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A Nanotechnology Foresight Perspective for South Africa

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Abstract **- This study aims to apply nanotechnology in industry and its impact on economic growth and sustainable development, creating job opportunities and reducing unemployment and poverty in society. From this perspective, one way of sustainable development is to pay attention to economic progress in the context of new technologies, especially nanotechnology. Nanotechnology is an important tool for addressing urban sustainability challenges, including climate change, water pollution, access to healthy food and public safety. It is a deep scientific horizon with high potential in the production of products and the processing of new technologies, where new technologies are evidence of the political, civic, economic, and social empowerment that are all building blocks, both for global goals and for grandiose visions and expectations for prosperity.**

Keywords**: Sustainable Development, Economic Growth, Industry, Nanotechnology, African Countries**

I. INTRODUCTION

The astonishing applications of nanotechnology can address the global challenges of economic development, poverty, growing inequality, depletion of natural resources, environmental degradation, and climate change. From high-efficiency solar panels to high-efficiency cars and planes, and from cheap water purification and treatment products to ubiquitous sensors that monitor ecosystems, the economic and environmental benefits of nanotechnology are enormous.

Nanotechnology is also characterized as “an enabling factor that is expected to affect all manufactured goods” and is now an integral part of advanced manufacturing. The most obvious techniques of the ongoing Fourth Industrial Revolution, referred to as “industry technologies,” are information technology, electronics and robotics, and nanotechnology clearly plays a critical and indispensable role as infrastructure that supports those technologies.

II. RESEARCH PROBLEM

The problem of research is reflected in the poor performance of the industrial sector and the absence of a successful strategy that contributes to industrial development at the level of the African economy. It is the extent to which nanotechnology is integrated and incorporated into manufacturing, and what future role technological progress can play in achieving sustainable development.

III. NANOTECHNOLOGY OVERVIEW

Nanotechnology relates to the ability to create materials and devices by processing individual atoms and molecules (up to 100 nm). Moreover, it involves integrating these structures into larger systems. Like information technology, nano components (building blocks of nanometer techniques) offer a variety of properties that can be used for a wide range of useful applications and have the potential to make significant improvements in current technologies. These include medical, food, clothing and defense applications, national security, environmental clean-up, power generation, computing, construction, and electronics [1].

Nanotechnology is the manipulation of matter at a molecular and atomic scale. It means artificially combining atoms and molecules to create particles and structures with functions different from the same material at a larger scale (also called bulk material, or material in the bulk form) [2].

IV. NANOTECHNOLOGY AND SUSTAINABLE DEVELOPMENT GOALS

Nanotechnology offers developing countries great opportunities and challenges to advance economic, environmental, and social development aspirations. Improving production systems through techniques and processes that use natural resources more efficiently, and at the same time produce less waste, should be the cornerstone of any manufacturing strategy.

African countries face many challenges related to inadequate local awareness of environmental issues, a weak policy environment, limited access to the latest technology and a mostly unskilled workforce. In addition, African countries have been late in joining the industry. Weak governance and political instability remain major constraints to sustainable development and industrialization in several African countries [3].

Nanotechnology is an emerging technology that promises new and exciting potential for the developing world and to fulfill these promises. South Africa must strategically position itself as a knowledge economy, through a collaborative effort involving the private sector, investment of large financial resources and well-thought-out, concurrent policies.

But this can only be achieved if the State develops a strong research agenda and strengthens its national innovation system so that it can effectively meet the country's development needs. It should be noted that industrial growth is vital for economic development in African countries while being able to contribute significantly to poverty reduction.

1. Trends in African Industrial Development

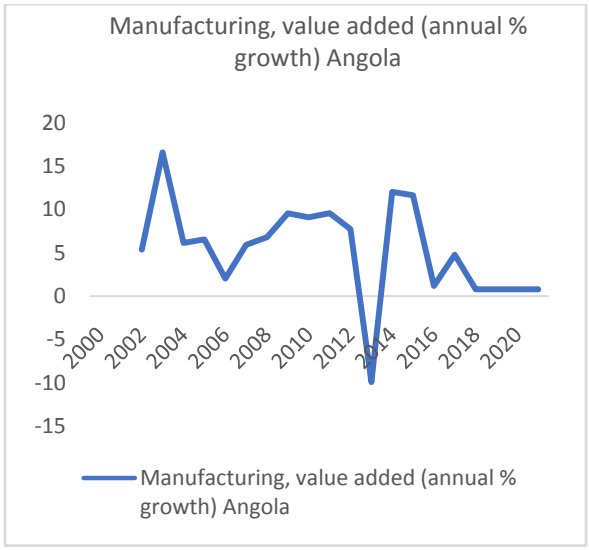
The share of manufactured goods in total exports remains relatively low, and primary products continue to dominate exports from most African countries.

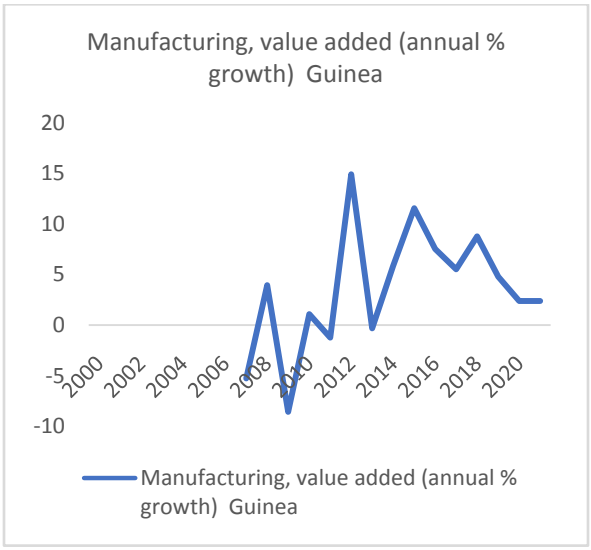
African industries continue to be dominated by low levels of technology, skills, and capacity use with limited scope to adopt computer-assisted manufacturing and knowledge-intensive production systems, and therefore tend to be uncompetitive in the global market.

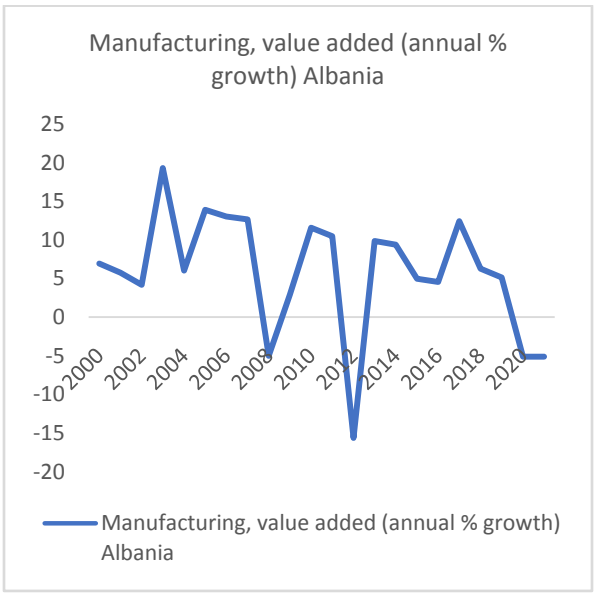
a. The Current Situation Sustainable Industrial Development in Africa

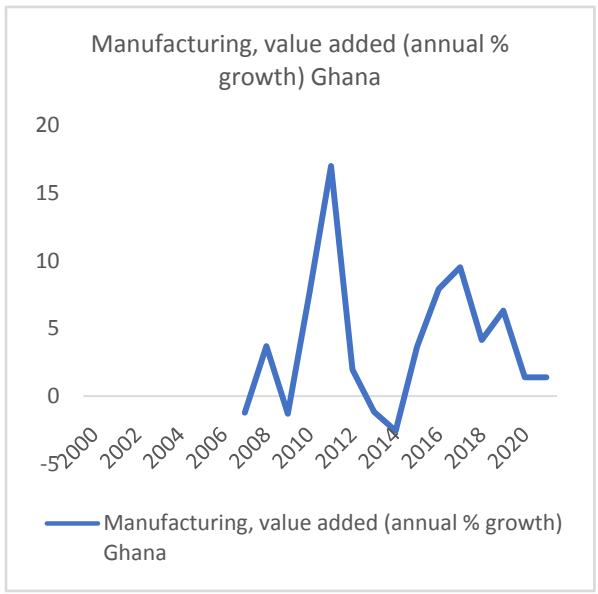
One of the main reasons for the low pace of ndustrialization in Africa is the region's inability to build technological capacity. At the beginning of the conversation that rapid industrial growth is highly desirable to diversify the economy, create jobs, and add value to the raw products and raw materials that are produced - thus reducing high poverty levels in Africa [4].

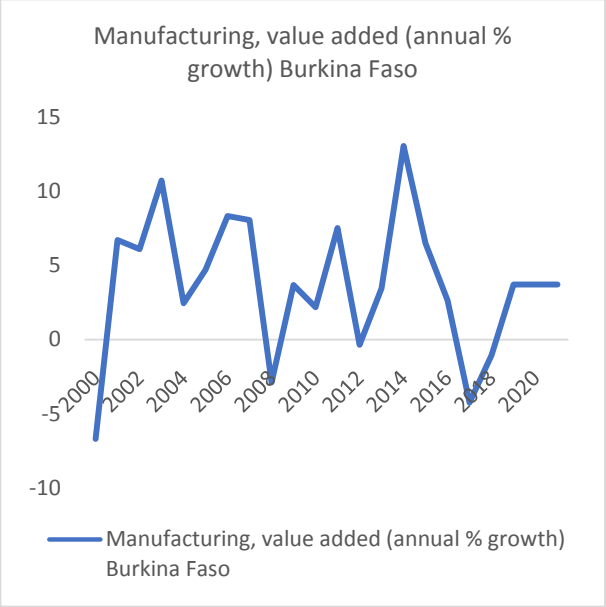
In this context of manufacturing in Africa is that domestic firms have weak technological capabilities and are embedded in fragmented learning and innovation systems. The weak technological capability of African firms can be attributed to a lack of technological support and infrastructure for domestic enterprises as policy failures in design and implementation have contributed to the poor industrial performance of African countries [5].










Manufacturing, value added (annual % growth) Burkina Faso
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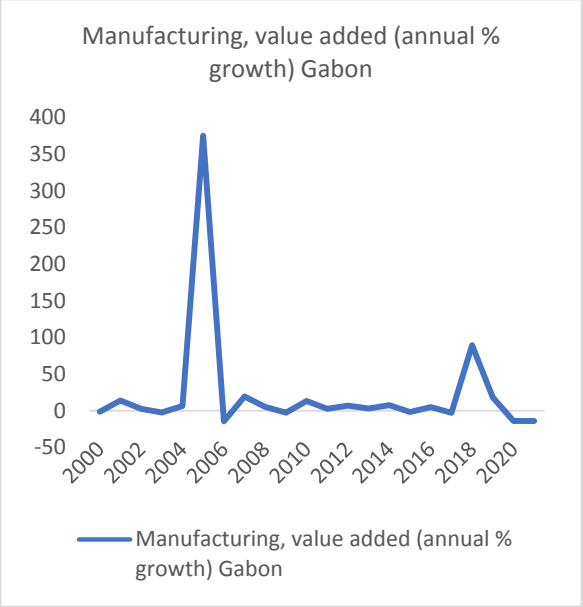
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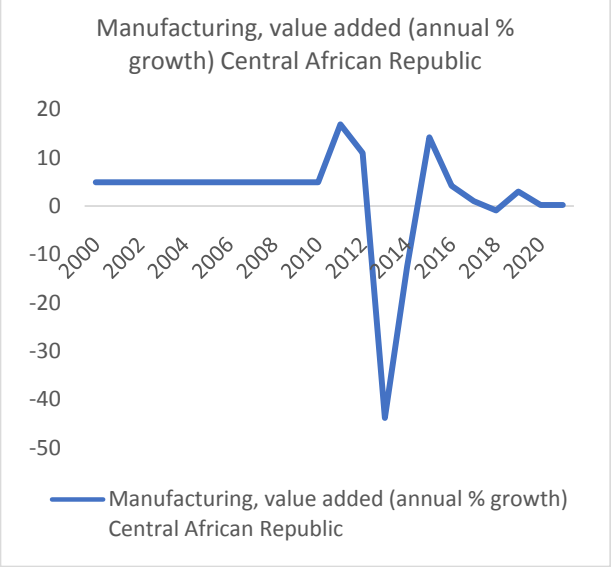
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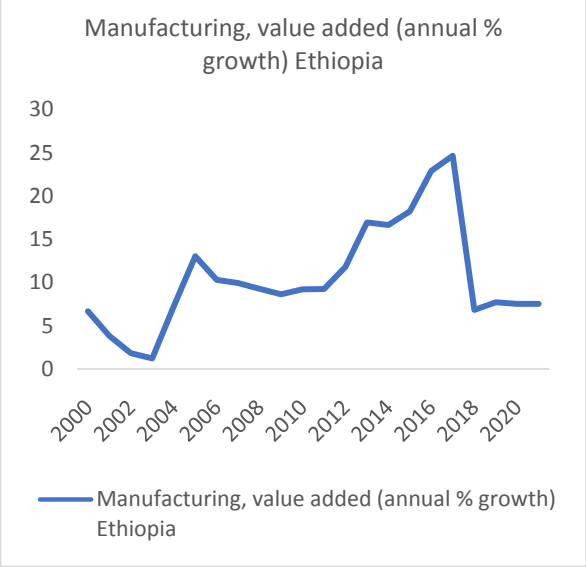
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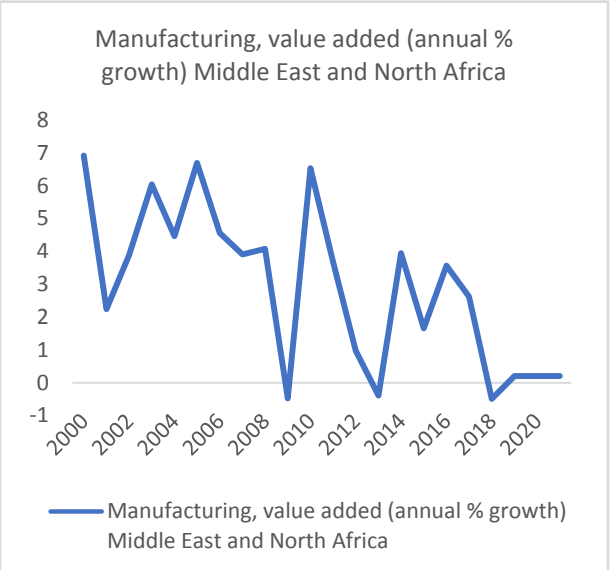
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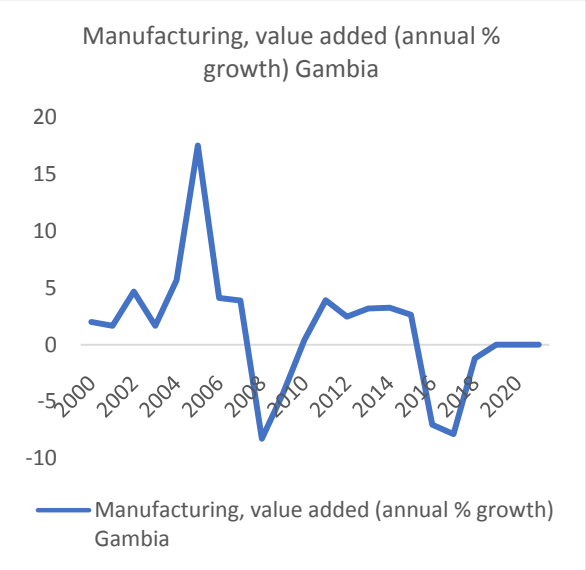
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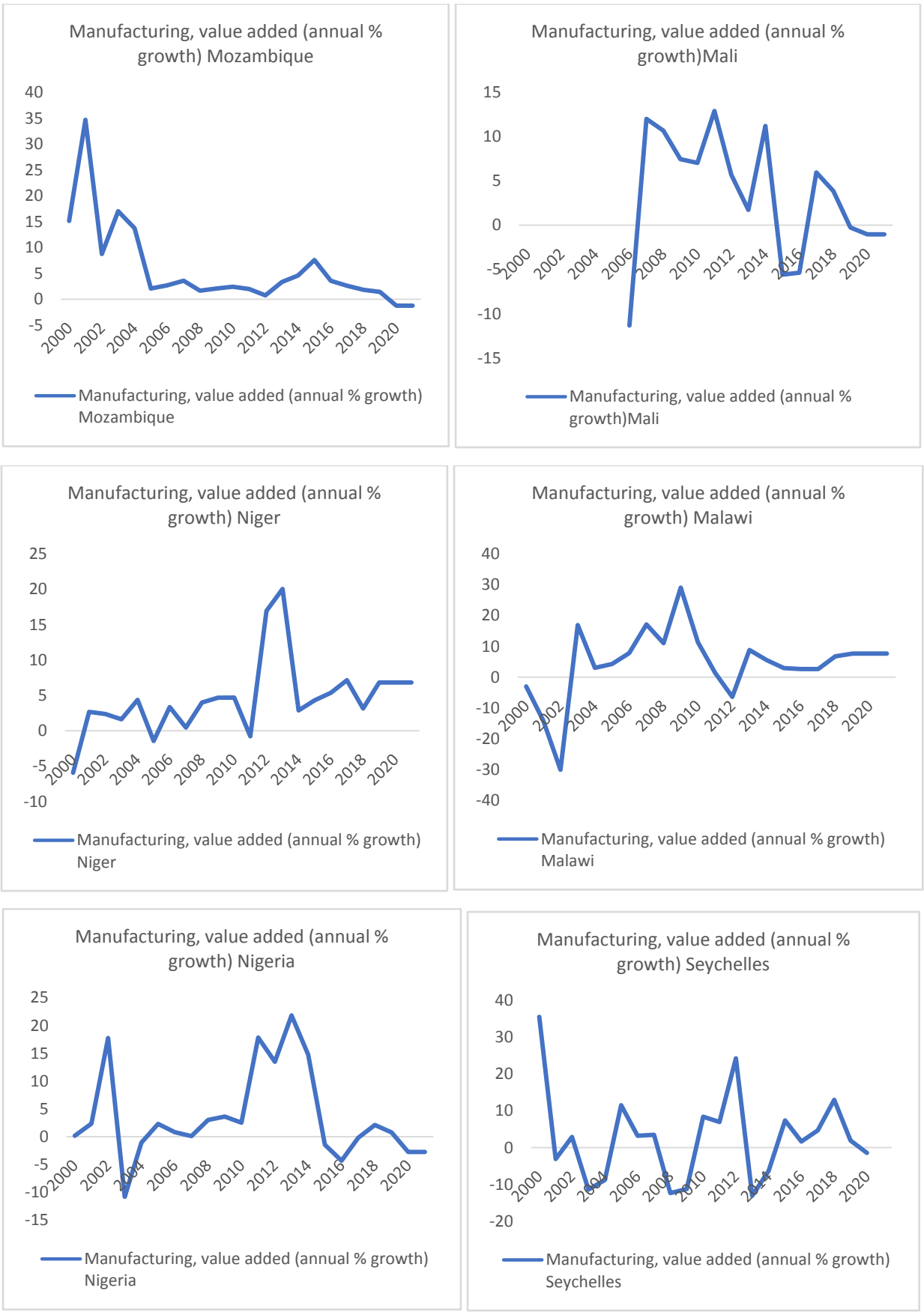


Source: Prepared by the researcher

Fig. 1 A comparative study of industrialization in South Africa

From the previous figure that it is clear the path of industrialization in Africa is characterized by weakness due to the African countries' lack of the high productive skills necessary for the manufacturing sector, as Africa suffers from low levels in terms of human development indicators in general, such as levels of education, health, and others. Based on the foregoing, African governments suffer from weak financial and organizational capacities necessary for the efficient operation of public industrial enterprises.

It should be noted that the weakness of infrastructure such as energy, transportation, communications, and others in the continent of Africa has hampered the establishment of an industrial sector capable of competition, as this led to an increase in the costs of industrial operations.

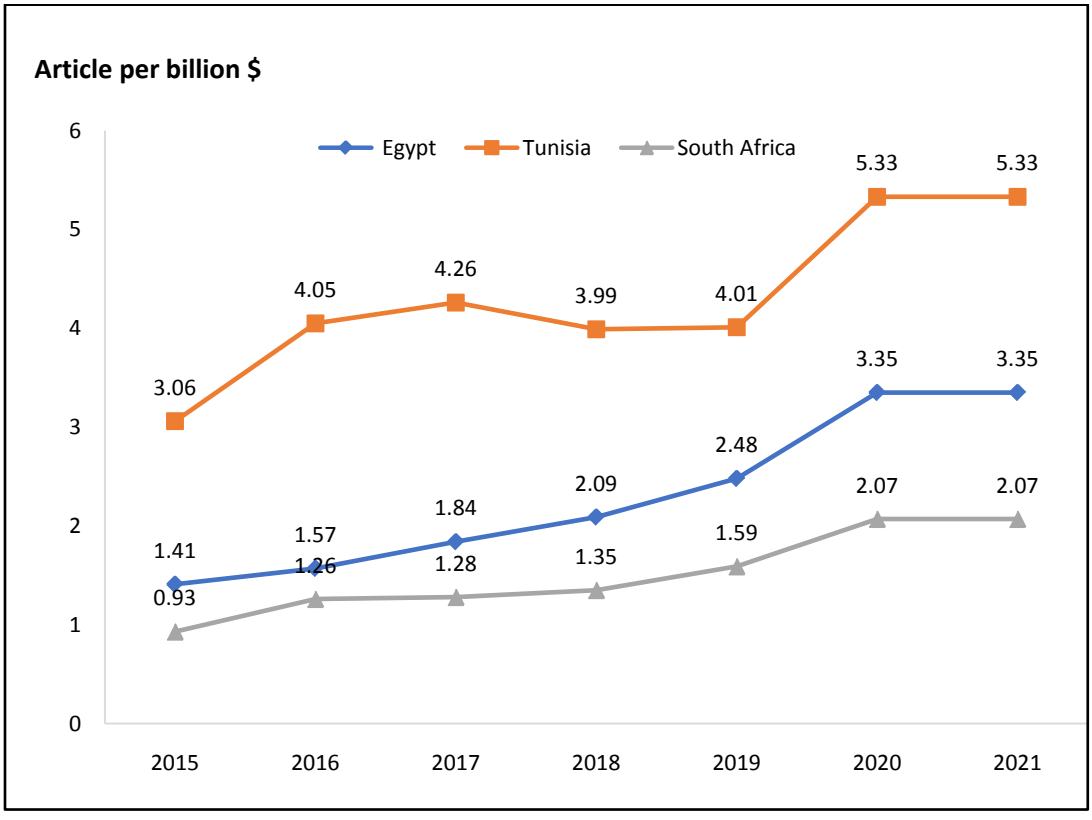
In the same regard, the limited technological capabilities in the field of innovation and the development of new industries are considered one of the most important weaknesses facing the industrial sector in Africa. The technologies used in the production process in Africa are often inappropriate, which reduces the competitive capabilities of African industries [6].

2. The Current Situation of Nanotechnology in Africa

a. Assessing Africa's Participation in Nanotechnology

Egypt established the Nanotechnology Center, where it supports industrial research with the aim of boosting the national economy. It focuses on the development of human capital, facilitating the application of nanotechnology in all sectors related to Egypt's economic development and protecting intellectual property for innovations with the possibility of marketing them.

Egypt also applies nanotechnology in the oil and gas industry to meet the growing demand for hydrocarbon products and ensure that hydrocarbon processes are environmentally friendly. Egypt uses nanotechnology to promote the agricultural sector and the food industry by changing the way crops and food are produced, processed, packaged, transported, and consumed.



Source: Prepared by the researcher from www. statnano.com

Fig. 2 Nanotechnology publications per GDP (ppp) (Article per billion $)

In Nigeria, the government has established a national steering committee for the development of nanotechnology. The committee is composed of relevant experts and stakeholders who have formulated a road map for the active development and use of nanotechnology in the country. The Committee is responsible for developing a policy framework and implementation strategies to meet national needs and aspirations through the deployment of nanotechnology.

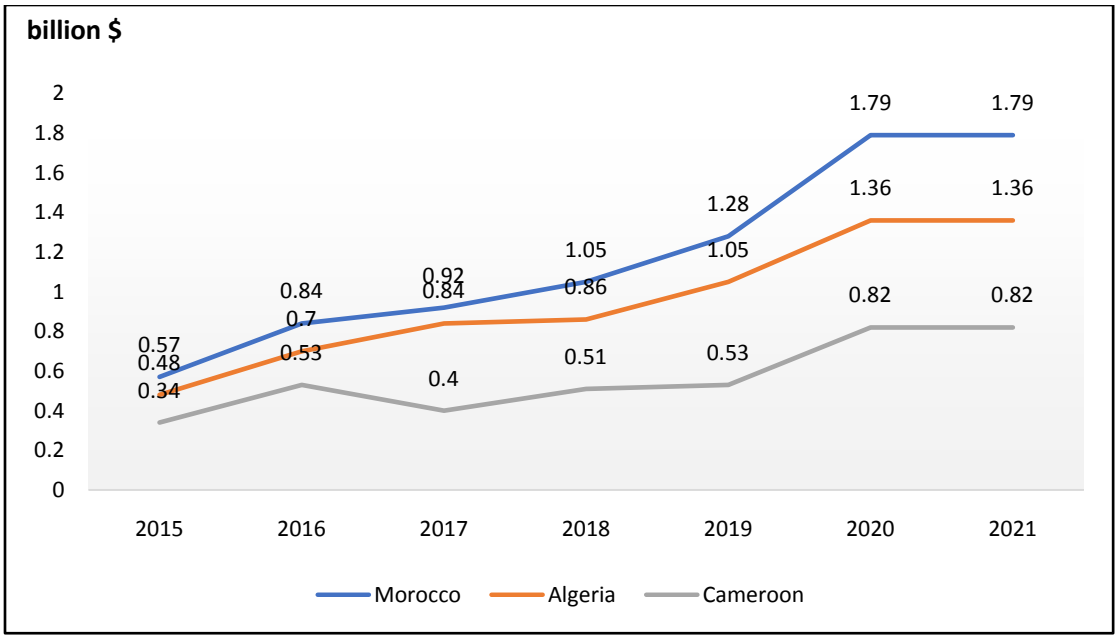


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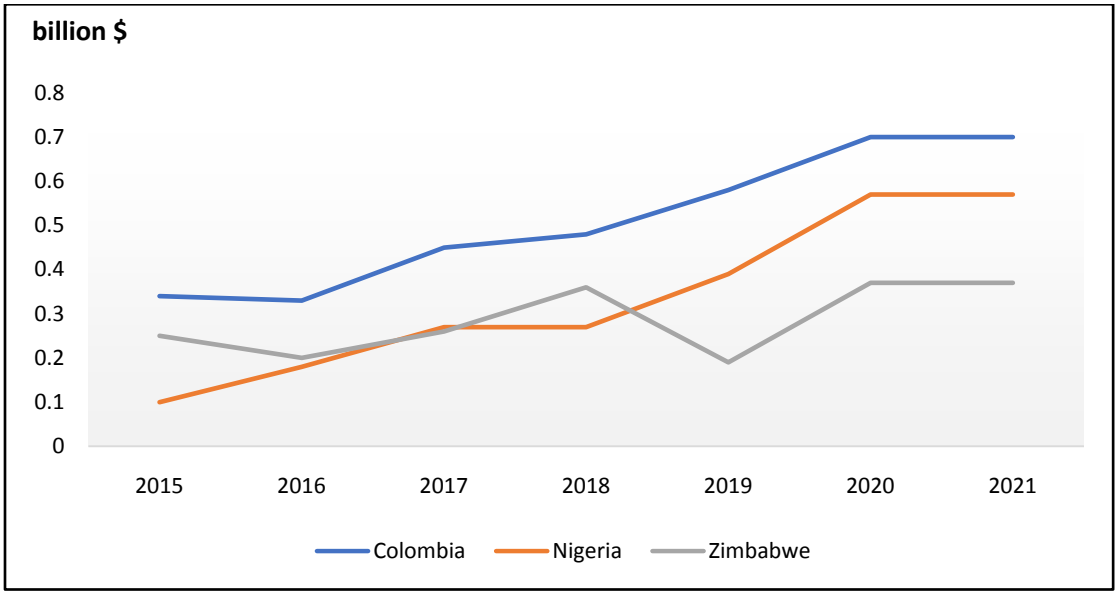
Fig. 3 Nanotechnology publications per GDP (ppp) (Article per billion $)



Source: Prepared by the researcher from www.statnano.com

Fig. 4 Nanotechnology publications per GDP (ppp) (Article per billion $)

Zimbabwe enacted a national science, technology, and innovation policy in June 2012 with the aim of promoting the use of emerging technologies, including nanotechnology, for national development. The state launched its first nanotechnology center through a partnership between the government and New York State University, working with local universities. This was followed by the issuance of a nanotechnology statement, which identified priority areas for the application of nanotechnology.

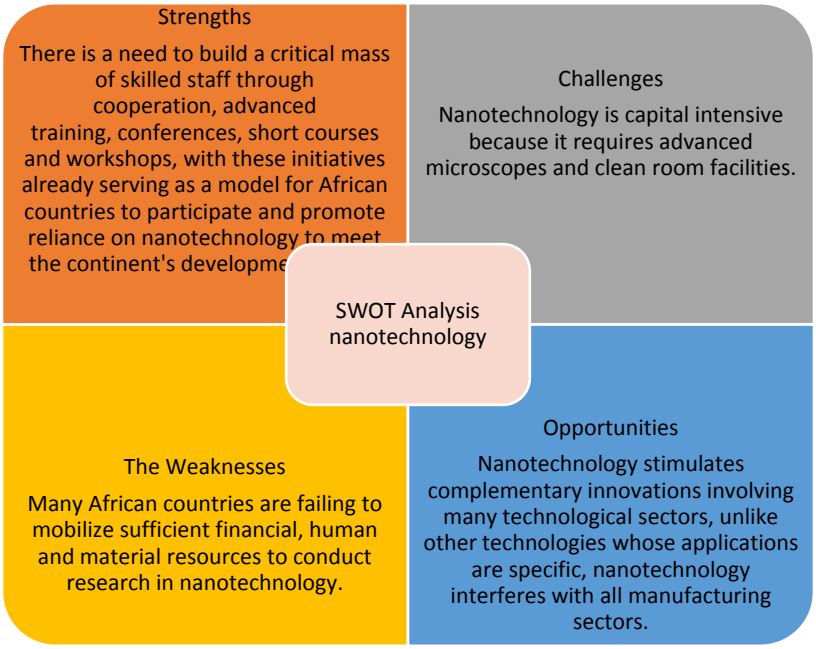
Zimbabwe is seeking to apply nanotechnology in areas such as water purification, power generation, pharmaceutical production, and mineral enrichment, to accelerate economic growth.

3. Social and Environmental Impacts of Nanotechnology Development in Africa

Nanotechnology is promoted worldwide as a technological revolution that will help solve a range of problems. Nanotechnology promises to provide new ways to solve some of Africa's chronic challenges such as treating tuberculosis and malaria, making water drinkable, preserving food, and diversifying energy sources, among other applications [7].

a. Analyzing the Potentials of Nanotechnology for the Transformation of Manufacturing Using the Quadruple Analysis Matrix

We will study the external factors surrounding nanotechnology as well as the internal factors that affect it, using the matrix of analysis of strengths, weaknesses, opportunities and challenges, known for short by the term SWOT, which is the acronym of the four words strength, weakness, opportunities, challenges, in order to reach the strategies and policies necessary to plan and accelerate the application of technology in Africa.

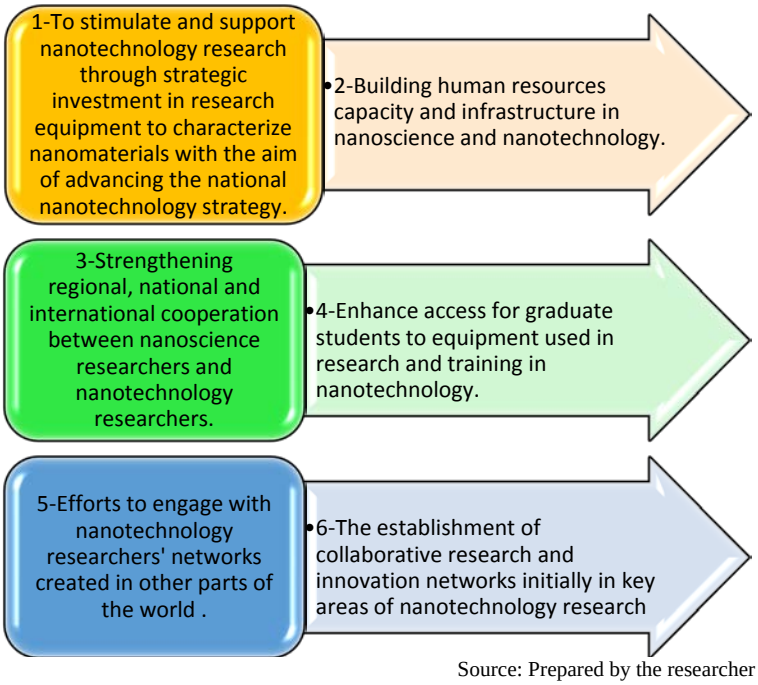


Source: Prepared by the researcher

Fig. 5 Quadruple Analysis Matrix of nanotechnology

b. African National Nanotechnology Strategy

To position South Africa as a key player in science and technology, which is progressing rapidly, it must follow the following objectives.

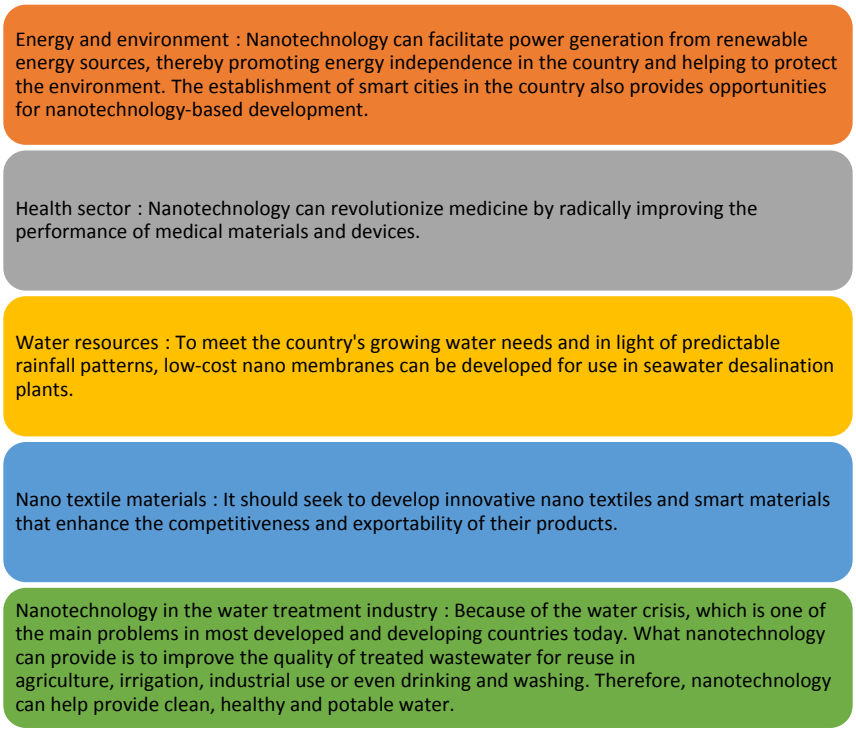


Source: Prepared by the researcher

Fig. 1 South Africa Policy Document

c. Nano Applications in African Countries to Develop Industry

Each developing country should identify a particular area of nanotechnology for specialization, particularly for developing countries, to develop its own network of skilled and experienced nanotechnology users and providers that reflect the economic needs and conditions of their countries and are therefore able to effectively address the concerns of their populations and enhance their quality of life.

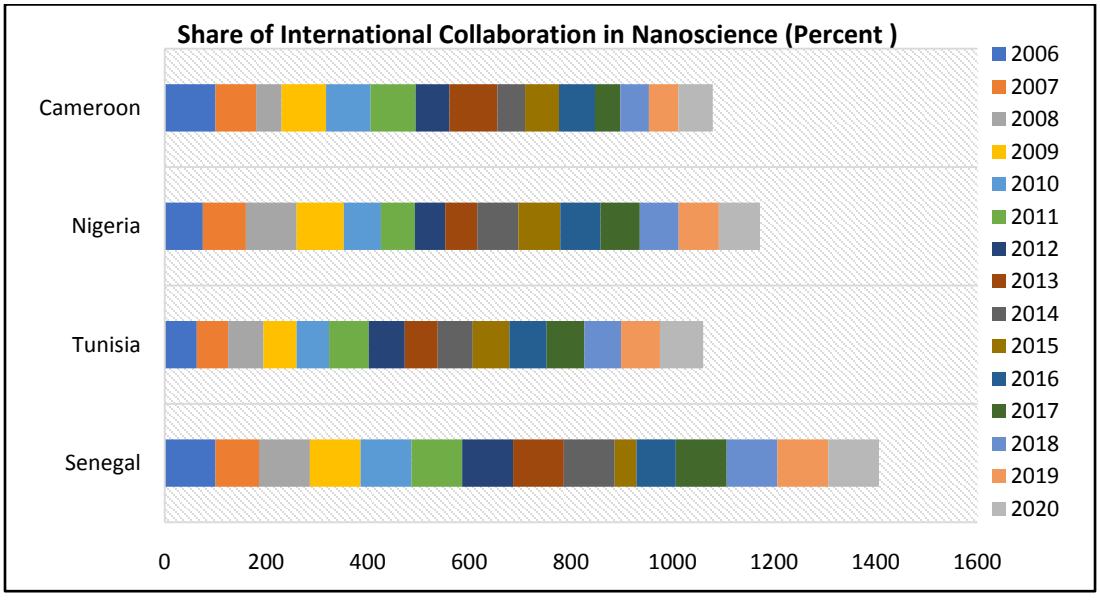


Source: Prepared by the researcher

Fig. 7 Nanotechnology applications in different industries

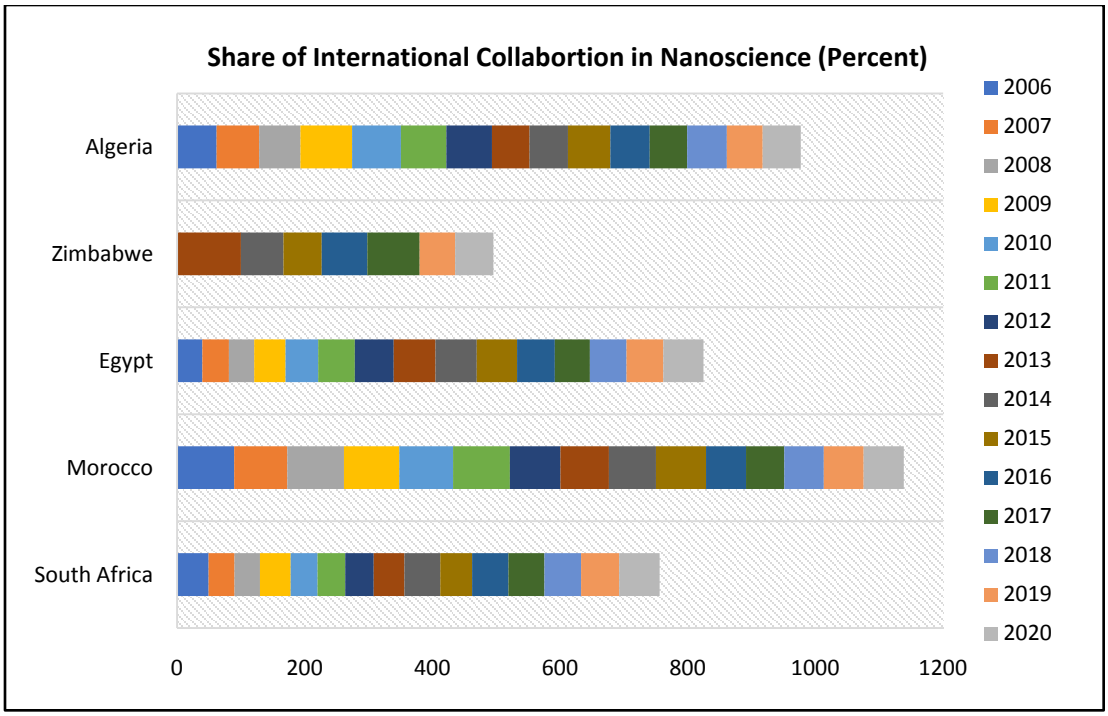
d. Research and Innovation in Nanotechnology in South Africa

First, the South African government is adopting economic growth, poverty alleviation and quality of life improvement through the development and exploitation of nanotechnology by setting the following four objectives.



Source: Prepared by the researcher from www. statnano.com

Fig. 8 Share of joint nanotechnology articles between one country and other countries

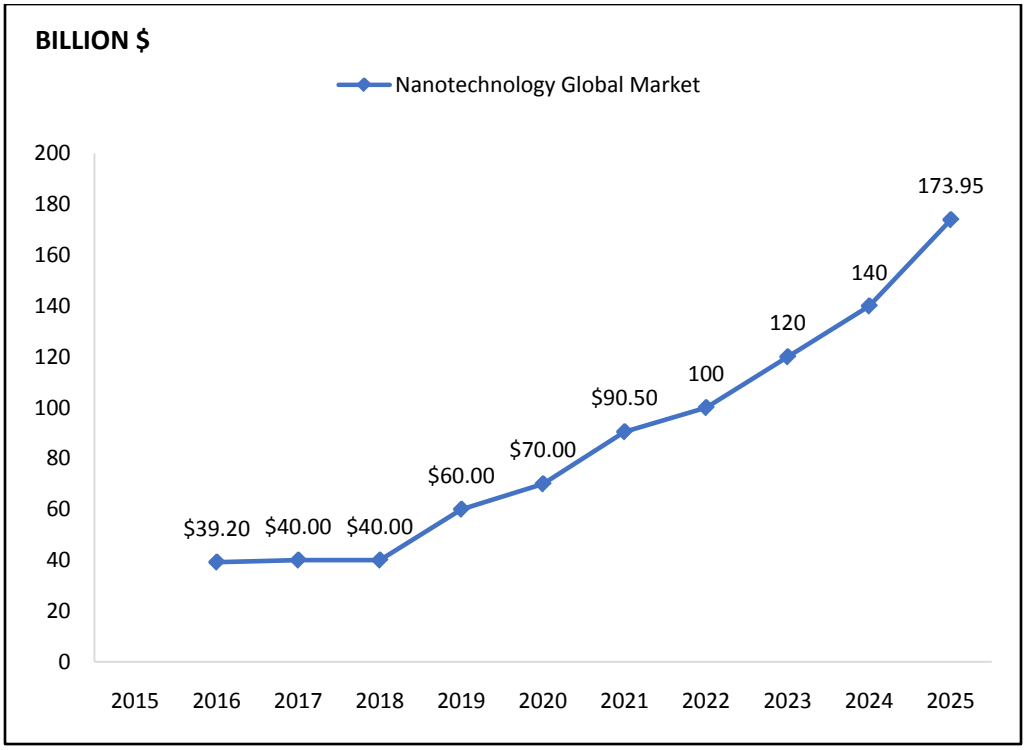


Source: Prepared by the researcher from www.statnano.com

Fig. 9 Share of joint nanotechnology articles between one country and other countries

4. The Global Market of Nanotechnology and Applications

Market studies suggest that the global market of nanotechnology will reach around $ 174 billion by 2025 experiencing a compound annual growth rate (CAGR) of 18%. During this period, various fields of nanotechnology will have different shares in the overall market with different growth rates. As shown in following graph (figure 10), global nanotechnology market is poised growing to reach approximately $173.95 billion by 2025 and $ 90.5 billion by 2021 from $39.2 billion in 2016, growing at a five-year compound annual growth rate [8].



Source: Prepared by the researcher from www.statnano.com

Fig. 10 Estimated Nanotechnology Global Market in the Following Years

Nanotechnology has diversified applications in almost every industrial sector. According to a study by BCC Research, "the largest end-user markets for nanotechnology in 2015 were environmental applications (38.8% of the total market), electronics (22.4%), and consumer applications (21.1%). Biomedical, consumer, and electronics applications should demonstrate the highest projected CAGR rates (i.e., 29.9%, 27.9%, and 20.5%, respectively) during the forecast period (2018-2022)". The following graph (figure 11) shows the estimated CAGR for different fields and subcategories of nanomaterials, nanostructures and nanotechnology applications [9].

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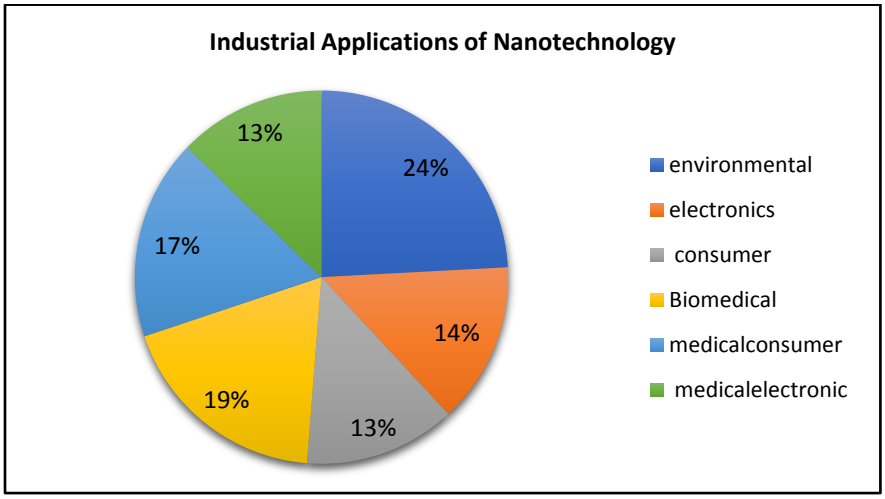


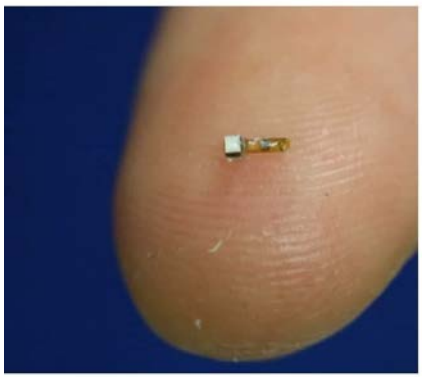
Source: Prepared by the researcher from www.statnano.com
Fig. 11 Nanotechnology industrial applications

5. Nanorobotics and Machine Industry

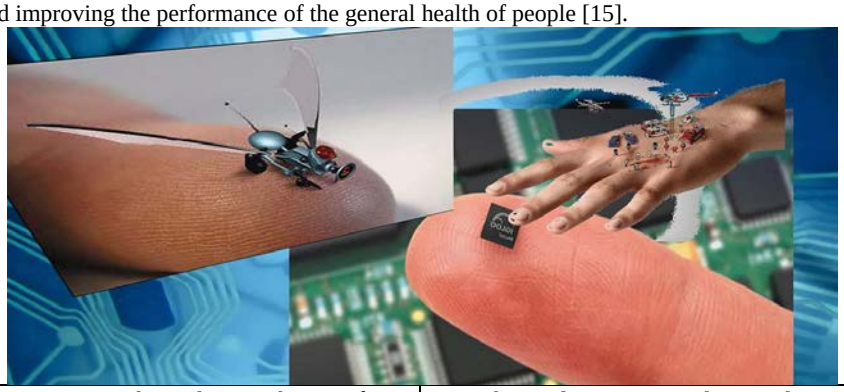
Nanomachines are advanced modern technology and engineering for making machines or robots and the like at a nanometer scale [11]. Nanomachines are a complete industrial revolution in connecting modern technology and medical science through nanotechnology [12].

As shown in the pictures on the finger of the hand, they are nanorobotics designed and manufactured for medical uses, early examination, and treatment of incurable diseases such as cancer, which are very small chips as you see them compared to fingerprint wrinkles [13].

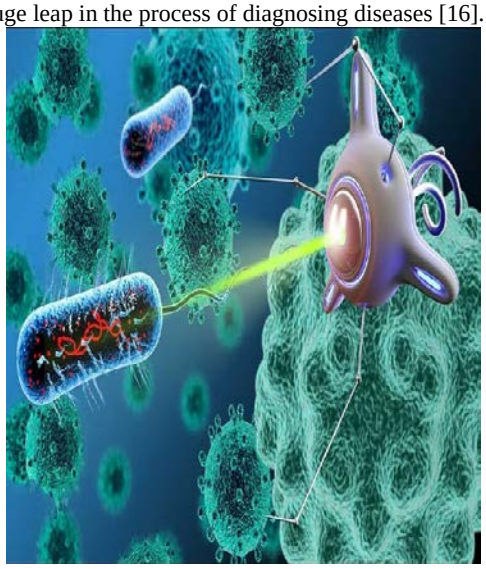
TABLE I NANOTECHNOLOGY USES

Nanorobotics are currently in the advanced research and development stage, and in the future, they will have a major role in medicine and perform operations with great accuracy, and it can enter and open the minute arteries that are clogged in vital areas of the body such as the brain and treat strokes without any intervention or surgical procedure [14]. 	In addition to its ability to detect the location of tumors, carcinogenic cells, and weak arteries prone to clogging with extreme accuracy and at early times, early detection helps to treat in a short time at a lower cost. 

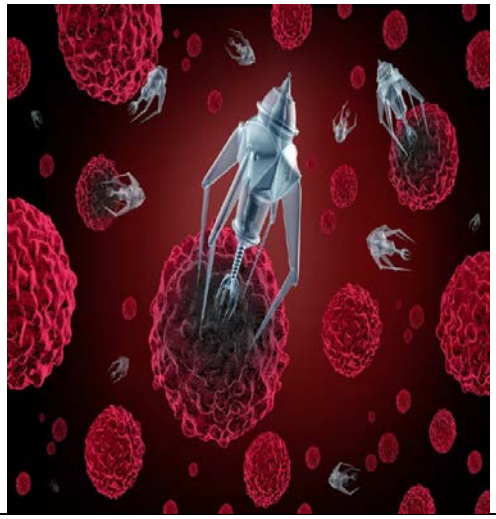
Among the potential applications of nanorobots in medicine are early diagnosis and early detection of diseases and speed of treatment in early stages, as well as the delivery of targeted drug to treat cancer, in its stages, biomedical devices for surgery, tracking drug movements, and knowing and tracking the pathways that these materials take during the stage Treatment, monitoring and treatment of diabetes, integrated health care around the clock and improving the performance of the general health of people [15].



Current experiments are taking place on the use of nanorobots in drug delivery, carrying and directing specific doses to tissues and organs to be treated only in what is scientifically known as Bioavailability. Nanobots will enable us to monitor some organ functions such as a patient's vital signs and represent a huge leap in the process of diagnosing diseases [16].



It can be used in surgery and surgical procedures inside the body, and its tasks are organized by a nanoscale control panel and a computer. Especially in sensitive and very small places that are difficult to deal with by surgeons. It can also be used in the diagnosis and treatment of cancer.
Nanobots are made of polymer and include biochemical sensors capable of identifying cancer cells and tumors.



Nanorobotics are characterized by their high accuracy, speed, and ability to reach critical areas due to their small size, and they will replace traditional treatment methods with faster and more accurate methods and reduce the error rate in treatment methods [17].

Source: Prepared by the researcher

6. Republic of Korea's Strategy to Promote the Development of Nanotechnology

The Republic of Korea has formulated a strategy to develop a development plan and stimulate research in nanotechnology with several objectives, including.

TABLE II NANOTECHNOLOGY INNOVATIONS AND INDUSTRIAL APPLICATIONS

Human Capital Development	Research Infrastructure	Funding For Regional Research	Governance of Nanotechnology Innovation Systems	Leveraging Regional and Global Resources
The Republic of Korea has begun training 13,000 nanotechnology specialists. It also supports the establishment of specialized nanometric centers and nanometers and engagement with strategic partners abroad.	Nanotechnology requires significant investments in research infrastructure. Built new specialized research centres (approach of the Republic of Korea) and established nanotechnology institutes in existing research facilities.	Promote the nanotechnology research agenda as a means of promoting national development or meeting the basic needs of the population, including clean water, health care, energy, and security.	Nanotechnology governance can be described as a set of institutional arrangements that guide the behavior of public and private actors. These arrangements may include regulations, laws, and incentives.	Policymaking is guided by politicians, parliament, ministries and other stakeholders who set the nanotechnology agenda, priorities and plans.

Source: Prepared by the researcher [18]

V. CONCLUSION

This search sets forward an ambitious long-term strategy for Nanotechnology in South Africa. The emerging aspects of Nanotechnology has been shown and human resource capacity and R&D capacity built in a way that the country Africa's well positioned in the next decade as a major player in Nanotechnology and a recognized implementer of Nanotechnology solutions. This strategy provides a realistic vision for such a Nanotechnology future in Africa.

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