This study gives the most pertinent answer of the question. I have already shown in the results and discussions that how there are many ways the 3DP technology will change the way of making objects and also the purchasing and selling process.

Selection of the approach: As I have already mentioned that I have taken both analytical and empirical approach in this study because this study method helped to analyze and describe the data and results in the best way. I expected to clarify the whole process that is going to be changed in the industry and I tried to find the answers of these questions at my best. I used every possible method to establish pertinent explanation of what I have done in this research.

Relevance: In my opinion the research methodology satisfy me at many levels to find the answers of my research problem. So I have no doubt to say that the methods I used was very relevant to this study.

"This research study clearly answers the question that how 3DP technology will transform the industry but at the other hand it also raises the question that if this 3DP technology will completely replace the traditional manufacturing process."

Further Scope: Although I have done the research on this problem yet there are many aspects on which in future someone can consider these for further works. Some of them aspects are described below

1) Improve 3D printers design and accessibility.
2) Make this technology more users friendly.
3) Reduce cost of 3D printers
4) Expand the applications of 3D printers

"To better understand the implications of these results further studies could address user friendly 3D printers to make a big change in the way we are making objects."

This research challenges the previous research studied that are limited to only how to make different objects by 3D printing technology. Further this study is about that the 3DP technology is not just about making different objects but it has many more impacts on many industrial processes.

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