Production and Maintenance in Industries: Impact of Industry 4.0

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Abstract

Purpose: *Production industries are undergoing a digital transition, referred to as the fourth industrial revolution or Industry 4.0, as a result of rapidly expanding advances in information and communication technology. The purpose of this research is to provide a conceptual insight into the impact of unique capabilities from the fourth industrial revolution on production and maintenance tasks in terms of providing the existing production companies a boost by making recommendations on areas and tasks of great potential.*

Design/methodology/approach: *A survey and a literature review are among the research methods used in the research. The survey collected empirical data using a semi-structured questionnaire, which provided a broad overview of the company's present condition in terms of production and maintenance, resulting in more comprehensive and specific information regarding the study topics.*

Findings: *The study points out that, the implementation of I4.0-technology leads to an increase in production, asset utilization, quality, reduced machine down time in industries, and maintenance. Sensor technology, big data analysis, cloud technologies, mobile end devices, and real-time location systems are now being implemented to improve production processes and boost organizational competitiveness. Moreover, the study highlights that data acquired throughout the production process is utilized for quality control, predictive maintenance, and automatic production control. Furthermore, I4.0 solutions help companies to be more efficient with assets at each stage of the process, allowing them to have a stronger control on inventories and operational-optimization potential.*

Originality: *The findings of the study was supported by empirical data collected through survey that provides an intangible understanding of the importance of distinctive capabilities from the I4.0 revolution on production and maintenance tasks. In this study, some recommendations and guidelines to enhance these tasks are provided that are vital for existing production companies.*

Keywords

Industry 4.0, production, maintenance, cyber physical system (CPS), industrial revolution, internet of things (IOT), Predictive maintenance (PdM), preventive maintenance system (PM) machine data, Additive Manufacturing, cloud technologies.

Abbreviations

3DP	*3d Printing*
AM	*Additive Manufacturing*
AR	*Augmented Reality*
CM	*Condition Monitoring*
CPPS	*Cyber Physical Production System*
CPS	*Cyber Physical System*
ERP	*Resource Planning*

HMI)	*Human Machine Interaction*
HRM	*Human Resource Management*
I4.0	*Industry 4.0*
IOS	*Internet Of Services*
IOT	*Internet Of Things*
IR	*Industrial Revolution*
IT	*Information Technologies*
PDM	*Predictive Maintenance*
PM	*Preventive Maintenance*
RFID	*Radio Frequency Identification Enterprise*
TPM	*Total Productive Maintenance*
UIDS	*Unique Identifiers*

1. Introduction

In today's competitive market, industries strive to adapt new technologies to meet customer needs and maintain market share. Industry has gone through three revolutions in the past 200 years, fueled by mechanization, electrical power, and electronics and information technology. Germany has announced the term industry 4.0 in light of recent technological advancements in Cyber Physical Systems (CPS), Internet of Things (IoT), and Internet of Services (IoS). This uprising is motivated by the desire for a shorter time to market, customized mass production, and increased effectiveness. Vertical integration of systems at different hierarchical levels of the value creation chain and the business process, as well as horizontal integration, characterize Industry 4.0 (I4.0) within and across the factory of several value networks. The various data sources in I4.0 will enable factories to predict and respond quickly to changes in production, delivery, failures, and so on, as well as compensate temporary scarcity. Flexibility in I4.0 will result in better working conditions and a better life-work balance for employees. Almost every aspect of human civilization globally is dependent on automation and the IoT. In today's competitive scenario, every company strives to increase cost savings, increased profitability, reduce waste , implement automation to prevent interruptions. Moreover industry aims at accelerating up production to operate more in real-time and in feature of the overall product lifecycle, where pace is critical for everyone, digitizing document flows, being able to react faster in case of production issues, and so on. This is the scope of the project, where I4.0 can play its role. Even in the face of a pandemic (such as the recent COVID 19), industries using Industry 4.0 technology can lead the company by operating remotely and with fewer people.

I4.0 refers to a new era of digitalization. Almost everything is digital; business models, environments, production systems, machines, operators, products and services (Alcácer & Cruz-Machado, 2019). The different components are interconnected within the digital scene, with the corresponding virtual representation. The buzz phrase “I4.0” (fourth industrial revolution) has been introduced, and with it, big promises to meet the most recent challenges in production systems have emerged (Anshari and Almunawar, 2021). The need of I4.0 is to transform regular machines into self-aware and self-learning machines to improve overall performance and maintenance management through interaction with the environment (Vaidya, et al., 2018).

The digital industry's internet transformation is still ongoing, but artificial intelligence, big data, and connectivity indicate the certainty of a new round of digital revolution (Roblek, et al., 2016).

The German Federal Government defines I4.0 as "a developing framework in which production and transportation structures in the form of Cyber Physical Production System (CPPS) intensively use the internationally information available and communications network for a widely automated exchange of information and in which production and business processes are matched" (Bahrin, et al., 2016). The fourth Industrial Revolution (IR) will be defined by complete automation and digitization of processes, as well as the use of electronics and information technologies (IT) in manufacturing and services in the private sector (Roblek, et al., 2016).
Industry 4.0 technologies facilitate different industries in digital transformation that supports environmental sustainability through sustainable energy and resource transformation (Beier et al., 2017). Industry 4.0 is not limited to energy sustainability, it has also a great impact on economic sustainability such as advanced digital manufacturing technologies, efficient production planning, waste minimization and smart material planning have contributed to improving system efficiency and saving cost (Jose and Ramakrishna, 2018) (Sharma et al., 2020).

Several studies have shown that maintenance is critical to a company's long-term viability. As a result, proper maintenance should be considered to sustain I4.0 and its achieve better benefits. Maintenance has traditionally been defined as the combination of all technical and associated administrative actions intended to keep an item in, or restore it to, a state in which it is capable of performing its required function. It has also been described as a method of monitoring deviations in process conditions and product quality to intervene when it is possible to stop or reduce them, machine deterioration rate before product characteristics become unacceptably poor affected, and to take the necessary steps to restore the affected portion of a machine to make it as good as new. Although every industry wants to implement Industry 4.0 with regard to industrial maintenance, but it takes a lot of time, money, and effort. Integrating elements of Industry 4.0 into maintenance operation does not require the purchase of new technology or the implementation of minor changes. It will take time to implement all the necessary tools, processes, and systems. Maintenance activities have an impact on the profitability and internal effectiveness of a company because of their importance and impact on various working areas such as quality, safety, production cost, working environment, and delivery on time, and so on. Maintenance must meet its demands in order to sustain the modern technologies, i.e. I4.0. I4.0 refers to the adaptability of value-creating networks, which enables machines and plants to adapt to changing orders and operating conditions through self-optimization and reconfiguration, with the goal of implementing distributed and interconnected production facilities in future smart factories. I4.0 tools and technology have evolved from an abstract concept to a practical solution. Regardless of how technology changes, the bottom line is the most important priority for many organizations. Based on the above discussion, the study is based on what has been accomplished in the literature regarding I4.0, experience, and knowledge as well as the overall impact of maintenance. Thus, the purpose of this research is to provide a conceptual insight into the impact of unique capabilities of the fourth industrial revolution on production and maintenance tasks in terms of giving existing production companies a boost by making recommendations on areas and tasks with greater potential.

1.1 Industry 4.0

The fourth IR will be defined by complete automation and digitization of processes, as well as the use of electronics and information technologies (IT) in manufacturing and services in the industrial sector (Roblek, et al., 2016). The value creation effects of efficiency gains and new business models are one positive aspect of I4.0, but technological change may have both a positive and negative impact on employment. Because connected machines gather a massive amount of data which can be used to improve maintenance, performance, and other issues, as well as analyses that data to define insights and patterns that would be impossible for humans to do in a reasonable period of time. I4.0 provides producers with an opportunity to optimize their operational activities quickly and efficiently by understanding what they are doing. A strategic competitive advantage, organizational agility, manufacturing innovation, profitability, improved product safety and quality, delightful customer experience, organizational efficiency and effectiveness, improved operations, and environmental and social benefits are among the benefits of I4.0 (Sony, 2020).

I4.0 is on its way and will have a significant impact on the overall transformation of industry because it represents progress in three areas such as Digitization of production (Management and production planning information systems), Automation (systems for collecting data from production lines and utilizing machines) and Automatic data interchange (Creating a comprehensive supply chain by connecting manufacturing sites). These characteristics not only have a high correlation with internet technologies and advanced algorithms, but they also indicate that I4.0 is a value-added and knowledge-management industrial process (Tiwari, 2020).

I4.0 encompasses a wide range of technologies and paradigms, such as Radio Frequency Identification (RFID), Enterprise Resource Planning (ERP), cloud-based manufacturing, and social product development (Lu, 2017). Interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity are I4.0 principles (Gomez, et al., 2021).The objectives of I4.0 are to achieve greater productivity and operational efficiency, as well as greater automation (LaneThames & DirkSchaefer, 2016). According to Roblek, et al., (2016), Digitization, optimization, and customization of production; automation and adaptation; human machine interaction (HMI); value-added services and businesses; and automatic data exchange and communication are the five major features of I4.0. The nine I4.0 pillars (HSRC, 2019) are shown in Figure 1.

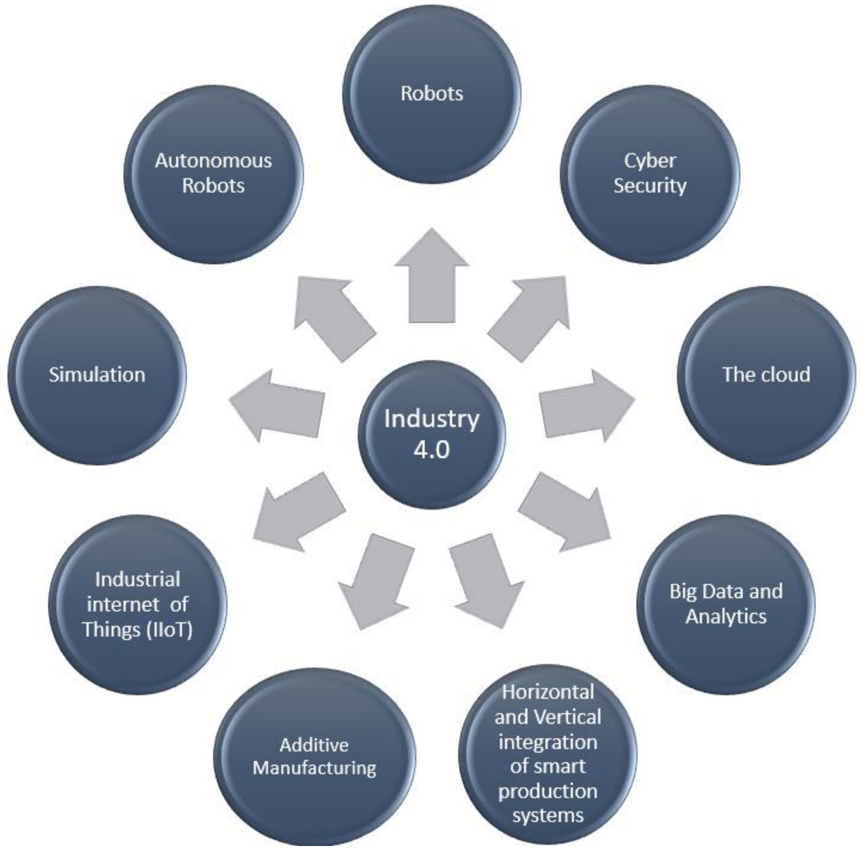

Figure 1: The nine pillars of I4.0.

(a) Horizontal and Vertical integration of smart production systems

Horizontal integration ensures that machinery, IoT devices, and engineering processes all work together seamlessly in the interconnected Smart Factory. Smart factories, which are at the heart of I4.0, cannot function on their own. Vertical networking is defined by the use of CPPS, which allow factories and manufacturing plants to respond quickly and appropriately to variables such as demand levels, stock levels, machine defects, and unforeseen delays. It can be modularly replicated and disseminated among manufacturing companies. It's also a wise strategy for the next generation of smart production processes (Peters, et al., 2016). The data gathered during the production process, as well as the systems used, are saved in the cloud. These systems increase the flexibility of the production line through virtualization, decentralization, and real-time abilities (Tung, 2018).

(b) Internet of Things (IoT)

IoT is a network of interconnected computing devices, mechanical and digital machines, objects, animals, or people that have unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (McFarlane, 2018). Machines and devices can now communicate with one another via the internet, thanks to this new technological concept known as the 'Internet of Everything' (Lee & Lee, 2015). The basic concept of this model is the pervasive presence all over us of a variety of things or objects – such as Radio-Frequency Identification (RFID) tags, sensors, actuators, mobile phones, and so on – that, through unique addressing schemes, are capable of interacting with each other and cooperate with their neighbor's to achieve common goals (Atzori, et al., 2010; Hozdić, 2015).

(i) Industrial internet of Things (IIoT)

The use of Internet of Things developments to (add value to) industrial processes, supply chains, products, and services (McFarlane, 2018). According to Khan, et al., (2020) "Industrial IoT (IIoT) is the network of intelligent and highly connected industrial components that are deployed to achieve high production rate with reduced operational costs through real-time monitoring, efficient management and controlling of industrial processes, assets and operational time"**.** The use of IoT technology in a business setting is referred to as the Industrial Internet of Things (IIoT), the fourth industrial revolution, or Industry 4.0. The concept is similar to that of consumer IoT devices in the home, but in this case the goal is to measure and optimise industrial processes using a combination of sensors, wireless networks, big data, AI, and analytics (Ranger, 2020). Improving workforce productivity or lowering costs are two potential goals, but the IIoT can also help businesses generate new revenue streams, rather than just selling a standalone product. The goal of IIoT is to improve the efficiency of industrial assets and operations, as well as to provide predictive maintenance (Khan, et al., 2020). It has been proposed that a Wireless Evolution for Automation (WEVA) solution for IIoT, which is based on open-source software and communication protocols. IIoT leverages IoT communication in business applications that are primarily concerned with machine interoperability (Liao, et al., 2020). Building IIoT systems, on the other hand, frequently necessitates upgrading existing production systems because IIoT data is not only obtained from existing sensors, gateways, and controllers but is also merged with the other application data (Jin-Sung, et al., 2021). If an upgrade is required, modifications to the present structure should be kept to a minimum, and the core system of the prevailing production system must be left unchanged and upgrading the IIoT system requires a significant investment (Jin-Sung, et al., 2021).

(c) Big Data and Analytics

To support real-time decision making, the collection and comprehensive evaluation of data from a variety of sources, including production equipment and systems, as well as enterprise and customer-management systems, will become the norm (Rüßmann, et al., 2015). Big Data has four dimensions: volume of data, variety of data, velocity of generation of new data and analysis, and scale value of data (Witkowski, 2017). Its primary goal is to manage and process large amounts of data to improve operational efficiency, improve decision making, and reduce workplace risks (NGUYEN, et al., 2020). Manufacturing big data includes information from production planning, quality control, procurement, inventory control, human resource management (HRM), and delivery (Chumnumporn, et al., 2020).

(d) Simulation

Simulation is a critical technology for creating planning and exploratory models to enhance decision making, and the design and operation of complex and smart manufacturing systems (Ferreira, et al., 2020). Simulation is a primary method for analyzing complex production systems and a critical problem-solving technique (Negahban & Smith, 2014). It can be used in I4.0 to simulate a virtual environment of the factory itself using real-time data and analyze productivity before making changes to the factory. This allows engineers to visualize the design much better, allowing them to identify problems and obstacles at an early stage. Models with a high degree of automation and integration with various systems can be found in simulation models focused on specific analysis (Montevechi, et al., 2020).

(e) Autonomous Robots

Autonomous robots transport raw materials, semi-finished goods, and finished products in a more efficient, faster, and intelligent manner. They perform on a complex logic algorithm, which means they don't need a predefined path to perform the tasks (Roche, 2019). Because of the need for more efficient, autonomous, and customizable processes, I4.0 is characterized by an increasing reliance on automation and system interconnection, and mobile robot navigation becomes an important tool (Gonzalez, et al., 2018). The navigation of autonomous mobile robots is divided into four stages: mapping, localization, planning, and execution (Siegwart & Nourbakhsh, 2004). The accessibility of technologies that use artificial intelligence for positioning and navigation can aid in transportation improvements in production processes that use intelligent vehicles, including the autonomous robots, in order to acquire effective solution for increasing the productivity and effectiveness of the production systems (Fragapane, et al., 2020). Robotics will play an important role in smart factories that will benefit from I4.0 design principles such as interoperability, decentralization, real-time capability, virtualization, service orientation, and modularity (Drath & Horch, 2014). The ability to establish fully automated production lines, leading to almost personnel-free factories and serious threats to the job market, particularly in the low-qualification segment, is a highly contentious aspect of the use of robots (GRAU, et al., 2021).

(f) The cloud

The cloud is a remote system that can be accessed via the internet. Cloud computing enables the storage of massive amounts of data. This capacity is primarily important for storing data generated throughout the production process, given that machineries and sensors generate so much data than humans and that such data is constantly connected (Velásquez, et al., 2018). Cloud computing reduces the need for technological resources by allowing storage capacity and processing capacity to be outsourced on demand, resulting in flexibility, agility, and adaptability (Thames & Schaefer, 2016).

(g) Cyber Security

Another critical issue is cyber security, which could have a negative impact on the business environment due to the harmful intents of cyber attacks; thus, preventable solutions and defense systems are required to mitigate the negative effects of terror incidents (Erboz, 2017). I4.0 is accompanied using standard communication protocols and increased connectivity, necessitating the need for advanced identity management and connect directly to users/machines that effectively guarantee safe and reliable communications against cyber security threats (Souza, et al., 2020).

(h) Robots

(i) Augmented reality and Virtual reality

Industrial augmented reality (AR) is an essential component of Industry 4.0 concepts because it allows employees to access digital data and update it with the physical world. AR is defined as the technology that bridges the gap between reality and digital environments (Damiani, et al., 2018). Its main advantage is that it does not require expensive hardware because it can be used with standard equipment (Hořejší, 2015; Damiani, et al., 2018). AR as an intriguing and precise system that provides information in various industrial sectors, with a particular emphasis on maintenance, and the development of a cloud-based platform that supports remote maintenance services (D.Mourtzis, et al., 2017). Human-Robot Collaboration, maintenance-assembly-repair, training, product inspection, and building monitoring are now at least five major areas of application for

AR in the industry domain (Pace, et al., 2018). AR, among other applications, is a promising technology that can improve a user's understanding of the following: movements of a mobile robot, movements of a robotic arm, and forces applied by a robot (Pace, et al., 2018). A camera framing the external world, a screen or a lens to project a video streaming, and the computational resources (PC, smartphone processor, microcontroller) required to handle the video recording, pose detection, and superimposition of visual symbols to it constitute the minimum hardware required to run an AR application (Santi, et al., 2021). Augmented Reality (the integration of virtual objects in real life via see-through head-mounted devices), Augmented Virtuality (the merging of real objects in a virtual environment), and Virtual Reality are the three possible types of reality combinations (Santi, et al., 2021). Virtual reality applications in virtual prototyping, web-based virtual machining, assembly, fault detection and learning, and many sorts of industrial procedures have received widespread attention (Damiani, et al., 2018). However, because of its "affordable" smart gadgets, VR has piqued the interest of many industries. As the manufacturing industry and its units collaborate with intelligent equipment, strong connectivity, data intelligence platforms, and simulation tools, VR opens up new possibilities for creating smart and intelligent solutions.

(i) Additive Manufacturing

I4.0 encourages the integration of intelligent technologies and manufacturing systems. Amongst which, additive manufacturing plays a critical role in meeting some of the fourth industrial revolution's most pressing needs. Additive manufacturing (AM) is a widely used technology that, along with rapid prototyping and 3D printing, has revolutionized manufacturing (Baldassarre & Ricciardi, 2017). Additive manufacturing, which includes 3D printing (3DP), is a critical pillar of Industry 4.0 (Sepasgozar, et al., 2020). Because of its ability to create sophisticated and complex objects with advanced attributes, AM may become a key technology for fabricating customized products (new materials, shapes) (Dilberoglu, et al., 2017). In addition to this, additive manufacturing emerges its role as an important pillar of Industry 4.0 in maintenance. Recently, the manufacturing industry such as aerospace and automotive sectors have invested in additive manufacturing to develop spare parts with improved strength-to-weight ratios, as well as for on-demand manufacturing and speedy maintenance of their product. However, restricted materials and expensive costs, as well as the uneven quality of 3D printed parts, are the bigger challenges to AM adoption in the manufacturing industry (Paul Lynch et al., 2020).

1.2 Production in I4.0

The foundation of human activity is production (P.H.Brill & M.Mandelbaum, 1990). A production section of an I4.0 item designing company is a part of the company that unites a sequence of automatic technologically purposed systems for the human less and paperless process of item production (Zakoldaev, et al., 2019). Production systems are regarded critical in terms of performance, timeliness, and cost. Complex interactions between different machining operations and process variables determine machine performance and component quality in modern production processes (Żabiński, et al., 2019). The new production systems, outfitted with "intelligent" devices linked to the computer system, through which products, machineries, and production systems gain communication capabilities, represent smart factories of the future and are critical to achieve the level of flexibility necessary to achieve the current challenge of increasing variability, customization options, and product life cycle reduction (Santos, et al., 2020). The goal of cloud manufacturing is to create production networks with high flexibility and dynamic reconfiguration, while intelligent big data analytics can provide global feedback to achieve high efficiency (Fragapane, et al., 2020).

1.3 Maintenance in I4.0

I4.0 requirements, as well as modern technological environments, necessitate a high level of dependability. Information and communication technology are constantly changing traditional practices, such as manual plant inspection and information retention on paper and moving us closer to computer-aided maintenance (Haider & Koronios, 2006; ANH, et al., 2018). Maintenance management has seen a significant evolution in its best practices as a result of IT development: conventional means for maintenance planning and monitoring have been integrated and improved by technologies such as the IoT, cloud computing, and artificial intelligence (Urbani, et al., 2020). The fourth generation is expected to focus on self-maintenance systems with zero downtime, self-maintenance, and self-healing features (Jain, et al., 2014). The maintenance function's role has shifted from an unpredictable and unavoidable cost center to a profit center, increasing the company's competitiveness. Recently, I4.0 technologies has been further explored to develop its application into Total Productive Maintenance (TPM) practices in large manufacturing companies. In this study, benefits and barriers are highlighted related to the implementation of I4.0 into TPM that will be helpful for companies to develop their plan to employ digitalization of TPM (Tortorella et al., 2021).

1.4 Predictive and preventive maintenance

Predictive maintenance (PdM) and preventive maintenance (PM) systems both are intended to enhance asset dependability while decreasing sensitivity to breakdowns. The primary distinction between both is that PM is planned on a regular basis, whereas PdM is done when needed based on asset conditions. PdM is a technique which uses data analysis tools and techniques to identify intrusions in your operation as well as potential defects in processes and equipment so that they can be fixed before they fail. According to Carvalho, et al.,(2019) PdM is a collection of tools that are used to determine when specific maintenance is required. To achieve good results for predicting failures or predictive maintenance, various techniques such as AI, smart data analysis, data-driven approach, and so on are used. One of the most important components of data-driven predictive maintenance is the data itself; it should be large and contain records of damage periods in addition to normal device operation (Chuang, et al., 2019). PM, one of the most popular maintenance policies, entails periodic inspections required for equipment upkeep as well as corrective actions. Identifying the appropriate PM interval necessitates the analysis of failure time data and is solely determined by age or service time (Kaiser & Gebraeel, 2009).

1.5 Condition based monitoring (CBM)

CBM schedules maintenance routines based on real-time condition monitoring (CM) data (Kaiser & Gebraeel, 2009). CM entails observing degradation-based measures from an operating system or device, such as temperature, vibration, and acoustic emissions, to determine its state of health (Maillart, 2006). Sensors enable continuous CM by collecting data, which enables intelligent decisions to be made using machine learning or artificial intelligence (AI) (Setiyo et al., 2021). The goal of CM is to measure certain physical parameters that would indicate an impending failure (Marai, et al., 2015). CM must also be a part of a smart manufacturing programme that aims to improve and optimize the operational efficiency of the production systems (Mykoniatis, 2020).

I4.0 promotes among other things, autonomous compatibility, agility, adaptability, decision-making, productivity, and cost savings. Industry 4.0 enables industry leaders to have a deeper understanding of and control over every element of their operations, as well as to use real-time data to improve productivity, streamline procedures, and accelerate growth. In order to assure asset function (reliability) and value (asset management), Maintenance 4.0 contains a comprehensive view of data sources, ways to connect, ways to gather, ways to analyze, and recommended actions to take. Continuous monitoring of machine data is used in CM to detect wear, making it easier to schedule repairs and reducing downtime. There is also the possibility of cheaper maintenance expenses because only worn-out components need to be replaced.

Figure 2 shows the year wise data pertaining to articles published in SCOPUS database and it can be clearly seen that the trend for Industry 4.0 is going upwards with a steep rise in the number of articles. This indicates the global efforts by the research community to research the various aspects of Industry 4.0.

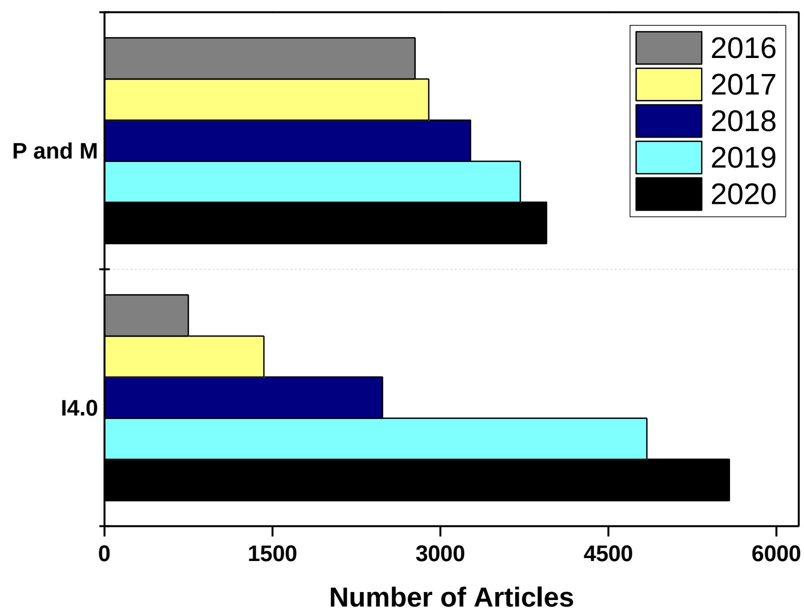

Figure 2: Year wise data pertaining to articles published in SCOPUS database (with key words as ("Industry 4.0" and "Production and Maintenance").

Through I4.0, which enables vertical and horizontal integration, it is possible to respond quickly to changes and problems in production processes, smooth production, particularly for consumer and customized goods, increase resource production efficiency, and achieve global infrastructure optimization (Gerekli, et al., 2021). I4.0 is making it easier for industries to collaborate and share data with their customers, manufacturers, suppliers, and other supply chain partners. It boosts productivity and competitiveness, enables the transition to a digital economy, and creates opportunities for economic growth and sustainability (Yuan, 2020). As businesses begin to use the IoT to connect manufacturing assets, big data analytics to monitor plants, and artificial intelligence to support decision-making processes, digitalization is changing the manufacturing landscape

(Felsberger, et al., 2020). As a result, manufacturing operations have become smarter as they gradually adopted information and communication approaches and technologies and merged them with production and process technologies on the verge of a I4.0 affecting various industries (Kusiak, 2018). For decision-making and production, I4.0 heavily relies on computers and data. From the standpoint of production and service management, I4.0 focuses on the establishment of intelligent and communicative systems such as Machine-to-Machine and Human-Machine Interaction, as well as dealing with data flow from intelligent and distributed system interaction (Alcácer & Cruz-Machado, 2019; Salkin, et al., 2017).

2. Methodology

Primary and secondary research approaches are used in this study. In both techniques, researchers conduct both qualitative and quantitative research to obtain a clear picture. In a mixed methods study, data is collected and analyzed using both quantitative and qualitative methods (Shorten & Smith, 2017). Because these methodologies can each address various issues, combining them can yield more in-depth results. Mixed methods analysis can be used for both primary empirical research and literature studies (secondary).

In a primary research study, “a researcher gets qualitative and quantitative data directly from research participants, such as through interviews, observations, and questionnaires, and then combines these varied data in a single study” (Johnson, et al., 2007). A questionnaire is a versatile data collection tool with the benefits of having a consistent structure, being simple and convenient for respondents, and being inexpensive and quick to administer to a wide range of cases across large geographic areas. The questionnaire is used to obtain primary data. In the current study ,a questionnaire was developed with the intent of studying about the current state of I4.0 production and maintenance technologies, and processes. To choose the sample from diverse persons working in I4.0 and utilizing a basic random sampling technique. As it provides different facets of a phenomenon, triangulation is considered a powerful research strategy, especially when a mixed method approach is applied (Kelle, et al., 2019). A mixed methods technique was used in this study to triangulate data, combining primary data from surveys with secondary data from the existing research literature. Online questionnaires are more cost-effective and take less time to distribute than personal or postal surveys (Walliman, 2018). As a result, Google forms employed social media platforms such as LinkedIn to conduct the poll. The poll contained thirty questions and got 55 responses. The data was collected from the people who are working in the industry across the different countries such as India, United Kingdom, United Arab Emirates, Qatar.

Secondary data analysis is a versatile approach that may be used in a variety of ways, it is still an empirical exercise that includes procedural and evaluative phases, much like gathering and analyzing primary data (Johnston, 2014). Research material released in research reports and other comparable materials is considered secondary research. In this secondary research, used a variety of methods/processes to help the researchers to understand the impact of I4.0 on production and maintenance. In this research it also discusses previous quantitative data reports from the past to help the researchers to understand the impact of I4.0 on production and maintenance. Secondary data analysis relies on the application of theoretical knowledge and conceptual skills to use existing data to answer research questions (Johnston, 2014). The literature review was critical in this study since it provided a knowledge background and conceptual limitations on the topic of research. As a result, finding proper research is critical, as it aids in the development of research objectives and surveys. Furthermore, the researchers obtained secondary data from the research paper, which was used to draw distinctions with the primary data in the discussion section.

At the current time, Industry 4.0 is considered to be a revolutionary element in the different industrial sectors. This study predominantly focused on results collected from different companies located within UK, Europe, Asia. Hence, in order to make these findings more applicable generally, it is required to explore the research objectives within other world countries' firms that adopt industry 4.0 technologies in their industrial environments. Besides, another possible limitation of the study is the size of surveyed companies, it would be good to consider the larger size companies. Moreover, a need to realise further conceptual framework research on the sustainable side and benefits that industrial 4.0 holds while investigating the related research areas such as energy, and environmental science.

3. Results

The primary research was conducted as a survey, with the following questions being sent to various people working in various sectors of the industry, and the results were successfully obtained from 55 persons, and the results are presented below. Only a selection of the original research findings is shown here. These results are most closely related to the concepts in I4.0 that focus on improving production and maintenance operations. This questionnaire was attempted by different industries. Figure 3 shows the manufacturing sector has a great interest in industry 4.0 technologies with 58.2 percent respondents and then construction business with 14.5 percent.

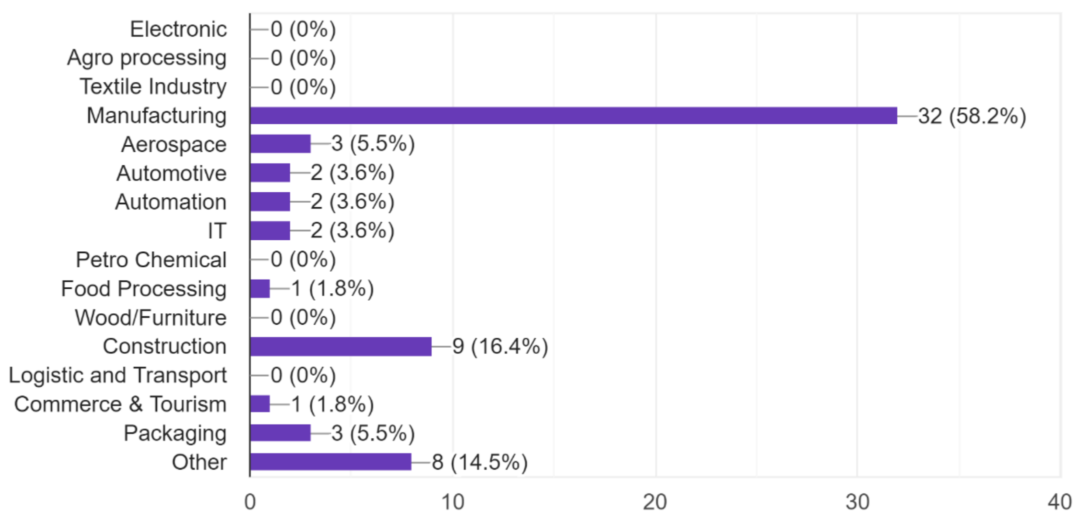

Figure 3: industry type of research samples

According to primary research, an increasing number of firms are in the process of implementing I4.0 plans for future expansion of production processes and maintenance. From the survey, it is important for most of companies to be implement I4.0 over the next two years to increase competitiveness and total value creation of products and services. Organizations are currently using I4.0 technologies to boost their competitiveness, and they are aware of the benefits of the new technology. From Figure 4, most companies utilize sensor technology, big data analysis, real-time location systems, and cloud technologies to optimize production processes and boost competitiveness. The bar diagram's vertical axis depicts I4.0 technologies, while the horizontal axis depicts the number of industries that use these technologies. The percentage represented on the bar graphs shows the proportion of the respondent for this particular question in relation to the total number of respondents.

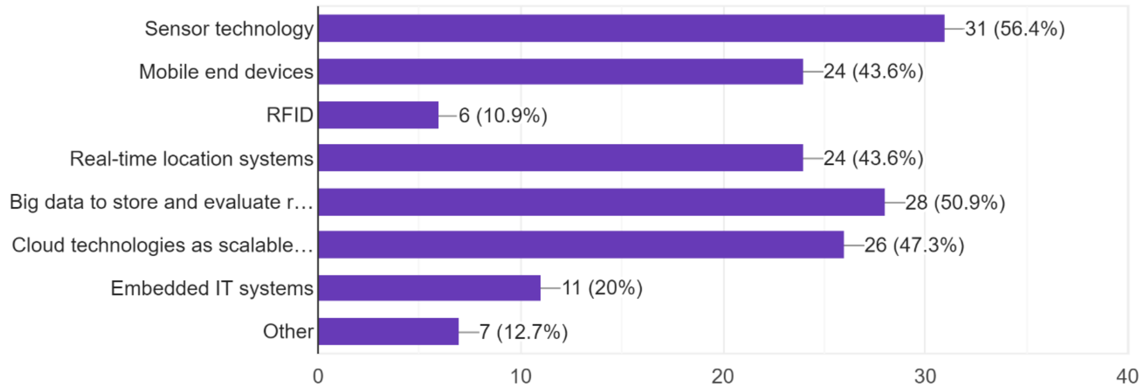

Figure 4: Technologies currently implementing in organizations to improve production operations and increase competitiveness.

Based on the survey, there is a medium level of digitalization and integration in the production phase, and only a few firms are fully digitized and integrated across both production and maintenance. Machine data and process data gathering during production is vital for future development, and most companies will monitor and analyze it with big data analytics to enhance output. Using real-time data, the data collected during the production stages (see Figure 5) can be used to control production quality, forecast maintenance, establish transparency throughout the manufacturing process, and automate production management.

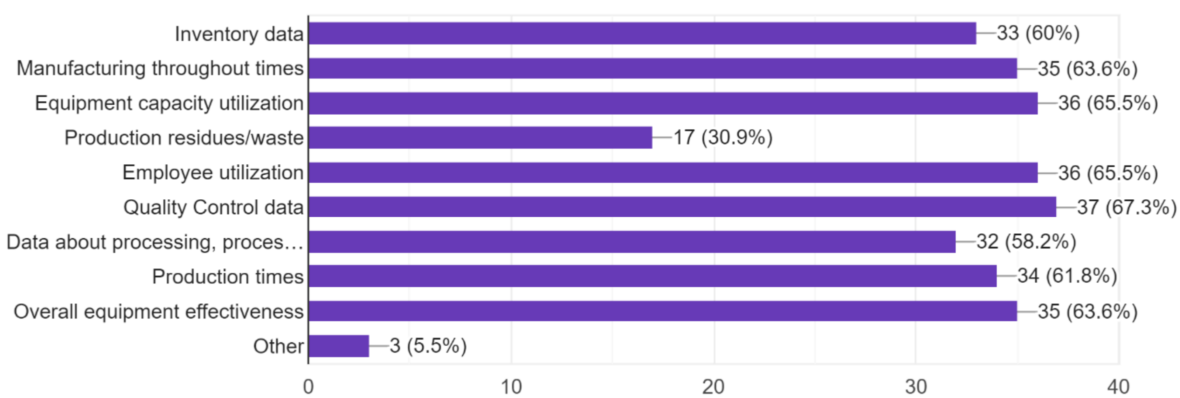

Figure 5: Data collected during production

Manufacturers have progressed beyond the pilot stage in their digital transformation initiatives. According to the survey results (see Figure 6), The acquired data can be utilized for predictive maintenance, quality management, and the development of transparency throughout the production process.

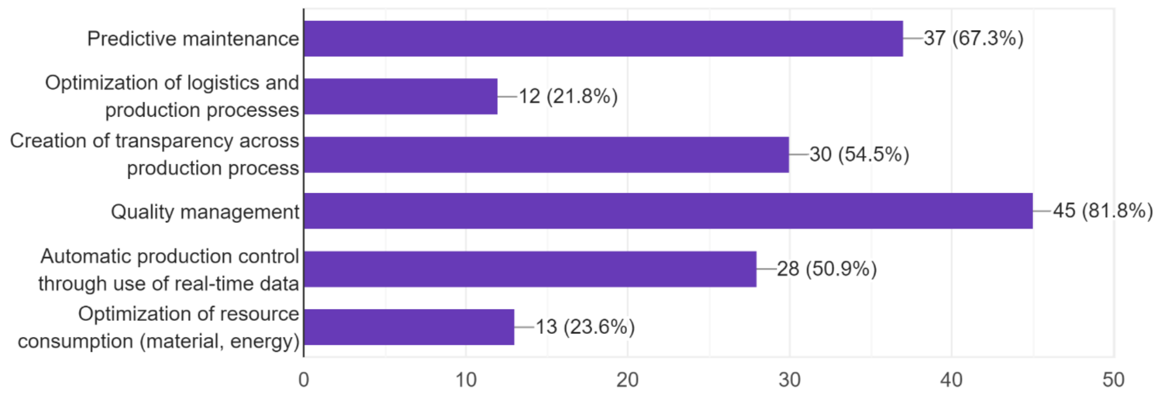

Figure 6: Utilization of collected data during the production.

Based on the survey results (see Figure 7), among the use case technologies described predictive maintenance, data driven shop floor management and machine condition monitoring have a significant impact on industries. 3D printing of spare parts, augmented reality smart glasses for remote expert support, mobile devices for work instruction documentation and training and camera-based abnormality detection are among the technologies with a moderate influence on industries.

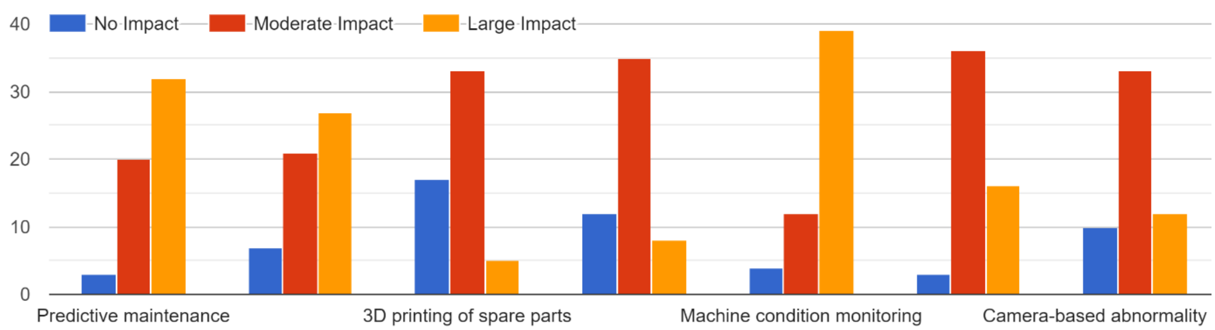

Figure 7: Impact of I4.0 technologies used in the organization

The survey results also identified that Machine downtime is decreased, and production, quality, productivity, and asset utilization are all improved because of Industry 4.0 (see Figure 8).

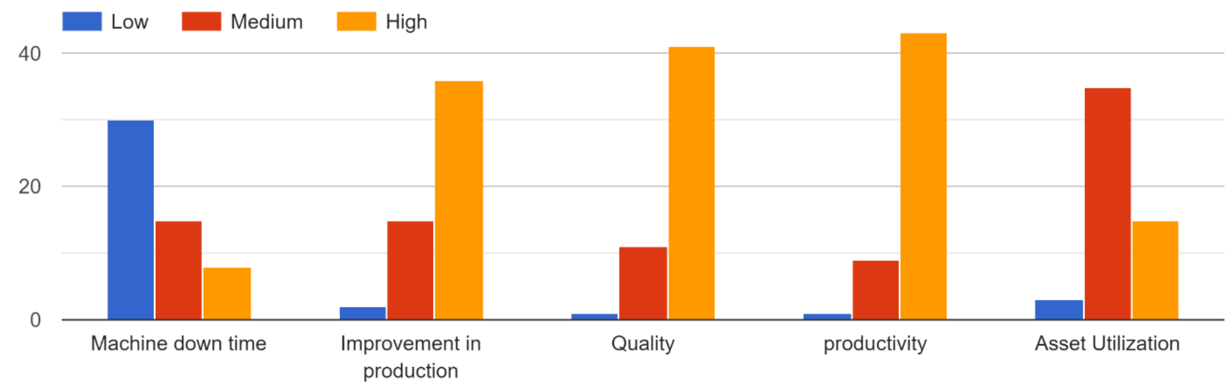

Figure 8: Impact of I4.0 in organizations

The survey results revealed that most of the organizations are investing in their production technology, maintenance, and IT departments to build systematic approach to I4.0 technology, however, research and development is the area which is still overlooked in the sector (see Figure 9).

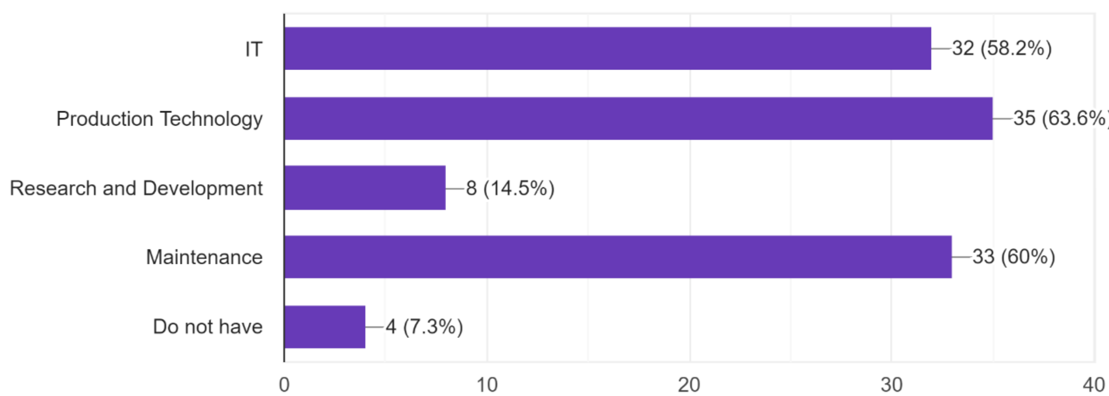

Figure 9: Areas of organization invested in the implementation of I4.0

4. Discussion on results

The participants in the survey are from diverse backgrounds ranging various small to large scale companies with significant revenues. Also, some participants are from startups. According to the participants, a greater number of companies are in the process of implementing I4.0 strategies, for further growth of manufacturing processes and maintenance in industries. The complexity of future solutions needs professional expertise in order to monitor the status of the machinery, evaluate its performance, detect equipment failure, and offer timely maintenance (Mihai, et al., 2021). Only a few organizations lacked an indication system since their strategy had not yet been fully defined; they were still in process of developing their strategy. In IoT, the perception layer is the source of data as well as the source of recognizing things and collecting information. It is the fundamental layer that supports the whole IoT system and is mostly made of a huge number of sensors, RFID tags, cameras, and other detecting devices (Liu, et al., 2021). Sensor technology, big data analysis, real-time location systems, and cloud technologies are being used by most firms to improve production operations and increase competitiveness (Liu, et al., 2021).

Organizations are implementing I4.0 technologies now to improve their competitiveness, and they are aware of the benefits of the new technology and plan to utilize it in the future (Ghobakhloo, 2018). According to the findings, in the production phase, there is a medium level of digitalization and integration, and only a few organizations are fully digitalized and integrated across both production and maintenance. The goal is to empower companies and the whole supply chain to save time, increase productivity, and minimize waste and expenses and respond to consumer needs in a flexible and efficient manner (Mihai, et al., 2021). The data generated by products or machines is critical for future development, and most industries will monitor and analyze the data using big data analytics to optimize production. According to the poll, most respondents believe that IT may be used to operate machines and systems in companies using various software. Multiple vendors' equipment and software are linked, with the links extending beyond the company's own walls into the value chain to external distributors and suppliers (Geissbauer, et al., 2016). Machine to machine communication is currently possible in most businesses. It will increase the rate of production. A cloud-based system that connects machines, devices, and systems (such as enterprise resource planning systems) from many organizations, easing transactions, operations, and logistics while gathering and analyzing data for use by everyone (Geissbauer, et al., 2016). During production, most industries collect, process machine data, and process data. Equipment capacity utilization, quality control data, employee utilization data, manufacturing throughout times, overall equipment effectiveness, inventory data, employee utilization, production process, and time are among the data collected during production about machinery, process, and products, as well as malfunctions and their causes.

Production, maintenance, and research and development divisions in several industries have incorporated cross-departmental information sharing. The data obtained during the production phases was utilized to manage production quality, predict maintenance, create transparency throughout the manufacturing process, and automate production management using real-time data. According to the poll, most companies use cloud services for data storage, data analysis, and the use of cloud-based software. Cloud computing lowers the investment in technical resources by allowing storage space and processing capacity to be rented on demand, resulting in flexibility, agility, and adaptability (Velásquez, et al., 2018). According to the report, the large percentage of industries have a medium level of digitalization of production equipment. Most industries have interconnected production equipment, which allows for IT access and information to be fed into some of the factory's output (Alcácer & Cruz-Machado, 2019). According to the poll, all essential aspects must be in place before Maintenance 4.0 can be implemented. Many industries are implementing maintenance 4.0 technology in their operations, and they are following a digital transformation plan and roadmap designed specifically for maintenance 4.0 (Chiarini, et al., 2021). For gathering and evaluating data related to maintenance, most businesses rely on existing software vendor solutions. Some industries have developed their own solution to gather and analyze data connected to maintenance, as well as capabilities for initial and continuous development. Companies have already introduced predictive maintenance, machine condition monitoring, data-driven shop floor management, and camera-based abnormality detection, according to the survey. The huge quantity of sensor, operational, and production data generated by each machine tool throughout operations is widely used to improve the process's stability and productivity (Isgro, 2021).

Now a days in industries implementing Industry 4.0 also entails integrating new technology into current lean manufacturing systems (Wagner, et al., 2017). The goal of lean manufacturing is to eliminate non-value-added tasks while keeping processes and equipment simple and easy to maintain. The method of integrating complicated IT solutions to connect machines, people, and processes generates an unresolved dilemma between the lean manufacturing industry and the rest of the world. 4.0 (Wagner, et al., 2017). Big data techniques necessitate a vast volume of raw data input. This reason contributes to the rise in popularity of another I4.0 technology, the IoT, which is capable of producing and collecting raw data. When IoT and big data are merged, the work of companies can be greatly simplified. The majority of respondents stated that I4.0 solutions improved their business performance in terms of efficiency, quality control, and strategic management, and that in some cases, the company's net income had already increased. The operative management level has better average scores than tactical and strategic management tasks (García & García, 2019). This can be addressed by the type of the technologies that support production processes such as AM or that enable data collecting, processing, or condition monitoring. The operative management level has better average scores than tactical and strategic management tasks (García & García, 2019). Sensors and actuators have a significant influence on maintenance strategy in terms of real-time tracking, continuous data gathering, and system availability. Communication and networking have a massive impact on contact and communication with agents. Organizations may use I4.0 technologies to forecast, when possible, problems will develop before they occur. Without IoT devices in place, preventative maintenance is performed based on routine or time (Epicor, 2021). M2M allows machines to communicate with one another and exchange data. They may use this data to autonomously optimize operations, alert when a system fails, and even self-repair.

Simulation, data analysis, and AI have a significant influence on the sectors for maintenance needs planning. Data analysis aids in the study of huge amounts of machine data in a short period of time and aids in the identification of faults. The simulation will aid in decision making for the maintenance planning need. As a result, I4.0 technologies enable manufacturers to execute targeted preventative maintenance. Smart decision making is a key component of I4.0, and it is facilitated through the analysis of sensor data (Amruthnath & Gupta, 2018). Real-time data from machines and sensors is recorded and displayed, allowing for real-time condition monitoring. The control station is not the only place where data can be visualized. Virtualization and augmented reality technologies have a major impact on the definition of maintenance activities. It will aid in the integration of real-world actions with digital elements or 3D digitization.

5. Research Implications and Future work

The research is beneficial to understand the role and impact of Industry 4.0 on production and maintenance. Furthermore, this research will also be helpful to recognize that how such integration may benefit production and maintenance in today's industry context. The research findings can help to determine which technologies a company should invest in to improve production and maintenance. As a result, this study can be used as a guideline for production companies to develop action plans and future initiatives to improve company performance.

It is imperative to highlight new research methods to continue advancing the role of Industry 4.0 on production and maintenance. It is vital to investigate the strength of industry 4.0 to improve the conceptual model with an extensive literature review on production and maintenance management, identify the impact of the potentials identified in the target system, analyze the gap between current and potential status for each process in different manufacturing companies. It would also be useful to extend the research by looking for particular firms that have previously adopted I4.0 technologies in production and maintenance, and then use the recommendations to build new procedures in a production process and maintenance. Moreover, this study is limited to some specific countries, hence, in order to make these findings more applicable generally, it is required to explore the research objectives globally that adopt industry 4.0 technologies in their industrial environments

6. Recommendations

- Consider the role of operational research, data analytics, and artificial intelligence in smart factory predictive maintenance decision making.
- I4.0 solutions assist companies in being more effective with assets at each level of the process, enabling them to have a stronger pulse on inventories, reliability, and operational optimization potential.
- More funds should be allocated for I4.0 maintenance implementation in-order to speed-up the process.
- Improve worker productivity, safety, and operation in an increasingly information-intensive setting where man-machine interaction is essential.
- Factory maintenance plans may not always be adequate since different external variables may be overlooked. So, monitoring the working conditions, offsets, and surroundings of the machines regularly can play an important role in maintenance.
- The use of 3D printing technologies should be encouraged. As the speed, reliability, safety, and quality of 3D printers increase, as well as their cost, 3D printers are poised to play a significant part in the industry's digital revolution and particularly in developing sapre parts needed for maintenance.

7. Conclusion

The research sought to investigate the role and impact of Industry 4.0 on production and maintenance. Furthermore, how such integration may benefit production and maintenance in today's industry context.

The study highlighted that the development of I4.0 technologies provides new options for the creation of new maintenance strategies and production processes, and it will be helpful for the industries to increase competitiveness and total value creation of products and services. The study illustrated that many firms are interested to implement I4.0 plans for future expansion of production processes and maintenance, and they are aware of the benefits of the new technology. The current research also highlighted that some organizations has already started the use of I4.0 technologies. However, the use of these technologies is limited, only a few firms are fully digitalized and integrated across both production and maintenance. The survey results highlighted that the most favourable technologies that are currently implementing in organizations to improve production operations and boost competitiveness are sensor technology (used by 56.4% companies), bigdata to store and assess outcomes (used by 50.9% companies) and mobile end devices and real-time location systems (used by 43.6% companies). However, Embedded IT systems and RFID technology are employed by only 11% companies, which emphasizes that these technologies need to be investigated further to explore their pros and cons.

The technologies included by the phrase I4.0 offer big data analytics and smart devices which can self-reconfigure and self-aware. Finally, it will be able to achieve a self-organizing and self-maintaining production systems that can operate at peak efficiency without the need for human intervention. The research also highlighted that the machine data and process data gathering during production are vital for future development and enhance outputs. This data can be used to control production quality, forecast maintenance, establish transparency throughout the manufacturing process, and automate production management. On the other hand, the ability to swiftly absorb data in order to efficiently and effectively identify and analyze, that data are probably the most significant challenge of I4.0. In I4.0 industries, PdM reduces the frequency of maintenance while increasing the time spent on unplanned and preventative maintenance, as a result machine downtime is decreased, quality, productivity, and asset utilization all are improved.

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Appendix

The list of the survey questions

1.What is the Industry Type.

2.Please estimate the size of your company’s domestic workforce.

3.Please estimate your company’s 2020 revenues.

4. How would you describe the status of your Industry 4.0 strategy's implementation?

5. Do you use indicators to track the status of your Industry 4.0 strategy's implementation?

6. Which technologies do you require in your company to increase its competitiveness? (Can answer more than one) Sensor technology, Mobile end devices, RFID, Real-time location systems, big data to store and evaluate real-time data, Cloud technologies as scalable IT infrastructure, Embedded IT systems

7. Which technologies are you currently implementing in your organization?

8.In which areas of your company have you invested in the implementation of Industry 4.0 over the last two years, and what are your future plans?

9. In what areas does your company have a systematic approach to technology and innovation management?

10. What is the level of Industry4.0 contribution that your organization requires in order to increase the competitiveness and overall value creation of your products and services?

11. What is the current level of Industry4.0 implementation in your organization?

12. To what extent are your products' life cycle phases (production and maintenance) digitised?

13. How important is data usage and analysis (whether generated by a product or by a machine) for future development?
14. In which areas does your company need to excel in order to achieve Industry4.0?
15. Which of the following technological competencies do you require of your employees in order to improve production operations? (Can answer more than 1)
16. How would you rate your equipment infrastructure in terms of the following features?
17. How would you rate the adaptability of your equipment infrastructure in terms of the following features?
18. Factory digitization allows for the creation of a digital model of the factory. Are you currently gathering machine and process data during production?
19. How is the information you collect used? (Can answer more than 1)
20. Which data is collected during production about your machinery, processes, and products, as well as malfunctions and their causes, and how is it collected?
21.Where have you integrated cross-departmental information sharing into your system?
22. Industry 4.0 envisions a work piece that guides itself autonomously through production. Is there already a use case in your company where the work piece guides itself autonomously through production?
23. Is your company's manufacturing process capable of responding autonomously/automatically in real time to changes in production conditions?
24.Are you already using cloud services?
25. How would you rate the degree to which your vertical value chain (from product development to production) has been digitized?
26. To what extent do you have a real-time view of your production and are you able to react dynamically to changes in demand?
27. How far has the digitization of your manufacturing equipment progressed (sensors, IoT connectivity; digital monitoring, control, optimization, and automation)?
28.How would you rate the degree of digitization of your horizontal value chain (from customer order over supplier, production and Maintenance)?
29. How much foundational Maintenance must be in place before embarking on the Maintenance 4.0 journey?
30.Maintenance 4.0 is about applying digital solutions to extract further capability from best in class strategy and organization. To what extent do you agree to the following statements?
31. In your organization, how much do you agree with the following statements about Maintenance 4.0?
32. What data strategy do you pursue as an asset operator (or, if you are a service provider or equipment manufacturer, what data strategy do you observe as the dominant asset operator strategy)?
33. What percentage of the maintenance budget is devoted to Maintenance 4.0 (for example, investment in technologies related to Maintenance 4.0 use cases, people enablement, and training)?
34. For the following skills/competencies, please indicate the level of importance for maintenance mechanics/technicians to implement Maintenance 4.0?
35. Please indicate which of the following use case technologies you have already implemented and which you intend to implement in the next 2-3 years.
36. In addition to the above, please use the space below to share any additional high impact use cases that have not already been listed.