

Implementation of flexible manufacturing systems in Africa: multiple case studies in the Gambia and Ghana



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ABSTRACT: In comparison to Europe, Asia, and America, the African manufacturing sector performs poorly. This is largely attributable in part to inadequate use of advanced manufacturing concepts and technologies, as well as the insufficiently skilled workforce. African manufacturing companies must adopt and implement advanced manufacturing technologies and concepts such as flexible manufacturing systems in order to boost growth and accelerate development in the sector. In this study, we conducted multi-case studies on the implementation of flexible manufacturing systems in the manufacturing sectors of two West African countries (The Gambia and Ghana). Six manufacturing companies from The Gambia and eight from Ghana were chosen. Many of the companies involved in the study are small businesses that specialize in mechanical parts/system production, welding, and fabrication. The findings revealed that the use of advanced manufacturing technologies and concepts, as well as the adoption of flexible manufacturing systems, is extremely low. The results also show that the major obstacles to the adoption and implementation of advanced manufacturing technologies are, cost and, lack of qualified personnel. Companies have agreed to adopt and implement advanced manufacturing technologies and concepts if the opportunity arises. They also require more information on some cutting-edge technologies before deciding whether to adopt and implement them. Some of the other major challenges faced by African manufacturing companies include, high energy costs and unstable power supply, poor transportation network, and, lack of adequate finance.

KEYWORDS: Flexible manufacturing systems, advanced manufacturing technologies, African manufacturing industry, Implementation of FMS

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I. INTRODUCTION

One of the key contributors to the economic development of countries is manufacturing. The manufacturing industry proves to be a priority for both developed and developing countries because of its added value to GDP, employment creation, and most importantly, the overall economic development achievements registered by institutions. These create motivation and encouragement for entrepreneurs to invest heavily in innovative manufacturing to maximize profit and optimize the use of resources. Currently, the global manufacturing industry registered a significant development and advancement in the used technologies, artificial intelligence, and innovative manufacturing concepts and models. These new developments in the manufacturing sector yield huge profits for industries that implement these advanced technologies and concepts. Flexible manufacturing systems (FMS) are one of these advanced manufacturing concepts employed by some industries to improve their performance and efficiency. The impact of these technologies and concepts is hardly felt in the African manufacturing sector because the continent experienced the lowest level of implementation and

adoption of these new technologies and concepts compared to the rest of the world. Implementing and adopting these new technologies and concepts in the African manufacturing industry will improve the manufacturing landscape and transform it. FMS strives to improve production flexibility, productivity, efficiency, and self-management, which are all aspects that manufacturers aspire to improve. The primary objective of this study is to discuss the application of flexible manufacturing concepts and technologies in manufacturing, as well as to conduct multiple case studies on the implementation of flexible manufacturing systems in The Gambia and Ghana. The study will also investigate the various dimensions of FMS that can help improve the African manufacturing industry, as well as research opportunities in the use of FMS concepts and technologies in the sector.

A. Manufacturing in Africa

The African manufacturing industry is constrained from multiple fronts compared to the rest of the world. This includes but is not limited to, lack of stable power supply, high cost of energy, bad transportation infrastructure, lack of sufficient investment, and the list goes on. These challenges are reflected in the poor returns and performance of manufacturing

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companies. Despite significant constraints, the African manufacturing sector has achieved considerable accomplishments, ranging from vehicle manufacturing in South Africa to garment manufacturing in Mauritius and East Africa and other specialized instances in footwear, Agro-processing, food and drinks, and consumer products (Velde *et al.*, 2018). The good thing is that African governments are now putting more attention to the growth and development of the manufacturing sector and trying to create an environment for the use of advanced technologies that will enhance the performance and efficiency of the sector. Africa has a large market size of over a billion people; this creates an enormous opportunity for manufacturers in terms of making profit in their investments. In order to meet the demand of customers, manufacturers have to adopt advanced technologies and concepts in their manufacturing processes. Unfortunately, the level of adoption and implementation of these advanced technologies and concepts in the African manufacturing industry is very low compared to the rest of the world.

B. The Gambia and Ghana manufacturing industry

The Gambia and Ghana are both West African nations with a population of 2.3 million (The Gambia Bureau of Statistics, 2020) and 30.8 million (Service, 2021) respectively. These two countries are the selected countries for this multiple case studies on the implementation of flexible manufacturing systems in Africa. Hence a brief context and background about these West African nations and the state of their manufacturing industries.

south borders the country, which has a total area of 4127.046 square miles. The nation has a 37.28-mile Atlantic Ocean shoreline to the west. Tourism and rain-fed agriculture are the mainstays of the country's economy. The economy of the country is unstable and prone to external shocks (Worldatlas, 2022). Aside from the tourism sector, the Gambian economy has a small domestic market and low levels of integration with regional and international markets. Because of the country's lack of economic diversification and limited complexity, attracting investors has been difficult, and as a result, The Gambia lags in terms of integrating global value chains, adopting new technologies, and improving market access, all of which could increase productivity (The World Bank, 2020). The Gambia's manufacturing industry is dominated by small and medium-sized enterprises (SMEs), whose products are mostly intended for the domestic market. The country still imports ceramic tiles and sanitary fittings, among other things, the sector has a lot of room for growth (Kiporop, 2019). The foundry industry has a lot of potentials because it uses scrap metal to make metal plates and finished iron for use in buildings and small repair shops.

Although there is a lot of opportunities for growth in the sector, The Gambia has one of the lowest performance in manufacturing in the continent. Massive resource investment in the manufacturing sector is required for the country's manufacturing industry to be competitive in the sub-region.



Figure 1 Map of West Africa (Bossard, 2018)

1) The Gambia

The Gambia is a West African country that extends along the Gambia River for 279.6 km. Senegal to the north, east, and

2) Ghana

Ghana is located in the heart of Africa's Gold Coast, with a 535-kilometer coastline that contains lagoons and mangrove forests. The country's tropical climate ranges from a Sudanian-

type climate in the north with a brief rainy season to the forested Guinean and Guineo-congolian regions in the southwest, which have a high rainfall regime(ATLAS, 2018). Ghana's economy has traditionally been driven by cocoa exports, and the country is now one of the world's major cocoa exporters. Agriculture continues to be a major source of income for roughly half of Ghanaians though, natural resources are abundant in the country. Ghana is one of the richer countries in West Africa, thanks to timber, gold, diamonds, bauxite, manganese, and oil. Despite having one of the most prosperous economies in the region, it is still heavily reliant on international funding (Admin, 2016). Over the previous decade, Ghana's economic growth has been among the fastest in Africa, outpacing that of certain high-investment emerging market economies. Ghana's economy has grown slowly but steadily over the last 25 years, with an average growth rate of 5% between 1990 and 2010. Ghana's industry accounts for approximately 25.3 percent of total GDP. However, as a result of government industrialization efforts, Ghana's industrial production is growing at a 7.8 percent annual rate, ranking it 38th in the world. Currently, it is anticipated that Ghana's average medium-term real GDP growth rate will be at least 8% annually (Addo, 2017).

Compare to The Gambia, Ghana's manufacturing industry is doing well and the future of the sector also promise great success looking at the industrial policy that the government of Ghana develops (one district one factory (1D1F)) and currently implementing.

C. Flexible Manufacturing Concepts and Technologies in Manufacturing

A flexible manufacturing system is a computer-controlled workstation and materials handling system that allows for the processing and/or assembly of a wide range of parts with minimal workstation configuration time and maximum workstation usage.

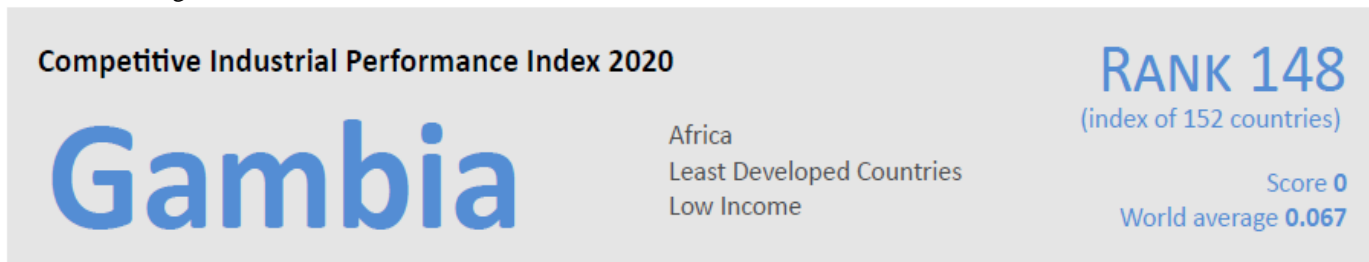
Aside from the processing equipment, FMS incorporates the material transport system, the buffer, the work piece warehouse, human resources, and others (Erdirin and Atmaca, 2015). The advent of the FMS assists manufacturing sectors in improving their performance and flexibility in producing customized products in medium volume (Singholi, Chhabra, and Ali, 2010).

Although FMSs are still not flexible enough to accommodate the ever-changing custom-made products demanded by clients, but the concept is designed in such a way that it can incorporate the new emerging technologies that will ultimately improve the flexibility of the system(s). Despite the fact that deploying FMS has some drawbacks, such as high initial investment cost, the impact it registers is enormous (Chen and Adam, 1991). Ranging from increased machine usage, reduced factory floor space, increased responsiveness to change, reduced inventory requirements, quicker manufacturing lead times, and opportunities for unattended production. These are capabilities that most manufacturers look for in their firms. The technologies deployed in the FMSs such as autonomous mobile robots, integrated CNC machines, container based industrial controllers and buffer storage systems transform the way we work and increase performance.

D. Flexible manufacturing systems in Africa

The use of advanced manufacturing technologies and concepts in the African continent is very low compared to that of Europe, Asia, and America. This is partly because of lack of investment, suitable infrastructure, and skilled personels among other series of issues. Although most African Governments develops some promising industrial policies that could improve and accelerate the industrialization process of their countries, the manufacturing sector remain underdeveloped.

FMS enables flexible and automated production in



Manufacturing sector summary (2018)

Export data are in current USD, all other values - in constant 2015 US dollars

GDP: 1,559 million | 684 per capita
 Manufacturing value added: 70.1 million | 30.8 per capita
 Manufacturing exports: 5.1 million | 2.0 per capita

See full manufacturing profile at stat.unido.org/country-profile
 Readers Guide: stat.unido.org/content/learning-center/cip-readers-guide

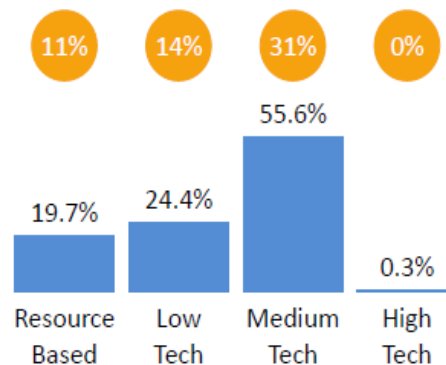
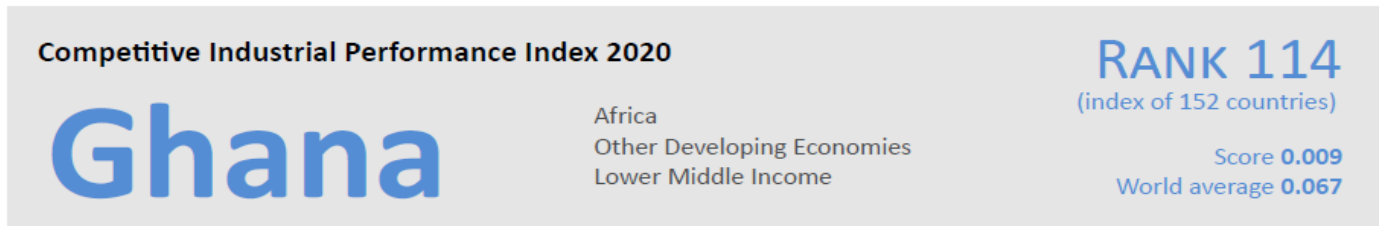


Figure 2 Competitive industrial performance index 2020 (Valentin, 2020)



Manufacturing sector summary (2018)

Export data are in current USD, all other values - in constant 2015 US dollars

GDP: 58.5 billion | 1,964 per capita

Manufacturing value added: 6,939 million | 233 per capita

Manufacturing exports: 1,662 million | 56.0 per capita

See full manufacturing profile at stat.unido.org/country-profile

Readers Guide: stat.unido.org/content/learning-center/cip-readers-guide

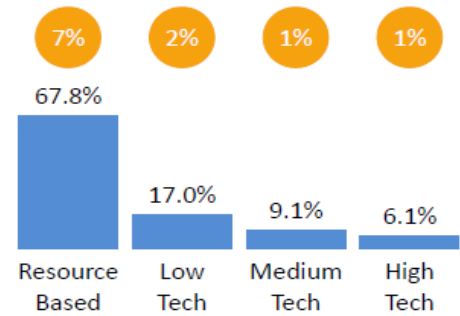


Figure 3 Ghana's competitive performance index 2020 (Valentin, 2020)



Figure 4 Real flexible manufacturing system(Košťál, 2019)

response to industry developments that are either predictable or unanticipated. The FMS concept employs computers to arrange machinery to establish automatic processing lines. Users or developers can customize a set of production systems, which primarily use computer-controlled machine tools and are supplemented by production assembly equipment, robotic arms, quality inspection machines, automatic optical inspection, and other equipment, as well as computer-integrated manufacturing (CIM) material handling and storage system (Shenchong, 2022).

For African manufacturing sector to quickly catch up, the need for adoption of advanced manufacturing technologies and concepts like FMS in the manufacturing industry should be a priority. Some of the key benefits offered by FMS is the high degree of flexibility with which manufacturing resources may be managed (such as the manufacturing time management and investing in research and development of new products), Small batch production and mass production. Its benefits also include reduced component inventory, faster and lower unit production

costs, improved human productivity and machine efficiency, quality improvement, greater system reliability, and CAD/CAM operation adaptability (Malhotra, Raj and Arora, 2010). Embracing cutting-edge technologies with automation is one way to maintain competitiveness and flexibility; this is a vital component of successful transformation of the African manufacturing industry. Manufacturing success depends on the adoption of new technology during accelerated innovation (Javaid, 2022). Leveraging these advantages offers by these technologies and concept can change the dynamics of the African manufacturing industry.

E. Multiple case studies on the implementation of the flexible manufacturing systems in the Gambia and Ghana

Although FMS implementation requires a significant investment and commitment from the user company, (Khan et al., 2020) the advantages it promises in terms of performance, efficiency and flexibility in the manufacturing sector are enormous. The manufacturing sector in Sub-Saharan Africa is

still performing below average, and The Gambia and Ghana are no exceptions. Manufacturing's share of Sub-Saharan African GDP has fallen from 14% in 2000 to 9.6% in 2010 and has remained at that level ever since (Dirk Willem te Velde, Maximiliano Mendez-Parra, Karishma Banga, Linda Calabrese, 2021). This is partly due to the industry's use of obsolete technologies and the low-level adaptation and implementation of advanced manufacturing technologies. Companies in the sub-Saharan region should embrace automation and the opportunities of 4th industrial revolution technologies in order to rapidly accelerate growth and development in the sector. Furthermore, African governments should develop their own digital transformation framework and adaptive industrial policies to support development plans.

Although the risk factors for investment in the African manufacturing industry are high (Signé and Johnson, 2018), these challenges can also be turned into opportunities. In order for the sub-region to quickly catch up with growth and development, investors must explore innovative financing arrangements and experiment with the deployment of advanced and emerging manufacturing technologies such as FMS.

Implementing FMS processes will result in multiple benefits (Hayes, 2022) including, lower manufacturing costs, increased machine efficiency, improved product quality, increased system reliability, shorter lead time, and increased productivity. If indeed the manufacturing industries of The Gambia and Ghana are able to leverage on this technology and reap these benefits, the manufacturing dynamics of these West African countries will be completely altered. Although the use of advanced manufacturing technologies in these countries are still low partly because of the lack of funds (Runde, Savoy and Staguhn, 2021) and skilled personnel's couple with the poor manufacturing infrastructure, the governments of these nations and some private companies are making efforts to create the opportunities for this paradigm shift. There have been some developments in the area of research and the use of modern technologies in some parts of Africa (Fofana, Nyarko and Takyi, 2022). For example, Google recently established its first Africa Artificial Intelligence Laboratory in Ghana, and Andela (Gerrard 2019) is a company with offices in Nigeria, Kenya, and Uganda that assembles high-performing engineering teams from Africa's most talented software developers. In this study the utilization of FMS is assessed across sampled industries in The Gambia and Ghana.

II. METHODOLOGY

In this paper, a multiple case study was conducted on the implementation of FMS in The Gambia and Ghana manufacturing industry. The focus cases were Mechanical part/system production, welding and fabrication, foundry production and food and beverage production. The research was conducted in 14 different manufacturing companies (Six from The Gambia and eight from Ghana). Following a typical research approach, a questionnaire was designed and validated to complement the case study data collection process. The questionnaire was divided into three sections:

(1) General company information; (2) the use of innovative manufacturing technologies and concepts in production and maintenance; and (3) future growth prospects. The goal of the survey was to investigate and collect data on companies' backgrounds, levels of adoption of advanced manufacturing technologies, and prospects. The questionnaire was later distributed to various levels of personnel in the manufacturing plant as part of the data collection research. Face-to-face interviews with engineers and technicians, as well as facility tours, were used to collect additional data. After the data collection process was completed, it was checked for missing data and outliers. Finally, the data was tabulated and ready for analysis using Microsoft Excel and Minitab.

III. RESULTS AND DISCUSSION

The presentation of the results is divided into three different areas (General information about companies, the use of advanced manufacturing technologies and concepts, and finally the forecast for the future).

A. General information of the companies under research

The result of the survey indicated that more than 70% of the companies under research are engaged in Mechanical parts/system production & welding and fabrication. Almost all the products produced by these companies are mainly for domestic consumption and almost 80% of these companies are small-scale enterprises.

These manufacturing firms have very low academic qualification requirements for employment, which may explain why they are unable to adopt new and advanced technology that requires the expertise of highly educated technicians and engineers. Out of the 14 companies studied, 7% employed people with bachelor's degrees, 43% employed people with secondary school education, 64% employed people with experience but no formal education, 28% employed people with technician certificates and diplomas, and 21% trained some of their employees on the job. There are no companies that employ graduates or postgraduates in their manufacturing facilities. This finding indicates that these companies' staffing profiles are weak in terms of academic qualifications and experience.

B. The Use of Advanced Manufacturing Technologies and Concepts

Next is the use of advanced technologies and concepts in the manufacturing sector. The adoption of advanced manufacturing concepts and technologies in Africa is extremely low when compared to developed nations (African Union, 2022); The Gambia and Ghana are no exception to this low adoption of these technologies. Manufacturing procedures are changing as a result of the expanding usage of industrial automation, cutting-edge robots, smart factories, the internet of things, and additive manufacturing or 3D Printing (Abbi, 2019). "The adoption of new technologies will be disruptive whether or not emerging economies use them to generate conventionally manufactured goods" (Mary Hallward-Driemeier, 2017). The adoption of flexible manufacturing systems in the African manufacturing sector is likewise quite

limited when compared to the number of businesses that use automation and contemporary technologies and the subsequent results from the survey proof these claims.

The result of the current level of automation deployment of companies under the research (Figure 5(a)) shows that, out of the 14 companies surveyed, only 6 (43%) have some form of automation in their company. The rest have no automation which confirms the claim that the adoption of these technologies are limited in these countries. Meanwhile, the firms that employed some form of automation in their manufacturing process, automate a few selected areas like processing and post-process handling (Figure 5(b)).

The major obstacles faced by these companies in terms of implementing these computer base control systems technologies are the high initial investment cost and the lack of skilled personnel (Figure 6(a)). On the obstacles of implementing computer base control systems in manufacturing, companies were required to identify the severity of the obstacles from scale 1 {not an obstacle} to scale 5 {major obstacle}, 93% of the companies agrees that the initial investment cost of these advanced manufacturing systems is a major obstacle for them and 71% claimed that the lack of skilled personnel is a major obstacle, while an overwhelming majority (85%) agreed that management commitment and nature of business is not a major obstacle.

On the implementation of computer-integrated manufacturing (CIM) technologies which are the core of FMS, the study also examines the adoption and utilization of these technologies since the successful applications of advanced

manufacturing technologies, such as integrated computer-aided design(CAD), computer-aided manufacturing(CAM), computer-aided engineering(CAE), computer-aided quality(CAQ), computer-aided planning(CAP), production planning and control(PPC) systems and other cutting-edge innovations like generative design, 3D printing, and the industrial internet of things, are seen as the solution to the challenges of manufacturing competitiveness (Azemi *et al.*, 2019). In terms of the utilization of these technologies, three scenarios were investigated, in use, plan to use, and no plan to use. The results (Figure 6(b)) indicate that the common application in use by most of these companies is CAD (50% of companies) followed by CAM/CAE (20% of companies) and CAQ/ IIOT (10% and 7% of the companies respectively). On average, more than 90% of the companies plan to use these technologies to improve their productivity and competitiveness but this is also tied to the availability of funds and adequate skilled personnel. Generative design, 3D Printing, and the industrial Internet of Things are the technologies that most companies are not using and have no plans to use them. This is partly because these technologies are new and suffer a lack of awareness of the impact of these technologies on the manufacturing systems. Although most of these companies utilized some form of communication network like local area network (LAN) and wide area network (WAN) in their plants but the connectivity is not integrated with their production equipment. In other words, they are not using the industrial Internet of things in actual manufacturing processes, but rather for internal communication.

Table 1 General Information of Companies under the Research

S/N	Company Name	Type of manufacturing engaged in	No. of Years in business	Annual Production capacity Approx.	No. of Staff
1	GM1	Mechanical parts/system production	21- 30 years	1000-100000 units	<25
2	GM2	Welding and fabrication	10 – 20	1000-100000 units	< 25
3	GM3	Mechanical parts/system production Welding and fabrication Furniture production	< 10 years	1000-100000 units	< 25
4	GM4	Foundry production	21 – 30 years	< 1000 units	<25
5	GM5	Food and Beverages	< 10 years	1000 – 100000 units	25- 50
6	GM6	Food and Beverages	21- 30 years	-----	<25
7	GH1		Less than 10 years	1000 -100000 units	Less than 25
8	GH2		21- 30 years	1000-100000 units	25 – 50
9	GH3		10 – 20 years	1000-100000 units	< 25
10	GH4		10 – 20 years	< 1000 units	< 25
11	GH5		<10 years	1000-100000 units	<25
12	GH6	Mechanical parts/system production	21- 30 years	1000 – 100000 units	Less than 25
13	GH7	Welding and fabrication	Less than 10 years	1000 -100000 units	< 25
14	GH8	Food and Beverages	More than 50 years	1000- 100000 units	200+

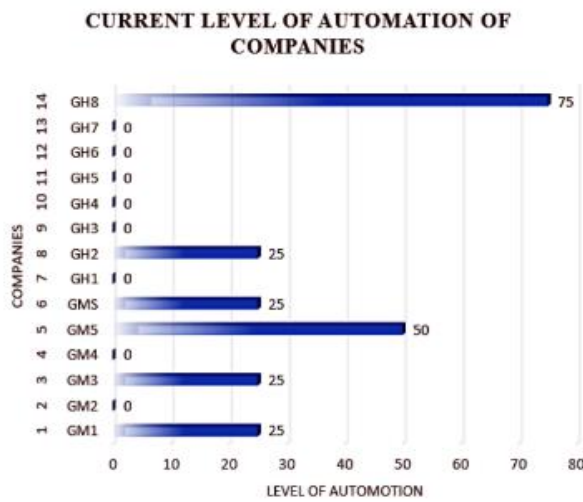
Note: The names of the companies are obscured by the GM and GH number series. Gambian companies are represented by GM, and Ghanaian companies are represented by GH.

1) The use of flexible manufacturing systems

The focus of this study is on implementing flexible manufacturing systems in these countries' manufacturing sectors (The Gambia and Ghana).

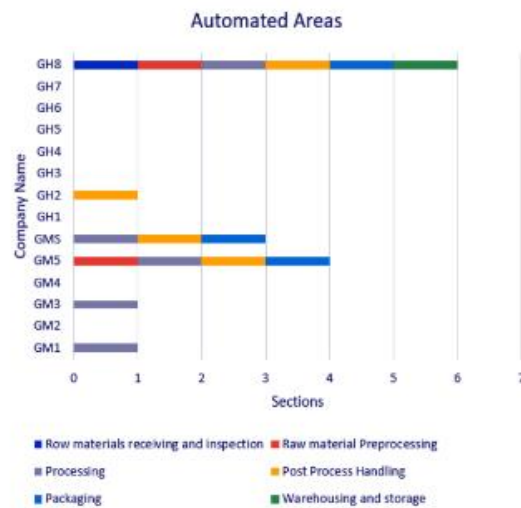
The result of the research shows that out of the 14 companies under the research, only one (1) firm deployed FMS concept in their manufacturing plant. It is rather unfortunate that most of these plants are still utilizing the conventional manufacturing concept and technologies which explain the inefficient performance and low production capacity of these firms.

Traditional manufacturing techniques, on the other hand, have intrinsic limitations that cannot be overcome. In other words, due to technological limits, it is not always possible to manufacture diverse components in terms of geometry, dimension, strength, and so on (Kilic, 2012). Using advanced manufacturing technologies and concepts like FMS overcomes these limitations and drawbacks.



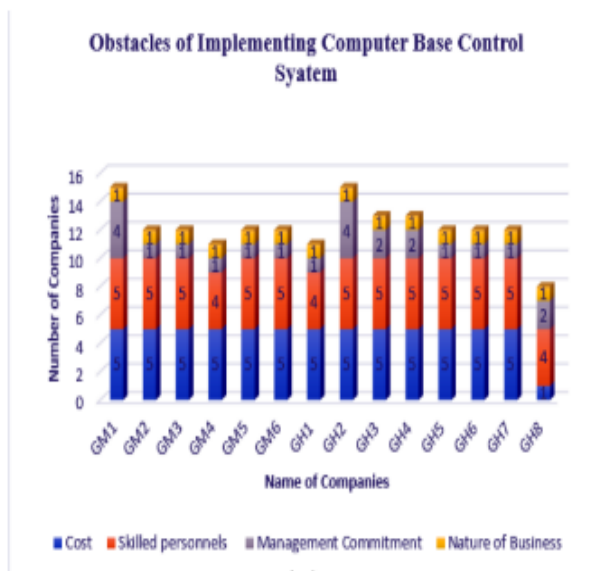
(a)

Figure 5a. Current level of automation of companies,



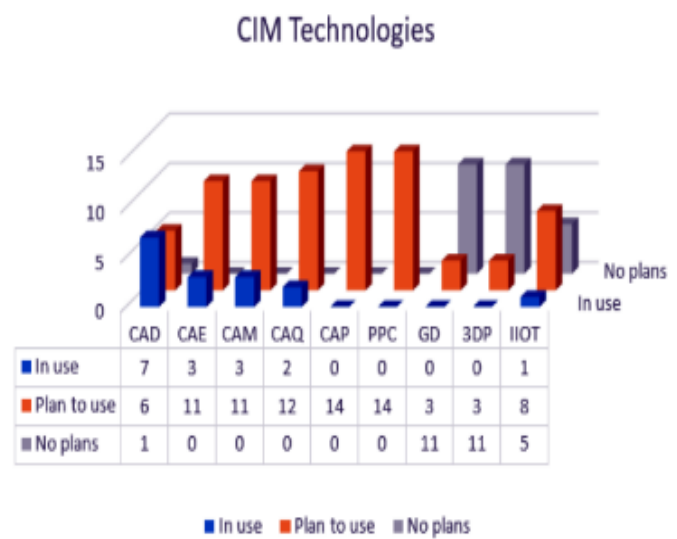
(b)

Figure 5b. Automated areas



(a)

Figure 6a. Obstacles of implementing computer base control system



(b)

Figure 6b. CIM Technologies use

Most of these companies if not all agreed to implement flexible manufacturing systems in their firms should the opportunities arise. This is encouraging looking at the level of adoption of these technologies and concepts. The fact that a lack of adequate funds and skilled personnel to operate these technologies continues to be a major challenge for the implementation of FMS is clearly shown in Figure 7. Furthermore, company owners should assess the advantages against the risks and consider if the effort will eventually be in the company's best interests before determining that a flexible manufacturing system is the best choice. Because most of the companies in this study are SMEs, a firm's size in terms of workforce and sales revenue may influence the company's adoption strategy. Smaller businesses use technology to gain a competitive advantage, whereas larger businesses see AMT as a way to reduce manufacturing costs (Darbanhosseiniamirkhiz and Wan Ismail, 2012).

C. Forecast for the future

The manufacturing industry is changing, and business owners are well aware that the future of manufacturing is digital, which has become an essential component of a successful manufacturer's business strategy (J.Devitt, 2017). Companies that embrace digital manufacturing benefit from lower risks, faster time to market, higher profitability, and a stronger market position(Siemens, 2021)

Although most African manufacturing enterprises have yet to adopt these cutting-edge technologies and processes, they are eager to do so if the opportunity arises. Most firms anticipate that in the next five years, the level of automation will be mostly automated, fully automated, and the implementation of FMS concepts, but these developments are dependent on governments creating conducive manufacturing environments. Looking forward, manufacturers believe that 5G connectivity will be critical to their overall company success(Moller, 2022). Company owners are starting to test and deploy 5G technologies, which are expected to boost a wide range of manufacturing activities that rely on network connectivity. Speed, latency, capacity, reliability, handoff, and efficiency are all expected to improve as a result of the technology(Institute, 2019). Against this backdrop, we also ask the companies involved in the research if they plan to utilize this technology in the future if given the chance. Unfortunately, most employees in these companies are unaware of the benefits of 5G connection in the manufacturing industry. For the time being, most of them are remaining neutral until they have more knowledge regarding the technology and its impact on the manufacturing sector, at which point they will determine whether to use it in their factories.



Figure 7 Obstacles of adopting FMS

D. *The different dimensions of FMS towards improving the African manufacturing industry*

The global market for smart manufacturing is anticipated to develop at a compound annual growth rate (CAGR) of 21.5 percent over the next seven years, reaching a value of over \$446 billion by 2029, according to a recent market research analysis by Meticulous Research (Reporter, 2022). How can developing nations, like those in Africa, take advantage of market disruptions to increase domestic and regional manufacturing? Adopting and implementing flexible manufacturing systems in the African manufacturing sector will assist the African continent in catching up with the rest of the world in terms of manufacturing technology use while also benefiting from high manufacturing added values offers by the sector. With a clear vision from governments, African manufacturing firms will need to adopt advanced manufacturing aggressively to compete both locally and internationally. The question remains, how do we compete while facing a lot of unique challenges due to socioeconomic and infrastructure constraints? Some of the major challenges that African manufacturers must address in order to properly implement and adopt these technologies and concepts are a lack of adequate investment and skilled workforce, as well as unstable and expensive energy costs and poor transportation infrastructure. The insufficient availability of data, as well as limited access to some companies' operational information and return on investment, make it difficult for researchers to conduct a conclusive study of the manufacturing models employed by these companies.

Flexible manufacturing systems have the potential to drastically alter the manufacturing sector, opening opportunities for new players to emerge and dominate in new markets. The African manufacturing industry plays a critical role in Africa's economic future, which is currently precarious, and the availability of these advanced manufacturing technologies may be the deciding factor in the continent's future regional and global success.

E. *Research Opportunities in the Use of FMS Concepts and Technologies in the African Manufacturing Sector*

Although the adoption and the use of advanced manufacturing technologies and concepts in the sector are limited now. African Governments and institutions are making a lot of efforts to change that by developing vibrant industrial policies that accommodate the use of these technologies (Rob Floyd, 2021). The manufacturing industry in Africa has significant room for growth and expansion, and as labor costs rise in other developing regions, the World Bank has suggested that these manufacturing jobs may migrate to Africa in the coming decades (Signé and Johnson, 2018). These paradigm shifts in the manufacturing sector will create a lot of avenues for research and development. The introduction of machine learning and artificial intelligence, 3D printing, smart robots, advanced industrial internet of things, and generative design is transforming the sector, but they are still in their infancy, and several challenges and gaps must be addressed before they can become a reality. A real-time response to client demands is not possible with the current flexible manufacturing technology (Javaid, 2022). Businesses are being forced to gradually change the nature of their production to large-scale

production and small series with a diverse range of products as a result of shortened product life cycles, market liberalization, intense competitive pressures, and constantly changing customer requirements (Kostal *et al.*, 2014).

IV. CONCLUSIONS AND RECOMMENDATIONS

The implications for educational institutions, industrial businesses, and African governments are significant. Training institutions in the African continent should develop training programs that will prepare skilled personnel for the sector. Some business owners are already considering incorporating some of the newest advanced technology in their facilities, but many of them are not well-positioned to be successful in doing so. To provide a stable and uniform framework under which all organizations aim to prosper, manufacturing companies particularly in sub-Saharan Africa need to radically change their approach.

Based on the case study analyses, the following are some the findings of this research study:

1) The adoption of advanced manufacturing technologies and concepts in the manufacturing sector of both The Gambia and Ghana is very low.

2) Some of the major obstacles to implementing advanced manufacturing concepts such as FMS are a lack of adequate funds and a skilled workforce.

3) There is a lack of understanding about the benefits and impact of new technologies such as additive manufacturing (3D printing), generative design, and the industrial internet of things.

4) Some of the companies involved in the research have agreed to implement these advanced manufacturing technologies and concepts if the opportunity arises.

5) Before deciding whether to integrate 5G connectivity technology into their manufacturing systems, enterprises need more information about the technology.

6) Some of the major challenges faced by African manufacturing companies include high energy costs and unstable supply, a poor transportation network, and a lack of adequate finance.

For African businesses to achieve lean manufacturing, reduce costs, defects, manufacturing times, and enhance quality, flexible manufacturing methods must be implemented. The flexibility that FMS offers will also make it easier for businesses to grow and quickly adopt new technology. FMS by itself is insufficient, action must be made to enhance results, as well as a culture of data-driven system development, must be established. African manufacturing companies should implement new procedures to benefit from new capabilities that could transform the industry as a whole. The workshop floor should always be the primary focus, and management should welcome and drive change. Adopting agile manufacturing techniques will also aid in the continent's rapid evolution and development to keep up with the rest of the world.

Despite all the obstacles, a revolution in the production paradigm seems inescapable. There is no doubt that FMS, smart factories, and smart products will quickly become indispensable components of our lives.

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AUTHOR'S CONTRIBUTION

Fofana developed the research study concept with the assistance of **Nyarko, Mensah, and Takyi**, designed the questionnaire, conducted the survey, tabulated the data, analyzed the data, and presented the results.

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