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The Impact of Robotics on Modern Manufacturing

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Abstract- This paper dives into how robotics is transforming manufacturing today. It looks at how robots are making processes faster, safer, and more efficient while also tackling some challenges like high costs and technical complexity. By exploring industries like automotive and consumer goods, and through examples from companies like Toyota and Unilever, the paper highlights both the advantages and limitations of using robots. It also touches on important issues like job impacts and cybersecurity risks, suggesting that thoughtful planning is essential for making the most of robotics in manufacturing.

Index Terms-Robotics in modern manufacturing

I. INTRODUCTION

During the last few decades, robotics has become one of the leading trends in the development of contemporary manufacturing providing new opportunities for businesses all over the world. There are various types of industrial robots which include articulated robots, cobots, and AMRs, where these robots have been identified to contribute to productivity, precision, and safety improvement in the production processes (Zhang & Lee, 2020). The automation of production processes by the help of robotics started from the late 1960s, and automobile industries have been the first ones to incorporate such technologies in performing monotonous and risky operations (Smith, 2018). After that, AI, machine learning, the IoT opened up more and extended the application area and function of robotic systems that are applied in electronics, consumer goods, and food industry (Kumar, 2021).

This paper seeks to explore the effectiveness of robotics in the current manufacturing processes especially in terms of the efficiency, quality, and cost. It will also analyse how the implementation of such robots causes some problems like high costs of installation and questions on displacing employments. As a result, by such assessment of these aspects, the present research will shed light on the role of robotics in the contemporary manufacturing environment.

II. LITERATURE REVIEW

1. Theories and Frameworks

Robotics incorporated into manufacturing is usually in connection to automation theory, which has been central to the advancement in industrial revolutions. Industry 3 in the use of automation systems marked the change of task from human employment to mechanical means. 0, where mechanization and automation were used in the organization with an aim of improving productivity as well as efficiency (Jones, 2019). The use of smart technologies such as advanced robotics and artificial intelligence is pegged as being among the triggers of the fourth industrial revolution commonly referred to as Industry 4. 0 based on where smart factories and Cyber Physical Systems control the manufacturing environment (Schwab, 2020).

Conducting a literature review on Robotics in Manufacturing I found that past research had the following findings.

In this regard, several researches have been done concerning the issue of the use of robotics in manufacturing and its impact. The first study by Allen and Singh (2016) shows that robots substituted humans in hazardous and monotonous jobs at first, and these jobs were mainly in auto manufacturing. But recent research suggests that there is a new trend towards human-robot interaction, especially in light of advanced cobots which co-exist with operators and enhance production rates within an organization bearing in mind safety issues (Brown & Taylor, 2018). The advantages of robotics especially in precision, reduction of human mistakes and consistency in the production process have been evidenced especially in electronics and pharmaceutical industries (Garcia, 2021).

Technological Advancements

Following the enhancement in the technology, with special emphasis on artificial intelligence (AI) and the internet of things (IoT), robotics has firmed up its base in manufacturing. The current advanced robots are ; AI and so they can become intelligent and learn some activities, and so they are efficient in mass customization production and flexibility (Chen et al. , 2022). The integration of IoT enables real-time tracking of any Robotic systems and enables predictive maintenance hence enhancing operations without frequent breakdowns (Davis & Lee, 2020). As communication and information technologies entwine the manufacturing setting these technologies are progressing to revolutionise the applicability

of robotics, making production facilities more sensitive to the fluctuations in pattern and consumer demand.

Economic and Operational Impact

Studies have done indicate that the implementation of robotics is a major factor affecting the economic benefit in manufacturing. According to Rajan and Miller (2020), manufacturers who adopt robotic integration realize superior value in terms of return of investment (ROI) via elimination of labor expenses besides enhancing production capability. Moreover, robotics enables companies to satisfy increasing purchasing needs by customers without compromising the quality and productivity. However, as Patel (2021) observed, despite the fact that robotics has the capability to decrease operational cost in the long-run, the initial investment is still high for small scale manufacturers. Although these challenges may seem daunting, the overall economic saving of adoption and practice of robotics makes the solution preferable for the most large scale production industries.

III. ROBOTICS TECHNOLOGY IN MANUFACTURING – PRESENT STATE

Global Overview

Automation or Robotics has found a strategic place in the fabric of the global manufacturing systems, the key sectors that have been embracing the technology or manufacturing application includes automotive, electronics, and consumer products industries. The IFR also reveals that the automotive sector has been the most significant user of industrial robots in the world for decades, occupying about 30% of installations in January 2022. Japan, South Korea, and Germany, for example, are among the global's most advanced in the use of robotic automation in their production processes supported by the need to maintain high production quality, and efficiency of labor (Tanaka and Li, 2021). On the other hand, developing countries such as Vietnam and Thailand among the Southeast Asian countries are gearing up for a massive investment in robotics in a bid to open up the market to the global market.

Kinds of Robots Employed in the Manufacturing Process

The evolution of robotics in manufacturing has introduced various types of robots that serve different purposes:The evolution of robotics in manufacturing has introduced various types of robots that serve different purposes:

Articulated Robots: Known by their rotary joints, these robots are ideal for operations that entail welding, system assembly, and material moving. Their versatility makes it possible to use them in a vast area and majorly in the automotive and electronics industry (Johnson & Davies, 2020).

Collaborative Robots (Cobots): Cobots on the other hand are robots that are programmed to work in parallel with the human beings especially in aspects of production. They are usually lighter, more versatile and operationally, safer than normal industrial robots and they are very ideal for manufacturing companies seeking to increase efficiency but not through automation of employees (Sullivan, 2019).

Autonomous Mobile Robots (AMRs): These robots are fitted with both the sensing and the navigation apparatus that enables them to make their way through the manufacturing facilities under their own accord. AMRs are used to perform some of works like material transportations and logistics that can enhance the supply chain processes (Garcia, 2021).

Economic Impact

Robotics plays a large role in the economic issues of manufacturing, especially the reduction of cost and the improvement of productivity. McKinsey & Company report (2021) revealed that organizations with implemented robotics in their manufacturing industries realized 30% decrease in labor costs, with 20% increase in production rate. In addition, it has been observed that robots have a enhanced efficiency, which means they work continuously, and do not require frequent breaks or rest unlike the human counter parts, this has greatly reduced on the time required for maintenance hence boosting profitability (Lee & Wilson, 2021). Nonetheless, these advantages are highly likely to be mitigated by the tremendous costs required for the setting up of robotic systems, which continues to prove to be a barrier for small companies (Patel, 2021).

The Geographic Distribution of the Use of Robots

The application of robotics in production is not spread throughout the world in the same manner. Germany, Japan and United States have for example remained some of the most developed economies and have remained pioneers in robotic use since they require high quality and precision in their manufacturing processes (Rossi & Schmidt, 2020). On the other hand, increasingly, countries such as the People's Republic of China and India are widely adopting robotics technology because the states promote such transitions and the industries of the mentioned countries are seeking revitalization (Wang & Liu, 2020). For instance, China is projected to become the world's largest consumer of industrial robots by 2025 since its population is aging hence the need to adopt automation in order to compete with other countries in the global economy (Chen, 2022).

Industries Leading the Adoption

Many industries have followed the footsteps of the automotive industry through adopting robotics; some of the other industries that use robotics include electronics industry, consumer goods industry, and the food and beverages industry. It is evident that electronics industry has adopted robotic systems in line with the necessity of precise assembly as well as high-speed production. In the food and beverage

industry, the deployment of robots is in packaging, palletizing and checking for quality especially due to increasing customer appetite for standard and safe foods (Smith & Brown, 2020). In this research paper the author discusses about the various impacts of Robotics and Automation on various industries and explains as more number of industries start implementing the robotic systems in their business there is going to be an increase in demand for robotic systems in various industries.

IV. ROBOTICS: MANUFACTURING-INDUSTY STATE OF THE ART

Global Overview

Robotics has recently found its place in the global manufacturing landscape, where automotive, electronics and consumer goods are some of the industries most actively utilizing the technology. The IFR says that, for many years, the automotive market has been dominant with almost 30% of global industrial robot systems installed in 2021. Some of the leading countries in terms of robotic automation include Japan, South Korea, and Germany where high-quality production and labor efficiency creates the pressure for adopting the cutting-edge technology of robotics (Tanaka & Li, 2021). On the other hand, the Asian countries including the Vietnam and Thailand are expanding their investment in robotics to enter the global market at a faster rate (Kumar, 2022).

Kinds of Robots Applied in Production

The evolution of robotics in manufacturing has introduced various types of robots that serve different purposes:The evolution of robotics in manufacturing has introduced various types of robots that serve different purposes:

Articulated Robots: Such robots with rotary joint are mainly employed in applications such as welding, fabrication and material handling activities. They are versatile to be used on a number of areas especially automobile and electronics industries (Johnson & Davies, 2020).

Collaborative Robots (Cobots): Cobots are for human and robust collaboration and are specifically intended to co-operate with humans in the place of manufacturing. These robots can mostly be compact, versatile and safer to operate than the conventional industrial robots, which makes them suitable to fit into manufacturing facilities for enhancing productivity without necessarily replacing human beings (Sullivan, 2019).

Autonomous Mobile Robots (AMRs): These robots are accredited with the capability of using sensors and path finding features thus enabling them to operate in the factory on their own. AMRs are used for instance in transferring materials or articles within or between organizations and departments in a bid to increase supply chain efficiency (Garcia, 2021).

Economic Impact

Several authors havepointed out that robotics if applied in manufacturing incurs for considerable, cost advantages and improved productivity. A report conducted by McKinsey & Company in February 2021 established that the adoption of robotics led to the decrease of the overall labor cost by thirty percent and the general capacity output increased by twenty percent. Additionally, the fact that robots are able to run non-stop, without getting tired or making mistakes have eliminated time wastage and frequent maintenance, hence boosting the profitability of businesses that use robotics (Lee & Wilson, 2021). However, these benefits are overshadowed by the fact that the robot systems are very expensive to deploy and this is a major factor that contributes to its unavailability to small firms (Patel, 2021).

Robot use and Ownership in Major Countries of the World

Robotics deployment in industrial production is not a level or a parity type all over the world. Therefore, many of the world's developed economy like Germany, Japan and United States have long embraced the use of robotic in their manufacturing systems especially since their manufacturing systems are characterized by the use of high quality and highly precise products (Rossi & Schmidt, 2020). Meanwhile, promising areas such as China and India are showing a constant trend of increasing the use of robotics also in manufacturing due to government initiatives as well as the attempts to upgrade the infrastructure of production industries (Wang & Liu, 2020).

China for instance, expects to be the largest consumer of industrial robots by 2025 due to intend in automation due to population ageing thus affecting industrial production competitiveness across the world (Chen, 2022).

Industries Leading the Adoption

The automotive industry has been the most prominent in the adoption of robots, but the Electronics Consumer goods and Food and beverages have also taken up the idea. The manufacturing industry is the most affected by this approach due to the ability of electronics in utilizing robotics in production due to its intricacy and the need for speed.

Within the food and beverage industry, robots are utilized in packaging, palletizing and inspection that can be seen in the constant demand for uniform and safe products (Smith & Brown, 2020). Many industries have now realized how automation can be of great importance and as this is realized the market for the robots is likely to expand in the various fields.

The Advantages of the Use of Robotics in the Current World Manufacturing Processes

Increased Efficiency and Productivity

Another advantage of robotics in manufacturing is to say the lest, is that it leads to a very high level of efficiency and productivity. Compared to manual labor, robots can work without getting tired, taking breaks, making mistakes or being paid for it hence they are able to work at a faster rate than any human being (Wright and Adams, 2020). This kind of operation ability makes it possible for the manufacturers to increase their production to meet with the increasing demand without necessarily hiring more workers or working more hours. There are also conclusions that installations of robotic application in factories led to increased production volume for 30-50%, starting from such industries as automotive and electronics (Miller, 2021).

Further, it permits task executions, which are not only quicker and more accurate as well. For instance, in the electronics manufacturing industry assembles small complicated parts in higher precision than the human being without errors and it minimizes or reduces the odds of having defects (Kim & Zhao, 2020). These enhancements have reduced the probability of recalls by lowering the general defective products, reduced warranty claims and boosted the manufacturer reputation for efficiency (Garcia, 2022).

Quality Improvement

Another utility deriving from the use of robots is providing improved standardization and quality of manufactured products. Robotics in quality control and testing makes it possible to test every product and make an evaluation under the same conditions and with no influences from human interference (Li & Parker, 2019). For instance, in the pharmaceutical sector the use of automation resulted in inspections of packages, identification of impurities, identification of correct measures and other aspects that are vital and play a significant role in upholding quality (Raj & Sharma, 2021).

Robotics has been especially helpful in the applications involving repetitive work and where there is tendency of having more frequent blunders. Through performing these tasks, they have been in a position to ensure they achieve high standards and at the same time control wastage, hence contributing to the reduction of costs (Xu, 2021).

Safety Improvements

Robotics therefore remains an advantage since work places have become safer for the humans. Some of the functions that require robots include; working with risky substances, working in high temperatures such as welding, and moving massive loads (Anderson & Williams, 2020). Hence have minimized the risks that are associated with them hence minimizing the occurrences of workplace injuries as well as accidents. A study by the Occupational Safety and Health Administration (OSHA) has it that workplaces that already have robotics in their operation have 25% reduction in their injury rates (OSHA, 2021).

Cobots which are used in human environment have complimented safety through minimizing risks of accidents within the workplace. Leveraging on sensors and safety features, cobots can feel for human inputs and either decrease their speed or come to a complete stop to avoid an accident (Sullivan, 2019).

Cost Reduction

Of course, the acquisition of robotic systems is relatively costly at first, but overall, they result in great saving in a long run. Automations requires few people as compared to humans, it therefore cuts on expenses on human capital. Further, the fact that robots do not tire or require rest also translates to more throughput ratios thus pushing down the cost per output (Patel & Singh, 2021). Robots also have high productivity that minimizes resource utilization and energy hence cutting costs in the production lines in the long run (Li & Wang, 2021).

A survey carried out by McKinsey & Company reveal that, manufacturing firms that have adopted the use of robots experienced a reduction in cost of production by 15-25 percent within two years of installing robotics systems (McKinsey & Company, 2022). They help reduce prices to consumers and give better margins which in turn is reinvested in better and/or newer technology.

Challenges and Limitations

High Initial Costs

Major challenges faced in the adoption of robotics within manufacturing companies include one-off costs involved in procuring and integrating the robotics systems into the manufacturing environment. Industrial robots, especially those with AI and Machine learning are known to be capital intensive investment (Ravi & Gupta, 2020). The cost of investing in robots includes the initial purchase cost, installation cost, and the operations cost which most SMEs cannot afford due to limited capital as compared to the giant companies. Chen and Lin (2021) indicate that one of the primary challenges that SMEs face is the inability to afford the initial large cost of robotics while the benefits of the technology are likely to yield long-term reduced costs.

Furthermore, implementing robots into newfangled production lines might entail extra cost such as fixing new equipment, purchasing new software and reorienting existing employees (Patel, 2020). This, in turn, raises the total cost of adoption: a factor that poses a great challenge to organizations planning to automate their processes. Although more extensive companies can afford the above costs, small

businesses effectively bear the costs, thus, limiting the robotics penetration rate in the manufacturing industry.

Technological Complexity and Integration

However, great challenges are observed to be associated with integrating robotics into highly developed manufacturing systems and processes. Today, as manufacturers adopt higher end robotics and automation systems that need to merge with older and existing machinery, production lines and software interfaces, implementability further becomes a complex challenge (Williams & Carter, 2020). Robotic solutions may cause disruptions in production processes because robotic solutions need major changes to existing structures hence incurs additional costs.

Also, there is a need for firms to employ competent technologists who will work on the robotic systems, operate, maintain as well as perform repairs. One limitation that arises from the technological design of robots especially the ones with artificial intelligence is that the operation requires specialized skills to achieve the best results (Zhao et al. , 2020). Often, finding and securing the right talent that is capable of operating such systems is a challenge for auto manufacturers leading to more instances of downtime.

Impact on Employment

Arguably one of the most hotly-discussed questions about robotics in manufacturing is the effect on employment. As for the benefits, robots may increase productivity and effectiveness to very high levels; on the other hand, the drawbacks point to the ROSA's potential to replace human workers in industries where manual labor is predominant (Smith & Taylor, 2019). Acemoglu and Restrepo (2021) have established that robotics used in industries to carry out routine tasks has a negative impact on employment resulting in loss of numerous jobs within manufacturing industries especially for low skilled workers. Some of the jobs that are affected by the use of robots include assembly, welding, and packaging, and this results in unemployment or need to undergo through retraining.

While the proponents of robotics have postulated that they are going to produce new jobs chief among them being robotics maintenance and programming, upward transformation and training of the workforce are inevitable (Patel & Singh, 2021).

To avoid such a situation, governments and companies need to work on education and training which may assist persons who have been laid off to join new fields and industries as their expertise is no longer required at their previous workplaces (Graham & Lee, 2020). However, such measures tend to emerge slowly, thus being miles behind the ever-increasing speed of technology development, which worsens the employment problem in the short run.

Cybersecurity Risks

There are a number of problems of security in modern era where robotic system is becoming more and more integrated through network and Internet of things. The dependency on data driven robotic systems challenges manufacturers with potential cyber risks that can compromise their production line, steal, or even modify control over robotic systems (Johnson & Davis, 2021). It was discovered from research carried out by Williams and Chen in 2022 an alarming 70% of manufacturers who invested in industrial robots, have fallen victims to some form of cyberattacks in the last five years as noted by.

Robotic systems connected to the cloud platforms or if they are part of large manufacturing networks, are vulnerable to hackers. It goes without saying that the impact of a cybersecurity threat may be significant, including from extended downtime to financial losses (Liu & Smith, 2021). Business owners also realize that they need to enhance cybersecurity to safe guard the robotic infrastructure used in manufacturing lines – which is yet another layer of cost and effort that has to go into automation.

Case Studies

Case Study 1: Automotive Industry – Toyota motor corporation of Japan

Toyota has been on the forefront in incorporating Robotics in its production lines with fabrication systems used in assembly and inspection. The company acquired a robotic system in its production processes where articulated robots are used for welding and assembling works (Suzuki & Nakano, 2020). These changes have enhanced production rhythm and quality and uniformity of the products. The introduction of robotics in Toyota's production line has seen an increase in production output by 40% and a decrease of defect rates by 25% as stated by the International Federation of Robotics, 2022. These systems have also improved the safety of the workers since the dangerous operations are managed by these systems, The number of worker injuries has significantly reduced (Toyota, 2021).

Case Study 2 concerns the electronics industry of the giant company Foxconn.

Electronics manufacturers including Foxconn that supplies electronics giant such as Apple, has widely adopted robotics in production assembly line to cater for high turnover. The application of assembly collaborative robots (cobots) by the company has enabled flexibility and improved the production lines by the company (Li & Chen, 2021). These cobots operate in collaboration with the operators to complete tasks that can be repeated thus improving efficiency without efficiency without straining on effectiveness. It was revealed that due to heavy investment in automatic robots Foxconn has been able to bring down production time by about 30 percent and the employment cost has gone down to 20 percent in

Foxconn, 2022. But it also yields some issues, for instance, the high investment in training and maintenance of the robotic systems (Huang & Zhang, 2022).

Case Study 3 involved the consumer goods company; Unilever This company has its major focus on the production of fast moving consumer goods such as soaps, detergents, and other related products.

Unilever one of the leading companies that the use of robotics in manufacturing of consumer items especially in packaging and handling. AMRs have been adopted by the company to optimize the supply chain operations of managing stock in the warehouses of the business (Gordon & Green, 2021). Such robots are fitted with enhanced mobility to enable them transport products from one section of the large warehouse to another. The integration of AMRs has made a 25% enhancement of the warehouse throughputs and a 15% savings in the operations cost (Unilever, 2022). Also, Unilever has also benefited from planning and implementing on robotics as it has increased on accuracy of inventories and time taken to restock thus enhancing its operations (Smith & Wilson, 2021).

To understand how the aerospace industry is benefitting from PLM, let us look at Case Study #4: Aerospace Industry – Boeing – that discusses Boeing's PLM journey in detail.

Robotic technology solutions have been adopted by Boeing to increase accuracy and work speed in construction of its aircraft. Robot applications in the firm include drilling/ assembly/fastening, composite material handling, and others as indicated by Johnson and Lee (2020). Using of these systems has enhanced assembly accuracy and decreased time for production of the products. Integration of robotics in Boeing has led to a decrease of assembly time by 20 % and less defects by 30% (Boeing, 2021). Nevertheless, the above advantages have been realized to have some drawbacks regarding high cost associated with bearing robotic technology and the difficulty of implementing such systems within the manufacturing line.

V. CONCLUSION

Robotics' application in today's manufacturing process has dramatically impacted the industry by providing both positive and a number of negative repercussions. For example, achieving positive results of robotics with regard to productivity and efficiency growth at different stages of production in such industries as automobile manufacturing, consumer goods, etc. For example, Toyota has employed articulated robots to boost the production efficiency and product quality (Suzuki & Nakano, 2020), Foxconn employs collaborative robots to increase flexibility and to lower costs of labor (Li & Chen, 2021). Likewise, Unilever has effectively implemented the use of autonomous mobile robots in its warehouse this has brought about efficiency and reduction of costs (Gordon & Green, 2021).

Nevertheless, as pointed earlier, there are a number of difficulties encountered when using robotics and these are as follows. High initial costs of robotic systems continue to be a challenge, especially to SMEs as they are usually expensive to invest in. In addition, there is a challenge of implementing robotics in the manufacturing line for it entails vast investment in physical and human capital (Williams & Carter, 2020). Employment is another area of concern, and this is because automation is bound to cause employment problems in one or the other, especially given the fact that there will be a new set of jobs requiring different skills and knowledge (Smith & Taylor, 2019).

All in all, robotics can bring significant improvements in terms of productivity, product quality, and safety in the work environment but at the same time, it has apparent economical and social consequences. These aspects should be in consideration when manufacturers want to invest in robotic systems so that they are ready to embrace the benefits that accost this technology together with its cons. Further research should be conducted to identify ways of handling cost and addressing the issues of workforce by employment of robotics so as to enhance the extent of use of robotics in manufacturing sector to have the maximum benefits.

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