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Upgrading the manufacturing sector via applications of Industrial Internet of Things (IIoT)

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A R T I C L E I N F O

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A B S T R A C T

Now a day's manufacturing has become more intelligent and data-driven. A smart production unit can be thought of as a powerful connected industrial system with materials, parts, equipment, tools, inventory, and logistics that can transmit data and communicate with one another in the age of the Industrial Internet of Things (IIoT). This IIoT refers to linked devices, sensors, and other equipment that may be networked in the industrial environment to provide remote access, effective monitoring, better data collecting, analysis, & exchange etc. In Industry 4.0, IIoT is fundamental to transforming cyber-physical systems and production processes through big data and analytics. This paper provides an overview of the IIoT and the technologies that underpin it. The primary benefits and features of IIoT in manufacturing are discussed in detail. Smart Transformations made into the manufacturing field through IIoT Culture are discussed diagrammatically. Finally, twenty-nine significant applications of IIoT in the field of manufacturing are identified and discussed. IIoT can monitor the transport, supply of the goods, consult details on things in warehouses, and check the conditions related to product storage and delivery and allow all dispersed and outsourced operations to be monitored. Therefore, the industry is being revolutionised by IIoT, altering the way industrial enterprises function daily to improve efficiency and performance levels.

1. Introduction

Industrial Internet of Things (IIoT) is the next level of Internet of Things (IoT) technology and is unique in its manufacturing transformation. Companies seeking a competitive edge today need just look at the capabilities that IIoT can offer the advantages all from maintenance, logistics providers, workflows for employees, and product delivery. IIoT enables manufacturers to digitise almost all parts of their businesses. Manufacturers can decrease the main risks associated with manual work and human error by minimising hand processes and entries. IIoT can help decrease cyber risk and human mistake data violations. There are hundreds of sensors that generate data in a typical industrial plant [1–3]. With IIoT, producers can proactively enhance performance by recognising possible bottlenecks, breakdowns, and production process gaps. Combining data from a site network may also contribute to more effective management of material flows early detection and identification of production, and optimising machinery and equipment performance at all installations [4,5].

IIoT influences are enormously and increasingly manufacturing industries, altering commercial and operational procedures and developing smart factories to increase operational performance, visibility, and insight that may simplify operations. Industry organisations are investing more in IIoT at the height of the fourth industrial revolution. Removing complexity from the deployment, connection, and management of devices is crucial to the success of IIoT. Its main benefit is to be capable of automating, monitoring activities remotely, and making choices prompted by data, therefore improving operational efficiency. Installation of machines and assets can influence industrial processes. IIoT

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solutions can continuously monitor and help establish a baseline for the performance and functionalities of different industrial assets. This baseline, together with the data, helps the industry to prepare for potential problems. Fully operational IIoT solutions include integrated security systems that employ monitoring and control device data to improve safety at work [6–8].

IIoT provides the essential functions in intelligent maintenance and operational management to harness potentials and lead to advances in the digital sense. The link to the device and an IIoT platform connects various software and systems through a strong and interactive vision. The IIoT has been augmented by combining data sources; enhance staff to have quick access to job instructions and operational information once the data reaches the cloud, software analyses and then decides to do an action such as sending an alert and changing the sensors/devices automatically without the user having to do it. IoT can evaluate the health status of workers and monitor dangerous behaviours that might eventually lead to injury, employing the usage of wearable devices. In addition to maintaining employee safety, IoT also focuses on safety concerns that might prove to be potentially hazardous [9–11].

IIoT applications provide event monitoring throughout a supply chain. These systems track the inventory globally and inform users of any substantial deviations. The visibility of inventories across channels and managers are supplied with accurate estimations of the materials available, work in progress, and the arrival time of fresh supplies. This ultimately optimises delivery and minimises cost-sharing in the value chain. A wide variety of linked projects within and beyond the plant is covered by the IIoT application area [12,13]. Many IoT-based manufacturing and control projects include comprehensive, intelligent manufacturing solutions with a wide range of features, including production floor surveillance, wearables, and enhanced reality on the floor, remote PC control, and automated quality control systems. It includes remote control of linked machines, equipment monitoring or management, and administration of distant industrial processes such as petroleum plants [14,15].

IIoT initiatives provide producers with a better understanding of their companies' operations and the operation of their production lines. The interest in the IIoT will probably increase as sensors become smaller and cheaper and the 5G network, in particular, gets more prevalent. It is likely to open up significant participants in the short term to the complete digital transformation of conventional processing into a digital factory. IIoT is useful in sectors where rapid development and quality goods are needed. It gives crucial assistance to the manufacturing businesses with comparable requirements [16,17] and describes a network of linked things connected to the web, including computers and electrical gadgets. Thereby facilitates the smooth interchange and consumption of data in a minimum way.

2. What is the industrial Internet of Things (IIoT)

The term "Industrial Internet of Things" is widely used in the industrial sectors as a digital transformation and connects critical assets, advanced predictive and prescriptive analytics, and modern industrial personnel. It is a network of industrial devices linked together by communications technology to create systems that can monitor, collect, exchange, analyse, and give critical new insights like never before. These insights are then used to assist industrial organisations to make better, faster business decisions [18,19].

With IIoT, smart sensors and actuators are used to optimise manufacturing and industrial processes. It takes advantage of the data that "dumb machines" have produced in industrial settings for years using the power of smart machines and real-time analytics. Smart machines are not only better than people at capturing and processing data in real-time, but they are also better at transmitting crucial information that can be utilised to make business decisions faster and more accurately, according to the IIoT's guiding principle. The IIoT connects people, goods, and processes [20,21]. Companies connect, monitor, analyse, and act on data in new ways with industrial IoT systems. IoT and IIoT have similar ways of working, which uses connected devices, but the main focus of IIoT is to improve the safety and efficiency of the production system.

3. Need of IIoT

IIoT may revolutionise almost all energy businesses, from production to transmission and distribution, and change the interaction between energy firms and customers. The needs and benefits of linked IIoT solutions in the industry are recognised by solutions providers themselves and energy businesses. Data centres, using machine learning algorithms with more complex models of data reading, send the data gateways gleaned by the sensors. IIoT Continues to produce considerable interest, activity, and efforts in the field of industrial automation. IoT concepts and technologies have an enormous impact on IT, consumer items, medical devices, the car industry, and other applications. In order to increase and extend efficiency and productivity in a wide variety of instances, IoT defines a linked world of the edge with computer applications [22–24]. Each device is unique for wired, wireless, and cellular connections in the internet infrastructure.

The manufacturing business is one such area that has greatly benefitted from technological advances. IIoT enables mass customisation, providing a source of real-time data necessary to predict, plan and route shop floors carefully. It contributes to a safe place of work. With wearable equipment, IIoT enables health status monitoring of employees and dangerous actions [25–27]. For assuring the safety of employees in hazardous situations, IIoT solves safety concerns. In the oil and gas sector, IIoT is used for monitoring gas leaks across the pipe network. The Industrial IoT gives a new view of the floor and field operations and manages business resources effectively. The machine use monitor begins with extracting pertinent data from sensors, SCADA on machine operating parameters such as, for instance, runtime, actual operating speed, product production, etc. Data are collected and processed in real-time on the cloud. The cloud collects the data and provides information on the use of machinery [28–30].

4. Research objectives

The IIoT is a means to revolutionise production digitally. This technology obtains essential insights into the performance of manufacturing. It utilises a network of sensors to gather crucial production data and leverages cloud software. This digital technology enhances efficiency and finds new methods to improve the production and supply chain processes. IIoT reaches different businesses and factories in more connected ways throughout the home and workplace. In recent years, manufacturing businesses worldwide have begun to speed up the age of intelligent manufacturing driven by IT. IIoT solutions provide a more robust framework, defined plans and a clear image of the business, and many manufacturers have begun to assess how smart manufacturing will be used in the future [31–33]. This being a review-based article, and we want to introduce the development in abroad perspective, the research objectives are accordingly decided as under;

RO1: To brief IIoT and its supporting technologies;

RO2: to study major benefits of IIoT in manufacturing;

RO3: to discuss collective features of IIoT for manufacturing;

RO4: to discuss Smart transformations made into manufacturing field through IIoT culture;

RO5: to identify and discuss significant applications of IIoT in the field of manufacturing.

5. Different supporting technologies of IIoT

Advanced analytics, automation, the IIoT, Industry 4.0, machine learning, artificial intelligence (AI), cloud platforms, and other digital advancements are all part of the industrial space's advanced technologies. These developments have the potential to increase the productivity of legacy operations at firms. These innovative technologies allow incumbent organisations to create entirely new, digitally connected business models and improve operational efficiencies and the customer experience in production and logistics [34–36]. So, in a nutshell, 5G, IoT sensors and platforms, edge computing, AI and analytics, robotics, blockchain, additive manufacturing, and virtual/augmented reality are all combining to create a fertile environment for the IIoT, which is expected to usher in what is commonly referred to as Industry 4.0. Fig. 1 shows the significant impact of IIoT on different areas of industry.

The IIoT enables unprecedented efficiency, productivity, and performance by merging machine-to-machine communication with industrial data analytics. As a result, industrial businesses in power generation, oil and gas, utilities, manufacturing, aviation, and various other industries are seeing significant operational and financial improvements. It is a set of middleware and software services used to do complicated computations, processing, and analytics over the Internet and provide storage, database networking, and other services [37,38]. In IIoT, Sensors collect data and take action. These actions on the cloud, thus for IoT a set of fully managed and integrated services that enable connecting, managing, and ingest IoT data from globally distributed devices in a large-scale process, analyse/visualise that data in real-time, and making operational changes and take action as needed. With then the use of the cloud, one can remotely access and operate equipment and devices. It is beneficial when equipment is located in multiple places or when people cannot reach the equipment securely [39–41].

Under global demand, industrial firms move quickly toward integrated, prefabricated, and technologically broad IIoT solutions and ecosystems. IIoT solutions often lead to a reduction in the supply times to a few months. Sensors and analytics together enable real-time access to previously inaccessible data. From manufacturing and supply chain optimisation to the support of municipal growth through smart cities, modern organisations use IoT apps and sensors. There are several impacts to the effective deployment of IIoT technology. It can help companies monitor complicated processes, save time and money, improve the customer experience, assist policymakers, make decisions, simplify business models and promote productivity [42–44].

The development of intelligent gadgets has also created security vulnerabilities and security accountability concerns. The role of IIoT adopters is to ensure the configuration and operation of their connected devices. The IIoT enables industrial firms to digitise processes and alter business models to enhance efficiency and reduce waste. In several industry sectors, such as manufacturing, energy, farming, transport and utilities, IIoT link billions of devices, provide value in a wide range of application fields including predictive quality and maintenance analysis, asset status monitoring and process optimisation [45–47]. IIoT is one of the most impacted and advanced sectors in the industrial business. It transforms the way firms, mainly industrial companies, do business in diverse industries. It has been chiefly utilised to operate and manage production operations, automate procedures, and collect data relating to assembly activities [48,49].

Broad applications employing IoT ideas and technology, such as smart grids, intelligent transit, smart houses, factories, and cities, are usually referred to as cyber-physical systems. IoT is starting to build a more linked environment through overarching communication, cost-effective sensors for strong analytics, and predictive software. The new technologies are demonstrated by new possibilities by edge-of-network devices, including smartphones, tablet computers, personal exercise equipment, and smart sensors [50,51]. Many industrial automation companies utilise cloud analysis and historians in several ways because they offer value and simply demand access to their data in their closed ecosystems via software and hardware gates.

In order to better plan, manage, integrate, analyse and improve the process by building a network of linked machines, systems, devices, and humans, the IoT promises a dramatic influence. This linked network gives numerous options for manufacturing firms, including operational improvement, customer experience, and the development and strengthening of the supply chain. The IIoT installation and utilisation have revolutionised industries in their working, communicating, and using data. Manufacturing has seen various changes rapidly, and a slowly evolving industry is now digitalising [52–54]. It enables firms to monitor progress in real-time and unprecedentedly evaluates the previous data acquired from their operations. The purpose of data collection and use is to enhance processes and create an environment that prioritises information-based choices [55,56].

The motivation of IIoT is that smart machines are more suitable to communicate critical information that may make business more quickly and accurately than to capture and analyse data in real-time. Connected sensors and actuators allow organisations to discover and save time and money on inefficiencies and issues. The technology allows the collection of data for Business Intelligence and Artificial Intelligence. IIoT offers enormous potential for efficiency, quality control, sustainability, safety, and traceability monitoring and development within production. IIoT is also the key to progress in predictable maintenance, zero failure vision, and enhanced efficiency in the maintenance and service, energy management, and asset monitoring environment [57–60].

6. Major benefits of IIoT in manufacturing

IIoT production management system analyses operational and machine data and their linkage using process sensors for manufacture. This shows which production parameters must be modified to prevent downtimes, delays, or faults as necessary. These systems evaluate the data gathered from the devices, provide it to users and forward instructions to the devices.

In order to build an intelligent asset management system, this is

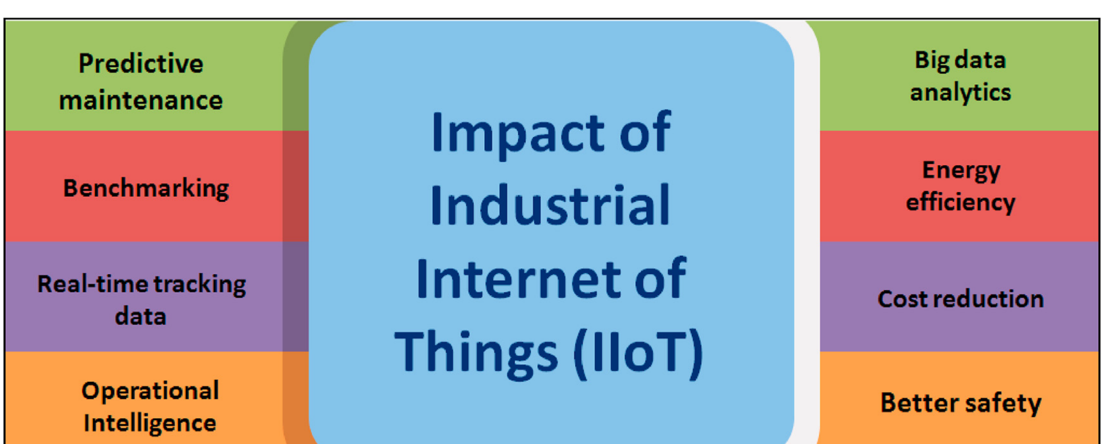

Fig. 1. Major impact of Industrial Internet of Things (IIoT).

implemented successfully. It uses a smartphone app to view the location of all its assets. The management can observe how much equipment and tools are at work and who is working with them. This gained a high degree of asset awareness and accountability through real-time data about tools and location and saved our staff enormous time for manual monitoring and tool search [61,62]. Fig. 2 shows the major benefits of IIoT in manufacturing.

Manufacturers utilise the newest operational intelligence to obtain successful operations from different systems, assets, and people, including information analysis and identifying underlying causes to take quicker and better business choices and achieve more incredible operating performance. The complexity of production can be eliminated through predictive analytics so that business information can automatically be provided to enhance product quality and turn asset maintenance procedures into predictive maintenance before breakdowns happen. Scalability for manufacturing is one of the major benefits of IIoT [63–65]. Manufacturers must utilise diverse software whenever they need it or when production demands.

Manufacturers are under constant pressure to cut manufacturing and operating costs and produce sustainable goods more effectively. The relevance of the IIoT is increasing quickly, while businesses are attaching great emphasis to technical benefits. It brings up a variety of prospects, in particular for the industrial sector. The value of a manufacturer depends on its assets' present level and quality. IIoT-connected devices allow producers to track their assets automatically and help them to create partnerships with suppliers and partners. IIoT will allow producers to identify changes in demand in real-time. This helps companies address abrupt demand fluctuations. This will help improve the warehouse administration, the distribution of assets, and the supply chains system [66–69].

With the IIoT, data analysis is efficiently feasible. The leading performance indicators for health and safety may thus be evaluated continuously to guarantee improved conditions in the workplace, such as several injuries, short and long period absences, disease rates, and almost misses. The frequency of accidents such as labelling indications can be addressed quickly. IIoT can monitor the use of resources such as power, fuels, water, etc. IoT sensors gather product data from different stages of a product cycle. This data pertains to the complete composition of the utilised raw materials, temperature and working conditions, waste, transit effect, and more on the finished goods. In addition, when the IoT device is incorporated into the finished product, the data about the customer's sense of usage may be provided [70–72].

By integrating IoT sensors for products and packing, businesses can obtain essential data regarding how items are used and how many customers deal with them. Smart systems for tracking the degradation of goods during transit and the effect of climate, road, and other environmental factors on the product may be utilised. It gives information that may be utilised in re-engineering products and packaging to enhance customer experience and, occasionally, even packaging costs [73,74]. IoT technology encourages predictive maintenance that streamlines and effectively supports a company. Efficient, predictive maintenance is achieved through data and real-time control with IoT technology. The IoT connects computer systems and sensors embedded into items and equipment to collect, transmit, and receive data [75,76].

7. Collective features of IIoT for Manufacturing Domain

Fig. 3 represents the various qualitative and versatile features of the Industrial Internet of Things (IIoT) to enhance the manufacturing sector's overall performance. The features and quality aspects, namely, error reduction throughout the process, use of smart and digital work machines/stations, reduction in costs involved, safety aspects, etc. further considered as the valuable inputs of IIoT to develop an effective and efficient culture for manufacturing-based organisations [77,78].

The Industrial Internet of Things is a network of essential assets, powerful predictive, prescriptive analysis, and contemporary industrial employees. It is an extensive network of industrial devices connected by communications technology that leads to systems. The latest advancements in the IoT industry may both be advantaged for novice professionals. Managers can know whether machinery requires maintenance and enhance maintenance planning thanks to acquiring essential information in real-time. The way that IoT enhances operational efficiency is

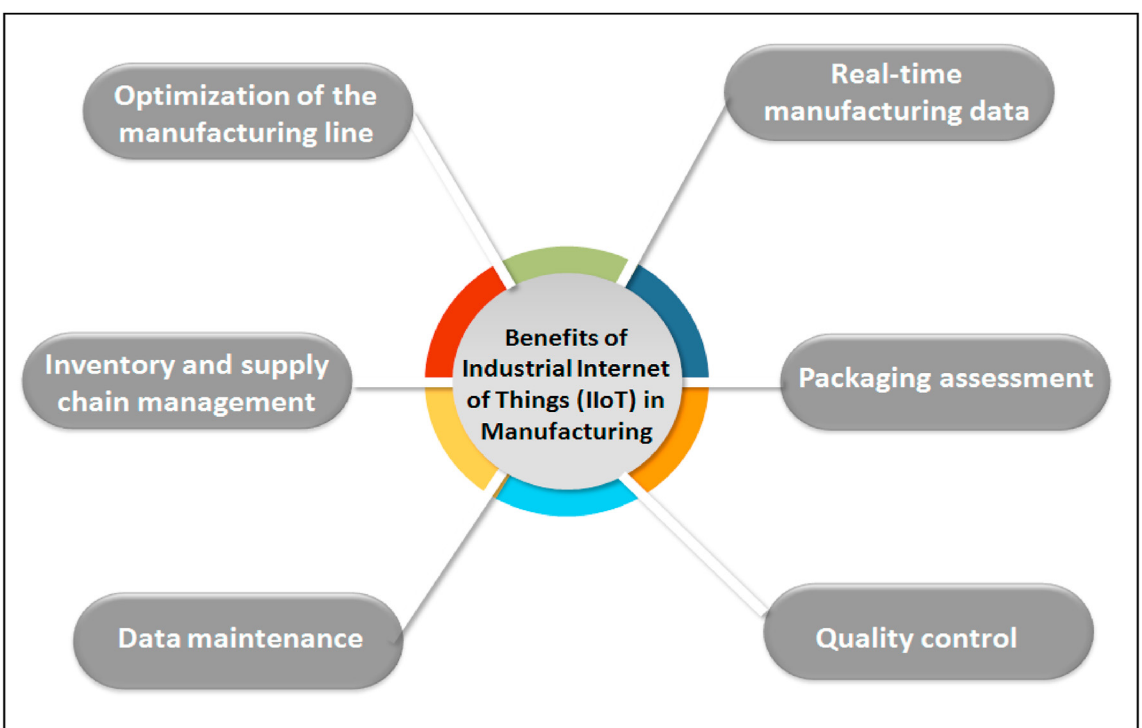

Fig. 2. Significant benefits of IIoT in manufacturing.

Fig. 3. Versatile features of IIoT for manufacturing domain.

one of the numerous benefits of manufacturing. Linked sensors can recognise the probable failure and activate an engineer's repair request [79,80].

Manufacturers use IoT to incorporate vibrant, competent, and automated production operations, in which maintenance schedules are independent. Thus, improved maintenance operations are triggered that offer enormous cost savings, lowering machine failure and enhanced machine life. Industrial IoT can alter production drastically. By automating and simplifying the process control plan, IIoT can assist in decreasing its related expenses. With sensors, businesses can verify the quality-critical variables automatically, lowering time and resources. This can utilise IoT sensors to simplify the process instead of human quality inspections [81–83].

In order to increase the efficiency of facility management, IIoT sensors are placed. Sensors combined with IIoT software can monitor temperature, vibrations, and other variables that can lead to operating circumstances that are less than optimum. Furthermore, intelligent lighting and intelligent sensors enhance visibility and control over company resources such as power, water, fuels, etc. Environmental sensors can monitor quality-critical situations and inform management continually. For instance, the temperature might be essential for quality in a pharmaceutical operation. Managers can monitor various variables and be quickly informed if they exceed the required parameters by utilising IoT-connected sensors [84,85].

Most organisations in particular concentrate on IIoT to cut operating, security, and performance costs. In contemporary industrial businesses, IIoT is the most implemented Industry 4.0 solution to fulfil various requirements. It is used in supply chains to monitor inventory levels in real-time and to trigger automatic supplier refilling. Events across the supply chain are easily tracked and provide a complete inventory overview. In combination with IIoT analytics, IIoT software and company platforms analyse product and material consumption patterns. It enables companies to eliminate process inefficiencies and save waste. For many years, companies have employed technological solutions to accomplish lean objectives, such as improved operation and enhanced performance [86–88]. IIoT solutions, specifically Industrial IoT automation, enable combination systems to provide the best performance and operating time throughout assets, product ranges, plants, and the whole organisation.

For analysis and application, secure storage is necessary for data obtained from sensors and equipment. The cloud allows for flexibility and efficiency in using the information to enable production enterprises to operate it. Manufacturing firms use intelligent networks to bridge the gap between manufacturing and corporate networks. This enables to decrease downtimes through remote access to systems, providing the company with precise, reliable, and resilient conditions from the plant floor. IIoT allows factory managers to track all the ingredients necessary to produce on the product level. In this approach, the inventory may be renewed without the production process. As soon as the Internet of Things becomes effective, inventory planning will be enhanced to forecast how long it takes for specific resources to expire and improve long-term planning accurately [89,90].

Industrial internet allows businesses to shift towards a more proactive predictive maintenance strategy. It allows firms to monitor machinery and equipment in real-time and plan maintenance when the machine needs them. This offers real-time visibility in all production processes in the manufacturing business. It has been challenging to compare the efficiency and quality of products in all plants in the past. Today firms can gather and analyse data at several plants using these technologies. It helps organisations change the management paradox from reacting to proactive by predicting the problems during the production cycle. For all devices engaged in production, IoT gives industrial firms detailed data [91,92].

IIoT includes machines that communicate without human involvement. In order to enhance productivity and increase product quality and consistency, businesses have taken on an increasingly large number of goods in the IoT manufacturing sector. The IIoT revolution is driven by powerful, affordable cloud computing, wired, wireless, and chip technologies for embedded computing. It can observe patterns of use so that a manufacturer may determine which product features are popular and what should instead be deleted. IoT is used by manufacturers to minimise bottlenecks while producing, to avoid excessive loads that might deteriorate equipment [93,94].

IIoT can disrupt corporate management in manufacturing. This provides new experiences, new procedures, and new goods. Comprehensive testing and training solutions can help organisations better to grasp the advantages of the use of IIoT. It can quickly evaluate their achievements and failures and quantify their disruptive worth and degree. IIoT uses networked sensors and smart devices, gathering data to promote artificial intelligence and forecasting analysis directly on the production floor. In the total digital transformation into the digital supply chain, IIoT plays a vital role in many sections and the value chain of the vast ecosystem, clearly including involving retail and consumer issues. IoT-enabled operations and services provide other plants with efficiency, maintenance, and data-driven opportunities [95–97].

8. Smart Transformations made into manufacturing through IIoT culture

Fig. 4 reflects the recent trends and transformations made by adopting IIoT culture for improving and channelising manufacturing-based industries. The changes and enhancive steps like; control over the overall quality theme, making safer working environment, production flow monitoring, optimisation of the process and production lines, digital management of supply chain and inventory systems, etc. makes the effective transformations of manufacturing sectors in the present competitive structures of industrial revolutions by making use of IIoT and its allied technologies [98,99].

The IIoT offers the possibility of linking the firm to manufacturing facilities, product design, development personnel, and supply chain management. The digital link between all sections of the plant will enable management to monitor the performance of employees, the efficiency of installed equipment, and end-user feedback. IIoT and intelligent industrial equipment enhance facility maintenance speed and quality. It can monitor temperature-sensitive equipment which is sensitive to minor changes in the environment. IoT sensors can warn facility management as quickly as possible alterations that may jeopardise production [100,101].

Industries can rethink business models using the IIoT. These devices

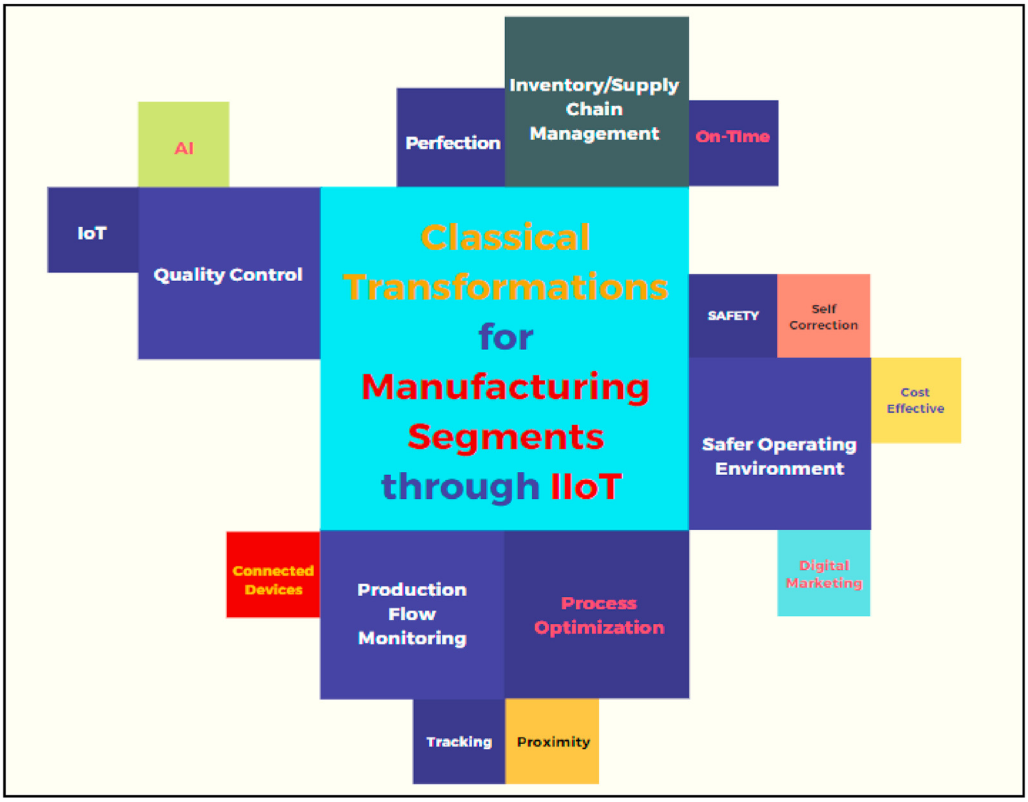

Fig. 4. Transformations through IIoT for manufacturing sector.

enable a shared data ecosystem with new income streams and collaborations to be established. IIoT, in a larger context, ultimately leads to connected ecosystems from individual initiatives and intelligent applications. In many other industries like healthcare, the aviation industry, robotics and cobots, oil and gas, mining, metals, and more, predictive maintenance and data-enabled services, and remote options in several areas, from service to operational control and optimisation are revised as well. IIoT devices also offer remote, real-time views on the location and distribution of property. Companies may use these data to enhance logistics and customer support and arrange better collection and return regions. IIoT enables efficiency in both maintenance and production, where operational efficiency and continuity are essential [102–104].

IIoT links machinery and devices in industries in which equipment functioning is essential for productivity and security. Companies employ IIoT technology to automate their former manual operations and management of assets on a remote basis. It makes predictive maintenance agile and responsive. This can monitor the state of the equipment and give automatic warnings when symptoms of damage appear on any part of the machine utilising sensor-equipped microprocessor units. The manufacturers may better identify environmentally and use variables leading to machine failure using IIoT technology. Functionalities like automatic warnings and event reports also help businesses be more agile and responsive when confronted with interruptions in the supply chain. There is more potential for IoT solutions for improving visibility and reducing inefficiencies [105,106].

The worldwide process industries can save millions and perform maintenance operations only when needed with the help of IIoT technology. This implies that operators can tackle faults and more effectively schedule downtimes before they become major problems. Likewise, industrial IoT equipment employs preventive maintenance for different climate control and better services depending on their customers. In order to track the tiniest moving parts in real-time, Industrial IoT provides cutting-edge technologies. These intelligent gadgets constantly monitor machines and deliver early warnings when a faulty component is identified, which results in long-term operational and maintenance cost reductions [107–109].

Extensive data analysis paired with IoT may improve the safety of all workers in the factory. IoT sensors gather product data from different stages of a product cycle. This covers the composition of utilised raw materials, temperature and working conditions, waste, the influence on the final products of transit, etc. In addition, when the IoT device is incorporated into the finished product, the data about the customer's sense of usage may be provided. All these inputs may then be examined for quality concerns to be identified and corrected. Using this technology, all stakeholders in the supply chain can trace interdependencies, material flow, and production cycle times by linking plants to suppliers. It can assist producers to foresee problems, decrease inventory, and perhaps lower needs for capital [110,111].

Maintaining assets in operation may cut operating costs considerably. Managers can identify when a piece of equipment fails before using sensors, cameras, and data analysis. These IoT-enabled systems can recognise warning signals, analyse data to establish maintenance schedules, and use the equipment before issues arise. IIoT turns maintenance into an active, fast, and automated job by utilising streaming data from sensors and devices to rapidly estimate current conditions, identify danger signals, provide alerts and automatically initiate necessary repair. This technique saves routine and preventative maintenance based on time, as activities are only carried out when required. It helps improve customer satisfaction with faster interactions and more control over their energy use by customers to save money. It is used to optimise the distribution of energy and take action to adjust demand loads [112,113].

The industries that embrace IIoT include production, logistics and transport, healthcare and power generation, and agriculture. Most investments have been made in the manufacturing business and are the major factor in the launching of IIoT. Manufacturers use it to make their warehouses smart. An intelligent plant is fully computerised manufacturing, and production facility where the systems are networked and data are shared in real-time on each production element. Intelligent meters track the fuel, water, and energy with the use of resources. This can save operating costs by making planning and management more effective. The adoption of the IIoT can alter the functioning of companies through greater connection [114,115].

In several businesses, IIoT is a current motto that is gaining momentum. In industrial sectors and applications, IIoT refers to the expansion and usage of the Internet of Things. With a heavy focus on communication from machine to machine, big data, and machine learning, the IIoT allows industry and organisations to operate more efficiently and reliably. IIoT includes industrial applications such as robots, medical equipment, and manufacturing processes defined by software. Businesses can collect and analyse increasing volumes of data at higher rates through linked and intelligent devices. This not only improves scalability and performance but also overcomes the distance between manufacturing floors and offices. The integration of the IIoT allows industrial companies to understand how their businesses move forward accurately and assist them in making educated business decisions [116,117].

IIoT's potential is enormous and should not be ignored. Connected devices combine staff, equipment, and databases into a vast network, improving administration at all production phases. Business executives recognise that power and confidence in digital transformation success, considering the dangers of IoT production. Solutions of IIoT can allow the supply chain data to be available in real-time. It makes tracking of goods, suppliers and slowdowns and inefficiencies easier. It can trace material flow and production cycle times by linking facilities to suppliers. These systems may also monitor operational information of original equipment and field engineers, enabling operating managers to control industrial units and use process automation and optimisation remotely. These technologies simplify the daily workflow without effort [118,119].

9. Applications of IIoT in the field of manufacturing

IIoT is the integration of machine learning and big data and, therefore, the efficiency of enterprises substantially. Scalability, real-time capabilities, interoperability, data protection, and security are key criteria for an IIoT architecture. The primary function is played by sensors, actuators, and intelligent devices, which gather data and transmit it to servers. They are further transformed into action-relevant "smart data" by utilising intelligent algorithms at the cloud computing level. Industrial IoT solutions can help firms choose which field service professional is suitable for the task by considering availability, ability, and location criteria. The technician may receive detailed mistake data in real-time to ensure that he reaches the plant with the proper tools and components. IIoT can monitor machinery actively and give an alarm if they vary from the set specifications. The manufacturer can save energy, decrease expenses, minimise machine downtime and enhance operational efficiency by maintaining the required work environment for machines [120–122].

IIoT provides valuable information for process improvers to access data and evaluate them more quickly, autonomously, and remotely and make the necessary process adaptations in an industrial business model. This also enhances the pace at which Operational Intelligence and Business Intelligence adjustments and enhancements are implemented to bring competitive benefits to many industries. The implementation of Industrial IoT systems enables automatic inventory monitoring, certification of plan compliance, and warning when deviations occur. It can allow the monitoring of production lines from the refining process to the packing of finished goods. This comprehensive real-time monitoring of the process recommends operational modifications to improve operational cost management [123,124]. Table 1 discusses the significant benefits of IIoT in manufacturing.

Inventory management solutions enabled by IIoT can track and find the raw materials from massive warehouses very quickly. This allows producers to constantly visualise stock locations, amount, status, tracking, and provide reports to mobile applications, and minimise the

Table 1
Significant application of IIoT in the field of manufacturing.

S No	Applications	Description	References
1	Machine monitoring	This technology developed a system for monitoring the machines that enhance productivity and optimise the use of machines. IIoT system deployed leverages real-time sensor data to show cycle durations, the number of components produced, downtime, and other useful indicators. The parameters of calibrated equipment, machine conditions, and environmental conditions are checked to determine whether they go beyond typical values to monitor the quality of the manufacturing process. An IoT solution alerts a person in charge through a mobile application if such a scenario is recognised. It assures the correct use of assets, extends equipment life, enhances dependability, gives the highest return on property and enhances manufacturing processes' efficiency.	[125–127]
2	productivity improvement	The market analysis shows that the major motivations for using IIoT technologies are optimising operational efficiency and increasing productivity throughout the internal value chains. IIoT is growing popular in industrial contexts and is being utilised progressively for industrial, automotive, pharmaceutical, electrical, high-tech, and petroleum and food-drinking supply chains applications. Many workers have access to the advantages of this technology. There are several alternative solutions, deployed applications, and technologies utilised throughout the IIoT.	[128–130]
3	Worker safety	IIoT has opened its doors particularly to improve worker safety for new and necessary advancements. It begins with connection, but since it is widespread and multidimensional. In terms of security, power consumption, cost, complexity, and network topologies differ considerably. Data on critical equipment and personnel location give valuable insights into optimising asset management and safety for employees. Global manufacturers are making a major investment in connecting equipment to upgrade current factories to smart ones by implementing IoT's anticipated advantages in production processing.	[131–134]
4	Improved maintenance	Maintenance is one of the primary concerns, costly and time-consuming, but can be well supported by using this technology. IIoT enables the efficiency of product and equipment operation. The whole manufacturing system can be hampered by a single breakdown of a machine in production. IIoT solutions allow firms to gain insight and can shift through data using analytics. It connects assets to processes, systems, and individuals in the manufacturing business. Operational processes can be better	[135–137]

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Table 1 (*continued*)

S No	Applications	Description	References
		integrated, which helps to increase productivity and reduced errors.	
5	Reduction in manufacturing expenses	Faults and deficiencies in the final product increase production expense and strain personnel. Manufacturers may use IIoT functions to alleviate various problems, and digital twins are one such feature. It digitally mimics the product being developed. By using sensors, manufacturers collect data from each unit about the whole operating mechanism of their equipment and the required output. The data, taken from the digital replica, allows management to assess the efficiency and precision of the system. It helps to detect possible bottlenecks in the product, which helps managers to develop a better product version.	[138–140]
6	Real-time information	By using this technology, manufacturers get real-time information into the resources available to monitor their supply chain. It provides information on process work, the collection of equipment, and the date of delivery of the necessary raw materials. Some IoT suppliers integrate their IoT solutions with firms' current ERP systems to prevent manual operating paperwork. Manufacturers use IoT assets to link equipment and systems, a paradigm change that allows real-time monitoring of assets. It gives the chance to monitor dependability, compliance, and security equipment in real-time. It also gives a platform for the management and control of assets for improved operation and output.	[141–143]
7	Perceive warning	The maintenance of equipment considerably reduces operational costs and saves manufacturers' costs. Managers from multiple manufacturing lines can detect when a machine fails by utilising sensors, cameras, and data analytics. IoT-enabled systems can perceive warning signals through data that helps managers to build maintenance schedules and equipment service before problems arise. This allows linked operational intelligence to be provided in real-time and allows industry stakeholders to operate plant units remotely. The data is used for key business insights and operational intelligence to enhance the operational efficiency of teams.	[144–146]
8	Built-in intelligent network	The manufacturer can build intelligent networks by automatically connecting machinery/equipment that communicates and coordinates with minimum operators' intervention. In this instance, companies can collect and contextualise data from remote assets and systems in operational applications. In addition, with IIoT, enterprises can link and unify to several operational data centres to provide data visibility in real-time across various production systems.	[147–149]
9	Tracking inventory	The best industrial IoT application monitors events across a supply chain, enabling global inventory tracking at the line-item level. It gives comprehensive and cross-channel inventory visibility that enables managers to obtain accurate assessments of the material available. This provides improved and efficient safety and addresses and ensures improved environmental, health and safety problems. IoT sensors gather a product data mix and other synchronised data from the product cycle stages. This information includes information on the composition, the temperature, and working environment of the raw materials used while manufacturing a product, the other waste, the relevance of transit, etc.	[150–152]
10	Simplification of the flow of production	IoT has several uses in production facilities. It can simplify production flow at a production facility because IoT devices monitor development cycles and automatically manage warehouses and inventory. The industries employ IoT devices to track worldwide inventory. In order to monitor the supply chain, industries employ IoT and obtain meaningful estimations of resources available. IoT devices also remove the requirement for operations manual documentation and implement the Enterprise Resource Program. They have the opportunity to have visibility in management departments across the channels and allow stakeholders to review the progress made.	[153–155]
11	It helps machines to discern problems	Production of goods involves extensive machinery activities. Machines may fail, and this may result in a change in the quality of the products. Time and work are needed to solve the problems with the equipment. IIoT and machinery learning consolidation helps machines to discern problems and to solve them by themselves. It allows machines to auto-heal utilising automatic healing systems and recovers control every time. The integrated sensors report the underlying difficulties to the production. The automated method saves manual work and saves time. It allows companies to automate the management of IoT-enabled production in workshops.	[156–158]
12	Smart pumping	By providing smart pumping solutions, IoT can enable companies to reduce the waste of water. The water tanks would have sensors that would control water pressure and flow. The specified measurements would automatically guide the pumps to shut off. It also provides information on real-time performance monitoring utilised by the industry. IoT technology supports businesses in reducing power, saving manual work and maximising productivity using water efficiently. This IoT-enabled allows industry to create a linked,	[159–161]

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Table 1 (*continued*)

S No	Applications	Description	References
		flexible and efficient system of pumping.	
13	Tracking machines	In production, IIoT is utilised to track machine and remote worker data. The employee may collect machine data in real-time, on the go, and integrated it into mobile applications. The asset tracking system IoT lets employees from remote locations track, monitor, and control assets. Industries implementing IIoT networks to manage their growing digital ecosystems. The integration of IIoT with AI and machine learning is built on predictive maintenance. The IIoT network uses machine learning algorithms to assess the probable failure of a component and sub-system with real-time historical data from Industrial IoT sensors and data from other relevant sources.	[162–164]
14	Smart Supply chain	In order to generate a highly linked supply chain of 'assets', such as items, pallets, and vehicles, IIoT enables better visibility of shipments. Products and supplies are simpler to follow, slowdowns and inefficiencies are identified. Different sensors, including GPS, temperature, and humidity, can be used to collect information. IIoT data provides for future compensation and sanctions audit capabilities. In other words, the operator can monitor performance in real-time.	[165–167]
15	Monitoring of product development	The IIoT can monitor product development at every stage, monitor material quality, temperature and production environment, the amount of waste produced by product, etc. In every stage of product design, shipping, and distributing ready products, the plant manager will receive complete reports. It captures patterns of application and data on how consumers usually utilise a product. Production managers can therefore process the packaging, decrease its prices and modify the design in a manner that resonates more profoundly with the final client.	[168–170]
16	Reduction in expenses	IIoT devices help industries drastically cut expenses related to regulatory compliance through remote monitoring of critical assets. Embedded sensors provide real-time data about the use of expensive machines, such as cranes and bulldozers, and the maintenance requirements. It also boosts operations via automated ordering for materials and the optimal positioning for machines and staff. This also proposes transit routes for equipment and supplies on a site. By integrating machine learning and industrial IoT data, managers can reduce the danger to both employees and equipment of safety.	[171–174]
17	Identify environmental variables	With IIoT, manufacturers obtain information into the patterns of use and the handling of the product of many consumers. Intelligent tracking devices also trace the degradation of products in transit, which may happen due to the influence of weather, road, and other environmental variables. It further provides insights on goods and package re-engineering for improved customer experience and packing cost performance. IIoT can obtain real-time supply chain information through the tracking of materials, equipment, and products.	[175–177]
18	Automate driving system	IIoT is helpful to enhance connected automobiles. These are computer-enhanced cars that automate many regular driving chores, even driving themselves, in certain circumstances. The benefits of self-driving automobiles are used to enhance customer satisfaction. Accident prevention is a significant stimulus since the automobile can react quicker than a human. This communication flows quickly and flawlessly across the various systems and automatically takes place without human involvement during the whole production process. IoT sensors may be helpful in facility management that can actively track the temperature, vibration, and other elements that could cause issue operating conditions. In this way, producers may decrease expenses, improve operational efficiency, conserve energy and reduce machine downtimes by providing conditional knowledge of machinery problems.	[178–180]
19	Reduces mistakes	IIoT solutions assist to reduces inventory management and production flow mistakes and frequently even avoid them. The software enables firms is used to monitor and track inventories across the supply chain. This allows for visibility in stocks across multiple channels and gives management accurate actions and temporal predictions. Production line processes may be monitored virtually in real-time with IIoT and can propose operational modifications for improved cost management and even identify production delays. Further prevents slowdowns and reduces expenses through trash disposal and unnecessary effort.	[181–183]
20	Gain useful information	Manufacturers can gain helpful information about using and handling a product by using IoT sensors for goods and packaging. Intelligent tracking solutions monitor items affected by the weather, road conditions, and other environmental variables. The growth of Industrial IoT makes the future factory a reality. The supply chain's handling, production, distribution, and administration will be automated in the future. Companies can improve existing operations and develop more successful business models by integrating linked systems, devices, and sensors into business processes.	[184–186]
21	Modify robot action programmes	Remote access features of IIoT can modify robot action programs and improve log file understanding. Video analysis may also contribute to the	[187–189]

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Table 1 (continued)

S No	Applications	Description	References
		improvement of certain robots' behaviours. IIoT is available from a central place to monitor and regulate the energy usage of heating, lighting, fire safety, employee security, and many other systems for numerous buildings. In industrial communication networks, the real-time machine data are transmitted to a central cloud application. IIoT solutions provide critical data-driven insights that improve the processes, including design, operations, factory manufacture, marketing, and sales.	
22	Security	IIoT devices are also widely utilised to provide employees with physical security. Many accidents occur each year on production floors and workstations linked to defective machinery. IIoT can assist in reducing the incidence of work-related injuries by providing the predictive maintenance described in the preceding section. It can also check compliance by workers with safety requirements and therefore make workplaces safer and production more productive. Industrial IoT monitoring permits the gathering of data in older facilities without interference in existing industrial control networks.	[190–193]
23	Testing of products	IIoT makes this procedure proactive by gathering comprehensive product data at various phases of the product cycle using thermal and video sensors. The products can also be tested at every step of production to verify that their attributes are specified. Support from IoT to monitor equipment and the results of each manufacturing stage provides manufacturers with a better guarantee that the source can identify quality issues. Manufacturers can thoroughly examine the outcomes of smart monitoring using customised end-user dashboards used by IoT service providers. This can also evaluate prices, efficiency, and the carbon impact of other resources so that their production processes have alternatives.	[194–196]
24	Continuous improvement	In order to gather and analyse data and use data in continuous improvement, Industrial IoT is described as a network of devices, machines, and sensors that have a connection between themselves and the Internet. Many IIoT applications exist, which have led a growing number of organisations to adopt this new paradigm to increase productivity and optimise their costs and profits. In order to gain access to this competitive advantage, the major IIoT applications are known, and the system is implemented. The automated equipment management system allows a centralised system to control and monitor all corporate operations are one of the primary IIoT applications.	[197–200]
25	Data collections	IoT-based sensors collect and distribute essential data in real-time over resilient networks. The fast flow of information across the production plant allows the continuous development of the dashboard measurements to transmit findings and make decisions easier. Manufacturers used this technology to function their devices and systems, leading to quicker and more informed decision-making. IoT enables direct contact between staff and network components to increase productivity considerably. It can monitor the working conditions and the wearable gadgets, assist in establishing a safe working atmosphere, and avoiding numerous mishaps.	[201–203]
26	Enhance the quality of product	The capacity to enhance the quality of manufactured products at any point is another most significant IIoT application and helps move raw materials used in this process to the end customer after receipt of the items. It is essential when assessing the company's effectiveness and implementing the needed adjustments in failure to optimise operations and quickly discover problems in the production chain. By monitoring, among other indications, equipment damages, air quality at the factory, and the incidence of disease infirm, dangerous scenarios which threaten employees may be avoided.	[204–206]
27	Decision making	For the decision-making process in the organisation, IoT may substantially enhance. It reveals crucial data on the performance and insights of the various devices inside the network. Cases for light industrial IIoT applications, such as meters and heavy industry applications, devices to subject to a wide variety of variables, from high heat and cold to moisture and vibration, are easily analysed. The IoT is concerned with smart machines for capturing and transmitting data, the sense of temperature, flow or volume changes, automation of efficiency, accuracy, and safety processes.	[207–209]
28	Remotely controlled	IoT applications allow objects to be remotely controlled across current network infrastructure and create opportunities for more immediate physical world integration in computer systems, resulting in reduced human intervention, increased efficiency, accuracy, and economic benefit. As a consequence, producers can collect and evaluate data from products for process optimisation. Intelligent sensors and actuators are utilised to improve manufacturing and industrial processes in the IIoT. This allows operational directors and plant managers to control the plant units remotely and benefit from process automation and optimisation. This makes it easy to simplify daily tasks. It offers the potential to benefit from the data that machines have created in industrial sites across many years from the power of smart machines and real-time analyses.	[210–212]
29	Intelligent factories		[213–216]

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Table 1 (continued)

S No	Applications	Description	References
		IIoT made the creation of intelligent factories and integrating systems possible for manufacturers. This allows detecting patterns, trends and facilitates informed decision-making in advanced analysis. Systems integration allows manufacturers to monitor their inventories and supply chain better and enhance their energy management. This leads to industrial automation, central monitoring and predictive asset maintenance, cost reduction, resource optimisation, greater profitability, and increased operating efficiency. The IoT may revolutionise all aspects of our life, construct intelligent houses, buildings, cars, etc.	

time between the ordering process and the delivery of stock items correctly. It can identify possible problems in real-time long before they influence production by detecting parameters such as vibration, temperature, ultrasounds, etc. [217–219]. This enables plant management and maintenance workers to plan and plan for reactive maintenance. Maintaining industrial assets in operation may reduce operating expenses substantially and save millions of dollars for corporations. Companies can identify when a piece of equipment fails, using sensors, cameras, and data analytics before doing so [220,221].

In IoT systems, warning indicators may be felt; data can generate maintenance schedules and prevent issues in equipment service. This technology permits fast and reliable collection of vast quantities of sensor data, which is then used to identify potentials of trouble and respond in milliseconds employing predictive maintenance algorithms. The IoT industry is a developing and expanding sector that accounts for most IoT expenditure worldwide. This has long been monitoring progress with sensors and systems. The machinery incorporated in an IoT system can send operating information to individuals such as producers of original equipment and field engineers [222–224].

The IoT sensors inside the factory send warnings depending on maintenance based on condition. Most machine tools are crucial and can work between a particular temperature and vibrations. An IoT sensor may actively monitor machinery and provide an alarm when equipment deviates from its specifications [225–229]. By establishing a regulated work environment for machinery, manufacturers can preserve energy, cut costs, prevent machine downtimes, and enhance operational efficiency. In manufacturing, IIoT can refine packing finished goods and fully monitor a whole production line. New technologies are introduced for operational modifications to better control the operational cost in manufacturing and other areas [230–233]. As the monitoring process is carried out very precisely, waste and needless effort are thus eliminated in actual production.

10. Discussion

IIoT is mainly utilised in Industry 4.0 and associated global efforts, all of which have titles, from intelligent manufacturing to intelligent factories. Industry 4.0 is a term used to describe a new industrial revolution that emphasises automation, innovation, data, cyber-physics systems, processes, and people. This also applies to agriculture, linked logistics, finance, government, healthcare, and cross-industries. This leads to more instances of IIoT application depending on the perspective and the sectors. The IIoT transforms the way a company's functions beyond the consumer level. As high-speed connection becomes more and more available, more firms use industrial IoT to enhance productivity and equipment maintenance.

Like the original equipment manufacturer and the field engineer, machines enabled by IoT can communicate operational information to partners. This allows operational directors and plant managers to control the plant units remotely and benefit from process automation and optimisation. The integration of IoT sensors in production equipment makes maintenance notifications based on conditions. Many essential machine tools are available to work in particular ranges of temperature. The manufacturing processes are accessed, identified, and controlled by industries using IIoT. It allows the industry to cover everything from the beginning of manufacturing till the finished product is supplied. The information from IoT-enabled production layers is used as the product-related input for the industry by the production unit. IoT devices allow companies to solve connectivity, computer, and control concerns correctly.

IIoT connects machines, equipment, and sensors on the shop floor to provide much-required visibility for managers and process engineers in production. Organisations can utilise sensors that can automatically trace components as they pass through assembly. Moreover, the Industrial IoT apps can provide supervisors and plant managers with a real-time picture of the performance of their teams by connecting with tools that operators need to fulfil their tasks and production equipment. Organisations can utilise this degree of visibility to detect the root cause of the problems. The IoT-enabled operation allows automating data gathering and spending more time on process improvement. The IoT integrated into product and packaging can help manufacturers obtain information about the usability patterns and handling of items from diverse users.

IIoT platforms enable devices with business applications to be integrated so that the data flow between linked personnel, systems, and objects becomes seamless. IIoT combined with analytics ensures that essential health and safety performance indicators are examined regularly, resulting in better working conditions. When indications start to delay, like manufacturing accidents, they can be dealt with promptly. In addition, IIoT devices, such as intelligent cameras and intelligent sensors, enhances safety for workers and assets. IIoT network enables monitoring of the driver performance, and vehicle state continues to improve security and fuel economy. Weather effects, traffic circumstances, and other product ambient variables are other factors to consider. This provides superior performance at both consumer and packaging costs. It gives access to information in the supply chain in real-time by tracking transiting materials, goods, and equipment across the supplied chain in these IIoT applications.

IIoT maintains the production flow up to date with improving communication speed and efficiency and production pace. Through real-time monitoring, the work typically carried out in the manufacturing cycle may be reduced and the waste removed. This improves employees' productivity, creates the proper storage conditions for tools, and reduces expenses. A manufacturer can adopt a condition-based management system, a proactive site management method, with the IIoT. With this technology, the supply chain can quickly access the inventory situation, enabling the value chain to optimise and reduce costs. It makes it possible for the supply management to follow step-by-step product line delivery and distribution.

11. Limitations and future scope

There are some limitations of this technology, such as during digitising of operations, industries much look to cybersecurity standards. There are some technological challenges during the integration of IIoT connectivity. Small scale industries cannot implement this due to its higher implementation costs.

In the future, IIoT will further boost production levels and become the motivator for more innovation. In addition, the employees themselves are altered via the partnership of manufacturers and suppliers as part of an intensive automation process. Industries will make the most of IoT's utilisation due to the large volume of data collected and processed in the production process. Everything will be evaluated and displayed for operation and cost optimisation. IT is the next technological wave to affect how the world connects and optimises equipment. In the future, IIoT will increase efficiency, productivity, safety, and business models. IoT empowers dozens of devices, sensors, industrial robots, cameras, and smart measuring systems to provide innovative manufacturing industries in smart manufacturing. Real-time information from sensors and other sources of information allows industrial devices and infrastructures to make decisions and develop insights and particular actions. IIoT is essential to the usage of linked ecosystems which helps for intelligent cities and industries. The data enables industries to identify mistakes and inefficiencies in the supply chain and promptly rectify them, increasing daily operational and finance efficiency. Proper IIoT integration will automatically improve asset use, identify problem areas, and even initiate maintenance operations.

12. Conclusion

Real-time manufacturing operating efficiency is driven by changes in production processes, supply chain, robotic facilities, embedded systems, and linked equipment. All of these contribute to risk reduction and, at the same time to innovation. Automated factories are becoming increasingly productive as the number of low-cost, dependable, and linked sensors. IIoT can soon be used for self-diagnosing, repairing manufacturing equipment, and assembling lines. This can reduce downtime, make efficient use of the assets, reduce overall costs, make the workforce more productive, increase the measurability of the results, make the end product more effective and achieve even greater efficiencies, and increased energy efficiency; businesses cut operating expenses and develop new income sources. Through this technology, more rapid and efficient production and supply chain processes reduce the product cycle time. IIoT shares and gain insight into the current developments in the industrial environment. Integrating sensors, data analysis, and cameras in IIoT enable machines to anticipate failures in advance. In the future, this technology will enable industrial businesses to make wiser and faster business decisions.

Conflicts of interest

None.

Declaration of competing interest

There is no conflicts of interest.

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