

**APPLICATIONS OF INTERNET OF THINGS (IOT) IN PHARMACEUTICAL SECTOR:
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ABSTRACT

Highly advanced technologies are required to compete in market shares on global scale, for the pharmaceutical and life sciences sectors. Companies in the pharmaceutical and life sciences industries devote greater time, effort, and resources for digitalizing their operations. In five years, 80% of businesses are anticipated to use IOT in their digitally transformed businesses, with the number of linked devices predicted to reach 50 billion by 2025. The Internet of Things (IOT) is revolutionizing the pharmaceutical industry by enabling and automating pharmaceutical manufacturing, drug discovery, remote patient monitoring and other processes. The potential for digitization to assist pharmaceutical companies in overcoming numerous obstacles is enormous. This article aims to provide readers a glimpse of various applications of the Internet of Things in the pharmaceutical industry.

KEY WORDS: IOT, drug manufacturing, pharmaceutical industry.**INTRODUCTION**

IOT is a network of internet-connected devices that can gather, analyse, and transmit crucial information using built-in sensors. By the end of 2025, there may be 50 billion integrated devices, according to estimates. 80% of businesses are anticipated to use IOT within their organizations over the next five years to automate every department. IOT has the ability to completely modernize the pharmaceutical industry by enabling and automating drug research, clinical trials, patient monitoring from a distance, access, and other processes.

Healthcare services must be more quickly and easily accessible in light of the Industry 4.0 transformation. Pharmaceutical businesses must also speed up the manufacturing process and transport medications in a secure manner in better regulated transit and delivery.

These procedures produce enormous amounts of data, which will be efficiently harvested, analyzed, and used for analytics for subsequent processes and upgrades. The analysis of obtained data provides useful insights into plant operations, forecasts the need for repair before equipment becomes inoperable, and tracks the supply chain throughout the production.

IOT in pharm fabrication

Industry 4.0, which refers to the digitalization of industry, was first used in a public context at Hannover Messe in 2011. The German Academy of Engineering and the Science and Industry Research Union define the

term "Industry 4.0" as the technological integration of cyber-physical systems into production and logistics^[1] as well as the use of IOT and services in industrial processes, such as the resulting consequences for value creation, business models and downstream services and work organizations.

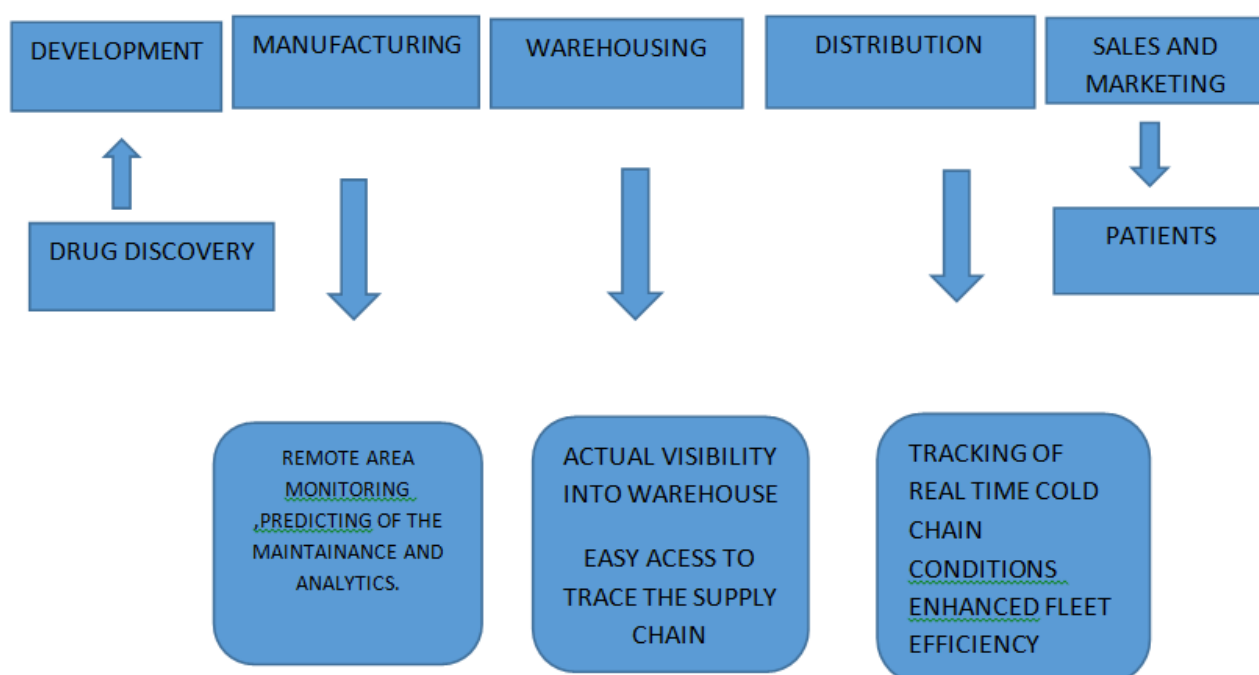
Companies that manufacture pharmaceuticals make use of cutting-edge technology and information systems. A number of specialized IT systems, some of which are centralized, are used to monitor the processes. While some local systems fall short of meeting all the requirements for high-quality manufacturing in a highly regulated sector. It is necessary to have 360^[2]-degree real-time views of the plant functioning across several systems in addition to monitoring individual systems. Additionally integrated will be automated data collection and real-time IOT data analysis from equipment on the plant floors. Direct communication between departments, plant floor operations, and management continues to be a barrier because there is no real-time data integration to improve process flow and on-time product manufacturing.

IOT-PM, or Internet of Things in Pharmaceutical Manufacturing: has the potential to fundamentally alter how pharmaceutical manufacturing plants run. It allows access to the production activities to be tracked at any time from a distance. Thus, real-time monitoring helps to reduce waste, improve equipment usage, and save expenses associated with manufacturing. Industrial IOT

is claimed to connect people, products, and processes; surely, the manufacturing sector will benefit the most. Equipment may already be connected, but the Internet of Things (IOT) offers further benefits by leveraging data and computational capacity.^[3] This produces insightful data about the plant workflow, monitors and controls the equipment performance well in advance of equipment failure.

The pharmaceutical production industry is moving toward a paperless environment with lower staff.^[4] Implementing the Internet of Things would result in a fundamental change toward outcome-based tailored therapies that would be carried out using individualized production techniques. In their manufacturing processes, 30% of the top 20 pharmaceutical businesses have

enforced IOT technologies. Apotex, a Canadian pharmaceutical producer, recently automated its manufacturing operations by implementing IOT-PM. Tools including autonomous guided vehicles, RFID tracking, sorting, and process flow tracking were adopted by the business to guarantee reliable batch production. Chemical and pharmaceutical firms must use IOT-PM to increase the efficiency of product development and manufacturing in order to thrive and expand in this cutthroat industry. Machines and equipment are becoming more capable of being digitalized in order to communicate online.^[5] Manufacturers want to increase operational effectiveness, resist competitive markets, and take the lead in the industry while offering services at reasonable prices.



Networks between machines, people, and the Internet are set up in a new context. The following list summarizes the main applications of IOT in manufacturing facilities.

- **Predictive maintenance:** This technique applies to all linked assets in industrial facilities. It is feasible to foresee equipment problems and act rapidly in urgent circumstances. By examining the data accumulated over time, algorithms can be created using the machine learning process. These support timely decision-making.
- **Connected Factory:** It says that the complete factory network is connected to the Internet with the potential of full monitoring and managing the circumstance.
- **Connected Mine:** All mining equipment, vehicles, and personal safety gear are connected in this mine.
- **Supply Chain Control:** This section keeps an eye on the storage conditions, tracks the flow of raw materials to the machine, and tracks the products for traceability.

Below are some of the fewer IOT uses in the supply and production of pharmaceuticals^[6]

- Smart serialization, which detects items automatically, gathers data, and feeds it into the system.
- Planning out machine and equipment maintenance.
- Medical Individualization.
- Drugs printed in 3D.
- RFID & sensors used in real-time logistics visibility to record and report parameters.
- Intelligent routing and warehousing.

IOT technologies are used in pharmaceutical production facilities to optimize and boost the effectiveness of their equipment and procedures. Thus, time and human mistake are decreased. It generates vast amounts of data throughout the process, all of which will be examined for analysis. By connecting equipment, networks, and systems, IOT-adopted solutions promote standardization and disseminate information throughout the factory floor.

Top companies^[7] have successfully embraced IOT, including Johnson & Johnson, who switched from batch to continuous manufacturing in order to get FDA

approval for the HIV drug Prezista. Using sensor technology, they can do away with the requirement for separate sample and testing procedures in the production process. IOT made it possible to connect those independent processes, preserving the integrity of the data. The bulk of Pfizer's significant manufacturing facilities now have an integrated manufacturing process because to the company's ongoing adoption of IOT. Merck, a different significant corporation, uses IOT tools to evaluate data from biologic processes, which results in the successful identification of a setback in the manufacturing facility that was resulting in extremely high vaccine waste rates.

IOT enables modular automation in a manufacturing facility, and production will be done in accordance with customer desires. With the aid of IOT, bottlenecks in various industrial processes must be located. Equipment is used routinely and wisely, without being left idle for extended periods of time. Pharma giant GSK^[8] is converting as many of their manufacturing sites as they can to continuous flow processing by implementing IOT and cloud computing technology.

The main objective is to use technology to reduce manufacturing costs and time while improving quality and lowering plant size. The engineers are creating engines to collect, store, analyse, and use vast amounts of data for process design and control purposes.

Pharmaceutical site managers follow best practices for learning manufacturing data, which can be used to promote process improvement through continuous factory operation within verified performance parameters. Due to these processes, the emphasis of data informatics has shifted from compliance to competitiveness.

Pharma companies can speed and customise the work flow to their needs without experiencing problems in processing the enormous amounts of data by outsourcing, but data integrity is still in doubt. Atachi Systems /4/ has used IOT-based MES (manufacturing execution systems) for the production of pharmaceuticals, which maintains the electronic batch manufacturing records for different pharmaceutical businesses without sacrificing data integrity. Tetra Science, an IOT company, has started an IOT platform where all data from various equipment and processes is saved in one place. The time required for analysis and decision-making can be cut by up to 40% by using the accumulated data directly. Unknown small changes to the pharmaceutical production process will result in catastrophic batch process failure, necessitating FDA supervision. Faster data collection from multiple manufacturing plant phases is made possible by IOT-enabled processes. This is necessary for the FDA's continuous process verification.

Using IOT technologies in manufacturing facilities results in standardisation, shortened cycle times, and data

integrity, which supports continuous manufacturing for pharma companies. IOT technology are utilised by pharmaceutical companies in their factories to make ordinary manufacturing easier. This method aids pharmaceutical companies in considerably reducing manufacturing costs and times while improving product quality. IOT supports data integrity and the process of standardising the manufacturing process. IOT solutions increase operational efficiency in a manufacturing plant by enabling visibility from production to distribution.^[9]

Major advantages of iot in pharmaceutical manufacturing

- As equipment and recipe parameters become more tightly connected and accessible and require fewer manual interventions, IOT functions as a catalyst for paperless manufacturing.
- As the health care sector develops diagnostic-based treatments, tailored drug manufacture for smaller-scale manufacturing employing IOT is required.
- IOT can collect data from a variety of processes and connect sophisticated machinery that depicts the process understanding beyond performance and efficiency.
- Shares information across the factory and with senior management by connecting diverse equipment operating on different plant floors. These present an easy way to standardise the procedure.
- An IOT-enabled smarter plant provides manufacturers with a solution, allowing them to access data in real-time for improved production monitoring and more visibility from the point of production to the market.
- When a problem arises, manufacturers pull the data as needed to track and trace the process, which prompts prompt and efficient recall of the products from the market.
- Quality by Design must be successfully applied, monitored by IOT, and comprehended completely of the procedure that works to increase safety and safeguard the brand's market worth.
- The normal process is unaffected by the cheaper and quicker data interpretation made possible by electronic batch records.
- IOT modularization of pharmaceutical production facilities is urgently required. IOT infrastructure enables automation and flexible production sizing based on consumer demand. This makes it possible to produce goods more quickly while still adhering to the regulatory standards for specific markets and areas.

Manufacturers and suppliers must both have a better understanding of IOT in order to utilize it effectively. IOT is increasingly frequently employed for simple fixes needed at a specific process point, but its full potential is still untapped.

For better understanding, research and development scientists and process engineers must work closely together. Technological advancements in manufacturing, when choosing new formulas or medicinal delivery techniques, they must use IOT.

How individuals handle and engage with the data produced by automated systems and IOT is a key component. To prevent misuse or excessive misunderstanding, certain data kinds must be separated and provided to the appropriate individuals exclusively. The primary challenges in managing IOT enabled processes and analytics would be timely data provision in creative and useful ways to the involved parties. Forecasting future manufacturing with extremely flexible and adaptable automated production is the problem of IOT adoption.

More and more departments now have IOT sensors installed within the pharmaceutical factory. These Internet of Things (IOT) sensors have been effectively employed in pharmaceutical firms to integrate data across many departments, including production units dispersed across various sites. So, with IOT sensors, businesses may remotely and in real time control everything that happens within the production unit. IOT helps to lower manufacturing costs, increase equipment usage, and reduce waste thanks to businesses' ongoing efforts to improve efficiency and control.

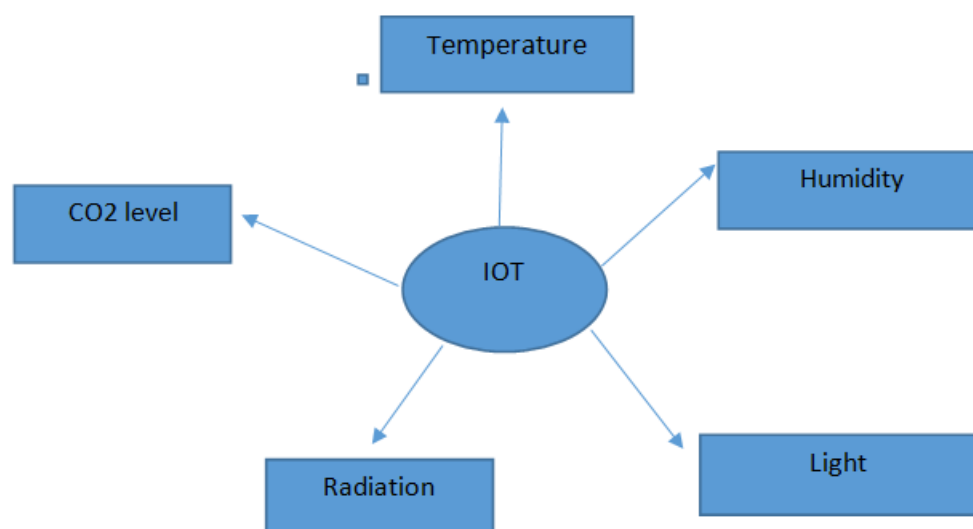
IOT in equipment mal functioning

Materials used in the pharmaceutical business must be handled carefully and in a controlled atmosphere. The

usage of IOT sensors and trackers in these situations is claimed to track and regulate the ideal conditions for handling chemicals and biomaterials while also guaranteeing faultless equipment operation. Pharmaceutical companies interested in unexpectedly shutting down equipment.^[10] They continuously track current conditions in order to utilize all industrial segments wisely and meet consumer demands.

The internet of things achieves this by continuously updating the status information of all equipment's component parts across all plant sites, including: Vacuum pumps, multi-media filters, air compressors, pH probes, sterilizers, heat exchangers, pressure gauges, and pH probes.

To maintain and repair equipment, prevent serious problems, reduce downtime, and ensure worker safety, IOT sensors' information is employed. This provides a complete picture of the equipment usage. When handling biomaterials, IOT sensors that are put in the manufacturing facility's environment are essential. Consequently, it is possible to monitor environmental indicators such as temperature, humidity, Light, Radiation and CO₂ level.



Plant managers regularly monitor the information and take required action as needed. Pharma businesses failed to comprehend that simply selling conventional medications would not support the company's growth or even maintain its competitiveness. As a result, they begin to spread the idea of the beyond pill.^[11] This sparked interest in leveraging cutting-edge tools and commercial approaches that gave rise to Pharma IOT. Manufacturers of pharmaceuticals today use huge data stored in the cloud to make informed decisions quickly.

IOT application in the pharmaceutical industry is seriously threatened by privacy and data security. Every

pharmaceutical producer places the utmost attention on the quality and safety of their goods. A subpar product will definitely have an effect on customer health and hurt the manufacturer's bottom line.

Manufacturers are more concerned about their data security that generated during the process and intellectual assets. To restrict visibility to everyone save the involved executives, updated security protocols must be used at every stage of data retrieval and storage. Despite these difficulties, businesses who install technology with confidence will benefit the most. The pharmaceutical

business ought to employ more sophisticated cyber security procedures.

IOT in drug discovery

The Internet of Things is about more than just devices; it's also about how they interact with one another and feel connected in real time^[12] market for artificial intelligence. The cost of health care in the US is predicted to exceed USD 320 billion in 2016 and increase by an additional 38% over the years.^[13] A market for artificial intelligence-based drug discovery apps accounts for 35% of these values. Artificial intelligence and machine learning are currently driving the early stages of drug development. Machine learning algorithms are being used by researchers to speed up medication development and create a robust, long-lasting therapeutic pipeline. Machine-learning algorithms have already gained traction in pharmaceutical labs because to advancements in cloud computing. This forecasts the future lab's digital connectedness and emphasis on introducing novel medicines to the healthcare markets.^[14] It typically takes 12–14 years and significant funding to bring new medications to market. Automating the drug discovery process reduced costs by up to 70%.^[15] Using artificial intelligence, a charitable organisation in London was located two possible medication targets for Alzheimer's disease, made the attention of pharmaceutical companies to focus their research and development on developing these treatments. Exscientia, a firm that creates drugs, uses an AI platform to design and screen compounds for new drugs.^[16] They quickly produce and test small amounts of substances, which could serve to improve the models created and contribute to newer ideas. IOT, cloud computing, machine learning, and other technologies are beneficial to provide a speedier, more affordable, and more effective option when looking for new medications.^[17]

Since the last two decades have seen such rapid growth in the data processing industry, it is now possible to create advanced algorithms through machine learning. These algorithms help with drug discovery by gathering data from devices, clinical trials, patients and converting it into different forms to store information on the cloud in categories. These were examined and employed in all phases of the drug discovery process, which will significantly reduce the lead time and costs associated. Companies now follow patient driven biology and data obtained from them to create more-predictive hypotheses, turning the traditional trial and error strategy of drug discovery process on its head. Artificial intelligence used to search through a big amount of data to uncover patterns that were concealed.

Various pieces of information are brought together during the drug discovery process using data sets to identify the behaviour pattern of the chemical under investigation. It displays its behaviour in relation to the patient's medical outcome for the substance under investigation for the previously collected data. It is

anticipated that one out of a thousand compounds that was initially determined to be a safe medicine and was later approved by the FDA.^[18] The conventional approach to drug discovery is more expensive and time-consuming. The future of drug development will be driven by the convergence of emerging technologies.

Clinical trial progression is steered by sophisticated intelligent hardware systems.

The Internet of Things links entities such as people, processes, data, and objects together. Integrating data, operational technology, and information technology enables better insights, streamlines procedures, and boosts productivity.^[19] Researchers still struggle to fully utilise digitalization's potential because of cultural inertia rather than technological limitations. The businesses are developing and adapting for the digital transition in addition to creating innovative treatments and personalized medicine. IOT-implemented technology allow for the production of traditional delivering new drugs more affordably, as well as spurring investments in more creative ways to produce drugs.

The environment for repeatability of studies is improved by IOT-based data analysis of drug discovery systems, which also decreases human involvement and human error in the process and tests.^[20] They use established processes to raise the items' quality. Technologies make it easier for scientists working on medication development to stop a drug from failing early on before it enters the clinical trial procedure. They can either abandon the method and preserve the data for future research projects or they can change the chemical of interest to address the problems. Drug development is a complicated procedure that must adhere to many strict laws before it can be sold. As a typical person Companies are apprehensive about investing enormous sums of money on conventional methods of drug development because only ten thousand compounds get released onto the market.^[21] Despite the IOT's enormous promise in the field of life sciences, many researchers are still not at a level where they can use it for their regular study.

Role of IOT in clinical trial

Manufacturing companies, marketers, and merchants can now integrate data to improve patient clinical results, which is a difficult task. IOT is gaining traction in the world of clinical trials as well.^[22] Nearly all pharmaceutical companies, contract research organisations, and service providers intend to boost their usage of the Internet of Things (IOT) in order to speed up the release of novel medications and biologics into the market and reduce the need for significant upfront investments.

The safety and effectiveness of investigational medications being tested in clinical trials can be better understood by collecting data in unique ways with IOT

and storing it in the cloud. Trials without sites and patient monitoring at home or in a nearby clinic, with clinical coordinators having immediate access to data collected by devices and delivered to the cloud. Organizations can expand the number of trials by adding more patients and geographical locations, which could result in the introduction of new pharmaceuticals to the market more quickly.

In the field of life sciences, an IOT-based revolution is only getting started. Pharmaceutical and biotechnology companies are in a position to accelerate the clinical outcomes where they invest millions of dollars and to reap the benefits. Trials of ingestible pills containing tiny cameras are being conducted to monitor the administration of medications for disorders that cause chronic diseases.^[23] Where patient data is constantly collected and monitored.

Complex designs are necessary for clinical trials, and the backing of the medical community is essential. This is a component of clinical studies' ongoing monitoring and information-sharing. The traditional approach is having patients interact directly with medical personnel in order to gather information and other clinical outcome factors. The use of IOT lowers these barriers, which is beneficial for the companies conducting clinical trials. IOT in clinical trials has the capacity to efficiently and effectively gather data and analyse it in a timely and secure manner. By fusing IOT networks with medical equipment, Clinical trial companies can remotely monitor patients. The subjects' passive and real-time data are gathered on things like body temperature, hydration levels, sleep patterns, and other aspects of their daily lives. Information transportation is efficient and effective way to this type of data collection. Patients can participate in the clinical trial in a comfortable way utilizing this approach of data collecting via the Internet of Things, allowing them to carry out their regular tasks.

IOT has the potential to revolutionize a variety of life science fields.^[24] Facilities across research sites can be connected by adding geolocation tags and micro environmental information to data sets. The phrase "internet of things" is insufficient to describe what includes instruments, animals, data, and lab employees that are geotagged, remotely monitored, and networked. IOT has become popular for caring for lab animals. It is also undergoing the medication development process. Radiofrequency identification platforms are used to keep track of the cage census for these animals. Newer styles of cages send out alerts if any housing conditions deteriorate and endanger animals. IOT provides access to environmental sensors and data entry forms so that the health of the animals may be continuously monitored. Remote site-to-site adjusting of the settings is required. The Internet of Things (IOT) could be used for transportation systems that monitor the containers and track the data in real time when moving animals between research groups during animal studies. Information from

animal studies is exchanged between research teams in real time so they can focus on developing the fastest medicine possible. The development method prevents time and financial waste. IOT applications should be expanded to include quality control and animal experimentation compliance in addition to animal husbandry and transportation. IOT devices are digital tools that are used in clinical studies to collect and analyse patient digital biomarkers.^[25] IOT has made clinical trials more efficient, patient-friendly, and cost-effective.

CONCLUSION

Although IOT technologies are still in their early phases of development in the pharmaceutical industry, there is no denying their influence on the global healthcare sector. The advantages of the IOT will be felt by the businesses who adopt it. IOT low-power, low-cost networks and solutions are still in their infancy. This article aims at various applications of IOT in the pharmaceutical production sector, the process of discovering new drugs, and clinical trials.

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