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Designing a SAAS Platform for Industry 4.0 Smart Manufacturing

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Abstract: The article discusses the concept of Industry 4.0 and its components, in the context of Software as a Service (SaaS) and the Internet of Things (IoT). It proposes a smart manufacturing platform built by utilizing web technologies such as AWS Cloud, React JS, Node JS, and MongoDB. The literature survey includes various research papers on integrating production systems into Industry 4.0 environments, the benefits, and challenges of implementing digital technology in manufacturing, and suggested frameworks for digital transformation and policy-based customization of workflow processes. The proposed system aims to optimize factory efficiency, improve production processes, enhance quality, and reduce costs through real-time data control, supply chain management, predictive maintenance, and remote monitoring.
Keywords: Industry 4.0, SaaS, IoT, Digital transformation, Smart Manufacturing

I. INTRODUCTION

We live in the age of technological progress, with the entire world innovating to become more digital, including the industries. The concept of "Industry 4.0" refers to the fourth generation of industrial revolution and digitization, during which, most manufacturing processes are being automated. Factory efficiency will increase, production workflows will be optimized, quality will be raised, and costs will be minimized because of the implementation of Industry 4.0. The ability to gather and analyze machine or sensor data allows factories to spot possible issues before they arise. They can reduce downtime and do preventative maintenance as a result.

Software as a Service (SaaS) is a cloud-based delivery paradigm in which users get software applications via the Internet rather than installing and running them locally on their devices. SaaS provides a wide range of business services such as real-time data control, supply chain management, predictive maintenance, and remote monitoring, a priceless tool for businesses working in the Industry 4.0. SaaS is being adopted increasingly in Industry 4.0 applications.

Internet of Things (IoT) is also a critical component of Industry 4.0. The connectivity of physical items like machines, cars, and other embedded objects with sensors, software, and network connections that enable them to gather and transmit data constitutes the Internet of Things. IoT is crucial to Industry 4.0 because it enables machines and systems to interact, share data, evaluate data in real-time, and make independent choices.

This paper describes a system that includes a SaaS platform built for smart manufacturing. Section II includes a literature review on current research and technologies used in the field of Industry 4.0. Section III includes information about the proposed system, methodology, and more details. Section IV investigates the outcomes of the proposed system. The article concludes with a summary and a look at its future.

II. LITERATURE REVIEW

A method for integrating current production systems into an Industry 4.0 environment is presented in Paper [1]. The information model-based automation structure and the information pyramid of automation are shown, and it describes the state of the art. The term "Cyber-Physical Production Systems (CPPS) Enabler" is also used by the author. This idea explains how to locate and establish links to current production systems as well as how to communicate with them, gather data, and transmit it. The notion of CPPS enabler is validated in the paper's conclusion, and the CPPS information server is demonstrated. In [2] article, important characteristics of cloud computing, such as extensibility and multi-tenancy, are studied. It suggests a SaaS platform for multi-tenant service implementation. It also suggests a structure for managing and developing its applications. Additionally, it draws attention to key cloud and clustering features. Additionally, it makes suggestions on how to deploy the SaaS architecture for multi-tenant applications.

Research on the difficulties and needs of maintaining Industry 4.0 is addressed in paper [3]. For Industry 4.0, it offers the features that a computerized maintenance management system possesses. By reviewing the newest technology, it offers a technique to enhance maintenance performance.

The report also includes several management styles that adhere to European norms. The author goes on to list additional maintenance-related problems faced by Industry 4.0, such as a lack of requirements, stock relevance, data scarcity, specialized knowledge, complex technological processes, and a lack of integration. The author offers a collection of recommendations for creating intelligent management systems, along with advice on how to configure and use them. A summary of the research on Industry 4.0 and smart manufacturing is given in the [4] paper, with an emphasis on how digital technology can be used to enhance production methods. The absence of uniformity and the requirement for specific expertise are just two of the major difficulties the authors list facing manufacturers when applying these technologies. Additionally, they draw attention to the potential advantages of smart manufacturing, such as boosted output, decreased expenses, and higher-quality goods.

In the paper [5], the most recent technological developments in manufacturing were illustrated. The foundational elements of Industry 4.0, which provide the basis for a complete model of an Industry 4.0 factory, are initially discussed in this study. The seven Industry 4.0 pillars - cyber-physical systems, the Internet of Things, AI, machine learning, big data, robotics and drones, cloud computing, 5G and 6G networks, 3D printing, virtual and augmented reality, and blockchain were identified in this study. It goes on to describe the technologies that form the foundation of Industry 4.0. To fully realize the impact of the most recent technologies on the fourth industrial revolution, this paper also identifies the most recent technologies that are the foundation of the fourth industrial revolution and explains how all these technologies could be applied to Industry 4.0 factories.

Paper [6] serves as an industry-focused example of digital transformation. It suggested a conceptual framework for the digital transformation as well as its goals. The analysis suggested a thorough digital transformation approach. The implementation of digital transformation in business is also covered in order to remove any risks associated with misaligned goals or visions. A Model-View-Controller (MVC) framework is suggested in Paper [7] for the policy-based customization of workflow processes. Whole job execution is then modelled as aspects, which are then chosen from the library in accordance with logic used for policy-based adaptation. The suggested framework can automatically change a workflow instance based on the characteristics of the surrounding and running models.

III.PROPOSED METHODOLOGY

The MVC (Model-View-Controller) architecture pattern is used in the proposed system. MVC is a software design pattern that is frequently used in modern web applications. It's emphasis on the "separation of concerns" ideology helps to segregate the software's business logic and the presentation aspects into respective components. The Model describes the data storage and access methods. The View is in charge of visual representation of the data on the user's device. The Controller serves as the brain of the application, acting as the link between the model and the view. It gets input from the view, makes the necessary model updates, and then notifies the view of the updates. Applications become more modular and easier to maintain when using the MVC paradigm.

A. System Architecture

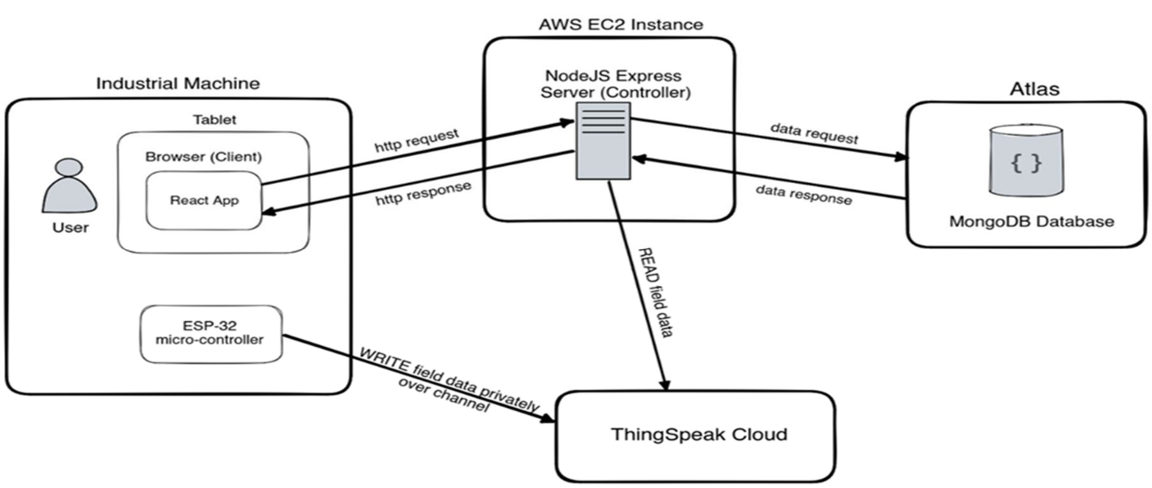

Fig 1. Proposed System Architecture

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The proposed application makes use of the MERN stack (MongoDB, Express JS, React JS, NodeJS). It is a well-known technology stack for developing modern web applications. MERN stack can be used in Industry 4.0 to create web applications that can be easily integrated with IoT devices, collect, and analyze data from sensors, and provide real-time insights into the manufacturing process. The technology stack is explained in detail further down.

React can play a critical role in modern and efficient user interfaces for industrial applications in the context of Industry 4.0. It is simple to integrate with other JavaScript libraries, frameworks, and tools used in the Industry 4.0 environment, such as Node JS, GraphQL, and Webpack. React is thus a versatile and adaptable choice for developing industrial applications. Node JS is well suited to Industry 4.0 because it allows developers to create scalable and efficient applications that process large amounts of data quickly. Node JS is a versatile and powerful technology that can assist manufacturers in Industry 4.0 in developing scalable, efficient, and dependable applications to improve their production process. A wide range of web-based apps, including IoT applications, creating APIs, cloud-native applications, and much more, can be created with Express JS. Sensors, IoT devices, and other real-time data sources are just a few of the sources of data that MongoDB can store and handle.

Scalable cloud computing resources are offered via Elastic Compute Cloud (EC2). Applications can be hosted in the cloud using AWS EC2. With the open-source IoT platform ThingSpeak, users can instantly gather, examine, and visualize data from sensors and other devices. Industry 4.0 makes extensive use of ThingSpeak to connect machines and enable smart manufacturing. Data from sensors can be transmitted to the ThingSpeak cloud over the internet by setting up a channel. This real-time data can be retrieved and used by web applications for a variety of tasks, including production analysis. Popular microcontrollers like the ESP32 are employed in a variety of industrial applications, including Industry 4.0. Manufacturers can monitor and manage the production process by integrating sensors and other IoT devices with ESP32.

B. Data Flow

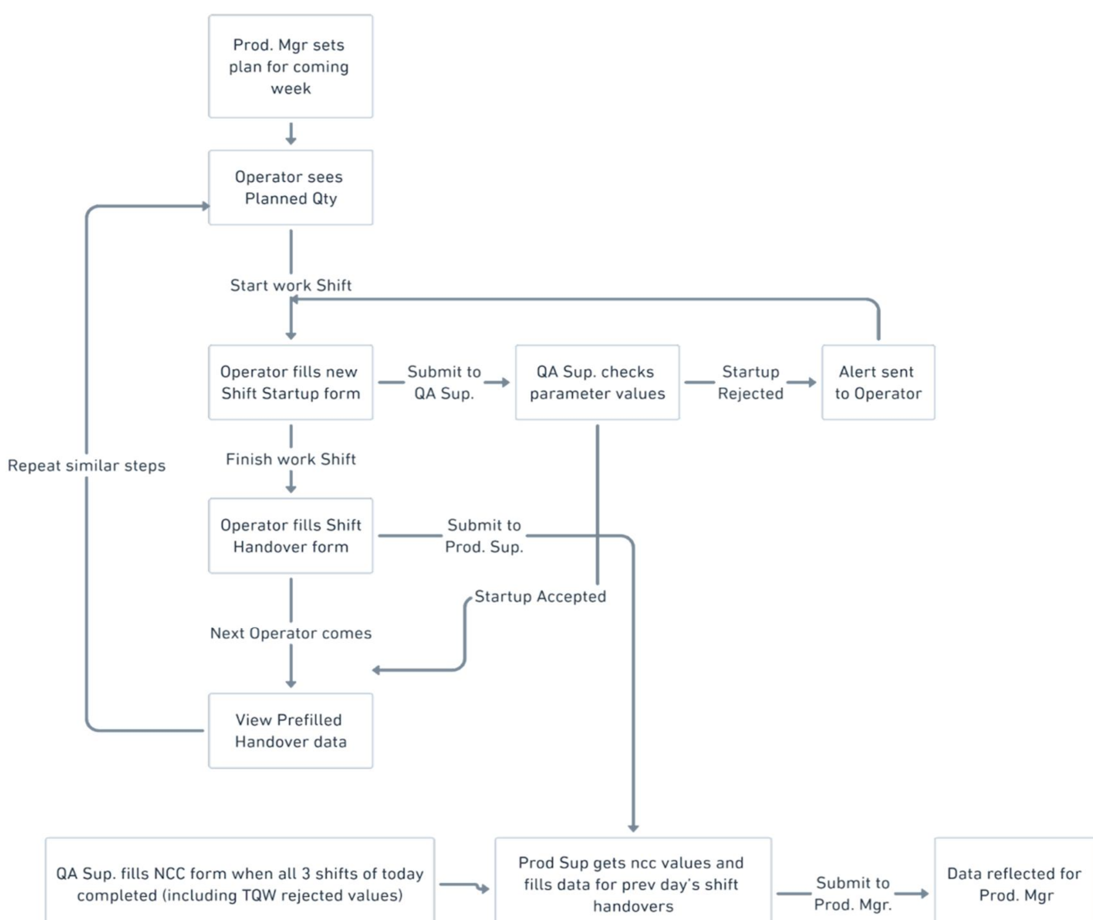

Fig 2. Data Flow

According to each company's requirements, data/user flow can vary. The data flow of our suggested system is depicted in the above image. Most organizations operate in a hierarchical fashion. There are operators, supervisors, managers, managing directors, and other positions in this hierarchy. Employees in various organizational hierarchies will thus utilize this system. Here is a more thorough explanation of the data flow.

The Production Manager creates a production plan according to the requirements of the organization. Machine operators will be able to see the production plan set by the production manager. Before starting the respective shift, operators will fill the shift startup form. Once it is approved by the QA supervisor, they will start their work. After completion of shift, they will fill shift handover form which consists of the details about the work they have done in their shift. This handover form will be submitted to the Production Supervisor. The Production Supervisor will collect data from all the operators and will submit them to the Production Manager. Production Manager will analyze, compare the actual production with target production and send the report to the higher authorities which includes GM/MD. This pretty much sums up the data flow of our proposed system.

C. Alert System

Alert System can be used to monitor production processes and notify workers of any issues that may arise, such as machinery breakdowns or quality control problems. It can be used to inform workers about various things such as change in production schedules or other critical information which can allow workers to respond quickly. We proposed two types of alerts, Instantaneous & QRCI. They are explained below:

1) Instantaneous Alert

Instantaneous alerts are an important aspect of any system that requires timely notifications to users. In the case of this particular system, two different methods are used to provide these alerts depending on the user's login status. When a user is logged in, a pop-up is shown using the Socket IO library to establish a bidirectional connection to the server. This allows for a seamless and immediate alert to be displayed directly to the user. On the other hand, if the user is logged out, email and SMS alerts are sent using NodeMailer for email and Twilio for SMS. These alerts are sent to ensure that the user is notified of important events, such as a startup form being rejected, which would prevent them from continuing with their work. By utilizing both pop-up and email/SMS alerts, this system ensures that users are promptly notified of any critical events.

2) QRCI

QRCI (Quick Response Continuous Improvement) is a system that allows for the efficient detection and resolution of issues within a plant or production line. When an issue is detected by an operator, they initiate an alert describing the problem. If the issue is not resolved within a small interval, typically around 60 minutes, the operator's supervisor is alerted. As the severity of the issue increases, more higher-level authorities are involved via alerts, with the manager being informed next. Once the issue reaches a major severity, a Plant QRCI is created from that Line QRCI. This new QRCI follows a similar escalation process as the Line QRCI, but with longer intervals and more higher-level authorities involved as the issue worsens. By implementing this system, the plant or production line can ensure that issues are detected and resolved quickly and efficiently, with appropriate stakeholders being alerted as needed to prevent major disruptions or damage.

IV. RESULTS

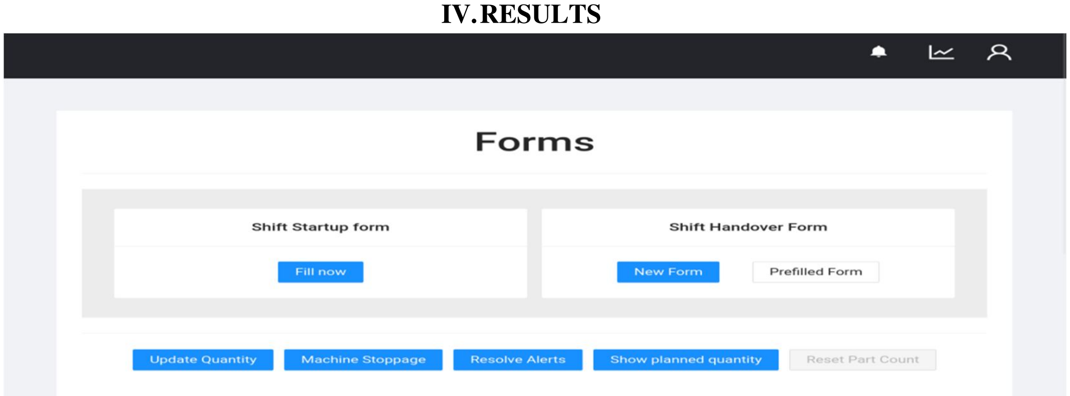

Fig 3. Operator Screen

Operator Screen (Fig. 3) consists of Shift Startup Form, Shift Handover Form and other tabs such as Update Quantity, Machine Stoppage, Show Planned Quantity, etc. Operator fills Shift Startup Form before starting shift & Shift Handover Form after completing shift. Show Planned Quantity contains a plan for a particular part i.e. number of parts to be made. Machine Stoppage can be used when a machine gets stopped due to various reasons.

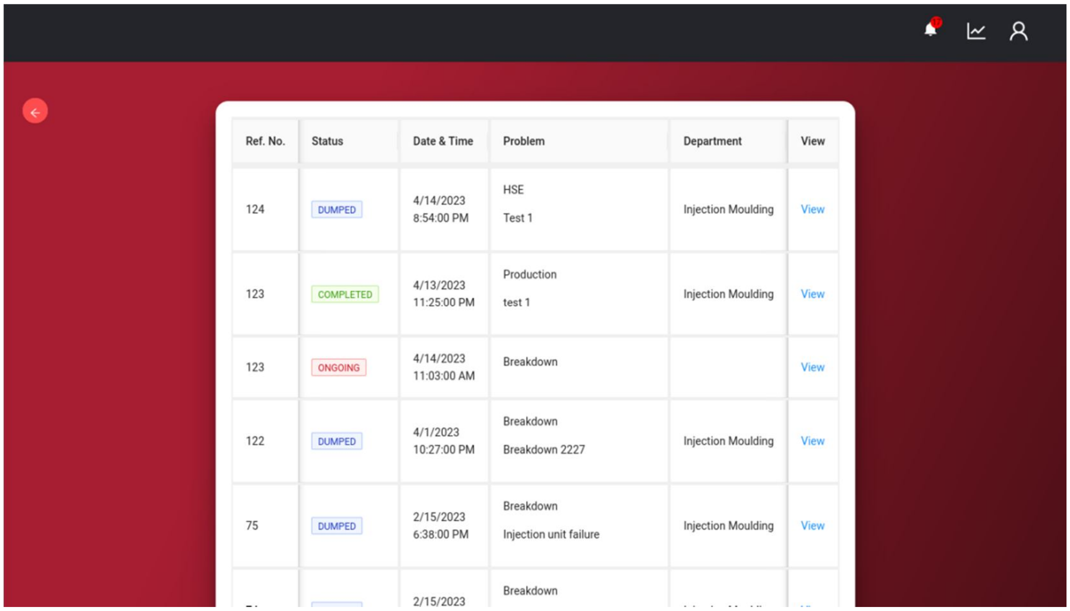

Fig 4. All Line QRCI Information

Line QRCI Information(Fig. 4) contains status of QRCI(Resolved, On-going, Aborted etc.), Generated date & time, Problem, Department, etc.

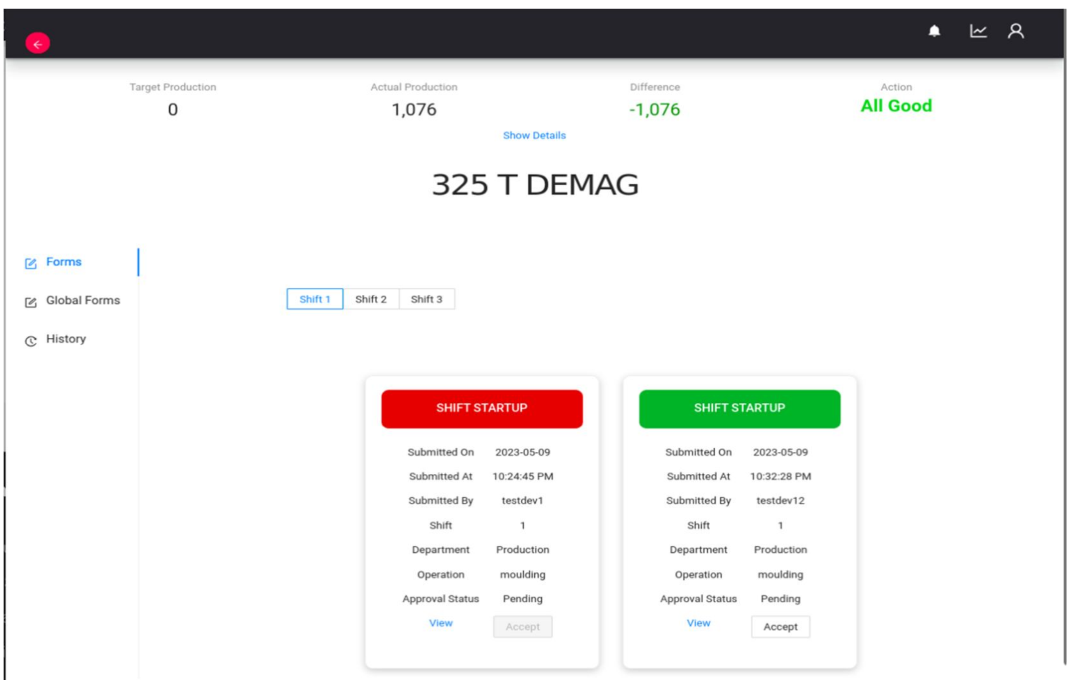

Fig 5. QA Supervisor Screen

Shift Startup Forms filled by Machine Operators are visible shiftwise. QA Supervisor can view the details and approve/reject the form. Operators can start shift only after approval from the QA Supervisor.

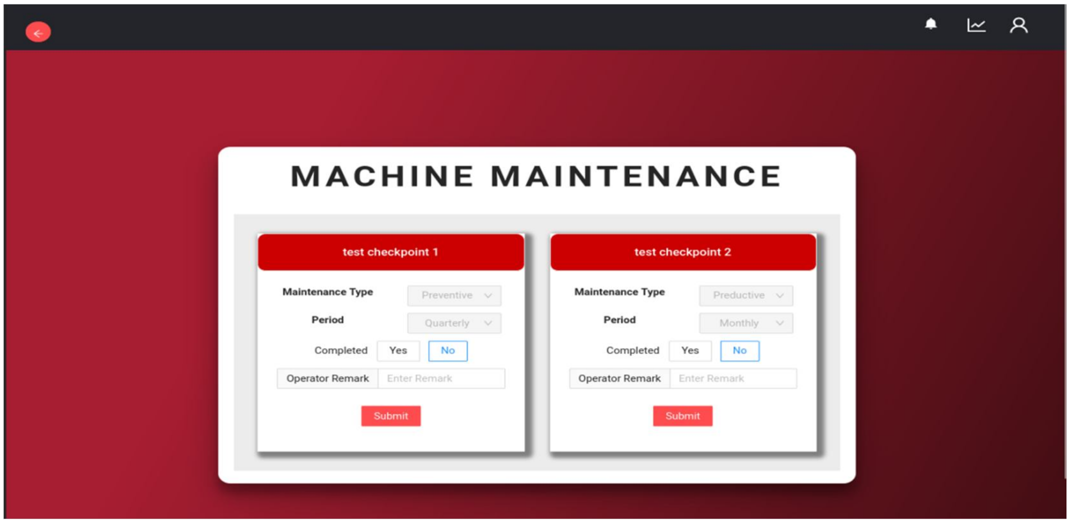

Fig 6. Machine Maintenance Screen

Maintenance Checkpoints of machines are generated from higher authorities. Checkpoints include Oil Check, Routine Maintenance, etc. The Maintenance Operator carries out the maintenance and submits the details to higher authorities.

V. FUTURE SCOPE

As the world is moving towards digitization, industries are also adapting to new technologies. The proposed system will optimize factory efficiency, improve production processes, enhance quality, and reduce costs through real-time data control, supply chain management, predictive maintenance, and remote monitoring. The integration of SaaS and IoT technologies in Industry 4.0 has been gaining traction in recent years, and this trend is expected to continue. The demand for digital transformation in the manufacturing industry is increasing, and SaaS platforms provide an efficient solution to achieve this goal.

The proposed platform can be further enhanced by incorporating emerging technologies such as Artificial Intelligence (AI), Machine Learning (ML), and Blockchain. The integration of these technologies can help in automating processes and making decisions based on real-time data. Additionally, the platform can be customized to meet the specific needs of different industries, leading to an increase in its adoption rate. Another potential future scope for the proposed system is to expand its reach beyond manufacturing industries. The platform can be adapted to meet the needs of other industries such as healthcare, transportation, and logistics, where real-time data control, predictive maintenance, and remote monitoring can play a vital role in optimizing efficiency and reducing costs. Overall, the future scope of the proposed system is vast, and it has the potential to revolutionize the way industries operate in the digital era.

VI. CONCLUSION

This paper discusses the implementation of Industry 4.0, which is the digitization of industrial processes. The implementation of Industry 4.0 has been facilitated by the use of Software as a Service (SaaS) and the Internet of Things (IoT). SaaS is a cloud-based delivery system that provides real-time data control, predictive maintenance, remote monitoring, and supply chain management, all of which are essential in Industry 4.0. IoT, on the other hand, enables machines and systems to interact, share data, and evaluate data in real-time. The article describes a smart manufacturing platform built on SaaS and proposes the use of AWS cloud, React JS, Node JS, and MongoDB in its implementation. A literature review of current research and technologies in Industry 4.0 is also presented, discussing the challenges and needs of maintaining Industry 4.0 and highlighting the potential advantages of smart manufacturing, such as increased output, decreased expenses, and higher-quality goods. The research papers reviewed in the literature survey present various methods and frameworks to integrate and manage Industry 4.0.

VII. ACKNOWLEDGMENT

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