Investigation of the Level of Automation in Some Selected Manufacturing Industries in Kano, Nigeria

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Abstract

This study investigated the level of computer numerical control automation in some selected manufacturing industries in Kano Nigeria. It details the extent of automation, type of operations automated, obstacles and motivators to automate. Earlier research works in the area shows that automation is very low and there was little or no data to indicate the extent and obstacles to automation, a gap that this work fills. To stay competitive, manufacturing industries need to be flexible and adaptive to new tools that enhance efficiency and effectiveness of operations. Tools such as Lean and Six-Sigma principles that were found to reduce waste in terms of cost, time, and improved quality operates better in well automated industries. A field survey was conducted where 20 industries were mapped out and served with questionnaires. Follow ups were made for clarifications, and data was collected and analyzed. The results from the study revealed low level of automation in the industries, but the motivation to automate is very high with cost of replacing manufacturing systems with automated ones being the major obstacle.

Keywords
Computer Numerical Control, Automation of Manufacturing Systems, Lean and Six-Sigma, Total Quality Management, Cloud Manufacturing.

1. Introduction
Located in the Northern part of Nigeria, Kano is the industrial hub of the North and second only to Lagos in the country by the number of manufacturing industries and industrial activities. Industries in the area include textiles and garments, food and beverages, plastic material processing, leather, auto assembly plants among others. Earlier research on automation in some of the industries revealed low level of automation (Umar and Nwachukwu, 2007). As new and competitive operation technologies and management tools evolve, the manufacturers in Kano and Nigeria in general face stiffer competition due to influx of cheap foreign goods and services promoted by the open market policy of the government and globalization.

The industries can reduce the impacts of globalization by adapting tools such as Lean and Six-Sigma. These are some of the tools that have led to tremendous improvement in the reduction of waste in both material and time in the manufacturing area and industries that adapted them are currently adjudged as globally competitive.
For the tools to be operated successfully however, factors such as Just-in-Time (JIT) manufacturing; Total Quality Management (TQM); Total Productive Maintenance (TPM); and Human Resource Management (HRM) must be implemented ((Alkhoraifa, et al., 2018). For these factors to be achieved, automation becomes very vital. Quality cost which is an element of TQM for example was found to be high at low level of automation of manufacturing systems and low at high automation. Manufacturing systems in industries comprise all machines and equipment that may be manual or powered. Industries are rated in terms of their output, and this depends to a large extent on the combination of their manufacturing systems. ((Amber & Amber, 1962)
The main reason of automating is to achieve higher productivity stay competitive in business. Previous research (Umar & Nwachukwu, 2007) show that automation in Nigeria is at its early stage and there is little or no data on automation in most manufacturing industries in Nigeria.

1.1 Objectives
This study determined the current level of automation, examine the motivating and inhibiting factors and feasibility of adapting it with the aim of improving productivity, quality, and competitiveness of manufacturing industries around Kano and Nigeria in general. The outcome can be accessed and utilized by the industries to adapt and improve automation and move toward the implementation of competitive tools such as JIT, TQM, TPM, Lean, Six Sigma, among others, in the industries.

2. Literature Review

Globalization has caused several changes and replaced classical forms of organizations which had functioned for decades. Internal expertise alone is no longer sufficient today. It is innovative cooperation networks that represent the key to success to remain competitive. Nowadays, the production structure in a globalized world is characterized by the involvement of various companies in the manufacturing process (Li, et al., 2010). As a result of globalization, some technical approaches have already developed in this area. These include the paradigm of cloud manufacturing (CMfg), which generally divides many manufacturing requests optimally among a pool of manufacturing resources ((Elwein, et al., 2019). Among the operational tools currently used in industrial manufacturing are Cloud Manufacturing, Lean and Six Sigma. As the work processes become more complex, one or more tasks are performed by machines. Automating of the plant will reduce labour, machine, and accessory times as well as material waste all of which are direct costs in manufacturing. Tasks done by humans which are often boring and repetitive and susceptible to errors can easily be automated and the work can be performed continuously and at high speed often with very minor errors.

Two classes of newly developed control systems which are mostly geared toward manufacturing applications are called Repetitive and Learning control systems. A repetitive controller (Solcz & Longman, 1991), (Tsai, et al., 1988) is designed for processes which operate in cycles. Repetitive controllers assume that there is continuity between the last point of a repetition and the first point of the next repetition. This statement translates to the assumption that the initial conditions of the system change slightly each time it undergoes a new repetition. The second class of controllers for repetitive systems, learning controllers (Middleton, et al., 1989), assumes that the initial conditions are reset to the same value each time a new repetition begins.

All the developments in the new manufacturing era are lumped together by the concept of Industry 4.0. it combines technology, robotics, artificial intelligence, and automation to create an efficient and effective manufacturing process. Investing in new technologies where digital solutions transform physical operations, means keeping the benefits for the organization at the forefront of industry strategy (Schuh, et al., 2020), (Arimoto, et al., 1984).

Automated systems can respond quickly to changes through faster decision making with attendant improvement in the production process, speed, and fewer delays. Safety is increased as hazardous and dangerous tasks performed by human workers are automated. Quality control of production is achieved with high precision automated manufacturing systems.

2.1 Manufacturing Systems Automation

Automation is mostly necessitated when high volume of products is involved, the product life cycle is long, excess material handling is involved and operation is difficult manually. Manufacturing systems in industries comprise all machines and equipment that may be manual or powered. Industries are rated in terms of their output, and this depends to a large extent on the combination of their manufacturing systems. Manufacturing systems can be classified in order of their automaticity. They include Hand tools and manual machines A_0, Powered machines A_1, Single –cycle automatic and self-feeding machines A_2, Automatic repeat cycle machines A_3, Self-measuring and adjusting, feedback machines A_4, and computer controlled and automatic cognition machines A_5 (Amber & Amber, 1962), (Umar, 2000). This categorization agrees with (Feigenbaum, 1983) though in his own case the categorization came under three, i.e., Manual machines; Mechanized machines; and Automatic machines.

According to (Schonberger, 1987), production efficiency of an industry will depend on the nature and age of the machinery. A Company operating with fully automated system may not necessarily perform better than another operating with manual machines and vice-versa. Most writers on the subject, however, urge that automatic systems were more reliable when it comes to precision and quality.

The ultimate development in the trend of mechanization is to have a completely integrated automatic sequencing beginning with the input of raw materials and ending with the final product without human labor or control other than to design and build the original equipment, process, and maintenance (Amber & Amber, 1962). According to (Cheng & Podolsky, 1996) there are three ways to achieve automation in manufacturing: Low-Cost Automation, Autonomous Control and Fail-Safe Method. As for Cloud Manufacturing, automation is a must.
Although automation has revolutionized the manufacturing industry and has multiplied productivity in industrialized nations, industries in Nigeria finds it difficult to modernize their production machines and equipment. High productivity in the Nigerian manufacturing industries is necessary for the sectors recovery in achieving competitiveness, boosting GDP, and uplifting the standards of living of the populace. It has been

reported that high automation level machines that are self-measuring and adjusting with feedback mechanisms (A_4) and/or computer controlled (A_5) constitute between 4.2% and 2% respectively for the textiles, food and beverage, metal component manufacturing, and automobile assembly plants, while automation of quality control systems categorized as manual, mechanized, and automatic were 23.67%, 34.42% and 41.90% respectively, Nigerian Manufacturing Industries .

3. Methodology

The target population for this survey are manufacturing industries in Kano, Nigeria. Field survey visits were undertaken, and personal interviews were conducted in a total of 20 industries producing different types of products. Questionnaires were administered to staff with experience in various sections of the industries to fill. Pre-testing of the survey questionnaire was carried out to ascertain the degree of understanding of questions (Figure 1).

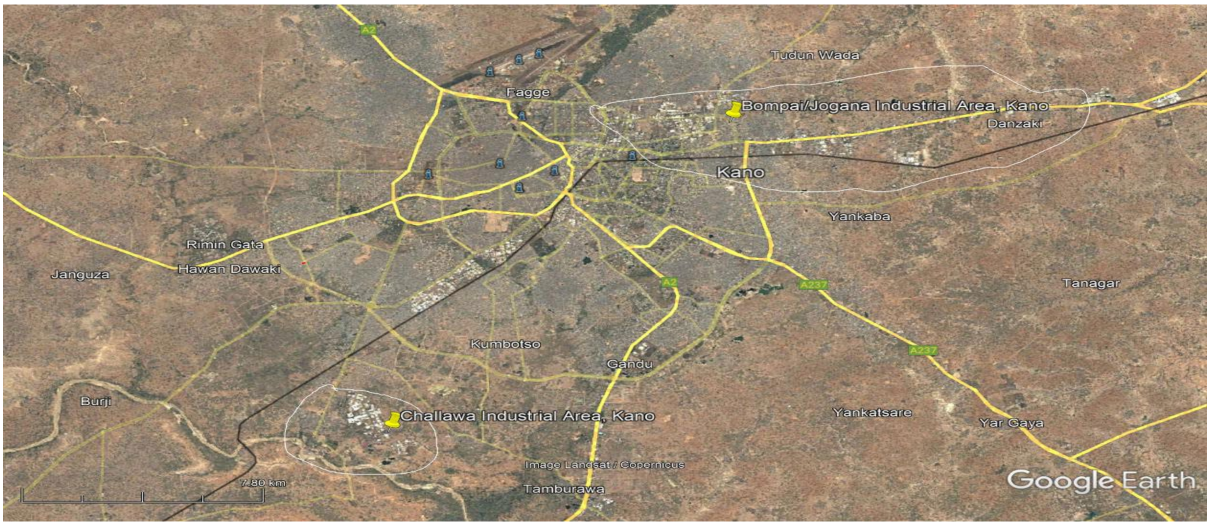

Figure 1: Placemarks indicating industry clusters of the study area. (Earth, 2022)

4. Data Collection

The questionnaires were divided into two broad sections.

Section 1. General Information

The section contains four questions (questions 1 to 4) and covers basic information of company, production volume, number of years in business, and number of employees.

Section 2. Automation

The section contains six questions (questions 5 to 10) covering information on current level of automation and prospects, type of operations and automated areas, obstacles, and motivators for implementing automation in the industry. All questions were multiple choices, clear and well understood.

5. Results, and Discussions

The numerical results, and the analysis using Pie charts and in descriptive form are present in the following sections.

5.1 Numerical Results

Table 1 shows the status of level of Automation of some operations in the industries. The operations include Receiving and inspecting raw materials, Raw material preprocessing, Processing/Filling/Wrapping, Post process handling and inspection, Packaging, and Area of warehousing and storage.

Table 1. Level Of Computer-Base Automation in the Industries

Status	**Operation Areas**					
	Raw Material Receiving and	Raw Material Preprocessing	Processing, Filling,	Post Processing, Handling, and	Packaging	Warehouse and Storage

	Inspection		Wrapping	Inspection		
Automated	0%	20%	30%	0%	30%	5%
Not Automated	100%	80%	70%	100%	70%	95%

Table 2 shows the results for motivation factors to implementing computer-based automation in the industries. The factors include Reduction of Cycle Time, Lower Production Cost, Improving Personnel Safety, Improving Product Safety, and Improved Product Quality.

Table 2. Motivation Factors to Implementing Computer-Based Automation

Status	**Motivation Factors**				
	Reduction of Cycle Time	Lower Production Cost	Improving Personnel Safety	Improve Product Safety	Improving Product Quality
No	25%	80%	40%	40%	20%
Yes	75%	20%	60%	60%	80%

5.2 Graphical Results

a. Types of Manufacturing Industries

The results of the survey on the type of manufacturing industry is shown in Figure 1. The pie chart shows that 35% are food processing, 35% are plastic processing, 10% are metal fabrication industries and 20% others.

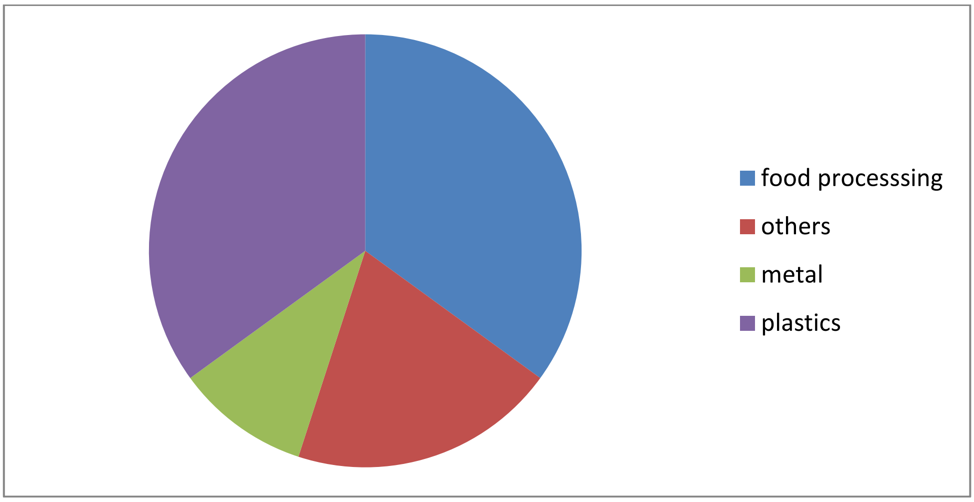

Figure 1. Type of Manufacturing Industries

b. Production Volume

The survey of quantity of product(s) produced is shown in Fig 2. The pie chart shows that 5% of the industries produce <
Less than 1000 units, 50% produce between 1000 and 100,000units, 30% produce between 100,000 and 1,000,000 units and 15% produce more than 1,000,000 units.

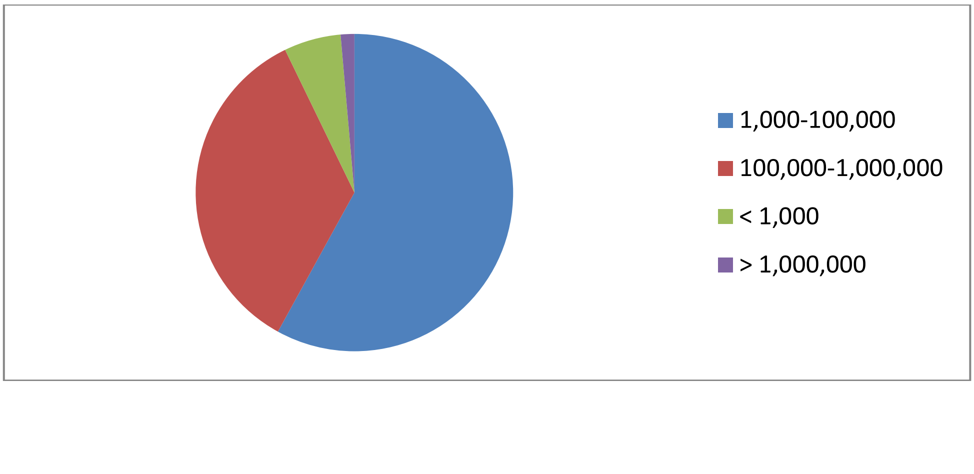

Figure 2. Production Volume

c. Age of companies

Figure 3. shows that 45% of the industries surveyed have been doing business for 10 to 20 years, 20% of the companies have been in business for less than 10 years, 35% are between 21-30 years old, 5% are between 31-50 and 0% or non were up to 50 years of age.

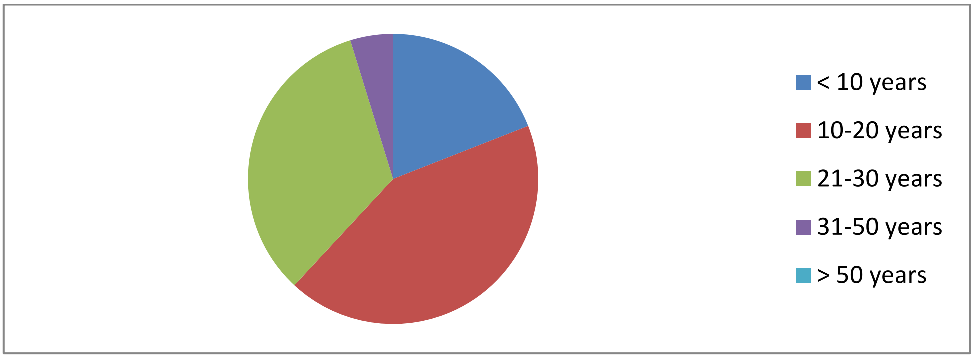

Figure 3. Age of companies

d. Number of employees

The pie chart in Figure 4 shows that 0% or non has less than 25 employees, 20% have between 25 to 50 employees, 40% have 51 to 100 employees, 20% have 100 to 200 employees while 15% have more than 200 employees.

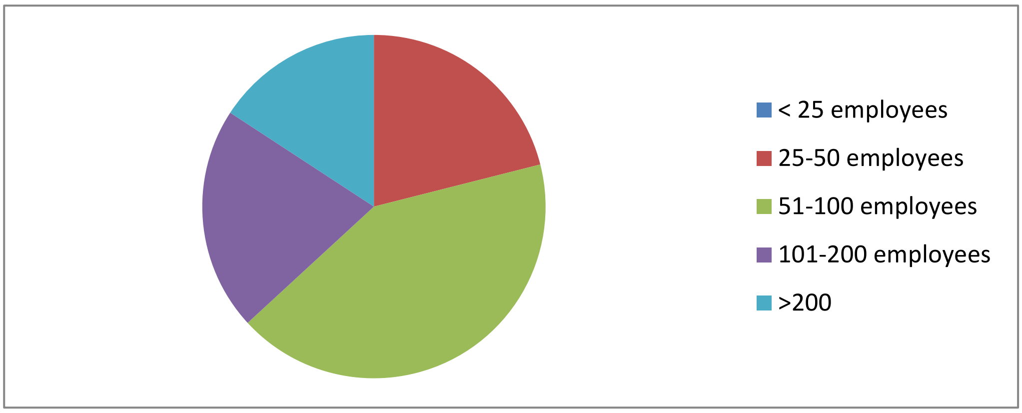

Figure 4. Number of employees

e. Level of automation

The result of the survey into the level of automation is shown in Fig. 5. It shows that 30% are sparsely automated, 20% are somewhat automated, 10% are mostly automated, 0% or non is fully automated and 40% have no automation.

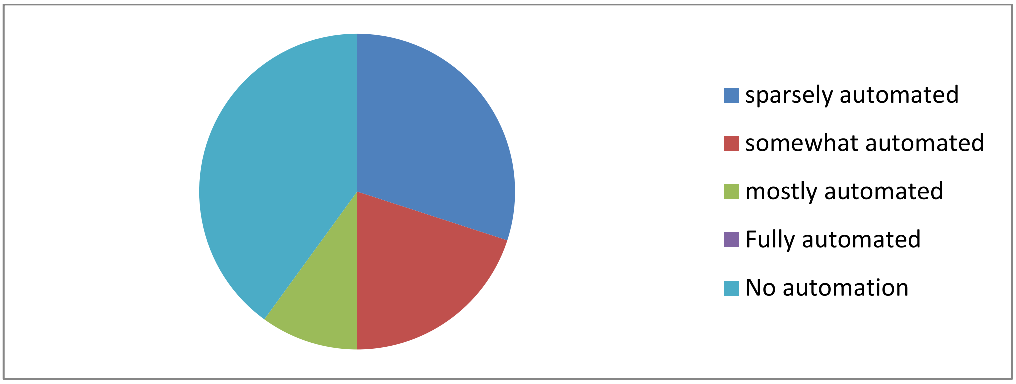

Figure 5. Level of automation

f. Prospects of Automation Envisaged in the Next 5 Years

The survey shows that is 25% will be sparsely automated, 30% will be somewhat automated, 30% will be mostly automated, 10% will be fully automated and 10% will have no automation in the next five years (Figure 6).

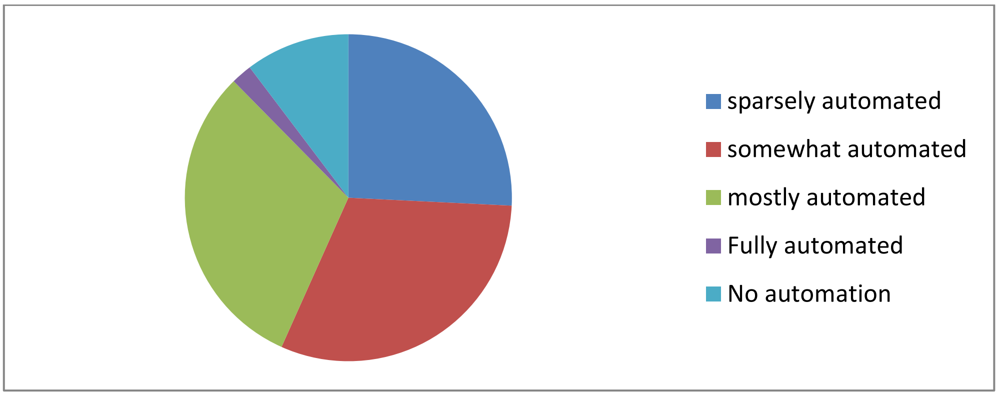

Figure 6. Prospects of automation envisaged in the next 5 years

g. Level of Automation of Operations

Figure 7 shows the level at which the operation is automated using computer-based automation. 25% indicated very small number of operations, 25% shows some operations are automated, 10% indicated that most operations are automated, 0% indicated that all of operations are automated, and 40% shows none of operations are automated.

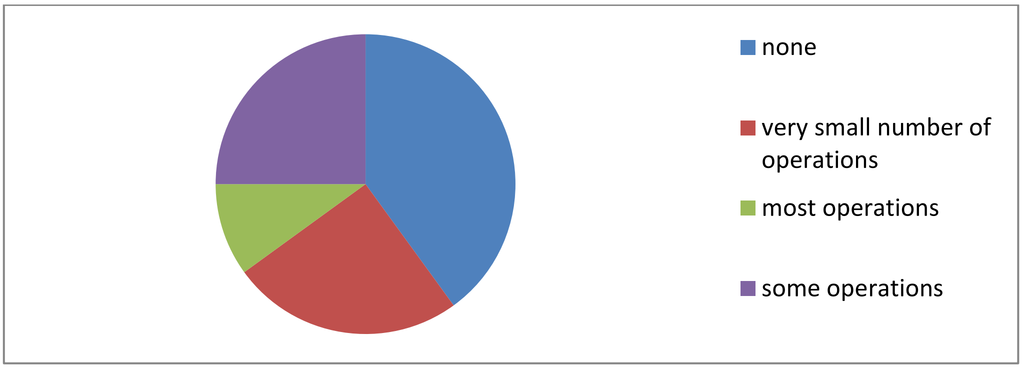

Figure 7. Level of automation of operations

h. Automated Operations

Some of the operations and their areas of automation are:

i. *Receiving and inspecting raw materials*: 100% of the companies surveyed have no automation in receiving and inspecting raw materials
ii. *Raw material preprocessing:* The analysis shows that 20% of companies surveyed have no automation, while 80% have automation in raw material preprocessing.
iii. *Processing/Filling/Wrapping*: The result of the survey shows that 30% of companies surveyed have automation, and 70% have no automation in Processing/Filling/Wrapping.
iv. *Post process handling and inspection:* The analysis of the data shows that 100% of companies surveyed have no automation in post process handling and inspection.
v. *Packaging*: The result of the survey indicates that 30 % of companies surveyed have automation, and 70% have no automation in packaging.
vi. *Warehousing and Storage:* The analysis shows that 95% of the companies surveyed have no automation, while 5% have automated warehousing and storage.

i. Obstacles for Implementing Computer-Based Automation

- ***Time as an obstacle***

The results of the analysis of time as an obstacle to the implementation of computer-based automation in food manufacturing companies are shown in Figure 8. About 60 % of companies surveyed indicated that time is not an obstacle, 20% of companies indicated that the time is a very small obstacle and 10% indicated that time is a small obstacle, 10% of the companies indicated that time is an appreciable obstacle, and 0 % indicated that time is a major obstacle.

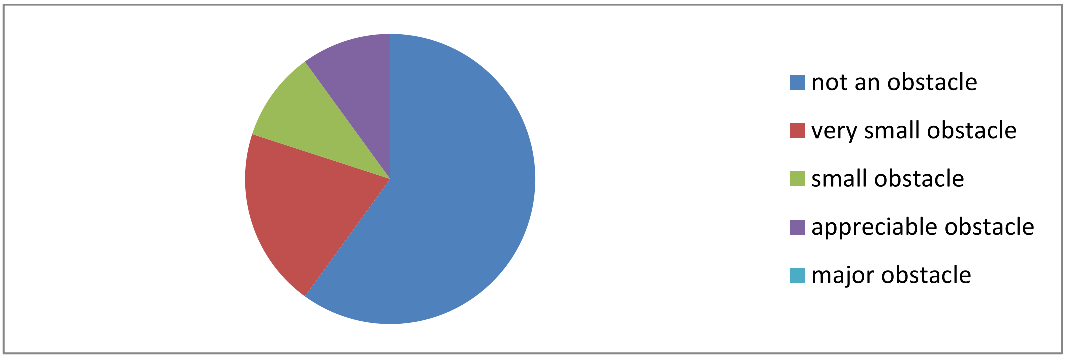

Figure 8. Time as an obstacle

- ***Cost as an obstacle***

The results of cost as an obstacle to the implementation of computer-based automation in food manufacturing companies are shown in Figure 9. 0% of companies surveyed indicated that cost is not an obstacle, 0 % indicated that cost is a very small obstacle, 10% indicated that cost is a small obstacle, 20 % indicated that cost is an appreciable obstacle, while 70 % indicated that cost is a major obstacle.

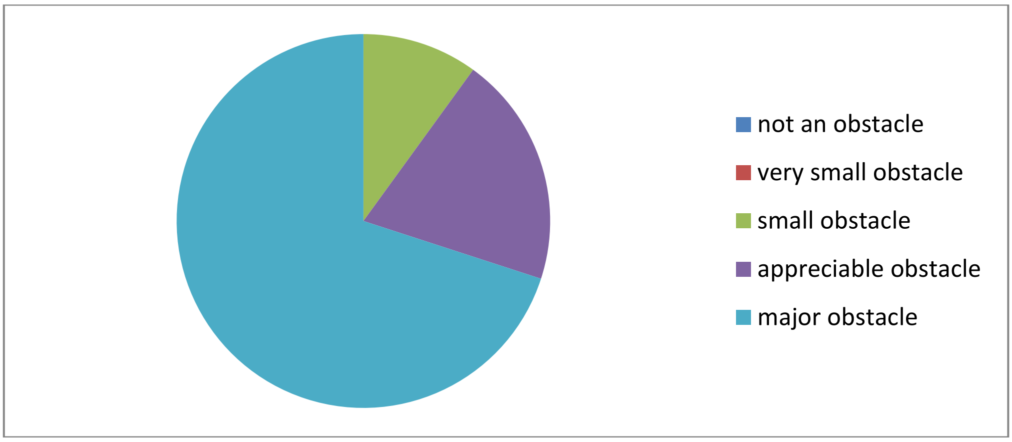

Figure 9. Cost as an Obstacle

- ***Technical skills of Staff***

The results of the analysis of technical skill as an obstacle to the implementation of computer-based automation in food manufacturing companies are shown in Figure 10. 15% of companies surveyed indicated that technical skills are not an obstacle, 15 % indicated that technical skills are a very small obstacle, 25% indicated that technical skills is a small obstacle, 25% indicated that technical skills is an appreciable obstacle while 30 % indicated that technical skills is a major obstacle.

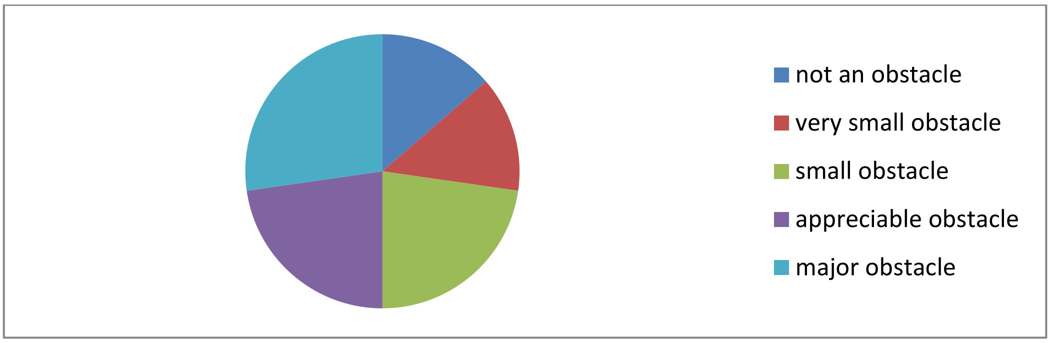

Figure 10. Technical Skills of Staff

- ***Management commitment***

The results of the analysis of management commitment as an obstacle to the implementation of *computer-based automation* in food manufacturing companies are shown in Figure 11. 10% of companies surveyed indicated that management commitment is not an obstacle, 20% indicated that it is a very small obstacle, 20% indicated that it is a small obstacle 20% indicated that it is an appreciable obstacle while 30% indicated that it is a major obstacle.

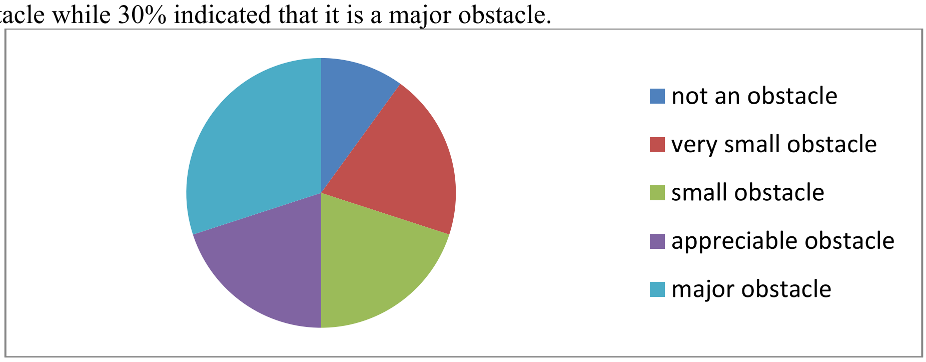

Figure 11. Management commitment

- **Nature of business**

The results of the analysis of nature of business as an obstacle to the implementation of computer-based automation in food manufacturing companies is shown in Figure 12. About 35 % of companies surveyed indicated that nature of business is not an obstacle, 20 % indicated that it is a very small obstacle, 20 % indicated that it is a small obstacle, 15% indicated that it is an appreciable obstacle and 10% indicated that it is a major obstacle.

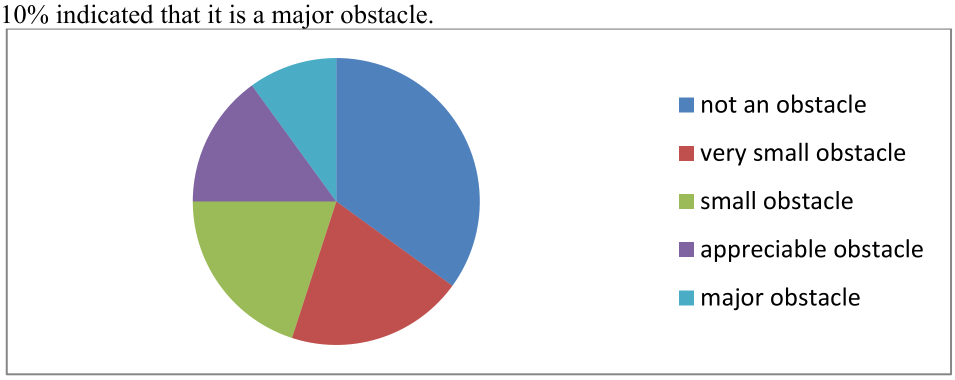

Figure 12. Nature of business

j. The Motivators to Implementing Computer-Based Automation

The results for motivators to implementing computer-based automation are as follows:

- ***Reduction of cycle time***

The analysis indicates that 25% companies surveyed don't consider reduction of cycle time as a motivational factor, while 75% considers it as a motivational factor.

- ***Lower production cost***

The result of the survey indicates 80% of companies surveyed are consider lower production cost as motivational factor, whereas 20% don't consider it a motivational factor. This result was also reported by (Raja, et al., 2020) that 'lack of a digital strategy alongside resource scarcity' emerges as the most prominent barrier in both developed and developing economies. The influencing barriers identified suggest that improvements in standards and government regulation could facilitate the adoption of Industry 4.0 technologies in developing countries.

- Improving personnel safety

The results indicates that 40% of companies consider improving personnel safety as a motivational factor, while 60% don't consider it a motivational factor

- ***Improving product safety***

The result for improving product safety is that 60% of the companies indicated that it is motivating factor whereas 40% do not consider it a motivational factor

- ***Improved Product Quality***

The analysis indicates that 20% of companies surveyed do not consider improvement in quality as motivational factor while 80% consider it a motivational factor.

6. Conclusions

About 35% are food, and 35% are plastic processing industries. 50% produce between 1000 and 100,000unit. Only 20% of the companies have been for less than 10years while 5% are between 31-50years by age. 40% have 51 to 100 employees and only 15% have more than 200 employees. None of the industries is fully automated and 40% have no automation at all. Only about 10% will be fully automated and 10% will have no automation in the projected next five years. Operations are fully automated using computer-based automation in none of the industries, while 10% indicated that most operations are automated. This indicates that computer-based automation in the industries is very low.

Some of the operations are: Receiving and inspecting raw materials: None of the industries has automation. Raw material preprocessing, 80% have automation. Processing/Filling/Wrapping, 30% have automation. Post process handling and inspection, none of the industries have automation. Packaging, only 30 % of companies surveyed have automation. Warehousing and Storage, only 5% have automated warehousing and storage. There this indicated that even simple operations are not well automated in the industries.

None of companies indicated that the time is a major obstacle in automation. 30 % indicated that technical skills are a major obstacle. 30% indicated that management commitment major obstacle. 10% of companies surveyed indicated that nature of business is a major obstacle, while 70% reported cost of automation as the major obstacle.
The Motivators to Implementing Computer-Based Automation in the industries include Reduction of cycle time with 75% indicating that it is a motivational factor. Lower production cost, with 80% of companies reporting it as a motivational factor. Improving personnel safety with only 40% of companies reporting it as motivational factor. Improving product safety, where 60% of the companies indicated that it is a motivating factor and about 80% of the industries reported improvement in quality as motivational.

Conclusively, it can be inferred that manufacturing industries in the study are no candidates for the introduction of competitive tools such as Lean, Six-Sigma Just-In-Time, Total Quality Management, Total Productive Maintenance, Cloud Manufacturing. To improve automation, the managements of the various industries must show commitment for change, the culture of competitiveness must be imbibed in the industries and the responsible agencies must ensure the availability of cheap capital to the industries and promote competitiveness in the Nigerian manufacturing sector.

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