3D PRINTING TECHNOLOGY – APPLICATIONS, BENEFITS AND AREAS OF OPPORTUNITY IN NIGERIA

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ABSTRACT

Three-dimensional (3D) printing technology, often referred to as additive manufacturing differs from traditional manufacturing processes in that 3D objects are built by successively creating layers of material on top of each other. Since development in 1980s, 3D printing has undergone technological transformation that could fundamentally alter production processes in a wide set of applicable areas.

Despite the accelerated advancement, both in academic research and industrial application that 3D printing technology has witnessed in diverse areas of human endeavor especially in advanced countries; the technology is relatively at its infant stage in developing countries like Nigeria. Thus, this work attempts to address the underrepresentation of research that is specifically concerned with the impacts that 3D printing can make in diverse sectors in developing countries like Nigeria. It addresses this issue by focusing its investigations on the applications of the technology, derivable benefits from the application of the technology as well as diverse areas where 3D printing can present a great deal of opportunities for Nigeria.

1.0. INTRODUCTION

Scientists and engineers are continually enthralling humanity on a daily basis with revolutionary technologies turning what was recently considered as science fiction or inconceivable futuristic into reality; thus, making lives much easier and stimulating. For instance, have we ever imagined being able to make our own designed glasses frame, sport shoes, kid's toys, or any other prototypes at home using raw materials and a single machine? These are made possible by 3D printing technology and it has much more complicated applications in science and industry.

There are diverse similar definitions and terminologies used to describe 3D printing such as additive manufacturing and rapid prototyping (Mohr and Khan, 2015). However, all of them describe the main distinguishing thought from ordinary subtractive methods which is Additive manufacturing.

On the whole, 3D printing is a process by which 3D solid objects of any shape or geometry can be made from a digital file. The creation is achieved by laying down successive layers of a specific material until the entire object is created. Each of these layers corresponds to a thinly sliced horizontal cross-section (similar to the output of an ordinary printer, this is why it is called printing) of the eventual object, in contrast to traditional subtractive manufacturing methods which is based on removal of material to create something (Mohr and Khan, 2015).
The technology has evolved from simple prototyping to fully integrated utilizations in direct manufacturing and as a result of its diverse applications, 3D printing is said to be one of the most significant industrial developments of this decade (Manners-Bell and Lyon, 2012; Mohr

and Khan, 2015). This has lasting implications on many companies in multiple industries such as production and manufacturing, research, business development and design (Cohen *et. all*, 2014; Mohr and Khan, 2015).

Mohr and Khan (2015) anticipated the global market size for 3D printing to grow from 3 billion USD in 2013 to 13 billion USD by 2018, and surpass 21 billion USD by the year 2020. Gartner reports similar numbers, forecasting the market to reach a size of 13 billion USD in 2018 (Basiliere, 2013). These numbers clearly show that the consensus among experts and researchers is that this technology is expected to keep growing, which makes it an important element to be tapped into by developing countries like Nigeria. This is why Nigerian industrialists and academics alike must follow the trends and developments of this technology closely in order to tap into the diverse areas of applications. This is the motivation for this research study.

Numerous cases from the industry especially in the global manufacturing sector prove evidence of the ongoing success of 3D printing (Mohr and Khan, 2015). Large global manufacturers such as General Electric, Siemens and Airbus are using the technology to produce fuel nozzles (General Electric, 2015; Catts, 2013), gas turbine components (Kleinschmidt, 2014) and aircraft parts (Airbus, 2014; Simmons, 2015). Other firms, such as automotive companies like Ford use the technology to produce tools for their production process, such as molds for casting (Ford, 2015). The consumer industry is not left out by embracing the technology in various ways as well, with the candy goods manufacturer Hershey's employing the technology to create customized pralines (Goldin, 2014).

1.1. RESEARCH MOTIVATION

Academic research about 3D printing has accelerated alongside the emergence of the technology in recent years especially in advanced countries. However, the technology is relatively at its infant stage in developing countries like Nigeria. Thus, there is a strong need to address the underrepresentation of research that is specifically concerned with the impacts that 3D printing can make in diverse sectors in developing countries like Nigeria. This study addresses this issue by focusing its investigation on the applications of the technology, derivable benefits from the application of the technology as well as diverse areas where 3D printing can present a great deal of opportunities for Nigeria.

2.0. DEVELOPMENT AND EVOLUTION OF 3D PRINTING TECHNOLOGY

Hideo Kodama of Nayoga Municipal Industrial Research Institute is generally considered the first to print solid object from a digital design (Bhandari and Regina, 2014). However, Charles Hull is generally regarded as the pioneer 3D printer designer, having designed it in 1984 while working for his company, 3D Systems Corp (Bhandari and Regina, 2014). Charles Hull happens to be the forerunner of the solid imaging process called stereolithography (STL) and its (STL) file format which remains the most commonly used format in the present day's 3D printing. He also initiated commercial rapid prototyping which was concomitant with his development of 3D printing. He originally applied photopolymers heated by ultraviolet light to accomplish the melting and solidification result (Bhandari and Regina, 2014).

3.0. OVERVIEW OF WORKING PRINCIPLE OF 3D PRINTING TECHNOLOGY

The key principle of 3D printing according to Bandari and Regina (2014) is stereolithography, which is a system for creating 3D objects by making a cross-sectional

outline of the object to be made. This signifies that any 3D item created using 3D drawing software is initially ripped into layers which are then successively printed by the machine on top of one another.

The beginning of any 3D printing procedure is the generation of 3D digital model, which can be made via a diverse 3D software programs. A scan of an existing artifact is also possible as initializing process. After the designing step comes the printing part where the model is 'cut' into layers, thus, translating the design into a file legible to the 3D printer (Oko institute, 2013).

The 3D printer generates the item by forming each layer via the discerning placement of material. Ponder on an inkjet printer which goes back over and over the page, adding layers of material over each other until the original works become 3D item. The material processed by the 3D printer is usually layered in conformance to the design and process.

The time required for the completion of the printing depends on the printer being used, the materials being worked on as well as the complexity of the structure. 3D printing technology has certainly progressed far. However, there is still a long way to go until it becomes a part of homes like regular 2D printers.

4.0. AREAS OF APPLICATION

3DP technology has a wide variety of application that cuts across numerous sectors and fields. It is applied in industrial designs, automotive design, consumer commodities, biomedical engineering and dentistry (dental); as well as aerospace among several others. Traditionally, large companies have been applying the technology to create prototypes before the final production until recent where the technology is being applied to full-scale manufacturing of products.

According to Technopolis Group (2013), designers and engineers have been employing 3D printers for over a decade, but usually in making prototypes swiftly and economically. Most of the applications are for prototypes, useful models, casting patterns and in some cases, for presentation models. With advancement in the technology, more items are being printed as ready made goods. About 28% of 3D printers' outputs are now end products instead of ordinary prototypes, and this is predicted to upsurge to 50% by the end of 2016 and 80% by 2020.

Notable among the various areas of applications are identified as follows:

1. Biomedical Engineering

In contemporary years, engineers and scientists have been able to artificially create body parts and parts of organs using 3D printing technology. The process of making the organ or body part is precisely similar to that of creating a plastic or metal part, however, difference exists in the raw materials used - biological cells usually produced in the laboratory. By making the cells exclusively for an individual patient, it is assumed with certainty that the organ will not be rejected by the patient's body.

Also, 3D printing is applied in the creation of limbs as well as some other body parts from metal or other related materials to replace lost or injured limbs. Prosthetic limbs are needed across the Globe, Nigeria inclusive, as a result injuries suffered when accidents occur or through one form of disease or another. Presently, prosthetic limbs are very costly and are

usually not customized for the needs of particular patient. 3D printing is however being adopted to design and create custom prosthetic limbs which will meet exact requirements of the patient. By scanning the body of the patient as well as current bone structure, designers and engineers are capable of re-creating the lost portion of such limb.

2. Automobile and Aerospace Manufacturing

High technology firms such as automobile and aerospace manufacturers have been employing 3D printing technology as a prototyping tool for some time now. However, with further advancement in the technology in recent time, functional parts usable for testing have been successfully created. This process of design and 3D printing has enabled these firms to progress their designs at faster rate than ever as a result of significant reduction in the design cycle. Previously, it usually takes several months to obtain physical prototype after the design stage. The design team can now within hours have a prototype handy for verification. The future of 3D printing in these industries lies with continuous creation of working parts directly from a 3D printer for use in the final product and not for testing purposes alone. This process is already in progress for future aircraft and automobiles.

Illustrating 3D printing revolution in the automobile industry, a number of luxury car manufacturers such as Bentley and Rolls-Royce now manufacture some parts cheaply by adopting the technology in preference to traditional manufacturing. Also, one of the foremost producers of electric cars - Tesla, also applies the technology to manufacture automobile components [Oko institute, 2013].

Meanwhile, Boeing and some other firms in the aerospace sector have also developed large internal Additive Manufacturing research groups [Technology Strategy Board, 2012]. The Boeing Company has been employing SLS (Selective Laser Sintering) for flight hardware in regular production for both military and commercial programs since 2002 [Boeing, 2011].

3. Architecture and Construction

City planners and Architects have been adopting 3D printers to make a model of the layout or shape of a building for many years. Ways of adopting the 3D printing concept to create entire buildings are now being explored. Already, there exists a prototype printer system which utilizes concrete as well as other specialized materials to make a structure comparable to a small house. The ultimate aim is to swap many cranes as well as construction workers with these emerging printing technologies. They would work by making use of the 3D design model generated on CAD software, to create a layer by layer outline on the building similar to the way a normal 3D printer works today.

A University of Southern California researcher meanwhile claims to have designed a huge 3D printer capable of printing a whole house within a day according to Bhandari and Regina (2014). This conceptual model uses concrete as base component in order to duplicate computer programs of houses. To ensure the compatibility of the house with plumbing and electrical apparatuses, it thus adopts a layered fabrication technology known as “Contour Craft”.

4. Mass Customization

3d printing processes permit mass customization which is the ability to individualize products according to needs and requirements of different individuals. Even within the same build chamber, 3D printing affords several products to be produced simultaneously according to the requirements of end-users at no extra process charge.

5. Food

Despite being a late-comer to the 3D printing party, food is one evolving application which is getting people thrilled and has the possibility of taking the technology into the mainstream. In any case, food is essential for human existence. 3D printing is emerging as a contemporary method by which food is prepared and presented.

Early forays into 3D printing of food lies with sugar and chocolate, and these developments have progressed swiftly with specific 3D printers hitting the market. Other initial trials with food include the 3D printing of "meat" at the cellular protein level (Bhandari and Regina, 2014).

Lately, another group of food that is being researched for 3D printing is pasta. Envisaging the future, 3D printing is also being considered as a complete method of preparing food as well as a way of balancing nutrients in an all-inclusive and healthy means.

6. Logistics and Supply Chain

3D printing technology has impact on inventory and logistics as products can now be printed on demand. It eliminates having the finished products stacked on shelves or stacked in warehouses. It ensures reduction in manufacturing lot sizes by enabling smaller manufacturing runs and this allows companies to reduce inventory holdings by being able to better match supply to demand. Whenever a product is needed, we just make it. And that collapses the supply chain down to its simplest parts while adding new efficiencies to the system.

Basically, 3D printing tears the global supply chain apart and re-assembles it as a new, local system. The traditional supply chain model is, of course, founded on traditional constraints of the industry, the efficiencies of mass production, the need for low-cost, high-volume assembly workers, real estate to house each stage of the process and so on. But additive manufacturing bypasses those constraints.

Other areas of applications are found in sport where it was recorded that Nike produced sport's shoe by using AM technique (Oko institute, 2013). Others include jewellery production, fashion designing, art, design and sculptures among others.

5.0. DERIVABLE BENEFITS FROM THE APPLICATION OF 3D TECHNOLOGY

Several articles and studies are utterly optimistic as to the significance and derivable benefits from the application of additive manufacturing and 3D printing technology at large. Atlantic Council, 2011 and Oko institute, 2013 are of the view that application of the technology can reduce assembly lines and supply chains and in some places, be eliminated for some products. The end product or large pieces of finished products such as a car can be manufactured by additive manufacturing in single process unlike traditional manufacturing where several numbers of parts are assembled. Those parts are usually dispatched from lots of factories from around the world. Factories which ordinarily may have their parts assembled from parts being delivered by other vendors. This no doubt expands the supply chain network of the assembling line.

Also, designs and not finished goods, would move around the world as digital files printable anywhere by any printer as its long it can meet the design bounds. At first, the Internet got rid of distance as an element in transferring information and presently, additive manufacturing is

eliminating it for the material world (Atlantic Council, 2011; Oko institute, 2013). This could be likened to the way a written document can be sent via email as a PDF and printed in 2D. Thus, an "STL" design file can be transmitted instantly to the other side of the planet via the Internet enabled devices and subsequently printed in 3D.
Thus, the potential developments, opportunities and benefits derivable from the application of the technology are discussed explicitly as follows:

1. **Mass Customization and personalization** – 3D printing offers great opportunity for products to be customized according to the needs of individual customers. The shape, appearance and function of a product can be tweaked to individual customer's taste, or the needs of the environment it is intended to operate. Products can also be individually designed from scratch where appropriate. This ensures possibility of high variety products.

2. **Reduced inventories** – Eliminating "headache" of need to stockpile large numbers of goods while trying to forecast sales are possible with 3D printing which could enable manufacturers and retailers to run with less stock, thus, producing only what is needed on demand. However, 3D printers would still necessitate some level of materials stock for operation;

3. **Reduced capital costs** – 3D printers will in principle decrease fixed capital costs for manufacturers by decreasing the need for large scale investment in factories and machinery. Apparently, the associated costs of 3D printers would be factored in by manufacturers, however, assembly lines and supply chains will be significantly reduced. This in turn reduces associated cost of goods.

4. **Reduced shipment costs** – 3D printing will reduce transport costs by eliminating the need for intermediate and finished goods shipment from one factory location to another. Albeit, there will be associated transport costs with materials, it is probably that these will be lesser and easier to come by.

5. End products can be created under single process with highly developed and specialized 3D printers. Supply chains, assembly lines and transports will thus be ultimately reduced significantly. New designs and functionalities are also feasible and easy to achieve.

6. **Less waste by-product** - 3D printers create less waste by-product than the traditional metal manufacturing techniques thereby reducing losses along the production line as well as increasing the overall efficiency of the system.

6.0. AREAS OF OPPORTUNITY IN NIGERIA

The various areas of applications of 3D technology discussed in the preceding section present a great deal of opportunities for Nigeria. Being a developing country, Nigeria still grapples with the challenge of meeting needs of its citizens in various sectors where application of 3D technology promises vast solution to some inherent problems.

We present various ways in which Nigeria could benefit from mass adoption of the technology to the routine operation of some key sectors in the country:

A. Medical and Biomedical Engineering Field

Nigeria, as well as other developing countries, is faced with diverse prevalent health issues, amputation being one of them. Frequent road accidents usually result in loss of body parts like hands and limbs.

3DP technology can be used in Nigeria to create 3D-printed prosthetic limbs as they are already being used as an alternative to handmade limbs in some cases in the developed world. Although 3D limbs do not offer better quality to handmade limbs, most patients prefer them because fitting of 3D limbs is easier and not time consuming compared to traditional limbs. 3DP therefore provides easier, faster and cheaper approach to deal with prosthetic situations in Nigeria than traditional limbs.

3D printing will thus be a saving grace in a country where healthcare services strive to keep up with its demand coupled with the high costs of medical care.

B. Manufacturing Field

Nigeria, being a highly populated country, no doubt provides huge market for consumer products. Hence, competitive manufacturing processes have to be developed daily to be ahead in a world which demands that products be made faster.

The performance of manufacturing industries in Nigeria is one of her biggest disappointments. One of the most controversial aspects of China's economic engagement with Nigeria is its success at exporting cheap consumer goods to the country. This has made many local manufacturing endeavours unviable. Adoption of 3DP technology in the country's manufacturing sector will no doubt reinvigorate it, thus ultimately improve the productivity of the country.

The primary use of 3DP technology in the manufacturing lies with rapid prototyping and making of niche products, which dramatically reduces both cost and turnaround time for developing prototypes and final products. Hence, time to market for products will be significantly reduced due, in part, to faster design and prototyping cycles as a result of 3D printings as well as elimination of tooling and factory set up time for new products.

Same goes for the use of 3D printing in other arenas, such as manufacturing some complex automotive parts. It usually can take several weeks or months to manufacture some car parts using conventional manufacturing methods. Some automotive companies, including big names like Honda, Ford and General Motors, are already exploring opportunities to use 3D printing in their production lines. These innovations will cut processing time to merely days. The only vibrant local automotive company in Nigeria, Innosson motors, can employ the technology in order to significantly reduce processing time and increase efficiency without jeopardizing the quality.

In addition, 3DP technology makes manufacturing less labour intensive, uses less material, produces less waste, and can use new materials that are light and strong. Depending on the material used, products made with 3D printing techniques can be up to 65 percent lighter but just as strong as traditionally manufactured products. Customization also becomes very easy, triggering new product strategies and customer relationships through collaboration with customers to create products. This customization feature of 3DP technology will no doubt excite Nigerian consumers who are mostly difficult to be satisfied.

C. Logistics and Supply Chain

With 3DP, possibility of mass customization will reduce inventory levels since goods can be made to order. Thus, many steps in the traditional supply chain can potentially be eliminated, including distribution, warehousing and retail. This will go a long way in reducing the cost of goods to the final consumers as significant percentage of cost of goods sold usually goes to supply and distribution chain.

7.0. CONCLUSION

3D technology is considered one of the revolutionary technologies developed by scientists and engineers in making lives much easier and stimulating to live in. It has a wide area of applications ranging from ability to personalize products according to the needs and requirements of individual to most sophisticated industrial applications.

Often described as additive manufacturing and rapid prototyping; 3D printing is a process by which 3D solid objects of any shape or geometry can be made from a digital file. The creation is achieved by laying down successive layers of a specific material until the entire object is created in contrast to traditional subtractive manufacturing method which is based on removal of material to create something. The technology is said to be one of the most significant industrial developments of this decade and is thus expected to keep growing. This makes it an important element to be tapped into by developing countries like Nigeria.

The technology has a wide variety of application that cuts across numerous sectors and fields. It is applied in industrial designs, automotive design, consumer commodities, biomedical engineering and dentistry (dental); as well as aerospace among several others.

The technology presents a great deal of opportunities for Nigeria, a developing country, that still grapples with the challenge of meeting needs of its citizens in various sectors where application of the technology promises vast solution to some inherent problems.

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