International Journal of Engineering and Management Research e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-5 (October 2021)
www.ijemr.net https://doi.org/10.31033/ijemr.11.5.18

Growth of Additive Manufacturing Due to Global Pandemic and its Effect on Supply Chain Management

Drumil Newaskar[1], Shubham Gandhi[2] and Preet Aligave[3]
[1]Student, School of Mechanical Engineering, Vellore Institute of Technology, Vellore, INDIA
[2]Student, School of Mechanical Engineering, Vellore Institute of Technology, Vellore, INDIA
[3]Student, School of Mechanical Engineering, Vellore Institute of Technology, Vellore, INDIA

[1]Corresponding Author: drumilnewaskar@gmail.com

ABSTRACT

Additive manufacturing is a revolutionary technology because of its ability to creates objects by adding material layer by layer rather than removing material from a block or by moulding procedure. Additive manufacturing has been around for more than three decades but still, traditional manufacturing is the dominant method for manufacturing. COVID-19 pandemic has been a torment globally and has brought distress and instability to the global economy. Due to this, the manufacturing sectors are badly affected. In this time of crisis, additive manufacturing has played a major role. This paper discusses the upsurge of Additive manufacturing due global COVID-19 pandemic and its worldwide impact on supply chain management.

Keywords-- Additive Manufacturing, Supply Chain Management, COVID-19 Global Pandemic

I. INTRODUCTION

Additive Manufacturing

Additive Manufacturing refers to a set of processes that can directly produce parts through the incremental addition of material layers of joining materials. As a promising innovative technology, additive manufacturing provides great opportunities for existing production processes. As technologies mature and new materials become available, additive manufacturing has seen explosive growth in a variety of manufacturing industries, including automotive, aviation, medicine, and electronics. There is a wide range of additive manufacturing processes and corresponding material options are plastics, ceramics, and metals.

Additive manufacturing (AM) is also known as 3-D printing. It is a transformative approach to industrial production that enables to create stronger and lighter parts. Due to technological advancements, it is now possible to make a transition from analog to digital processes. Because of the digital revolution in recent decades, communication, architecture, imaging, and engineering have evolved. Additive manufacturing has brought flexibility in manufacturing operations and is also very efficient.

Additive manufacturing uses Computer-aided design (CAD) software or 3-D object scanners to create the parts and objects with precise measurements and geometries. With the help of CAD software, precise objects are created digitally which are then printed layer by layer using 3-D printers. Even though the terms "rapid prototyping", "3-D printing" is used to discuss additive manufacturing, these processes are actually a subset of additive manufacturing.

Additive Manufacturing Process

1. Create a 3-D model of the object to be printed. This model is designed with the help of CAD software or a 3-D object scanner.
2. The CAD file is converted into standard additive manufacturing file format –an STL file.
3. The STL file is then transferred to the 3D printer using custom machine software.
4. Consumables are then loaded and the setup of printer is done with printing parameters.
5. 3D printer builds the model by depositing material layer by layer. The layer thickness tells the final quality and depends on the machine and process.
6. After building the part, it is then removed from the build platform and its support structure.
7. Finally, post-processing is required, such as cleaning, polishing, painting, and finishing of the surface to the desired standard.

Processes

Binder Jetting – This system uses a 3-D printer style head to manoeuvre on x, y, and z axes to deposit the layers of powdered material and a liquid binder as an adhesive.

Directed energy deposition - This technique is used with a wide variety of materials such as ceramics, metals, polymers.

Material extrusion – Material extrusion is a very well-known additive manufacturing process. Metal extrusion uses spooled polymers that is extruded or drawn through a heated nozzle which is then mounted on a movable arm. The nozzle moves horizontally while at the same time the bed moves vertically, which builds the

melted material layer by layer. Through precise temperature control or by using chemical bonding agents' proper adhesion between the layers occurs.

Material jetting – In this technique, a print head moves back and forth, similar to the head on a 2D inkjet printer. In material jetting, the print head moves in x, y, and z axes to create 3D objects. Layers get hardened as they cool or can also be cured by UV light.

Powder bed fusion – Power bed fusion technology is used in various additive manufacturing processes, including Direct Metal Laser Sintering (DMLS), Selective Laser Sintering (SLS), Selective Heat Sintering (SHS), Electron Beam Melting (EBM), Direct Metal Laser Melting (DMLM).

Sheet lamination - Two types of Sheet Lamination methods are: Laminated object manufacturing (LOM) and Ultrasonic additive manufacturing (UAM). LOM uses visual and aesthetic appeal to create objects by using alternate layers of paper and adhesive. UAM uses ultrasonic welding for joining thin metal sheets. It is low energy and low-temperature process. UAM is used with metals such as aluminium, stainless steel, and titanium.

Vat polymerization – In this technique, an object is created layer by layer in a vat of liquid resin photopolymer. Mirrors are used to direct UV light which cures each resin layer through photopolymerization.

Types of Additive Manufacturing

Stereolithography (SL) – In this method, the parts can be directly fabricated from CAD models without tooling or fixtures. It's a simple and cost-effective way of fabrication of 3D structures.

Fused Deposition Modelling (FDM) – It uses a temperature-controlled extruder to extrude the thermoplastic filament material and deposit the semi-molten polymer into the platform during a layer-by-layer process. The monofilaments are driven by two rollers acting as a piston to drive the semi-molten extrusion. At the top of every finished layer, the bottom platform is lowered and also the next layer is deposited.

Laminated Object Manufacturing (LOM) – In the Laminated Object Manufacturing (LOM) technique, a 3D part is created sequentially layer by layer from a perfectly crossed paper roll and serves as a disposable base for the portion to be manufactured. The paper roll has a thermostatic adhesive coating on the underside, and the lamination is done by using a heated stainless-steel cylinder.

Selective Laser Melting (SLM) – This process is obtained through various powder binding mechanisms. In order to reach a high density, the metallic powder particles are completely melted and then fabricated into 3D structures.

Selective Laser Sintering (SLS) – It is a multi-layered manufacturing process that allows the generation of complex 3D parts by merging successive layers of powder material on top of one another. The blending is obtained by treating the specific areas with the thermal energy provided by the focused laser beam.

Digital Light Processing (DLP) – Digital light processing is a 3D printing process that works on optical polymers. DLP needs a more traditional light source like an arc lamp which has a liquid crystal display panel, that is applied to the entire surface of the optical polymer resin vessel in one pass.

Electron Beam Melting (EBM) – In the Electron Beam Melting process, the raw material, metal powder, or wire is placed under a vacuum and fused together from heating by an electron beam. (M. Varsha Shree and V. Dhinakaran, 2019)

Advantages

Complexity does not cost more – It usually does not costs more to print a more complex part instead of a simple cube of the same size. The more complex the parts are the faster and cheaper it is made through additive manufacturing compared to traditional manufacturing.

Variety is free – If an area must be changed, the change can simply be made on the primary CAD file, and thus the new product is often printed directly. No assembly required – Moving parts like hinges and bicycle chains are often printed in metal directly into the goods being produced, which can significantly reduce the part numbers.

Little interval – Engineers can create a prototype with a 3-D printer immediately after finishing the part's stereo lithography (STL) file. As soon because the part has printed, engineers may then begin testing its properties instead of waiting weeks or months for a prototype or part to return in. Little-skill manufacturing – While complicated parts with specific parameters and high-tech applications got to be left to the professionals, even children in grammar school have created their own figures using 3-D printing processes.

Few constraints – Anything you'll think of and elegance within the CAD software, you'll create with additive manufacturing.

Less waste – Because only the material that's needed is used , there's little or no (if any) material wasted.

Infinite reminder materials - Engineers can program parts to possess specific colours in their CAD files, and printers can use materials of any colour to print them.

Disadvantages

Slow build rates - Many printers print material at a speed between one to five cubic inches per hour. Depending upon the part needed, other

manufacturing processes could even be significantly faster.

High production costs - Sometimes, parts are often made faster using techniques apart from additive manufacturing, therefore the overtime can cause higher costs. Adding to it, the best in quality additive manufacturing machines or printers would cost anywhere from $300,000 to $1.5 million, and material for the production will cost $100 to $150 per pound. Considerable effort in application design and setting process parameters - Extensive knowledge of cloth design and thus the additive manufacturing machine itself is required to make quality parts. Requires post-processing - The surface finish and dimensional accuracy could even be lower quality than other manufacturing methods.

Discontinuous production process – This means only one part can be made per printer at a given point of time.

Limited component size/small build volume – Large parts have a restriction while coming to additive manufacturing and we require bigger spaces for bigger comp-ponents and in turn require a bigger machine for it which would again increase the cost.

Poor mechanical properties - Layering and multiple interfaces can cause defects within the good produced.

No Mixing Allowed - The mechanical properties of a finished product are dependent upon the characteristics of the powder utilized within the method. Additive manufacturing typically uses a pre alloyed material within the bottom powder.

Supply Chain Management

Supply Chain Management is the control of the movement of goods and services from the production to the time it reaches the consumer. It comprises of all processes that turn raw materials into finished goods. It entails actively streamlining a company's supply-side operations so as to extend consumer satisfaction and achieve a competitive edge up the industry. SCM refers to manufacturers' efforts to style and execute supply chains that are as reliable and cost-effective as possible. Supply chains include everything from manufacturing to product creation, also because the information systems want to coordinate these activities. (Emmanuel Roy, 20121)

A lot of problems faced during supply chain can be sidestepped with additive manufacturing. With the current geo-political stress's parts get held up at times on the borders and are no able to reach in time for production. A lot of cross-country trade issues can be avoided by transferring the designs over the internet and produce parts on demand at the required location. The digital inventory is the most effective addition to the supply chain through additive manufacturing. This gets rids of the enormous amounts of physical inventories (its storage and maintenance) as well as cost of transportation. We only need to procure one raw for an assembly instead of multiple parts and their assembly process.

There are certain drawbacks to the procedure as well. With the rise in cybercrime keeping important patented designs on the cloud could lead to a leak of sensitive company product designs. AM also pushes down the manufacturing process down in the supply chain as compared to traditional manufacturing process. This could lead to quality issues in the final product if consistency is not maintained.

II. TRADITIONAL SUPPLY CHAIN MANAGEMENT

Supply Chain Management is the control of the movement of goods and service s from the production to the time it reaches the consumer. It comprises of all processes that turn raw materials into finished goods. It entails actively streamlining a company's supply-side operations so as to extend consumer satisfaction and achieve a competitive edge up the industry. SCM refers to manufacturers' efforts to style and execute supply chains that are as reliable and cost-effective as possible.

There are a few different types of supply chain models. Some of them are:

i. Agile Model: This is ideal for businesses which provide specialty order items to the consumer. Example: Louis Vuitton, Zara.

ii. Continuous Flow Model: This is used for products which have a high demand in the market with little to no fluctuations.

iii. Custom Configured Model: This for products which require some custom configuration during production and assembly. Example: Custom made automotive.

iv. Efficient Chain Model: This is predominantly including the businesses which are in a highly competitive environment and end efficiency is a priority. Example: Mobile phones.

v. Fast Chain Model: It is used for trendy products with a short life cycle. Example: Consumable items

vi. Flexible Model: This model provides flexibility for high as well as low volume product movement.

vii. Supply Chain Operation Reference (SCOR) Model: This model evaluates waste, establish standards and continuous improvement in the SCM system.

In today's competitive business environment, selection of suppliers represents one of the most critical issues faced by manufacturing firms. The cost of raw

materials comprises a serious portion of the product's final cost and therefore the selection of appropriate suppliers significantly reduces the purchasing costs in manufacturing firms. (Ashish Deshmukh and Hari Vasudevan, 2014) Two practices of supplier selection in today's time are:

i. One supplier can satisfy the buyer's entire requirements and the buyer needs to make only one decision: finding the best supplier.
ii. More common type (multiple sourcing), more than one supplier must be selected, because no single supplier can be able to satisfy all the requirements of the buyer.

Hence, for effective supply chain management, firms got to select both the simplest set of suppliers and find on what proportion quantity should be allocated among them for creating a constant environment of competitiveness (Alyanak and Armaneri, 2009). Moreover, with the changing environmental requirements, affecting the manufacturing operations, increasing attention is additionally required to tend to develop effective environmental management (EM) strategies for the availability chain.

III. PROBLEMS ARISING DUE TO COVID-19

Countries are trying to minimize the spread of virus by minimizing travel and trade activities. This has made a severe impact on the supply chain of products leading to losses. Lockdowns are imposed to minimise the spread of virus but it brings along with its major losses in trade. It is being countered with a slower approach by imposing regional lockdowns to suppress the virus from spreading fast. This will reduce the overall damage and losses caused as compared to a complete longer lockdown. The restrictions imposed to contain the spread of the virus have led to severe shortages and imbalance in most markets. The reduced labour capacity, as well as transportation capacity were the reason for these losses in trade. These losses propagate through the complex supply chain networks that exist already. Companies which have a direct exposure to the COVID-19 outbreak are taking actions to save costs and minimize losses, including:

i. Resource allocation and assembly ahead of time to provide a buffer in case of a short-term disruption (i.e., short-term lockdown).
ii. Moving inventory away from severely affected areas or quarantined areas to places where it can be easily accessed for shipping to plants.
iii. Procuring extra inventory and raw material which are in short supply in severely affected areas
iv. Keeping the customers updated about the delays and adjusting product allocation according to demand to increase revenue or meet the terms defined by the contract.
v. Offering a discount of available inventory to increase short-term revenue.
vi. Offering incentives to vendors who maintain a consistent supply chain.
vii. Making a recovery strategy to be implemented as soon as the situation returns to normal.

Companies are doing their best to figure out the changes in the supply and demand volume changes to make forecasts for the upcoming quarters. It is hard to get an exact figure for the procurement of materials as a second wave of COVID-19 has further affected the recovering supply chains.

IV. THE SHUTDOWN OF MANUFACTURING SECTORS AND ITS REASONS

The COVID-19 pandemic has disrupted most of the industrial manufacturing jobs that cannot be carried out by the workers remotely. The manufacturing sector has had a huge impact on its operations due to the disruption of supply chains. Many major industrial companies have closed down their manufacturing plants and even had to lay off employees. According to data from the Annual Survey of Industries (2017-18), India's factory sector employed 15 million workers, which amounted to about quarter of all workers (60.2 million) in the country. This number was hit hard during the COVID outbreak as most of the jobs are on-site and cannot be done remotely. The coming of Industry 4.0 or the Internet of Things technologies have shown an increase in productivity in the manufacturing sector but it has negative impact on the labour share as it reduces number of jobs. The health of the consumer and workforce is the topmost priority of the manufacturing industry. Closure of plants completely or partially might be necessary for severely affected regions for an extended period of time. Major manufacturers are running their plants with the bare minimum number of employees. Some of them have been exempted from the complete lockdown to maintain a continuity of process (e.g., Steel Authority of India). Before the pandemic, the manufacturing sector made up around 16% of India's GDP. The "Make in India" program was intended to increase this to 25% by the year 2022 as well as create more jobs in the sector. The manufacturing sector employs around 56.4 million people in India could see 15-16% people lose their livelihood across different sectors like textiles, capital goods, food products, metals, plastics, rubber, and electronics, due to the pandemic outbreak. Since the launch of Make in India, FDI (Foreign Direct

Investment) in the country has followed an optimal trend. With the pandemic, we face an altogether different and dark reality. More than 9 million (90 lakh) people have lost their jobs in the manufacturing sector as a fallout of the COVID-19 outbreak. The global FDI inflows have witnessed a sharp decline. The industry is in a very vulnerable state given that most of the employed workforce has to work on-site and social distancing is not easy given the worker-dense environment. Immediate action needs to be taken if anyone is found COVID positive among the ranks of the workforce.

V. EFFECT ON OPERATIONS AND SUPPLY CHAINS

There will be a lot of shaken links in the supply chain as many suppliers will face operational and financial issues. Deep we dive into the supply chain, the more problems we will detect. This will not only affect the Original Equipment Manufacturers but also show ripple effect throughout the supply chain. Last mile or lower tier suppliers who are not in direct contact with Original Equipment Manufacturer and do not have a huge online presence will face a lot more problems. The industry must adapt and evolve to the given circumstances and plan for changes in the supply chain and their workforce. This outbreak has made companies think about shifting towards automation technologies more (e.g., Robotics, Industrial Internet of Things, Additive Manufacturing) to decrease the workforce involved throughout the operations and supply chains of their plants. Enhancing the visibility and responsiveness to avoid disruption.

VI. IMPACT OF COVID-19 ON SUPPLY CHAINS

The Supply Chain is a logistics network that is made up of manufacturers, suppliers, warehouses, distribution centres, and retail outlets and customer. The standard Supply Chain procedure involves, raw materials being sent to factories where goods are manufactured, these products are then shipped to warehouses for storage and then to retailers and subsequently to customers. Covid-19 pandemic is the latest, in an increasing number of unexpected disruptions that have been hitting the supply chain.

Supply Capability Decreasing: -

i. Travel restrictions lead to loss of belly cargo, about 52% of ton-kilometres of freight flew in the belly passenger plane.
ii. Thus, air transport prices have seen a rise.
iii. Logistics companies like FedEx and Ups have cut down on limits. Also so has the demand dropped (of certain goods), in both affected and unaffected places.

Particular problems which have come up due to the pandemic are: -

i. There are huge shifts in demand for specific/certain items, which also causes other problems like mentioned ahead.
ii. Shortages, e.g., lack of hand sanitizer and paper products, comes down to manufacturing constraints.
iii. Bulk Storage/Rationing, e.g., many retailers respond to shortages by rationing certain items.
iv. Prioritization, e.g., retailers prioritize supplies and deliveries of certain items with high demand and better profit margins (household and medical).
v. Reduction in the number of Stock-Keeping Units (SKUs) that retailers offer to make their supply chains more manageable or flexible, many retailers have been reducing product variety. To focus on to items that are currently in high demand and make more storage space for the same which takes options away from consumers. (Imran Ghori, 2020)

Fundamentally, managing supply chains during a crisis is not business as usual Also, there is an imbalance in transport, several container ships were stocked at one place, and there is a shortage of them in one place and a surplus in other. Also, the reduced freight capacity is prevalent.

About Statistics:

i. 94% of the Fortune 1000s are seeing major Disruptions-Fortune Magazine
ii. 57% of companies have reported that their lead times have worsened since late 2019, of that 57% say their lead times are doubling.
iii. 14% of the facilities that make active pharmaceutical ingredients are in China, thus major shortages of various products being caused, as major producer gets hit by disruption.
iv. 44% of companies said they have no particular plan on how to deal with China-based trade disruption.

Several small logistics companies have run out of business or have had to change from their main task to sustain. Manufactures which are dependent on several different suppliers to assemble one single product faced problems as they would be having problem in obtaining few parts as their supply chain got disrupted. Altogether, those people are most affected who were dependent on few suppliers, obviously for cheaper per-unit costs of products, so those have survived who quickly found alternatives like switching to other cheap labour countries. 221 countries and territories have reported at least one Covid case as of March 2021. With more than 115 million cases including

more than 2.5 million deaths worldwide according to WHO. World experiencing the worst recession since World War 2. The global economy contracted by 4.9% according to IMF. According to World Trade Organization forecasts world trade volume declined by 9.2%. Supply chains have been disrupted in the past in catastrophic events like the 2003 SARS outbreak in China, the 2004 tsunami in Indonesia, and the 2011 mega earth-quake in Japan. These events led to a shortage of parts and products and disrupted Global Supply Chains but these were recovered in a matter of weeks. As most of these events are geographically limited and occurred in short time periods. Whereas Covid-19 has spread throughout the globe and has been around for more than 1 year now. It has forced Billions in lockdown and confinement zones. (Vijay Tambrallimath and R. Keshavamurthy, 2020)

VII. IMPACT OF ADDITIVE MANUFACTURING IN OVERCOMING THE PROBLEM OF DISRUPTION OF SUPPLY CHAINS

The current supply chain is inefficient as the most common means of shipping goods is from one country to another through water ways, which is not fast enough, and takes at least few days.

Although because of waterways, the products are made affordable. Cause if goods are shipped through airways, general public for sure would not be able to afford many of them.

Shipping products according to demand is difficult, if one needs few spare parts, they always have to order them in bulk, otherwise it would be too costly again and in turn there are high levels of inventory costs. Now let's see how it would change things if we shifted to localised manufacturing through additive:

i. Earlier parts were shipped through the three known methods, airways, roadways and waterways, but now they could be transferred through internet. Thanks to additive. Thus, this solves the major issue of the current supply chains. Now small businesses can get their parts locally manufactured, just by locating a 3D printer nearby and as it gets more common, the process gets easier. This would lead to a completely different type of manufacturing era resulting in reinventing the whole supply chain through a manufacturing revolution. This system would also not allow to gain monopoly easily.

ii. Need of warehouses would be greatly reduced, as parts instead of being stored in warehouses, can be stored in computers and printed as and when needed locally. This again brings down the cost of the product.

iii. The logistics expense would be of a different type as most of the transportation would be local and of shorter distances, so it will help save a lot on transport expense by eliminating air and water freight.

iv. The number of products produced can be controlled as to near to the point of consumption, allows to produce goods in quantities just as much as required. This again saves a lot on excess cost of storage and stocking.

v. Reduction of the number of parts in a single product is also possible, as such complex geometries which couldn't be manufactured through conventional manufacturing methods, can now be done by 3D printing.

vi. As Printers have become smaller and cheaper and are becoming much cheaper day by day, plus, as they are not very difficult to operate, and anyone can be easily trained to operate them, thus for manufacturing products and components, one would not have to rely on big manufacturers. A local manufacturing supply chain would be developed.

vii. A lot of components are printed faster than built from scratch. Thus, lead time in manufacturing such products also will be greatly reduced.

viii. As with current technology we are even able to print Metal parts, thus various automobile manufactures have started to test it. Previously different components were made in different places and then transported and were assembled at another place but with additive technology one could print and assemble everything at a single place giving an advantage of saving time and transport cost as assembly and manufacturing are taking place close to each other.

ix. Additive manufacturing generates significantly less waste than traditional manufacturing methods. In case of a milling machine, it works by removing material from a block that is bigger than the product. The removed material ends up as wate because it usually comes form of shavings or kindling that cannot be reused. In Additive manufacturing instead of removing material, it adds material layer by layer to build the product, so that only what is required is used. Thus, additive manufacturing can reduce material costs and waste by almost 90 percent.

x. When compared with traditional manufacturing processes, additive manufacturing can significantly reduce energy usage by using less

material and eliminating steps in the production process.

xi. The additive nature of the process allows for the fabrication of complex geometry, which unlike of traditional subtractive manufacturing methods, do not require specialist tooling. Thus, production can switch from one part to other almost instantly, and this has been demonstrated by those with Additive Manufacturing capabilities producing products on demand.

xii. Additive manufacturing is sustainable as it can use solar energy to produce products which in turn results in elimination of any harm to the environment.

VIII. EFFECT OF COVID 19 ON THE 3DING COMMUNITY

The community of AM users came together and formed a response network to contribute to the PPE and ME relief effort, by manufacturing devices on their 3D printers. (Elen J Parry and Craig E Banks 2020) These efforts were often collaborative and were being referred to as a 'citizen supply chain'. The Additive Manufacturing community have actively shared designs, digital files and knowledge etc., through digital networks making it a simple task for anyone with access to a 3D printer to contribute.

Many other facts that became evident due to COVID19:

i. By operating locally, manufacturers can increase their responsiveness and directly supply the product by reducing supply chain complexities. Major positive outcomes of localized manufacturing include reduced lead time and in most of the cases even lower costs.

ii. Additive Manufacturing has shown to be a very effective tool for rapid prototyping and for producing clinically certified MDs and equipment on demand, which formerly could have taken between months and years to develop. Nonprofessional Additive Manufacturing has also prompted remarkable innovation and collaboration from Additive Manufacturing communities, with a significant number of low-risk devices, PPE and ME being produced locally.

iii. Ventilators, Swabs for testing, face shields, Splitter multiplying ventilator capacity, antimicrobial polymers, Hand sanitizer holders, Non-invasive positive and expiratory pressure masks, Oxygen valves were manufactured through 3D Printing locally in various cities to decrease the time taken to reach the markets. Most of these products are only possible to manufacture with 3D Printing due to their complex geometries and ability to alter the design as per the needs of healthcare sector. (Pawan Arora and Ranjan Arora, 2020)

IX. DIVERSE APPLICATIONS

The development of additive manufacturing has witnessed a rapid growth in the number of companies adopting this technology. Applications and use cases vary across industries, but largely include supporting tools, visual and functional prototypes - and even end-use parts. As the potential applications of additive manufacturing increases, companies have started to find ways to create innovative business models and opportunities using technology. Additive Manufacturing is being widely used in various kinds of industries including automotive, manufacturing, healthcare and consumer goods. Additive manufacturing is being used by major car manufacturers to manufacture gear sticks and safety gloves, fashion designers are producing additive manufactured printed handbags and shoes and companies are producing custom foot insoles with the help of a single scan of a customer's foot. The possibilities really are endless and we are looking forward to seeing what comes out of the industry over the next few years.

X. CONCLUSION

Additive Manufacturing printing completely reinvents the way things are conceived, designed, produced and distributed, significantly lower development and production costs, immensely simplifying supply chains, and lower carbon footprint. AM has a great potential of producing locally to reinvent and simplify the global supply chains, and it has been observed that more and more companies are on the verge of turning to additive manufacturing rather than using the conventional methods of manufacturing in order to stay competitive and create customized products faster.

Additive manufacturing will act as a facilitator for substantial changes within the global manufacturing sector, and leaders will be known by their ability to harness its disruptive power.

In future, the production of goods will be driven closer to the consumer, democratizing manufacturing on a large scale and allowing products to be mass-customized, designers will be free to create entirely new innovative and custom products, as the line between ideas and physical reality fades away. Manufacturers will no longer tethered to overseas factories as supply chains will be shortened and with a new ability to custom-produce anything, anywhere.

REFERENCES

[1] M. Varsha Shree, V. Dhinakaran, V. Rajkumar, P.M. Bupathi Ram, M.D. Vijayakumar, & T. Sathish. (2019). Effect of 3D printing on supply chain management. *Materials Today: Proceedings.*

[2] Vijay Tambrallimath, R. Keshavamurthy, Abhinandan Badari, Lohith Ramesh, & Gagan Raj. (2020). Emergence of additive manufacturing in global scale during the crisis of 2019-nCoV (novel corona virus). *Materials Today: Proceedings.*

[3] Pawan K. Arora, Ranjan Arora, Abid Haleem, & Harish Kumar. (2020). Application of additive manufacturing in challenges posed by COVID-19. *Materials Today: Proceedings.*

[4] Ashish Deshmukh & Hari Vasudevan. (2014). Emerging supplier selection criteria in the context of traditional vs green supply chain management. *International Journal of Managing Value and Supply Chains.*

[5] Alyanak, G. & Armaneri, O. (2009). An integrated supplier selection and order allocation approach in a battery company. *Makine Mühendisleri Odasi*.

[6] Elen J Parry & Craig E Banks. (2020). COVID-19: Additive manufacturing response in the UK. *Journal of 3d Printing in Medicine.*

[7] Imran Ghori. (2020). *How Covid-19 is affecting the global supply chain*. Available at: https://news.ucr.edu/articles/2020/04/29/how-covid-19-affecting-global-supply-chain.

[8] Emmaneul Roy. (2021). *Supply chain management: What is SCM and why it is important?*. Available at: https://businessyield.com/management/supply-chain-management/.