A study on AI and ICT for Sustainable Manufacturing

Omolayo M. Ikumapayi, Joseph F. Kayode
Department of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado Ekiti, Nigeria
ikumapayi.omolayo@abuad.edu.ng, kayodejf@abuad.edu.ng

Sunday A. Afolalu,
Department of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado Ekiti, Nigeria
Department of Mechanical Engineering Science, University of Johannesburg, South Africa
adeniran.afolalu@abuad.edu.ng

Emeka S. Nnochiri, Kayode O. Olowe
Department of Civil Engineering, Afe Babalola University, Ado Ekiti, Nigeria
nnochiri.emeka@abuad.edu.ng, oloweko@abuad.edu.ng

Ojo P. Bodunde
Department of Mechanical and Automation Engineering, Chinese University of Hong Kong, Shatin, NT,
People's Republic of China
opbodunde@mae.cuhk.edu.hk

Abstract

In manufacturing, artificial intelligence, as well as the utilization of information and communication technology (ICT), opens a plethora of chances and possibilities that all lead to the fundamental objective of sustainable manufacturing. Intensive search efforts in the fields of AI and ICT, multiple AI approaches, such as machine learning, have now been built in the industry for the purpose of sustainability in manufacturing processes. Therefore, the goal of this study was to conduct a thorough an overview of the scientific literature on the applications of artificial intelligence and smart information and communication technology to solve problems in the manufacturing industry and ensure sustainable manufacturing. It prioritizes in defining different problems in the current manufacturing industry and providing research results on AI-enabled solutions to these problems while justifying its positive implications. Also, the possible uses and added benefits of AI and ICT in the prediction, management, and advancement of industrial activities and processes are studied. The results from this research presented a positive growth of companies that have employed AI and ICT in recent years. This study looks at the potentials and performance of AI and ICT in the manufacturing industry and how the application of such technology can bring about sustainability in the manufacturing sectors.

Keywords

Sustainable manufacturing, sustainability, manufacturing, Artificial intelligence (AI), Information and Communication Technology (ICT).

1. Introduction

A popular definition of sustainability dates from a study published by the Brundtland Commission of the United Nations, which defined sustainable development as solutions to achieve current requirements without jeopardizing future generations' ability to satisfy stated or implied needs (UNBC, 2020). For present and future generations, sustainability is and will be a critical problem. The common perception that natural resources are limitless, and that the environment's regenerative potential can compensate for all human activity is no longer accurate. As a result,

sustainability challenges will have an impact on all elements of human life, including economics, politics, social issues, and the environment. Manufacturing, as the backbone of a modern lifestyle, will be impacted by sustainability concerns, and it will play a critical role in forging a sustainable path forward.

The production of goods using optimized processes that reduce detrimental effects on the environment and preserve the environment and its natural resources is called sustainable manufacturing. The safety of products, workers and the environment are all enhanced through sustainability (Kagermann, et al., 2015). Industrial growth now has the challenge of addressing the increasing worldwide demand for wealth and consumer products and trying to assure the social, environmental, and economic sustainability of man. Industrial value generation must be focused on the future of sustainability to address these issues (Vinuesa, 2020). Currently, the fourth stage of industrialization is creating value in the early economies. The manufacturing industry is already feeling the effects of the shift to Industry 4.0. It focuses on the development of intelligent factories and products while integrating them into the IOTs and services (EPA, 2022). This shift to Industry 4.0 offers countless possibilities for achieving sustainable production using facilities for widespread information and communication technology as well as artificial intelligence techniques.

AI involves the ability of a computer or a machine to do tasks similar to humans such as decision-making and dilemma analysis (Venkat, 2020). It is concerned with the modelling of human intelligence by machines, particularly computer systems. AI is widely employed in a variety of areas, including gaming, finance, retail, commercial, and government, and is slowly making its way into the manufacturing sector, helping industrial automation (Tucci *et al.,* 2022). Information and communication technology (ICT) has been identified as a significant enabler with a great capacity to affect the manufacturing industry in a sustainable way when combined with AI (Taisch, 2020). Many stages of the manufacturing process continue to benefit from advances in ICT. Throughout the flow of the supply, intelligence is shared.

Artificial intelligence can analyse data from important manufacturing process tools like sensors, machines, and people, then use programs to optimize operations and achieve efficient manufacturing. This information from various components of the manufacturing process can then be utilized and managed by efficient ICT systems. This research paper aims at proving the positive influence of AI in providing sustainable manufacturing methods. Also, the different problems faced in the manufacturing industry are tackled through this research, therefore, providing a powerful means of sustainable manufacturing (Borges *et al.,* 2021).

2. Literature Review

Artificial intelligence (AI) refers to a computer-controlled robot's capacity to perform functions that have been modelled according to the activities of humans who possess superior intelligence. The phrase is commonly used in efforts aimed at developing systems with human-like mental processes and characteristics, such as the capacity to generalize, reason, seek meaning, and learn from past encounters. Since the 1940s, when the digital computer was first introduced, it has been recognized that computers can be trained to do exceedingly complicated tasks, such as chess, with surprising skill. Despite recent advances in the processing speed and storage capacity of many computer systems, no program can equal or match the intellectual adaptability and behaviour of the human being across larger areas or in activities that need a substantial quantity of shared knowledge. According to psychologists, human intelligence is defined by a mixture of several diverse talents rather than a single quality. The advancement of the following intelligence components has been the sole focus of AI discoveries: problem analysing, using language, reasoning, perception; and learning.

ICT refers to the combination of telephone and audio-visual networks with computer networks using a single connecting system or single wiring. ICT is a wide area with ever-changing concepts. Any product that can save, retrieve, control, send, or receive data in a digital format, fall under this category. The basis of the ICT is the use of communication signals which are transmitted through signal delivery, cabling, etc., with the aid of an administration system to unite telephone and computer networks. ICT still goes farther than the above-mentioned encompassing all types of communication technology, such as radio, television, mobile phones, computers, satellite systems, etc. It also comprises the numerous services that this technology renders to society some of which are distant learning and video conferencing. Moreover, ICT encompasses both analogue and digital technologies (Mikalef & Pateli, 2017). Information and communications technology (ICT) is a descriptive term for information technology (IT) that emphasizes the essence of integrated information transfer or communication using different forms of data transfer such as telecommunications (the use of signals and communication lines) and computers in allowing users to save access, send, understand, and control information.

The production of goods using optimized processes that reduce detrimental effects on the environment and preserve the environment and its natural resources is called sustainable manufacturing. The safety of products, workers and the environment are all enhanced through sustainability (Mikalef *et al.,* 2019). Manufacturing has long been a pillar of the contemporary economy, with technological advancements substantially altering the processes and output volume for a wide range of industries, including food manufacturing, home products, chemicals, and electronics. Manufacturing sectors create new products by transforming items, resources, or substances. The manufacturing industry is already feeling the effects of the shift to Industry 4.0. It focuses on the development of intelligent factories and products while integrating them into the IOTs and services (EPA, 2022). The synergy of processes and systems that can create various products of good quality and efficiency, as well as render essential services using limited resources with more sustainable ones is characterized as sustainable manufacturing. Sustainable manufacturing aids a brand in building and creating a better repute, new market access and cost savings. Information and communication technology (ICT) has been identified as a significant enabler with a great capacity to affect the manufacturing industry in a sustainable way when combined with AI (Taisch, 2020).

2.1 Industry 4.0 (AI and ICT) and Sustainable manufacturing

The term 'Industry 4.0' describes the technical perspective of the Cyber Physical-System (CPS) which is incorporated into many factory processes of manufacturing or fabrication, and the integration of the technology of Internet of Things (IoT) into this same factory or industrial processes. This incorporation can be seen in the use of smart factories and products in manufacturing processes. The resources-human, material (machines) and capital are linked together vertically in a CPS generated social network, while the horizontal links cut across the corporations involved in the value chain of the CPS network. Digitalisation and sustainability are issues that affect all aspects of the manufacturing process. Both approaches include life cycle management policies such as assembly and disassembly, refabrication, recycling, etc.

Industry 4.0 has merit and worth in walking towards sustainable manufacturing. Sustainable manufacturing centres on developing an ideal manufacturing process where both raw materials and by-products become recyclable, reusable and possess the ability to preserve value in the manufacturing process. To this end, Industry 4.0 incorporates the ease and reliability of the AI and ICT technologies to improve the functioning of the machining process, improve process modelling, identify and test opportunities, as well as develop and modify business ideas to produce the best implementation results (Dwivedi, 2021). This advanced industrial system is powered by developed manufacturing technology. The pillars of technological development entail autonomous robots, augmented reality, horizontal and vertical integration, industrial IoT, cybersecurity, additive Manufacturing (AM), big data and analytics (Bai. 2020). The value of robot manufacturing is improving, with more autonomy, adaptability, and interaction with people and other robots.

2.2 AI and ICT for Smart Sustainable Manufacturing

The manufacturing sector is known to be prone to pollution and contamination of the environment through a lack of proper environmental analysis and proper quality checks. Therefore, the manufacturing industry has shown a trend of combining with information technology to provide a means of adequate environmental data collection and efficient material utilization to minimize the effects on the environment (Williams, 2011). Intelligent manufacturing includes computer amalgamated manufacturing, high adaptability potential, and design fixes, information technology, and more fluid training programmes. Several established and developing countries are speeding up their strategic plans to revitalize their diverse manufacturing sectors by implementing smart and efficient industrial layouts. Most major economies, including the United States, China, and the European Union (Bogle, 2017) have said that smart manufacturing is a top priority. The US Smart Manufacturing Leadership Coalition established the Smart Process Manufacturing roadmap, which is a system aimed at implementing intelligent and efficient process manufacturing operations in the twenty-first century to reduce hazardous emissions and pollution of the environment (SMLC, 2011). Germany proposed intelligent manufacturing to complete the Fourth Industrial Revolution. Considering this, China emerged with the Made in China 2025 strategy, as reported by (State Council of the People's Republic of China (2015), to achieve manufacturing industry development and transformation during the next industrial revolution. This means that these major economies and corporate bodies agree to achieve the sole objective of smart and sustainable manufacturing. So, AI and ICT applications are being made to better equip global economies through the manufacturing sector. The following are the problems of the manufacturing sector that have been resolved by the incorporation of AI and ICT safety of consumer products and quality of packaging, management of supply logistics and visibility, duplicate identification, cloud capacity and computational

functionality, review of regulations and standards and environmentally conscious products and manufacturing methods (BMCsoftware, 2020).

Several kinds of research have been done but are non-specific to the topic of providing a solution to manufacturing problems through AI and ICT. The manufacturing sector has quite a lot of issues that could be addressed by the implementation of AI and ICT these issues include breaching the skill gap between employees, training new labour, cost of robotic and automated systems. Therefore, this research is anchored on finds to provide a solution to manufacturing problems through the implementation of AI and ICT.

3. Applications of AI and ICT

Various uses and applications of AI and ICT are mentioned in this section. These points are analysed and evaluated to describe the strides made in the manufacturing industry due to the utilization of these techniques under artificial intelligence and smart information technology. Overall, each point backs up the claims and goals of the organizations that were overviewed in the review of literature relevant to the topic of study.

3.1 Quality Control

For ages, the role of manufacturing in society cannot be overemphasized and the introduction of more efficient manufacturing methods has been introduced to ensure that all products manufactured are safe and up to the required standard for such a product. The quality control process of a firm is set up to ensure that product quality is maintained or improved. Also, the quality of products and operations is analyzed to ensure a limited impact on the environment. The formation of a culture in which both management and employees strive for excellence is required for quality control. The importance of quality control in the manufacturing sector cannot be overemphasized as it leads to better consumer satisfaction and in turn higher revenues. In manufacturing (Okechukwu, 2020) stated the following as the steps needed to achieve and maintain a satisfactory level of product quality: the product must meet a minimal standard of quality to be easily marketed on the market, accurate standard measures must be created to measure quality, a reasonable variation from the pre-established norms must be established, and a sufficient level of quality must be obtained at the lowest possible cost. It was further noted that in manufacturing, it is imperative that the nature and processes involved in quality control be realized and stated (Okechukwu A. 2020). The quality management and control goals are to create customer-acceptable quality standards, uncover defects or anomalies in the raw materials and manufacturing processes to ensure that production runs smoothly and without interruption, examine manufacturing methods and operations and make recommendations for how they might be improved, assess the level of a product's quality deviation during the production process, investigate the sources of the departure in detail, take such procedures as are necessary to achieve the product's target quality, limit the impact of products and operations on the environment.

3.2 Prediction of Equipment Failure and Equipment Predictive Maintenance

Based on (Lee & Scott, 2009) three maintenance techniques employed for equipment which is corrective maintenance or at times called run-to-failure maintenance, is performed only after the machine or asset has failed or is possessing abnormal operating conditions. This results in a prolonged duration of downtime and a significant loss since it causes halts in the manufacturing processes and activities while scheduled maintenance, otherwise called preventive maintenance, is when routine maintenance is performed on a regular basis. Although failures are prevented, maintenance is done before the machine fails and it may be unnecessary and predictive maintenance This form of maintenance employs techniques to forecast when maintenance is needed to be carried out to reduce potential downtime. It continually monitors the machine's condition over time and enables early failure diagnosis based on historical data. In this case, Artificial Intelligence is employed to monitor and get diagnostic information regarding the health status of equipment and machinery. (Odua, 2020) Proposed the following as procedures to be followed during predictive testing: selection of sufficient historical data for analysis and processing, data is managed so that it can be fed into the algorithm and utilized appropriately, an appropriate ML algorithm is developed based on the given dataset and its implementation and finally, the data is passed into and confirmed by the machine learning algorithm. The second step entails developing a mathematical model to minimize the cost of maintenance. Sensor data is used as the model input, and the final output is a judgment on how many machines should be kept running.

The application of Artificial Intelligence in Equipment predictive maintenance has been reviewed down to two major components which include Condition-based maintenance and Statistical based maintenance which involve the

use of artificially intelligent software to study patterns to develop new models which predict the maintenance routine of equipment. The various predictive maintenance methods described by (Murat, 2020) are as follows:

(a) Condition-based Maintenance (CBM): involves maintenance based on continuous machine or equipment monitoring of their health. This is only done when necessary. Maintenance actions can only be carried out if they are done out after several method deteriorations are occurring. CBM is not anticipated.

(b) Statistical-based maintenance: employed when necessary. It is supported by the monitoring of the equipment or the machine nonstop. It utilizes prediction tools to determine when maintenance procedures are paramount and so, it is often timed. It also aids in failure detection early through analyzing the data trends using the prediction techniques like engineering methods, statistical insight strategy, integrity factors, and machine learning.

3.3 Supply Chain Management

AI was conceived with the goal of developing and producing robots with the ability to think and act beyond pre-set instructions. Since the late 1970s, AI has shown tremendous promise in enhancing human judgment and productivity in many commercial endeavours, thanks to its ability to discern business trends, comprehend business phenomena, seek answers, and actively analyze data. Artificial intelligence's application in supply chain management has been restrained despite its extensive use as a decision-making tool. This study examines various sub-fields of AI that are best suited for tackling practical challenges pertinent to SCM to fully realize the potential benefits of AI for SCM. In doing so, this study examines the track record of AI applications in SCM (Hokey, 2008)

3.4 Directed Automation

In industrial manufacturing, the deployment of AI and robots is particularly obvious, as they change the way mass production is done. Robots can do repetitive operations, improve skills, eradicate human errors, develop automation techniques, and design functional prototypes. Because of the increasing scope and size of digital systems, and the deficiency in verification strategies that can successfully deal with this pattern, experts are still exploring different means of automating design testing. Artificial intelligence (AI) techniques have been used to improve performance and reduce engineering effort in the quest for effective solutions. Machine-learning approaches can assist in the creation of tests for simulation-based verification. Present research indicates that combining machine-learning techniques into a coverage-directed test generation (CDG) paradigm can automate the test generation process making the process less prone to faults (Banzhaf, 2010).

3.5 Controlled Automated Production

Artificial intelligence assists enhance efficiency by automating manual or repetitive procedures. Robots are already performing physical tasks like assembling and hauling. Industrial robots are used in this way to replace human activities perform that are basic and manual tasks aiding employees to stay focused on harder tasks. Artificial intelligence systems would also be able to enhance manufacturing processes by tracking every stage of the process, including cycle time and amounts used. Machine learning techniques can be used to foresee the fill rate of machine builds in additive manufacturing, allowing production planning to be maximized. Flexibility will play a big role in the future of manufacturing. Manufacturers will need to find solutions to accommodate this demand without sacrificing efficiency as consumers seek more customized products. The rise of technology such as AI and additive manufacturing breakthroughs will assist firms in delivering products by allowing them to create items that are pertinent to their customers. It will also make it easier to communicate data across the value chain, resulting in better customer service and quicker deliveries. Technology advancements such as cloud computing, big data, and machine learning have major implications for the manufacturing process. Artificial intelligence is the obvious next stage in this progression, and it will play a critical role in improving manufacturing productive capacity, efficiency, and visibility. Manufacturers will have to use dynamic production methods, which means they must be able to quickly adapt to new technologies and respond to changing client demands and market conditions (Ravi, 2017).

4. Case-study of artificial intelligence and ICT in manufacturing

Table 1. Revenue representations of random companies that apply artificial intelligence and ICT in manufacturing in millions of dollars. (Source: macrotrends)

YEARS	APPLE	IBM	AMAZON	MICROSOFT	TESLA

2011	108,250	106,916	48,080	69,943	204
2012	156,510	102,874	61,090	73,723	413
2013	179,910	98,367	74,450	77,849	2,010
2014	182,800	92,793	88,990	86,833	3,200
2015	233,720	81,741	107,010	93,580	4,050
2016	215,640	79,919	135,990	91,154	7,000
2017	229,230	79,139	177,870	96,571	11,760
2018	265,600	79,591	232,890	110,360	21,460
2019	260,170	77,147	280,520	125,843	24,580
2020	274,520	73,620	386,060	143,015	31,540

The revenue values shown in Table 1. represent the revenues of five US companies that apply artificial intelligence in the manufacturing of consumer products. The revenue values show growth and that in turn proves that the application of artificial intelligence to the manufacturing process of company yields positive results or have very little negative outcomes in the worst scenarios.

AI has resulted in more productive, error-free, and sustainable operation procedures and products. Companies like Microsoft, Tesla, and Facebook are already transforming AI for manufacturing organizations and the workforce. This has brought about huge returns over the years. Before we proceed, let's look at some industry-related facts that can't be ignored:

(a)The most essential benefit of artificial intelligence, according to 44% of industrial leaders, is that it provides data that can be used to come to a decision.

(b)For 61 percent of marketers, artificial intelligence is the most critical component of their data planning.

(c)Companies who used AI saw a 50% boost in leads, a 60%–70% reduction in call time, and a 40%–60% reduction in costs.

Some of the industries that have been dramatically affected by AI:

The medical industry has been impacted. Disease detection using X-rays, natural language processing (NLP) which helps determine components in drugs for drug agencies to foster drug safety, and machine learning aiding in trend analysis and predictions. ML has the capacity to find comparable qualities within a community.

Cutting-edge technology and software have been kept out of reach from the Construction industry for a good period. However, several new businesses have already begun to use and incorporate AI in construction planning and pre-construction activities. By reducing human error and better leveraging big data, adopting AI and ML into the construction sector can only improve the process, making it faster, more dependable, and more optimized.

AI is already having a good effect on the retail industry. More merchants will invest heavily in AI in the future years to provide excellent service to its receivers. Merchants are expected to incorporate augmented and virtual reality into their marketing campaigns The use of augmented and virtual reality in marketing initiatives is predicted to become more common. Product catalogues that are both interesting and eye-catching are likely to gain in popularity. This will have an impact on the profit margin, effectiveness, and productivity of the retail industry. Claims conclude that this year, retail investment on AI is estimated to surpass $7 billion (2022).

The Education sector is one sector where AI will have a significant impact. The only thing that needs to be done is to identify the adjustments that need to be made and to plan how we will achieve success in implementing those changes. Utilizing AI to develop a personalized, effective, and experiential sessions path for any issue can be of huge impact.

The volume of information gotten from customers, and business strategies will be of great benefit to businesses. Conventional business analytics technologies aren't working as well as they should. AI technologies that analyse data, provide findings and make recommendations autonomously are pushing regular spreadsheets and editors. These help companies make better decisions and modify how they use data with these newly developed tactics.

In conclusion, Artificial Intelligence is exploding into life and only grows in demand. AI will soon be deployed in more and more domestic and industrial activities.

5. Conclusion

In summary, sustainable manufacturing ensures that the product being manufactured is not of harm to the environment or consumer. The research covers how artificial intelligence and ICT can be used to ensure the most efficient result in various manufacturing procedures stretching from quality control to supply chain management.
A few companies which have used artificial intelligence in the manufacturing process are seen to have consistent revenue growth which proves sustainable manufacturing because if the products were not being manufactured to consumer quality, there would be a decrease in the demand and therefore negative revenue values. Thus, Artificial intelligence is necessary and effective in sustainable manufacturing.

Acknowledgments

The authors wish to acknowledge the financial support offered by the Afe Babalola University Ado Ekiti in the publication of this manuscript.

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Biographies

Omolayo M. Ikumapayi is a Senior Lecturer in the Department of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado Ekiti, Nigeria. He earned his Ph.D. degree at the Department of Mechanical Engineering Science, University of Johannesburg South Africa. MSc degree in Mechanical Engineering (option in Design and Production) from the University of Lagos, Nigeria, and his BEng in Mechanical Engineering from the Federal University of Agriculture Makurdi, Nigeria. He is a registered Engineer with COREN, Member of Nigerian Society of Engineers (MNSE), Member of Nigerian Institution of Mechanical Engineer (MNIMechE), Member of Chartered institute of purchasing and supply management of Nigeria (MCIPSM), Member of the Academy for Entrepreneurial Studies (M.AES) and Associate Member of the Certified Institute of Shipping, Nigeria (ACIS) among others. His research interests include additive manufacturing, simulation, processing using agro-wastes powders, surface modifications, characterizations, tribocorrossion, Friction stir processing/welding, automation, mechatronics, and nanotechnology.

Sunday A. Afolalu, PhD is a full professor in the Department of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado Ekiti, Nigeria. He is a research-oriented and creative problem-solver scholar with a cumulative of over Eighteen (18) years of industrial and academics/teaching experience. He is equally a certified and registered member of COREN, NSE, and CIPSMN. He has published several articles in peer-reviewed Learned Journals, Conference Proceedings, and Book of chapters which are majorly Thomson Reuters, SCImago and Scopus indexed Journals. His current research interest areas are Laser Additive Manufacturing, Nanotechnology, Production Engineering, Surface Engineering, Modeling, and Simulation. Fluid Mechanics, Kinematics and Tribocorrosion

Joseph F. Kayode is a Ph.D holder from The Federal University of Technology Akure, Nigeria at the Department of Mechanical Engineering (option in Production Engineering) and his M.Eng in the same Faculty of Engineering. He obtained his B.Eng in Mechanical Engineering from The Federal University of Technology Minna, Nigeria. He is currently a lecturer and Researcher at Afe Babalola University Ado-Ekiti, Nigeria. He was one-time Teaching Assistant at The Federal University of Technology Akure, Nigeria. He is a COREN Registered Engineer, MNSE and MNIMechE. His research interest include production, welding, manufacturing, material, mechatronics

Emeka S. Nnochiri has his first degree, Bachelors of Engineering (B.Eng) in Civil Engineering from the University of Ado-Ekiti (now, Ekiti State University, Ado-Ekiti) (2002). He holds a Masters (M. Eng.) degree in Civil and Environmental Engineering (Transportation Engineering Options) from the Federal University of Technology, Akure, Nigeria. He bagged his Doctor of Philosophy (Ph. D) in Civil Engineering (Geotechnical Engineering option) from Ekiti State University, Ado-Ekiti, Nigeria. At present, he lectures in the Department of Civil and Environmental Engineering, Afe Babalola University, Ado-Ekiti, Nigeria.

Kayode O. Olowe is the current acting head of the Department of Civil Engineering, Afe-Babalola University where he engaged in teaching and research at undergraduate and postgraduate levels. He holds a Ph.D. degree from the University of KwaZulu-Natal, Durban, South Africa in Civil Engineering for his research in the development and application of a mathematical model for assessing Nutrient Kinetics in Surface-water. His research interest is in environmental pollution, solute transport, water distribution system analysis, Water quality modeling, and has published several papers in reputable journals. He has received many research awards which includes Water Research Commission (WRC), South Africa, the JW Nelson Endowment Fund, and University of KwaZulu-Natal's research grants.

Ojo P. Bodunde is a Ph.D research scholar at the Department of Mechanical and Automation Engineering, Chinese University of Hong Kong. He obtained B.Eng and M.Eng degrees at the department of Mechanical Engineering (option in Production) from the Federal University of Technology, Akure, Nigeria. He is a registered Engineer with COREN, Member of Nigerian Society of Engineer (MNSE), Member of Nigerian Institution of Mechanical Engineer (MNIMechE). His research interests include additive manufacturing, simulation, nanotechnology, 3D printing, 4D printing, Smart manufacturing, cloud manufacturing etc.