Sustainable Manufacturing in Africa: The Pros and Cons- A Pragmatic Review

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Abstract. Manufacturing is an essential aspect of every thriving economy. It is a driver that cannot be overemphasized. This is so because production of goods and service is what ensures a continuous growth of the economy. It is therefore imperative to ensure the sustainability of this key tool. This study reviews the various elements of manufacturing, the strengths and constraints of sustainable manufacturing especially in Africa. The study concludes that manufacturing is sustainable provided the needed support from key players is available and can drive an economy to fast development.

1 Introduction

The production of consumer goods through economically sensible methods that lessen environmental impact while preserving energy and other natural resources is known as sustainable manufacturing [1]. Manufacturing is a critical component of economic growth, commerce, efficiency, and growth in the twenty-first century. Manufacturing in the twenty-first century is very different from that of the late twentieth century because of production decomposition and modularization, the arrival of new competitors, the integration of ICT (information and communications technology)-enabled services into physical products, and the continuous improvement of manufacturing technology [2]. The manufacturing sector of the economy tends to have an impact on the performance and stability of the entire economy, according to experimental findings from developed and varied emerging economies [3]. Manufacturing in the twenty-first century affected not just how labor was performed and things were created, but also how people interacted with one another and the world as a whole. Its numerous outcomes have had an impact on Earth's political, ecological, and

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cultural spheres [1]. The rapid development of labor-saving inventions, the rapid advancement of medicine, the increased wealth and quality of life for the average person, and the rise of specialized professions are just a few of the major benefits of the industrial revolution of the twenty-first century, while the drawbacks include: an increase in bad behaviors, overcrowding in cities and industrial towns, pollution, and other ecological woes [4].

The digital computer and industrial processes to manufacturing were developed in the 1950s, but it was discovered that the consequences of digital computers are startling, and they gave the chance to run manufacturing as a system rather than operating it as a compendium of essentially different bits and pieces of activity as had been done previously [2]. Thus, the Systems Approach to Manufacturing concept and the Computer Aided Manufacturing System concept were both developed in the 1960s. The industrialized world struggled to create and implement the concepts and methods of the systems approach to production and the Computer Aided Manufacturing system in the 1970s and early 1980s in order to capitalize on their inherent potential benefits. Late in the 1980s and early in the 1990s, a strategy was developed that stimulates and utilizes people's abilities to operate production equipment, and then develops and employs manufacturing technology in a way that complements those human qualities. In the twenty-first century, a new tendency emerged: a trend toward actual and substantial achievement of highly human-resource-oriented computer integration, automation, and optimized overall manufacturing firm operation. This movement is divided into two parts: integrated technical approaches to product and process, and very human-oriented management methods to manufacturing business operation [4].

Based on United Nations estimates, Worldometer forecasts that Africa currently has 1.4 trillion people (1,414,248,464), or 16.72% of the world's population while 43.8% of the population is urban. Africa's population density is 45 people per km2, and its overall area is 29,648,481 km2. Unfortunately, among developing nations, Africa falls considerably behind the rest of the world in development. In 2017, about $145 billion was contributed to the industrial value in Sub-Saharan Africa (Figure 1) [5]. East Asian developing countries, on the other hand, are well ahead. Only one nation in the entire continent, South Africa, is currently considered to be industrialized. The majority of Africa's total manufacturing value added is really driven by North and South Africa's faster rate of industrial expansion (Figure 2) [5]. Manufacturing in Africa grew at a quicker rate than the rest of the globe in the twenty-first century, growing at a rate of 3.5 percent each year from 2005 to 2014. Several nations, including Nigeria and Angola, have already had annual output increases of more than 10%. [5](Balchin et al., 2016). The value of output in Sub-Saharan Africa has increased as a result, going from $75 billion in 2005 to more than $130 billion in 2016. Manufacturing growth is frequently viewed as Africa's best opportunity of escaping its low-income condition [5].

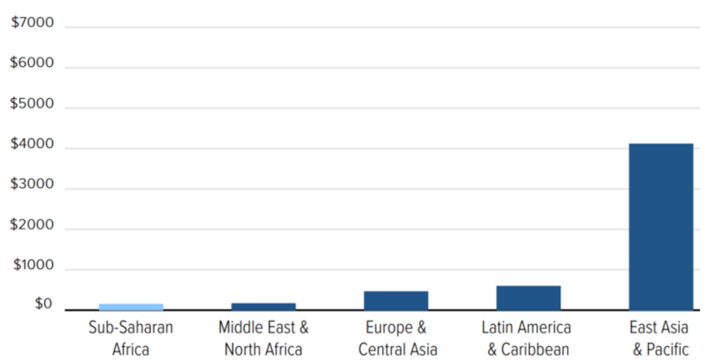

Fig. 1. Manufacturing value added across regions [5].

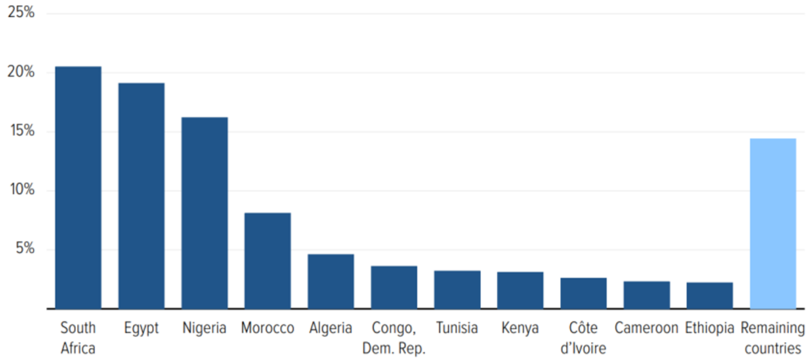

Fig. 2. Manufacturing value added share in some African countries [5].

2 The world of manufacturing

2.1 Overview of Manufacturing

The manufacturing industries have witnessed different levels of technological revolution spurred by market demand [6]. The effects of technological advancement on the manufacturing industries in the 21st century cannot be over-emphasized as it has greatly repositioned the traditional manufacturing industries such that all its components have been tuned positively for higher productivity, hence, making this sector of the economy highly competitive [7]. The transformation of raw materials into a completed finished items or products is the focus of manufacturing. Before the advent of 21st-century manufacturing, raw materials were converted manually with the hands and crude tools (human labor technology) into finished products which sometimes do not meet up with standards and expected satisfaction [8]. In recent times, manufacturing industries have been equipped with highly sophisticated machinery capable of converting raw materials into finished goods [9], making this system highly efficient, flexible and in particular, The length of Product Life Cycles (PLC) is decreasing without lowering quality.

Recently, there has been increasing global concern for environmental damages majorly as a result of manufacturing processes [10]. This gave rise to the concept of sustainability in manufacturing, which, according to the United States Environmental Protection Agency's (EPA) definition released in 2022, is the production of goods using practical, cost-effective techniques that minimize environmental damage while preserving energy and natural resources. Hernándeza et al [10] suggested a uique method for improving sustainability in manufacturing techniques, which includes reusing products/components, recovering and reusing components, reproducing and redesigning products to use salvaged materials/resources.

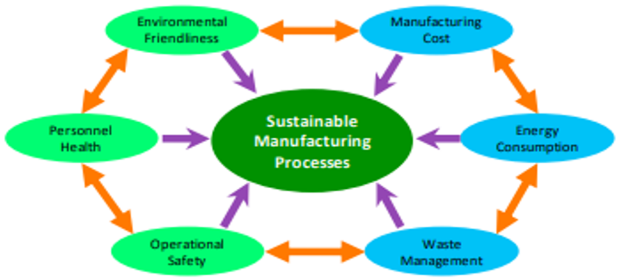

Fig. 3. Sustainable Manufacturing Processes [10].

2.2 Elements of Sustainable Manufacturing

Sustainable manufacturing is the production of manufactured items using non-polluting techniques that preserve energy and natural resources, are also financially viable, and are secure for workers, communities, and consumers. According to Baskaran and Manzoor [11], it is a way for developing technologies that change materials without emitting greenhouse gases, using non-renewable or harmful resources, or producing trash. The flow of environmental waste is identified, quantified, assessed, and managed with the goal of reducing and eventually minimizing environmental impact while also attempting to maximize resource efficiency. It is also a technique that integrates concerns about the design of the product and the process into manufacturing, planning, and control [12]. Sustainable manufacturing is frequently used interchangeably with "Green manufacturing," which is concerned with waste that has an environmental impact [13]. When human activity consumes resources and produces waste at a rate that outpaces nature's capacity to transform them, it is not sustainable [14]. The present rate at which mankind use the earth's resources is unsustainable and, if not managed, may have negative environmental consequences. The notion of sustainability has been implemented in the manufacturing business and is referred to as sustainable manufacturing or sustainable production [15]. Although manufacturing methods give mankind material riches, they also use up a lot of resources and create a lot of waste. Environmental harm is caused by waste produced during product usage, during product production, and after the product has reached the end of its useful life. Therefore, it is anticipated that people use available resources in a way that does not affect the environment and that future generations of humans experience the same standard of living that we do. As a result, massive and continuous efforts are required to ensure that the global environment is preserved and given top priority over all other issues.

It is important to consider sustainability at all levels for any product that would be manufactured [16]. The numerous distinct interpretations of the'sustainability' notion are one of the reasons for the enormous number of definitions. According to the researchers, the enormous number of words and definitions in the field of sustainable manufacturing is a barrier to information sharing, especially among industry and academia [17]. In the field of sustainable manufacturing, Despeisse et al. [16] argued for the use of more uniform language and vocabulary, but Garretson et al., [18] claim that a consistent nomenclature is required for the creation and best practices to be implemented in the sector. A well-known method for assessing the environmental impact of the production process of a particular product is life cycle analysis [14]. The quantitative advantages of green manufacturing are related to waste (reduced costs for waste handling, waste categorization, waste treatment, waste disposal, and waste storage) or the product's life cycle (reduced costs for transportation, packaging, overall

product cost, cost of production, cost of user operation/use, cost of maintenance/service, and overall cost to the consumer). Together these are commonly known as the elements of sustainable manufacturing. Ebrahim et al., [15] opined that there are majorly four fundamental elements of sustainable manufacturing including sustainability driver as the input, sustainability enabler and measure as the processes and sustainability impact as the output. The study determined the components for each fundamental element needed for manufacturing companies to achieve manufacturing sustainability.
Jawahir and Dillon [19], on the other hand, in Figure 4 below illustrates the six major factors that have been proposed as significantly affecting the sustainability of manufacturing processes. Manufacturing costs, energy use, and waste disposal can be regarded as deterministic factors, whereas the impact on the environment, employee health, and operator safety may be more difficult to identify.

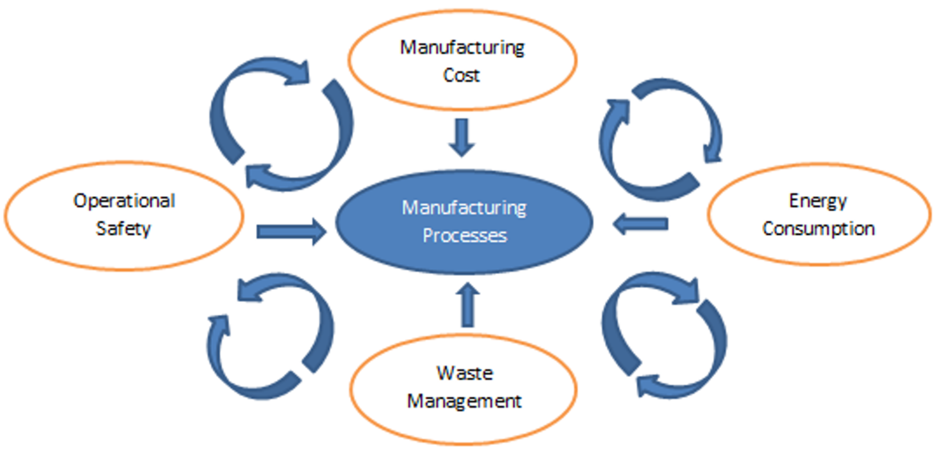

Fig. 4. Major Elements Of Sustainable Manufacturing [19].

2.2.1 Manufacturing cost and sustainability

The environmental impact of products is mostly established at the design stage, hence it is preferable to make design choices that support sustainable manufacturing which accounts for between 70-80% of the total cost. It is necessary to specify a wide range of metrics for assessing the economic pillar of sustainability, including total cost, profit, and cost per unit, in order to pursue sustainability [14].

2.2.2 Energy Consumption

The term "energy consumption" refers to all necessary energy required during the manufacturing process, specifically the power consumption by machine tools during the manufacturing process. This involves maintaining local environments, jig and fixture maintenance, in-line inspection of production equipment, machine transfer, and so forth. The indicator identified while applying the reduction element of the post-use stage for product life cycle is how much energy the machine tool uses overall. Additionally, metrics such as the percentage of recycled energy, renewable energy, and recovered energy due to heat are examples of metrics identified when utilizing recycle, recover, redesign, and remanufacture [20].

2.2.3 Waste Management

The entire amount of materials slated to go into products that end up in the garbage stream is referred to as trash material generation. These waste streams include byproducts of metal removal activities as well as damaged or broken components. Utilized consumables that are utilized just as an aid or intermediary component and are not included in the final output, as well as used coolant or lubricants, are some of the components that contribute to the overall amount of trash that enters the waste stream [20].

2.2.4 Operational safety

For each component of the metrics utilized in measurement for each scenario, general recommendations and specific measures are structured [20]. Amount of injured consumers, societal community awareness, toxic/corrosive chemical exposure, injury rates, the amount of workers engaged in risky operations, physical load index, chemical pollution in the workplace are a few examples of several metrics used in assessing in the case of decrease element of the post-use phase for product life cycle while for recovery, percentage of high energy components that are recycled or remanufactured and number of satisfied customers are a few examples of several metrics used to measure the reduction element of the post-use stage for product life cycle [20].

2.3 Constraints of sustainable manufacturing

Incorporating systems and processes that can produce high-quality goods and services while using fewer and more sustainable energy and material resources, while also being safer for workers, clients, and the surrounding environment, and capable of minimizing environmental and social impacts over the course of their entire life cycle is known as sustainable manufacturing [21].

One of the proffered solutions towards attaining and achieving higher level of sustainability in a society is production and consumption of sustainable products [22]. Sustainability through environmental preservation secures the availability of resources for future generations while also improving human quality of life by meeting requirements. However, many developing countries in this era are still in the early stages of sustainable manufacturing due to several limitations. A limitation may also be referred to as a challenge, an obstacle, or a set of conditions that hinder progress. It is considered a factors that prevents or hinders sustainable manufacturing [22,[23]. It is therefore necessary to identify the constraints needed for improving the level of sustainability in some developing countries. This will enable building strategic plans toward enhancing the level of sustainability in African competitive manufacturing business environment.

Businesses and individuals are under pressure to integrate sustainability methods into organizational operations due to the global scenario of natural resource depletion and environmental, economic, and social injustice [24]. According to Panuju et al. [22], Ivascu [24] and Abubakr et al. [25], the concept of sustainability covers three sectors such as social, economic and environment. These are necessary for developing the life cycle viewpoint, which takes into account the phases of material extraction, manufacture, use, and end-of-life. The first two sectors have been in existence for decades while the environmental sector is relatively new. The existing sustainable key performance indicators perspectives are as shown Table 1 [25].

Table 1: Perspectives on key performance indicators (KPIs) that are sustainable [25].

Sustainability Dimension	KPIs
Environmental	Green house gas emission rate, caron (footprint) rate, percentage of waste generated, percentage of reuseable materials, power used per thousand, total amount of water consumed, rate of renewable energy, sustainable rate of water consumption.
Social	Employer satisfaction, employee training hours, health and safety, diversity, equality, and overall social initiatives spending
Economic	percentage of revenue allocated to recycling initiatives, pace of technological investment, percentage of production sites with a certificate for environmental compliance

Sustainable manufacturing can be designed only inside the constraints (local and global) shown in Figure 1 which may differ from a country to another because of differences in geographical, socioeconomic, political, and cultural conditions [22]. As shown in Table 2, it is consequently required to define the design concepts, especially the concepts of sustainability design for distinct items that could differ. Local constraints are limitations whose outcome can be applied to a single product design concept. Large manufacturing businesses and Small and Medium Enterprises are two types of sustainable product manufacturers (SME) [22].

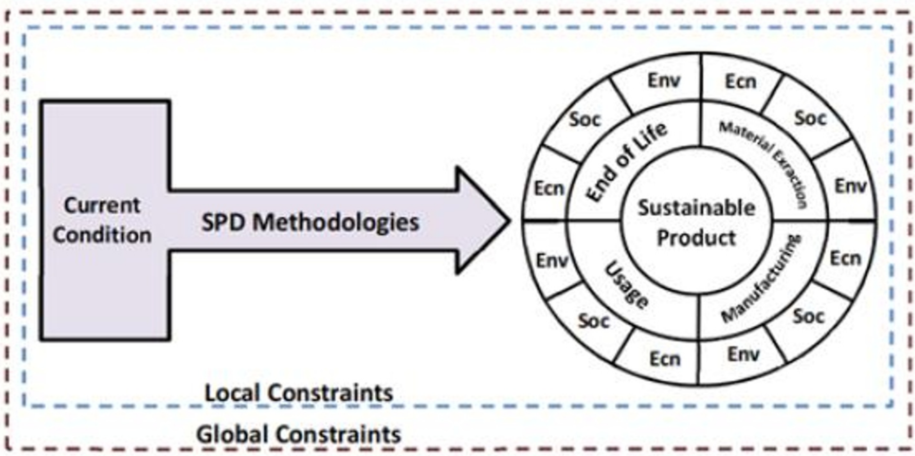

Fig. 5. SPD Methodologies in Achieving Product Sustainability[22].

Table 2. Product's Sustainability /Design Concepts in Product's life Cycle Phases [22].

Phases	Environment	Social	Economic
Material Extraction	Eco-extraction process; waste treatment	Ethical obligation; societal influence; policy adherence	Extraction Process at a Low Cost
Manufacturing	Eco-Maufacturig process; waste treatment; eco-packaging	Ethical obligation; societal influence; policy adherence	Low manufacturing costs; low distribution costs

Usage	Energy and natural resource conservation; use of renewable energy; Low emission level	High reliability; safety; comfort; low noise level; ethical duty; societal influence	Reasonable sales price; minimal operating and maintenance costs
End of Life	High reusability; non-toxic waste; and high recycling.	sociocultural impact; ethical responsibility	High after-use economic value; minimal recycling and remanufacturing costs

Figure 6 depicts how human activities have led to a rise in the level of greenhouse gases in the atmosphere during the last 150 years.

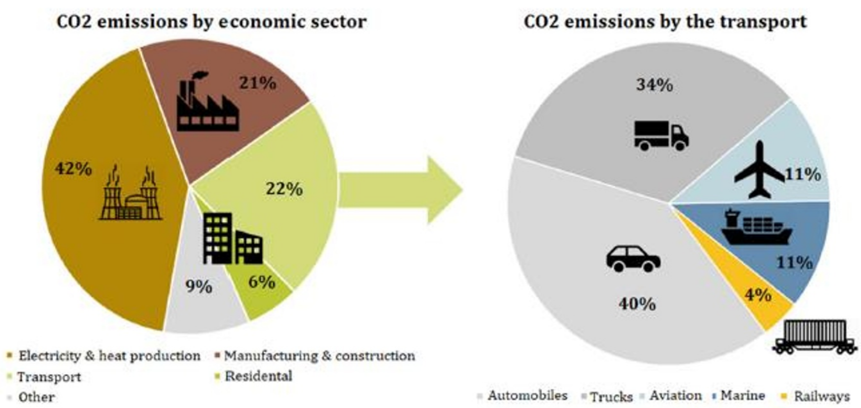

Fig. 6. Global greenhouse gas emissions by the transportation sector [26].

Some developing countries, notably Nigeria, have taken measures in recent years to oversee the operations of their industrial sector. The challenges have been in the areas of compliance and enforcement as well as the creation of a safety-net framework that would give businesses and their stakeholders a complete view of the sector's total environmental effect [27].
In light of this, businesses ought to switch to more environmentally friendly production methods, like reverse logistics approach, green manufacturing, green lean, cleaner production, green supply chain management, and circular economy [28]. Adopting these methods will allow businesses to enhance their environmental performance while also reaping significant benefits in terms of labor efficiency, product quality, and money production, as well as a reduction in the likelihood of accidents and insurance costs [28].
Economic development, evaluation of sustainability practices, and prioritization of barriers, drivers, and indicators have all become more complex as a result of the incorporation of existing benchmarks including social, economic, technical, and environmental. When it comes to current constraints, the existing literature on sustainable manufacturing methods assessment is quite sparse. Quantitative and qualitative data have recently been used in sustainable manufacturing decision-making methods to evaluate sustainable manufacturing technique. [29]. The study shed light on several multi-criteria decision-making processes (MCDM) strategies, as well as advances toward sustainable manufacturing applications using MCDM methods. Pangestu et al. [30], defined six important parameters for sustainable manufacturing and classified them as quantifiable (cost of manufacturing, waste

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management, and energy consumption) and unquantifiable (environmental impact, human health, and operational safety). According to Lakhan et al. [31], the primary drivers driving globalization are the economy, innovation, society, environment, and regulation. Dwivedi et al. [32], highlighted thirteen potential hurdles to long-term value chain flexibility projects. They incorporated techniques and mathematical procedures to numerous drivers, indicators, and enablers of Sustainable manufacturing practices for ease of implementation and assessment. Through the use of cross-impact matrix multiplication and modified total interpretative structure integration, they created a categorization system. Mala et al. [26], create an iterative solution approach derived from a Lagrangian multiplier method for making sustainable manufacturing decisions, which is displayed in a mathematical model as a constrained on-linear program. A fuzzy decision support system was developed by Zarte et al. [33] to take into account social, environmental, and economic aspects simultaneously. The decision support system model identifies the greatest opportunities for boosting the sustainability of the production program and offers suggestions for how to do so [34-38].

3 Conclusion and Recommendation

3.1 Conclusion

In order to demonstrate how the sustainability of manufacturing in Africa affects production costs, energy consumption, waste management, and operational safety, a thorough literature research on the topic of content analysis was conducted. All research topics were addressed through the presentation of in-depth descriptive and thematic data that identified the most recent themes and trends. All of these sustainable manufacturing elements demonstrate that the core tenets of manufacturing in Africa are equally taken into consideration. Since green manufacturing benefits the economy, society, and environment, it is essential to accomplishing the SDGs goal. As a result, "sustainable manufacturing" refers to the production of manufactured goods using non-hazardous substances, reduced energy consumption, making use of renewable energy, resource-efficient, reduced materials cost, and secure environment for workers, and communities.

3.2 Recommendation

Future research is recommended to enable a thorough evaluation of the sustainability of manufacturing systems for an ongoing development. In order to welcome commercial power suppliers who use renewable energy, the government should, more crucially, fully reform the electrical sector, separating itself from everyday pricing and investment decisions. Given the recent sharp drops in the price of renewable energy, which have led to lower manufacturing costs and a greener environment.

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