A REVIEW OF INDUSTRIAL 4.0 TECHNOLOGIES AND THEIR APPLICATION TO MANUFACTURING SUSTAINABILITY

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Abstract

Despite being a relatively recently developed concept in business and marketing, sustainable marketing is already altering the rules. Sustainable marketing aims to satisfy the wants of the current generation without destroying the future and is based on social and environmental sustainability concepts. This is achieved through Industry 4.0, which is revolutionizing marketing and businesses across the globe. Recent advancements in automation and manufacturing techniques have led to Industry 4.0. Data management, industrial competitiveness, manufacturing processes, and efficiency can all be categorized under the umbrella term "industry 4.0." A few crucial supporting technologies mentioned in the "Industry 4.0" movement include digital twins, artificial intelligence, the Internet of Things (IoT), and cyber-security systems.

On the other hand, inventory management has been more complex as the sector has grown, but technology is helping to tackle these problems. The warehouse is the essential component of the supply chain's 4.0 revolution. Real-time monitoring of manufacturing facilities, distribution centres, and warehouses is feasible due to the Internet of Things. A key component of the 4.0 industry is the internet of things (IoT), which helps businesses operate more efficiently. These technologies are the key drivers of automated and digital industrial settings. The United Nations (U.N.) Agenda 2030 stresses sustainability as the cornerstone of business strategy and advocates for smart manufacturing, energy-efficient building, and low-impact industrialization. Industry 4.0 technologies assist in making corporate operations more sustainable. However, only a few studies performed in-depth analyses in these two subject areas. This study uses a thorough literature review methodology to assess the current state and potential directions for future research on Industry 4.0 technologies to achieve manufacturing sustainability. In relation to several Industry 4.0 technologies, industrial sustainability is thoroughly covered. This study has highlighted new research areas and upcoming Industry 4.0 research initiatives. This study will help businesses and academic institutions use Industry 4.0 technology to achieve sustainable manufacturing.

Keywords: Conceptual framework, Internet of things, Sustainability, inventory management, sustainable development, innovation, Industry 4.0, modern technologies.

Introduction

The 4.0 industrial revolution is now occurring across the planet (L. Da Xu & Duan, 2019a). The invention of automatic manufacturing machines driven by steam and water in the eighteenth century led to the first industrial revolution. The second industrial revolution began when mass production using electric energy was introduced at the beginning of the twentieth century. The third industrial revolution started in the 1970s when electronic devices, computers, and information and communication technologies began to automate the industry (Agrawal et al., 2018). As a concept and strategic initiative, Industry 4.0 was launched in 2011 by the government of German (Habib & Chimsom, 2019). A number of other developed nations have taken similar measures, including the U.S. Made in China, the Advanced Manufacturing Partnership (AMP), and the British Smart Factory. Industry 4.0's significant components are collaboration, cognitive robotics, flexible automation, cyber-physical systems, sensors, cloud computing, big data, computer simulations, and additive Manufacturing (Doshi, 2020). The advancements in computer-integrated manufacturing and flexible manufacturing systems of earlier decades have led to the development of 4.0 and smart manufacturing/factory (interchangeable). Modern technology allows Computer-integrated Manufacturing, and Flexible Manufacturing Systems may be further advanced and deployed at lower prices (Ivanov et al., 2021). Industry 4.0 includes a number of components, including flexible automation, cyber-physical systems, the Internet of Things, sensors, collaborative robotics, big data, computer simulation modeling, and additive manufacturing. (L. Da Xu et al., 2018). This digitization develops new business models and opportunities for value creation by making it possible to integrate processes and systems across organizations and industrial sectors (I-Scoop, 2022). Industry 4.0 has significantly impacted how people live their everyday lives in every area, including shopping, eating, working, entertaining, etc. (Reljić et al., 2021). Even thinking and attitude are changing due to how people live and behave (Cotet et al., 2020). Industry 4.0 has dramatically influenced supply chains, manufacturing services, and systems (Lundgren et al., 2022). Industry 4.0 is characterized by intelligent factories, cutting-edge goods, and demanding consumers who expect excellent service (Lampropoulos et al., 2019). Businesses and enterprises are lucrative, sustainable, and digitalized. The supply chain is well-known, interconnected, and integrated. The core principles of Industry 4.0 are digitalization, visibility, connection, and interoperability. Inventory management and optimization are changing significantly due to Industry 4.0's rapid development of new technology (Craveli, 2017).

Various business sectors are experiencing profound changes due to IoT (Jan et al., 2019). To create a more intelligent and responsive environment for us to live in, we need to blend the physical and digital worlds. Inventory management is crucial to supply chain management (SCM) since it is connected to production and pricing (Manavalan & Jayakrishna, 2019b). The key goal of inventory management is to optimize customer service while minimizing the cost of inventory by establishing the proper inventory replenishment strategies (Yasaman Mashayekhy et al., 2022a). Furthermore, industry 4.0, the basis of today's evolving technology in producing and delivering goods and services, heavily relies on inventory management. With Industry 4.0, things are easier now because everything is interconnected and more advanced than we used to have (Aceto et al., 2019).

Methodology

Our study explores how industrial 4.0 technologies and their application to manufacturing sustainability. As well as covering Industry 4.0, Section 1 includes the introduction part, section

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2 and 3 presents the methodology and research questions, Section 4 includes materials and methods for the literature review and section 5 of Industry 4.0 analyses how various technologies interact with Industry 4.0. Section 5 and 6 investigates sustainable manufacturing and Industry 4.0 and evaluates how different technologies are connected with industry 4.0. Section 7 includes how different factories, commodities, consumers, and enterprises might transform industry 4.0. Section 8 discusses the new generation of manufacturing systems and services based on industry 4.0. Section 9 discusses the implications of Industry 4.0 for businesses; section 10 discusses the IoT's role, its initial preparation for industry 4.0 and the structural implementation methods and requirements. Sections 11 and 12 present the methods, procedures and requirements for Industry 4.0 and the influence of inventory management in industry 4.0. Section 13 discusses the influence of IoT in inventory management and the role of industry 4.0 in the retailing sector. Section 14 brings the paper to a conclusion.

Research Questions

The following research questions were developed for the current study:

Q1: How does Industry 4.0 contribute to adopting sustainable manufacturing techniques?

Q2: How can the industrial sector's sustainability be improved by Industry 4.0 technology?

Q3: What critical research issues relating to Industry 4.0 technologies for sustainable manufacturing need to be resolved soon?

Materials and Methods

As the world gets increasingly technologically advanced, industry 4.0 will play an increasingly important role that cannot be overlooked. Through the Scopus database, we collected and compiled information about sustainability and industry 4.0. Over 89 papers met our research criteria and were included in the literature review. Additionally, this paper discusses a few practical observations and experiences related to industry 4.0. It is not possible to provide comprehensive information on industry 4.0 in this paper due to its word limit. The paper discussed sustainability, as well as industry 4.0.

Sustainable Manufacturing

There are three elements of sustainable manufacturing: processes, products, and systems that contribute to economic growth and sustainability and create jobs in industries (Stock & Seliger, 2016). These elements must positively impact economic, social, and environmental factors to ensure manufacturing sustainability (Turner et al., 2019). As a result of integrating various systems and processes, sustainable manufacturing can produce products with minimal resource consumption and sustainable resources and is safer for customers, employees, and communities (Machado et al., 2019). The first definition of sustainability was given in the Brundtland Commission report, which the U.N. published in 1987. Sustainability is defined as "development that meets current needs without compromising the ability of future generations to meet their own needs" (Borowy, 2013).

Additionally, this term was used in many U.N. projects, such as the Sustainable Development Goals 2015 project. This definition does not apply to commercial operations (Sartal et al., 2020). There have been several attempts to propose a definition for S.M. in previous publications (Machado et al., 2020). Sustainable manufacturing is defined as designing an industrial system that can protect the environment and human health while ensuring the natural resources for a high quality of life (Jayal et al., 2010). The U.S. Commerce Department defines S.M. as "the creation of products that minimize negative environmental effects, energy consumption, and natural resource consumption while also being safe for employees, consumers, and the community" (U.S. Department of Commerce, 2010).

Industry 4.0

Industry 4.0, a shift toward digital transformation, connects the physical and digital worlds (I-Scoop, 2022). We will not go into great depth about the technologies mentioned above in this paper, but we will quickly discuss how they support Industry 4.0. There are two primary schools of thought on the terminology and applications of IoT and Industry 4.0 (Posey et al., 2022). Industry 4.0 and the Internet of Things are viewed as identical and interchangeable terms by another school of thought (Alqoud et al., 2022). Another school of thought contends that IoT is a means to Industry 4.0 and may be seen as a facilitator of the idea of Industry 4.0 (C. S. Tang & Veelenturf, 2019). In this paper, we consolidate our study from a stance and investigate creative solutions for issues about Industry 4.0.

The German government first promoted Industry 4.0 (Fourth Industrial Revolution) (Habib & Chimsom, 2019). It represents a new generation of increasing productivity using technologies like RFID tags, the IoT, the Internet of Service, cloud-based services, big data, cyber-physical systems, and so on (Doshi, 2020). The steam engine was introduced to industry during the First Industrial Revolution (Agrawal et al., 2018). Mass production replaced hand manufacturing, causing new issues and challenges for the industry to overcome. The Second Industrial Revolution emerged due to increased energy use in production. The emergence of information technology (I.T.) and the development of the automated era served as the catalysts for the Third Industry Revolution (M. Xu et al., 2018). All facets of the supply chain now have new views thanks to Industry 4.0 (Liu et al., 2021). Organizations may reduce waste, become more responsive, and make real-time decisions with Industry 4.0 (Rosin et al., 2020).

In contrast, the sector has produced many data since sensors and control systems are used so often. Data with a considerable volume is also referred to as big data and is stored in the cloud (L. Da Xu & Duan, 2019b). Intelligent CPS systems will be further self-directed in their active decision-making and machine communication when using smart manufacturing to automate (Vaidya et al., 2018). Industry 4.0 has helped the manufacturing sector of supply chains and all other sectors, including the distribution and transportation sectors.

Industries such as aerospace, agriculture, construction, food and beverage, pharmaceutical, and services have all been impacted by Industry 4.0 technology (Manavalan & Jayakrishna, 2019a). A multitude of opportunities for sustainable manufacturing is also presented by Industry 4.0. Information exchange in the closed-loop supply chain and sustainable manufacturing depends on the digital cyber network (Carvalho et al., 2018). Environmentally friendly products and procedures should address closed-loop life cycles via reuse and remanufacturing. Organizations need specialized infrastructures that can introduce cutting-edge business models to put Industry 4.0 technology into operation. New business models, especially "disruptive ones," must provide consumers with intelligent products and services in a wholly digital environment (Javaid et al., 2022). Through autonomous virtual metrology, the concept of

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Industry 4.0 would be enhanced to move to Industry 4.1 as the next step and achieve the automation objective of zero defects. Industry 4.0 is a concept that has generated much attention across a variety of disciplines. Still, it has yet to be successfully used on a big scale in everyday life. IoT supply chain solutions have yet to undergo much academic or commercial research (Cheng et al., 2022).

The digital and physical worlds are connected by technologies that enable Industry 4.0. For example, manufacturing systems and services are connected by the following technologies:

- **The Internet of Things (IoT)**

The AutoID Centre's executive director was the first person who uses the term "Internet of Things" (IoT) (Chakraborty, 2022). The concept of network devices enabled machines to function dynamically as integrated systems without the need for human interaction. It effectively blends the physical and digital worlds used to create things and processes in various industries (Khaleel et al., 2017). All the devices are connected by wireless Internet technology, enabling interactions that improve functionality. Sensors, which provide a significant quantity of real-time data, may also provide system knowledge of the surroundings. Sensors and gadgets are linked together via embedded computers and networking. The Internet of Things connects various systems, objects, sensors, and people via low-power, wide-area networks and wired high-capacity networks (Goyal et al., 2021). The Internet of Things may significantly impact how resources are employed, how open and visible the whole supply chain is, how agile the supply chain is, how it can be controlled in real-time, and other factors (Kumar et al., 2022).

- **Big Data Analytics and Business Intelligence**

Big data can be described simply as enormous data collections that exceed actual databases and data processing infrastructures. Big data includes the process of storing, processing, and displaying data. On the other hand, business intelligence is a field that involves data analysis to identify trends, patterns, and insights. Findings based on data give precise, perceptive perspectives of the company's procedures and the outcomes those processes deliver (Yang et al., 2020).

Businesses now adopt vast volumes of data from many sources. All operational and management choices must depend on data analytics. Any organization cannot ignore data and data analytics. Data are beneficial and necessary for maximizing services and product quality, reducing energy use, and increasing production efficiency. Predictive models, decision support tools, processes, and dashboards can turn data into insights that can be used. Today, data is the most important resource for a company. The success of corporations and businesses depends on data analytics (Yunana et al., 2021).

- **Cloud Computing**

Online data storage and access are made possible through cloud computing. You may access your cloud from numerous computers if you are linked to a network. The data is then saved on distant servers. The cloud facilitates data access and storage of massive amounts of data. Because it enables several computers on a local network to access data, it has become a popular kind of technology among firms of different sizes and staffing levels in several sectors, from banking to data sharing. We are moving to the cloud and working on the cloud. It is located in the sky (Achar, 2021). Cloud-based access: Everything appears "in the cloud" these days. However, what exactly is this nebulous concept?

The quick answer is that it is at the other end of your internet connection, where you may access apps and services and securely store your data. There are three reasons why the cloud is significant:

- It involves no effort on your part to keep or manage
- It has an almost infinite capacity, so you will not have to worry about running out of space
- Cloud-based applications and services are available anywhere; you only need an internet-connected device

This is crucial since there is a shift from office-based to mobile jobs. Consequently, the cloud is an ideal site for commercial software such as customer relationship management (CRM) systems - software that customers need consistent access to at any time, from any location, and on any device (Subramanian et al., 2021). Many small businesses ask for help to afford storage for an expanding amount of data. Some people need more advanced computational and analytical abilities to analyze huge volumes of data. However, the value of data, analytics, and computer skills is significantly higher. Cloud service providers are expanding their opportunities for small businesses by providing low-cost data storage and processing (Vrchota & Pech, 2019).

- **Cybersecurity**

The technique of preventing cyberattacks on systems, networks, and programs is known as cybersecurity. These cyberattacks typically aim to disrupt normal business operations, extort money from users, or access, alter, or destroy private data. Effective cybersecurity measures are challenging to implement because there are now more devices than people, and hackers are becoming more inventive. As devices and data sets become easier to access, industrial systems become increasingly vulnerable to attacks. Implementing cybersecurity is necessary to identify new vulnerabilities and issues and ensure that industrial systems and businesses are protected from attacks (Ervural & Ervural, 2018).

- **Augmented Reality (A.R.)**

Augmented reality (A.R.) uses digital visual elements, music, or other sensory cues to improve the representation of the natural world transmitted through technology. A growing trend in this direction is being observed by businesses using mobile computing and business applications. The modern consumer is getting pickier and pickier. Businesses must offer customers various services, including custom product design, specialized manufacturing, and post-sales support. Technologies based on augmented reality could give companies a competitive edge and increase their commercial potential in such a cutthroat environment (Devagiri et al., 2022).

- **Autonomous Robots**

Like humans, autonomous robots are capable of independent decision-making and appropriate action. In order to be truly autonomous, a robot must be able to observe its surroundings, form opinions based on what it sees, and be taught to recognize and perform a task or manipulation in that environment. Simple actions like starting, stopping, and navigating around obstacles are a few examples of these decision-based behaviors in robot mobility. Robots with accurate autonomy are intelligent devices that can work by themselves and in a given environment without guidance or human interaction. With this level of autonomy, workers can delegate risky, unpleasant, or tiresome tasks to the robot, freeing them to concentrate on the rewarding and important aspects of their jobs. Nowadays, robotics is widely used in industry. Self-sufficient, autonomous, and communicative robots are essential to work units in Industry 4.0; they are no longer just human tools (Bousdekis et al., 2021).

- **Additive manufacturing**

Machines in additive manufacturing are programmed to deposit material in geometric forms layer by layer using CAD software or 3D object scanners. As the name implies, additive manufacturing is a method of creating objects by adding materials. In contrast, it is frequently necessary to remove material during the traditional process of making an object through milling, machining, carving, shaping, or other procedures. Manufacturers can offer a wider variety of products and more customization thanks to additive manufacturing, or 3D printing, significantly reducing design time and costs (Haleem & Javaid, 2019). HMLV (high mix, low volume) manufacturing offers the most significant benefits from additive Manufacturing (Kocsi et al., 2020).

View of Industry 4.0 from the perspectives of factories, commodities, customers, and organizations

Digital technologies are used in Industry 4.0 to increase industrial agility, flexibility, and customer response. The internet, wireless sensors, software, and other cutting-edge technology may be used to create an intelligent factory that increases productivity and improves customer satisfaction (Ghadge et al., 2020). Industry 4.0 can help businesses produce more individualized products, increase operational efficiency, and react quickly to market changes. Developing intelligent products, processes, and procedures is a component of Industry 4.0. Because people, things, and machines are constantly connected, workers, equipment, and resources can interact with one another with ease in an intelligent factory. The next stage of the manufacturing process is improved with the help of tools, products, and transportation equipment. Real-world and virtual objects are connected (Michael et al., 2015).

- ***Factories:*** Industry 4.0 connects and automatically exchanges information between all of the manufacturing facilities in a factory, including sensors, actuators, machines, robots, conveyors, etc., making the factory conscious and intelligent enough to predict and maintain its operational performance, control its production process, and manage its manufacturing operations. Industrial processes like product design, production scheduling, product services, etc., operate independently as self-contained modules, even if a decentralized system also manages them. An intelligent factory has embraced Industry 4.0 (Sung, 2018).

- ***Businesses*:** An extensive network of communication between multiple organizations, including suppliers, manufacturers, customers, commodities, logistics, and resources, among others, has been made feasible due to Industry 4.0. Each entity adapts its configuration in real-time in line with its demands and position within the network to optimize profit for all entities while reducing expenses, pollution, wasteful raw material usage, CO2 emissions, etc. (Yuan, 2020).

- ***Customers***: Customers now have a new, advantageous buying choice due to Industry 4.0. Customers have access to any product, in any quantity—even one—and with any function. Additionally, customers are free to change their orders and requirements throughout manufacturing. Smart goods, on the other hand, educate customers about the production process and provide suggestions based on their individual tastes (Nagy et al., 2018).
- ***Products***: Utilizing Industry 4.0 technology, sensors, additional components, and processors may transfer data and knowledge to the manufacturing system in order to gather customer feedback as well as to customers in the form of valuable recommendations. Additionally, it aids the manufacturer's transition to a business model based on a product-as-a-service, boosting sales, tracking product performance, and informing customers when and which components require replacement. Such a product is known as an intelligent product in Industry 4.0. A state-of-the-art product is fully cognizant of its production procedure, working conditions, delivery window, usage, lifetime, location, and other crucial details (Sinha & Roy, 2020a).

A new generation of manufacturing systems and services based on Industry 4.0

Intelligent networks of interconnected systems, machines, and work units may function independently, coordinate autonomously, and communicate. Industry 4.0 involves all of this (Tonelli et al., 2021).

- ***Real-Time Capability***: In Industry 4.0, everything runs in real-time, which means data collection, monitoring, and maintenance must take place in real-time
- ***Interoperability***: Interoperability is the ability of all entities to engage in communication, interaction, and teamwork over the IoT. IoT includes people, smart manufacturing, and related technology. Interoperability requires a fully developed ecosystem where all organizations can work together adaptably and without communication gaps. For instance, people who work on assembly lines and the products they produce are not isolated from one another.
- ***Virtualization***: For an intelligent factory, a virtual twin or digital twin could be developed to significantly improve current processes and outputs and shorten the time it takes for new products to become profitable. The operations in the fictitious digital factory are an exact duplicate of those in the real-world manufacturing facility. Engineers and designers may operate on the virtual digital factory in total isolation while adapting, changing, and testing improvements or additions without interfering with the operations of the present plant.
- ***Decentralization***: Industry 4.0 is made possible by decentralization, which enables the various systems in the intelligent factory to make decisions independently and by the overall organizational goal.
- ***Modularity***: Smart factories can quickly adapt to changing circumstances and needs because of their modular design. When it is time to replace, extend, or update a

particular product or production line, the impact on other products or production lines is lessened because of the modularity of items and manufacturing systems.

- ***Oriented Services***: Customers may be interested in services offered within or outside intelligent factories due to the Internet of Things. Services may be provided before or after the purchase of a product. One crucial element of the industry is the Internet of Services (IoS) (Davis et al., 2020).

The implications of Industry 4.0 for businesses

Data exchange and communication between companies and their customers, suppliers, manufacturers, and other supply chain actors are made more accessible by Industry 4.0. Urgent orders from customers may be successfully and effectively handled. Products' location and state may be monitored and controlled. Better product quality control is used, and improved inventory control. Equipment settings automatically vary depending on the materials used, the products produced, and other environmental circumstances. Customized items made for mass production take into consideration each customer's preferences.

It is also possible to accurately predict problems and monitor equipment remotely. Any business can use a flexible digital continuum to connect customers, partners, partners, and manufacturing equipment. Positive impacts of Industry 4.0 on customer experience, compliance, quality, and business operations (Mastos et al., 2020).

As a consequence, Industry 4.0-related technologies and solutions are revolutionizing industrial sectors all over the globe. Even though the life sciences industry often lags behind other sectors in its adoption of Industry 4.0, with proper planning, considerable advantages may be made. The potential is further increased by regulators' adjustments to the reality of Industry 4.0 and digital transformation. Other factors, including difficulties in hiring and the need to boost resilience, are also hastening the move toward Industry 4.0 solutions. It is also feasible to achieve a good return on investment using the advantages mentioned above. Continuous development with an Industry 4.0 emphasis is key to being competitive in a world that has undergone a digital transformation (Javaid et al., 2022).

IoT's Role and its initial Preparation in Industry 4.0

Industry 4.0 and its new technologies have questioned conventional inventory management strategies. An automated inventory management system's optimization objective is carried out by the storage agent (SA). In contrast to other traditional approaches, it used the Markov decision process (MDP) to solve ambiguous issues like "busy storage space" and "misplaced product." by utilizing IoT to track the location of components remotely (Yousefi et al., 2020). This may quicken shipping and manufacturing.

Additionally, it promptly alerts the warehouse manager and offers exact product status information. RFID tags can govern material movement within and outside intelligent warehouses, enabling superior inventory management and efficient warehouse scheduling (Pramanik et al., 2020). Innovative projects to automate and run warehouses using industrial wireless networks (IWN) have been started by some businesses. According to the report, IWN has many benefits, including increased mobility and flexibility and a labour force reduction. The constrained space of a warehouse can be efficiently organized using wireless communication technology. To avoid the limitations of wire networks and save time and money, Moxa classifies its products using RFID and wireless networks. Industry 4.0 implementation strategies vary from company to company. In other words, depending on the organization, Industry 4.0 will have different outcomes and solutions. Since Industry 4.0 technologies are still in their early stages, significant investment and research must be made in this area (Sinha & Roy, 2020b).

The key performance indicators (KPIs) for determining how Industry 4.0 technology would affect specific supply chain industries. Order fulfilment is one of the industries that would be most affected by implementing Industry 4.0 and tracking items with IoT and RFID tags, according to the study in the report. New technology has, more often than not, undeniably positive effects on this supply chain sector. Since inventory decisions can be included in a time-dependent model, it may be helpful in practice (Yasaman Mashayekhy et al., 2022b; Nara et al., 2021; Y. M. Tang et al., 2022).

Toward a Structured Implementation of the Internet of Things (IoT) in Industry 4.0: Methods and Requirements

The study provided an automated warehouse management system (WMS) implementation guide and instructions for a telecom company. This system uses Microsoft Visual Studio, barcodes, and a labelling line in the warehouse to display information on access, location, receipt, and expiration. The investigation's findings demonstrated that the inventory management system has become more affordable to operate and easier to obtain items. The use of technology also allowed the business to free up warehouse space. Not only would this save time, but it would also improve inventory management procedures. Real-time visibility and perfect inventory accuracy are made possible by the IoT. In order to quickly connect suppliers and orders to the integrated system, this study provided a framework for intelligent SCM that enables managers to dynamically monitor stock levels. The antiquated practice of manually reviewing inventory before barcoding all inputs into the ERP system has been replaced by new automated code acquisition technology. Intelligent shelving and pallets are the main components of smart inventory management in warehouse stocking. This approach—the blueprint for applying Inventory management using Industry 4.0 would make tracking and tracing goods in the warehouse quicker, more accurate, and more secure. In an intelligent warehouse, mobile devices might regulate the material flow. RFID, wireless sensors, and other enterprise-level middleware technologies are used in a specific IoT-based paradigm for inventory management decision-making.

An information platform also analyzes data to ensure inventory costs stay as low as possible. For the warehouse management system (WMS) to choose and prepare a docking space and set up the just-in-time and just-in-sequence delivery, transporters will be able to communicate with it about their location and expected arrival time. To implement Industry 4.0 technology, all stakeholders and participants in the supply chain must collaborate closely and coordinate at every point along the value chain. RFID sensors will simultaneously provide the delivery information. Additionally, they distribute the tracking data throughout the entire supply chain. The tags on the pallets will send signals to the WMS when the pallets are moved to a specific location, giving management real-time information about inventory levels and enhancing their ability to choose the settings needed to improve customer service levels. Manufacturing and logistics processes can be managed by converting a product into a smart object using RFID and universal plug-and-play (UPnP) technologies. Another study revealed a creative strategy for developing intelligent products and changing the manufacturing process to reduce energy consumption utilizing the idea of the industrial Internet of Things (IIoT) (Alias et al., 2017; Cimini et al., 2019; Lee et al., 2018; Li et al., 2022; Yasaman Mashayekhy et al., 2022b; Nantee & Sureeyatanapas, 2021a, 2021b; Nara et al., 2021; Y. M. Tang et al., 2022).

The objectives of digital security controls (DSC) are achieved by the reverse supply chain management (R-SCM) system, which is based on a heterogeneous IoT network. Intelligent containers are used to manage inventory, and a LoRaWAN context network using RFID and Bluetooth Low Energy (BLE) is used to inspect industrial facilities. Data intake, geographic dispersion, data size, and network latency were the four performance tests used to evaluate this system's performance. The warehouse management system employs mobile, highly automated, and adaptable robots. Using an Internet of Things (IoT)-based cyber-physical system, this could be fixed by designing a path for these mobile vehicles that are free of collisions (Cañas et al., 2020; Fernández-Caramés et al., 2019; Garrido-Hidalgo et al., 2019; Y Mashayekhy et al., 2022).

The Influence of IoT on Inventory Management in Industries 4.0

- **Spare Parts Manufacturing**

The transportation sector is being drastically changed by the Internet of Things, which has an impact on the supply chain for replacement components. The spare parts supply chain is becoming more crucial as more cutting-edge technology penetrates markets. IoT enables distribution centres, neighbourhood repair shops, and suppliers to retain greater control over when, how, why, and where replacement parts are utilized. To ensure that current technology and machinery continue to operate as intended, the Internet of Things has developed into a customer service centre. A semiconductor manufacturing company's smart inventory management system has allowances for both consumable and unforeseen spare parts. According to a KLM study, there are a number of problems with using the Internet of Things (IoT) to manage spare component inventories for maintenance, repair, and operations (MRO). Inventory costs and availability issues are reduced when IoT technology is applied to the inventory system for aeroplane spare parts.

Maintenance schedules and the requirement for replacement parts are estimated using IoT, machine learning, and big data analytics. When MRO replacement parts were employed in the automobile sector, disparities in patterns, lead times, and pricing were discovered, indicating the need for the Industry to utilize 4.0 technology to enhance inventory control (Fatorachian & Kazemi, 2021; Keivanpour & Kadi, 2019; Yasaman Mashayekhy et al., 2022b; Olsen et al., 2020; Winkelhaus & Grosse, 2020).

- **Agriculture Products and usage of IoT**

IoT may be utilized in the agricultural sector to monitor specific information from production through transportation for precision agriculture. It enables stakeholders to learn about the status of the inventory in real time. Cloud technology may be used to help the agricultural supply chain thanks to IoT. RFID-based technology was recommended in the research on agricultural logistics. The study looked at how RFID was used in agricultural productivity and how effective the system was (Hamdy et al., 2018; Yasaman Mashayekhy et al., 2022b; Maulana et al., 2021; Mostafa et al., 2019).

- **Food Industry and IoT**

Food firms may get real-time data on food safety through the Internet of Things (IoT), including information on carbon dioxide, heavy metals, humidity, temperature, transit times, and storage conditions. Informally, it is referred to as "active cold chain management" (Khan et al., 2020; Maheshwari et al., 2021a, 2021b; Yasaman Mashayekhy et al., 2022b).

- **Pharmaceutical Industry and IoT**

Studies on pharmaceutical supply chains show that using Industry 4.0 communication technology reduces the possibility of inaccurate demand forecasts and maximizes the use of warehouse storage space. The leading cause of pharmaceutical returns is that RFID makes it possible to calculate precisely when drugs are about to expire or have already expired. Information integration may reduce waste and promote sustainability in the reverse flow, which is crucial to supply chains for medicines and other perishable goods (Bader et al., 2022; Balas et al., 2020; Yasaman Mashayekhy et al., 2022b; Mostafa et al., 2020; Shah et al., 2019).

- **People with Disabilities and the Role of IoT**

People with impairments may have an easier time shopping in shops thanks to RFID through IoT-based inventory management. Disability-friendly lifestyles and more independent living are made possible by intelligent houses. IoT technology has made it possible for persons with disabilities to depend less on their caretakers (Bigliardi et al., 2020; Jeyanthi, 2018; Malik et al., 2021; Perussi et al., 2019).

Industry 4.0 and the Role of the Internet of Things in the retail industry

The expansion of Internet connection into real-world things, locations, and devices is known as the "IoT." The Internet of Things allows opportunities across various industries, including transportation, healthcare, the workplace, and retail. These two most popular IoT retail applications provide a broad overview of how this technology might be used in this field:

- **Data gathering and sharing:** To gather essential information about the entire product and purchase lifecycle, sensors may be used in retail IoT goods, locations, and devices. The store management uses this data to make decisions, enhance operations, and provide better customer service.

- **Acting based on collected data:** Machines and linked stores with IoT capabilities may be entirely or partly automated to improve retail operations and processes' effectiveness, sustainability, and resilience. The IoT has practically limitless potential; as a result, innovative applications have already been developed and integrated into the retail sector (Ashima et al., 2021; Balaji & Roy, 2017; Culot et al., 2019; Rejeb et al., 2020).

Conclusion

This paper examined how Industry 4.0 technology, notably IoT, would affect inventory management. A supply chain may be improved by becoming an integrated supply chain 4.0. Traditional inventory replenishment techniques must be more suitably responsive to new technologies, given the distinctions between fourth-generation technology and older generations, and they cannot manage IoT systems. The potential and trend of IoT technologies for sustainable inventory management were examined using literature reviews. Our findings show that numerous industries are doing more research in this area. This subject is receiving more attention from journals and publishing more articles. The main focus of this study is on the platforms and mechanisms enterprises use to adopt new technology. This subject is anticipated to get more attention since each organization needs a unique solution to change to a higher degree of high technology. Industry 4.0 increases the intelligence of manufacturing facilities, products, and supply networks while enhancing the responsiveness of industrial processes and services to customer demands. Through a brief analysis of industry 4.0 and associated technologies, this paper mentions potential changes in factories, products, customers, and enterprises in the context of the industry 4.0 environment. We looked at the features of Industry 4.0's production procedures and products and the benefits it provides businesses.

To be more precise, the article concentrated on optimization and inventory management systems. This study examined how Industry 4.0 could affect inventory management and optimization. Many businesses and corporations need help managing inventory efficiently and effectively. Due to the fact that every industry and organization uses a different method, this has long been a problem in industrial practice. Learning more about suppliers and consumers is necessary, or conventional modeling and optimization methodologies and approaches have limitations. There will be an increasing number of innovations in modelling, and optimization approaches and methodologies as Industry 4.0 is deployed and developed.

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