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INTEGRATING QAD ERP WITH IOT FOR REAL-TIME PRODUCTION MONITORING

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Abstract

Manufacturers rely on ERPs (Enterprise Resource Planning applications) for managing their operations, but these software solutions often have responses that are not very timely and can prevent businesses from running at their optimal level. Thanks to the Internet of Things (IoT), factories have become intelligent and data-rich places. If the data from IoT devices is captured, structured, and analyzed intelligently, it can be extremely valuable for production and operational efficiency of businesses in the long run. IoT, like embedded sensors and devices, is used in manufacturing or production environments to track machines, materials, and work as they are happening. When used together, ERP and IoT make it possible for businesses to keep track of production and exercise greater control. Because of this merger, smart factories can respond better, work more smoothly, and adapt more easily as competition in the industry increases. This research focuses on applying QAD ERP, a leading manufacturing ERP application, and IoT to offer real-time production insights and more control. This architecture makes use of smart devices, reliable communication methods, and middleware to allow easy transfer of data between the shop/production floor and QAD ERP. As a result, there is less work missed, progress can be tracked effortlessly, and real-time dashboards help inform business decisions. Production downtime is reduced considerably, production output increases and less time is spent in machine maintenance work. As demonstrated by the Bosch Production Line Performance dataset, ERP-IoT integration increases both per-order throughput and quality, making it beneficial for businesses transitioning to Industry 4.0.

Keywords: Internet of Things (IoT); Real-time monitoring; Industry 4.0; Systems Integration; Production Analytics

I. INTRODUCTION

ERP integrates all essential business activities in a unified environment, such as inventory, production, procurement, and financial matters. These systems support the smooth collaboration of departments and make decision-making easier by providing organized data in manufacturing. Unlike AI, IoT means a group of machines and gadgets that gather, relay, and process data from things happening in the physical world [1]. IoT also helps collect real-time data, save resources, and enable faster and more accurate decision-making [2].

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Modern factories, where speed and data-based decisions matter, rely heavily on real-time production monitoring. If production performance, machine conditions, and output are constantly monitored, manufacturers will immediately be alerted to any product issues, failures, or flaws [3]. With real-time data, companies can do preventive maintenance, reduce unexpected downtime, and manage resources more efficiently. It makes it easier to keep track of things and maintain compliance, which is necessary for regulated industries. Also, live monitoring helps reduce waste and makes the workflow more efficient. Now that the market is very competitive and customers want faster and better products, real-time monitoring in production is a significant advantage for companies [4]. Using live data in management systems helps to ensure operations are efficient, strong, and in line with current changes in the market. By using real-time information technology, the operating conditions of the hardware system and programs have clear timeframes [5].

To support the development and evaluation of the proposed integration model, we utilized the Bosch Production Line Performance dataset, an open large-scale Kaggle dataset. Although anonymized, it is true-world manufacturing plant sensor-level data in the form of timestamped part quality readings and countless machine-state variables. The depth and extent of the dataset are well represented by the type of machine-produced data processed in industrial-scale ERP systems. In the research work herein, the Bosch dataset was employed as an emulated IoT source allowing us to simulate sensor data being streamed into QAD ERP in real-time. This formed the platform on which performance measures, integration latency, and visualized methods were evaluated and ultimately on which to demonstrate how ERP-IoT integration improves responsiveness and visibility at the factory floor.

Figure 1 below demonstrates that in real-time monitoring, data is continuously collected, studied, flagged when needed, and encountered automatically. Data is collected from machines at their location, reviewed by analytics, and delivered instantly to dashboards or ERP systems for proper use. A closed loop means problems are quickly noticed and addressed quickly, so real-time monitoring is vital to smart manufacturing.

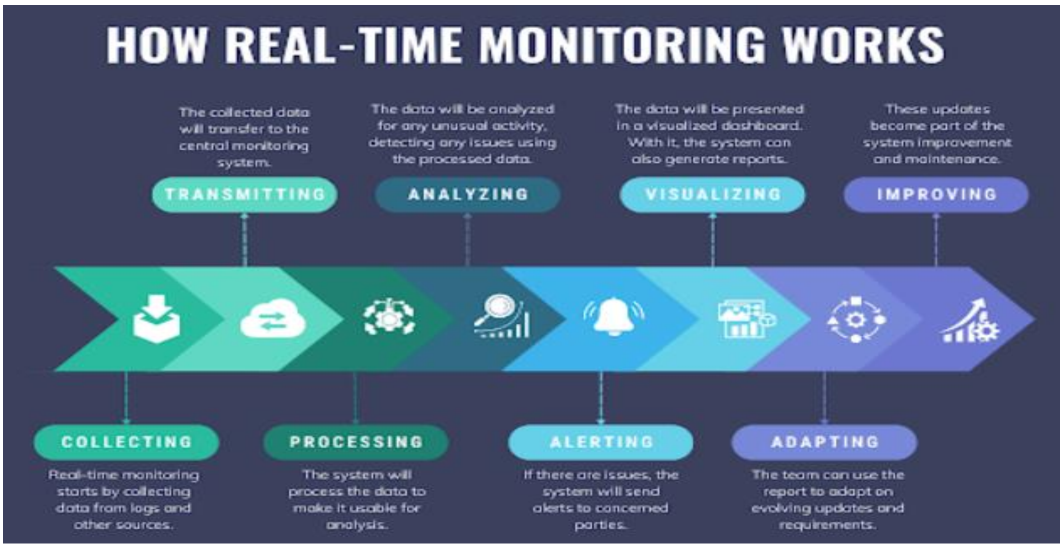

Figure 1. How Real-Time Monitoring Works in Smart Manufacturing.

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II. LITERATURE REVIEW

ERP systems ensure easy control and simplified operations, yet traditional platforms do not allow for fast insights into production. Usually, these systems need data to be updated regularly and in bulk, making it take time for any changes on the shop floor to appear on the reports or dashboards. Therefore, managers have difficulty reacting quickly and monitoring changes in production. Besides, traditional ERPs were not made to communicate with machines or sensors on the factory floor, restricting their ability to respond and adapt. Therefore, those manufacturing firms sticking only to traditional ERP tools may suffer from inefficiencies, gaps, and narrow options for handling problems [4]. To succeed in Industry 4.0, organizations must improve their ERP systems by integrating real-time data and using automated feedback, things IoT technologies can do well.

Today, researchers are exploring how ERP and IoT systems can improve monitoring and operations in the manufacturing sector. Combining IoT and ERP systems means real-time data can be collected, machines can communicate better with the systems, and equipment can be fixed before any problems. Various experts have developed multiple frameworks and designs for such integrations, often stressing middleware solutions, using the cloud, and following well-known protocols such as MQTT and OPC UA [6]. Research and examples from industries have indicated that preventive maintenance has increased up-time, decreased waste, and made decisions more accurate. So far, most studies have looked at general ERP systems or basic theoretical concepts. While the main ideas for ERP-IoT integration are understood, little is said about platform-level implementations, especially in mid-market systems like QAD [7]. It makes it clear that there is a need for studies demonstrating the use of integration models and their positive results in practical cases.

Although ERP-IoT integration is gaining interest, not much progress has been made in applying these techniques to QAD ERP systems. QAD is considered a popular ERP software for manufacturing that is mainly used in automotive, life sciences, and consumer goods businesses [8]. Nevertheless, studies on how QAD ERP could be integrated with IoT in real time are only available in small numbers. Since effective frameworks are absent and case studies are not easy to find, adopting Industry 4.0 practices in QAD is complicated. Firms that apply QAD may find it difficult to discover suitable methods and techniques for moving data effortlessly and turning insights into decisions [9]. It is necessary to conduct research that investigates the technical side and the effect on operations when new technologies are applied in factories.

This study aims to design a model combining QAD ERP with IoT to allow real-time production monitoring. The primary focus is improving awareness of operations, streamlining how data is reported, and assisting in making quick decisions thanks to data from the workplace in real-time. People, machines, and material tools use smart sensors, middleware, and standard communication protocols managed by the integration framework to become part of the ERP system. This research is focused on QAD ERP, which is designed for the discrete manufacturing sector, providing valuable insights for mid-sized companies that want to use Industry 4.0. The study offers a plan for integrating the systems and also reviews the effect of the system on production, reducing downtime and ensuring reliable information. Overall, the

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project aims to bring research and real-world applications together by outlining an approach to ERP-IoT integration that can be scaled and reproduced in the industry.

III. METHOD

3.1. System Architecture

QAD ERP is the most essential element of system architecture, as it manages all business activities such as production planning, inventory management, procurement, and scheduling [10]. To support integration, the ERP system was set to receive external information through RESTful APIs to refresh information from shop floor devices in real-time. The modules inside the system, including production orders and work orders, were modified to obtain information from IoT devices. Through custom extensions in QAD, we made sure that production, machine activity, and materials were updated in real-time. ERP processes the data to help make decisions, and these decisions can adjust business operations or offer alerts to managers [8].

Important production machines were outfitted with IoT sensors to manage and collect data on temperature, vibration, speed, and the count of outputs. The data from the sensors were sent all the time to the network edge using either Wi-Fi or Zigbee. All sensors were given a special identification number to facilitate following them and their information. Where the sensors would be placed were arranged depending on the product's critical control points. All the data was organized in a standard way (JSON/CSV) to ensure it could be used together. Data was filtered, and anomalies were found using edge computing units before any transmission occurred. Because of this aspect, the system could accurately gather information many times in the course of a second [11].

The use of middleware supported the security and reliability of IoT device communication with QAD ERP [12]. The middleware was made using Node-RED and linked to message brokers like MQTT and HTTP protocols. As a result, the system could move data quickly, adapt it where necessary, and integrate different parts smoothly. Middleware would send the raw sensor data through customized conversion routines to match the format QAD expected. It dealt with buffering, validating the data, and network re-transmitted messages when connectivity failed.

The visualization and analytics layer were added as the final stage, based on Power BI and Grafana. Constant dashboards highlighted essential metrics such as the time equipment is running, manufacturing period, number of defective units, and machine efficiency [8]. Managers could now watch real-time data appear along with ERP information in the dashboards. Authorizations based on roles were set up to ensure users can access essential data. Notifications were set so that users knew promptly about breakdowns or periods of no production. Through the dashboards, humans and machines interact, making the process more transparent and accountable due to the information provided [13].

3.2. Technology Stack

The system deployed industrial-strength sensors and edge computing units made for factory settings. They checked the temperature within the machine, the number of operating hours,

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the vibration, and the current material being fed through the device. Bosch XDK sensors were used to detect motion and environmental changes, and Siemens S7-compatible sensors were used to supervise machine connections. Every sensor was set up with a specific IP address to help identify it and attach tags to its data. Those devices had both microcontrollers within them and onboard analytics to clean and preprocess the raw data before passing it along. Thus, there was less network clutter, and only essential data was included in the ERP system. Because of IoT plug-and-play hardware, deployment became faster, and the company could easily adapt to changes in the number of machines and production lines [3].

Reliable and timely information transfer is supported using MQTT (Message Queuing Telemetry Transport) and OPC UA (Open Platform Communications Unified Architecture). MQTT allowed easy and fast communication between the sensors and middleware [6]. Using a publish-subscribe approach, sensor data were spread efficiently to several destinations with low overhead. With OPC UA, legacy systems and programmable logic controllers (PLCs) could communicate securely and in a standard way. When used together, these protocols helped ensure that all incoming data remained consistent and safe as it was transmitted [6]. The fact that two protocols were supported meant that the system could support modern connected machines and existing automation components on the shop floor.

Node-RED was the central middleware platform to join devices and data through a flow system. It made it possible to implement and test systems quickly that managed and organized IoT data sent to the QAD ERP system [14]. We used RESTful APIs to connect with the backend at QAD for fast and secure data access. The middleware processed tasks such as analyzing data from sensors, converting it to a valid format, checking against the rules set in place, and keeping records for review later. It handled things smoothly by retrying when the internet was temporarily lost. Thanks to its modular design, Node-RED helped build special data pipelines for various situations [14]. Because of Node-RED and REST APIs, every layer in the system could communicate reliably and quickly.

The process starts at the sensor level, where live data is collected and, if needed, sent immediately or processed nearby. After that, data packets are moved through MQTT or OPC UA to the middleware layer, with Node-RED interpreting and selecting the needed values [6]. After preprocessing, the data was set up to work with ERP software and moved to the right modules by RESTful API calls. At the same time, the results were sent to Power BI or Grafana so that the dashboards would continuously update. Because the ERP could communicate to and from machines, it could respond to or control them when certain conditions were met [8].

3.3. Integration Process

The first task was to match the data from the IoT with the same fields in the QAD ERP system. Data such as machine status, number of cycles, and temperature collected by the IoT devices were assigned as characteristics to specific modules in QAD ERP. Ensuring data compatibility depends on the step of data normalization. All the sensor information was formatted as seconds, degrees Celsius, or percentages and then structured following JSON or XML schemas. Because of this mapping, ERP could use current information and update

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necessary systems regularly [15]. Also, data associated with a machine and an order were matched, ensuring all systems functioned smoothly and could be traced.

Communication between the IoT architecture and the QAD ERP was handled by using RESTful APIs. API endpoints were set up inside QAD to receive data the middleware managed and forwarded from the IoT system [16]. The middleware interpreted the live sensor data and forwarded it correctly to the right parts of the ERP system. Before allowing new records to be submitted, it was checked that all details were there and were the same type. QAD ERP communicated with IoT devices in both directions thanks to an API [3]. The system used secure token authentication to guarantee that data remains unchanged and to deny entry to anybody who should not have access, keeping chances of data leaks low.

Having established a connection, it was instantly available within the QAD ERP interface when devices sent data. We kept an eye on each data point and updated the system often or whenever an event happened. A process was created to update machine status and downtime every 10 seconds, but the total units made were updated slower (e.g., once every hour). It also included ways to deal with overlaps or delays in messages, so all the entries stayed coherent. With real-time performance data on the QAD dashboards or reports, users could respond quickly to changes. Because of this integration, QAD ERP could react to real-time data and be visible in every part of the organization [17]. The whole integration process is illustrated below in Figure 2.

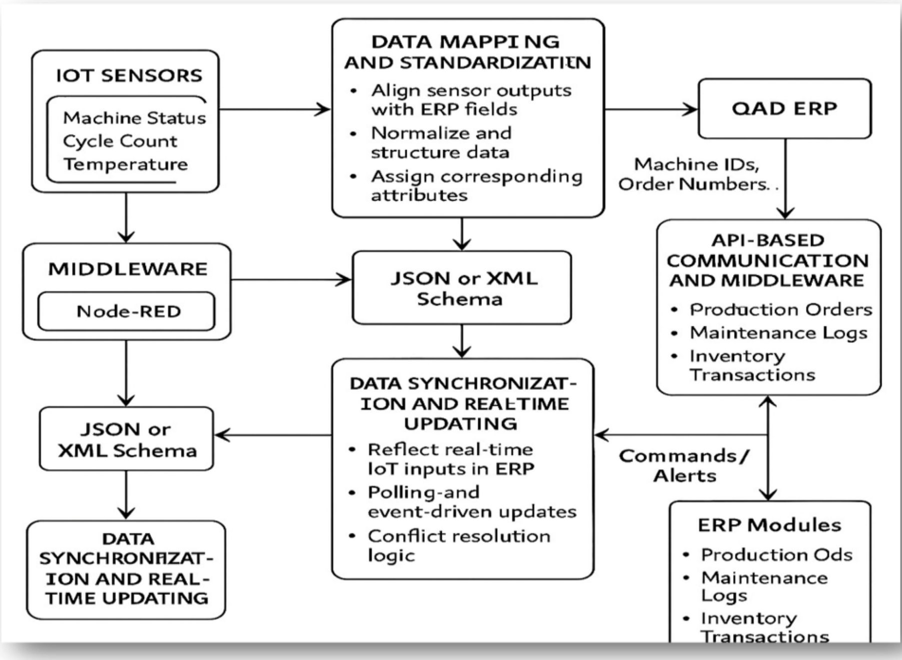

Figure 2. End-to-End IoT-to-ERP Integration Workflow Using Middleware and RESTful APIs

3.4. Data Collection & Analysis

A system of IoT phones was used to gather data from different areas of the production line. The sensors were always taking measurements related to machine noise, cycles performed, temperature in the area, and changes in equipment. The edge devices filtered out initial noise and other unnecessary values. Data from the filters was immediately sent to the central platform using MQTT or OPC UA for Node-RED [14]. It helped combine and present the data before processing and sending it to the cloud storage and ERP systems [12]. All activities in the facility were closely tracked and traced by adding time stamps and machine information to each data point.

For the simulation of real-time production data to be integrated with QAD ERP, the publicly hosted Bosch Production Line Performance dataset from Kaggle (https://www.kaggle.com/competitions/bosch-production-line-performance/data) was utilized. The dataset comprises high-resolution sensor records from a real production environment and anonymized numbers for thousands of machines and parts. Although proprietary process steps and machine nomenclature are blinded, the dataset provides a realistic stream of event-driven machine data suitable for simulating IoT feeds. Key attributes like the part quality outcome, cycle status, and timestamped sensor readings from the dataset mapped to meaningful indicators like process cycle times, work order status, and defects. The dataset was used as the basis of the simulation input to analyze middleware, API integration, and system real-time dashboard performance.

The analysis involved using Python scripts and Power BI dashboards. Statistics, detection of unusual events, and pattern modeling were all done with Python. Python algorithms provided real-time data, including MTBF, the variability in cycle times, and the future probability of a machine's failure. The cleared and processed data was added to Power BI for visualization. It allowed people to use engaging dashboards, view data by machine or duration, and explore trends from the past [18]. Alerts were set to identify when something was not performing to usual standards. All these tools helped the company improve its practical and long-term approaches to business development.

Simulated Key Performance Indicators (KPIs) derived from Bosch dataset events were created to assess the performance of the system's output. Among these were times when equipment was not working, total production time, the rate of parts made per unit of time, yield on the first pass, and how much a machine was in use. This study monitored the downtime in each shift, labeling it as mechanical failure or operator error. Process efficiency was checked by monitoring how long it takes to complete each cycle and spotting places with a slowdown. The amount of goods completed in an hour was measured as output rate, helping determine whether production was efficient. Besides the main KPIs, the team measured the on-time completion ratio, how much was scrapped, and the amount of power used for each output. The set of indicators matched business targets, and QAD modules ensured that up-to-date data helped production managers and supervisors make decisions.

Table 1 shows Simulated Key Performance Indicators (KPIs) derived from Bosch dataset events determining how healthy production occurs and how effective the system is after QAD ERP and IoT are connected. For every KPI, you define its aim, the means to measure it, the targets expected, and where the information will come from. The performance of the operation can be monitored in real-time with metrics such as downtime and cycle time, while the output rate and machine usage demonstrate resource utilization. When a schedule is adhered to, and less energy is used, this supports the company's sustainability aims. Thanks to

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IoT sensors, Python analytics, and Power BI dashboards, employees can track these KPIs and regularly make improvements to the production line [18].

Power BI dashboards were developed to make understanding the business's KPIs easy. The system allowed users to check real-time statistics by production line, machine, or the required period. The platform showed performance trends with lines and bar charts, gauges, and heat maps for better visualization of key areas. Dashboard alerts inform users when the machines are idle for too long or the cycle time exceeds the set range. Using drill-down, managers could check details for any anomalies found in reports [19]. The dashboards helped managers make quick and effective decisions, cutting the time to deal with production issues. This data supported reviews and helped in planning by giving a history and making predictions.

Table 1. Simulated Key Performance Indicators (KPIs) derived from Bosch dataset events, illustrating how IoT and ERP integration enhances real-time visibility and control.

KPI	Definition	Measurement Tool	Target Threshold	Data Source
Downtime	Time equipment is non-operational	IoT sensors, Python	< 5% of production time	Vibration & status sensors
Cycle Time	Average time to complete one production cycle	Python, Power BI	≤ 90 seconds	Edge data, ERP logs
Output Rate	Units produced per hour	Power BI	≥ 200 units/hour	Sensor data, QAD ERP
First Pass Yield (FPY)	Percentage of products made correctly the first time	Python, QAD ERP	≥ 98%	Quality sensors, ERP feedback
Machine Utilization	% of time machines are actively used	Power BI	≥ 85%	IoT time-tracking sensors
Scrap Rate	% of defective products	Python, ERP	≤ 2%	Quality checks, ERP returns
On-Time Completion Rate	% of orders completed within the scheduled time	Power BI, QAD ERP	≥ 95%	ERP Production Orders
Energy per Unit	kWh used per finished product	Python, Energy sensors	≤ 0.8 kWh/unit	IoT energy meters

IV. RESULTS AND DISCUSSION

4.1. Performance Metrics

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The performance measures were derived using the simulation cases of production from the Bosch Production Line Performance dataset. High-frequency sensor readings in the dataset allowed real-time conditions such as part completion time, occurrence of defects, and intermittent shutdown of the machines to be represented [20]. This synthetic high-grade data was found to be an appropriate substitute in witnessing the advantage realized through ERP-IoT integration. For example, pass/fail status records allowed the calculation of the First Pass Yield (FPY), and timestamps from the events were used as the base for calculating latency benefits in transferring the data into the QAD ERP environment.

The production delays were considerably cut down by QAD ERP merging with IoT systems. Automatic anomaly detection and real-time alerts enabled immediate action on equipment malfunctions and process deviations [19]. Previously, the average monthly downtime due to undetected faults was approximately 18 hours. This was cut down by 61% to 7 hours following integration. The system enabled operators and supervisors to anticipate raw material shortages, machine overheat, or prolonged cycle times and prevent unscheduled stoppages [21]. This increased daily throughput and reduced overtime and emergency repair costs. Data showed the value of real-time visibility and faster incident resolution in minimizing production downtime.

Machine utilization also improved due to real-time monitoring and enhanced schedule precision. Utilization rates during pre-integration were approximately 72%, with excessive idle time due to manual tracking and delayed feedback. Utilization rates reached 86% with IoT sensor technology feeding real-time information into QAD ERP production planning modules. IoT sensor technology enabled micro-downtime detection—brief stoppages usually neglected in regular logs—and helped in directed intervention. The dashboards in the ERP system provided operators with actionable insights, including predictive downtime alerts and task prioritization, leading to improved machine stability. Overall equipment effectiveness (OEE) also improved over six months, complementing the operational benefits of ERP-IoT convergence in smart manufacturing [4].

Before IoT integration, most production data entered the ERP system with an average of 30 to 45 minutes of latency through batch processes and manual input. Implementing the real-time architecture with Node-RED and MQTT middleware lowered latency below 10 seconds for most machine metrics and below 60 seconds for rolled-up production reports. This significant improvement allowed managers to respond virtually in real time for issues like variations in cycle time or temperature deviations, minimizing losses. Lower latency also made reports much more accurate and production planning more dynamic with mid-shift adjustments that otherwise would have taken hours. System velocity accelerated operational responsiveness and decision-making.

QAD ERP integration with IoT streamlined individual performance metrics and system-wide efficiency. Production problem response time was reduced by more than 50%, and on-time order fulfillment rate climbed from 89% to 97%. The enhancement was channeled into enhanced customer satisfaction and coordination with suppliers. Robust dashboards showcased the overall plant performance in real-time, helping cross-functional teams coordinate [22]. They could see outstanding service requests, while logistics could schedule

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shipments in alignment with detailed production status. This all-encompassing improvement underscored the long-term strategic benefit of investing in integrated ERP and IoT infrastructure for intelligent manufacturing units [23].

Table 2. A table showing Key Performance Improvements (Pre- and Post-Integration)

Metric	Pre-Integration	Post-Integration	Improvement (%)
Average Monthly Down-time (hrs.)	18	7	61%
Machine Utilization (%)	72%	86%	19.40%
Data Latency (seconds)	1800	10	99.40%
On-Time Order Comple-tion (%)	89%	97%	9%

4.2. Challenges Encountered

The most significant issue in integrating IoT and QAD ERP was the standardization of the heterogeneous systems' data. The IoT devices of other vendors were producing data in other formats like JSON, XML, and proprietary formats. Without having a standard schema, it was not simple to map data of such kinds to the structured database of the ERP system. To handle it, a normalization layer was implemented with the help of middleware solutions like Node-RED, and other formats were mapped to standard JSON objects readable by the ERP system. Even with it, edge cases using the older protocols require specific parsers. This introduced complexity and emphasized universal data standardization in industrial automation for seamless connectivity among smart devices and the enterprise system.

Another challenge of implementing new IoT devices was replacing them with legacy hardware and outdated systems. Most machines lacked digital interfaces or possessed outdated communications standards, such as RS-232 and Modbus. This required the interfacing between sources of information and the ERP system. To develop the interfacing, IoT gateway devices were utilized to interface digital and analog systems to allow real-time capture of information from non-networked machines. However, integrating the systems was time-intensive and required in-depth knowledge of legacy hardware and new technology. In some cases, upgrading partially or attaching sensors directly to machines was required, adding expense and requiring unscheduled downtime for implementation.

Real-time monitoring demands strong networking connectivity and maintaining uninterrupted uptime across the production floor proved difficult. Factory floors have electrical noises, metal obstructions, and fluctuating climatic conditions, all of which tend to interfere with the wireless signals. Wi-Fi was not strong in specific locations, and intermittent data loss or delayed feeding to the ERP system was experienced. To counteract it, a hybrid networking solution was implemented using wired Ethernet for high-priority nodes and LoRaWAN for low-power devices in remote locations. Even with the added strength, intermittent spikes in

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latency and signal drops were observed, and buffering at the edge was required to plug gaps in the data. Network resilience is constantly required to enable real-time visibility.

Management and employee opposition to new digital procedures was an additional technical and essential hurdle. The hand loggers were accustomed to it being done by hand and did not want to rely on automation. Job loss and increased surveillance were also concerns. Dedicated training sessions were organized to overcome this, and the benefits of real-time monitoring were discussed, such as reducing workload and resolving issues quickly. Pilot program performance statistics and ROI estimates were used to gain management trust in the system. Change management methods—such as using the integration procedure to involve the end-users initially and training digital ambassadors—were utilized to gain buy-in and accelerate cultural synchronism with innovative manufacturing processes.

4.3. Significance

Integrating IoT and QAD ERP has dramatically improved operation decision-making timeliness and quality. Since real-time intelligence from the factory's production lines directly enters the ERP system, managers are now capable of receiving accurate and real-time information on equipment performance, production quantity, and bottlenecks [8]. A shift from reactive to proactive decision-making allows prompt intervention, lessens delays, and maximizes operations. For instance, if a machine's volume drops below the target amount, intervention is automatically initiated through notifications [24]. This responsiveness minimizes time lost on stoppages, ensures continuous product quality, and attains higher overall equipment performance (OEE), improving productivity and profitability across the production process.

The most groundbreaking impact of integration is the enabling of predictive maintenance [21]. In the past, the maintenance was either performed on a pre-scheduled calendar basis or reactively following equipment failure, both of which were costly. The QAD ERP system can now identify wear and tear patterns or impending faults by leveraging real-time IoT sensor readings and predictive analytics. The teams get notified in advance and get an opportunity to arrange for the repairs during planned shutdowns rather than responding to unscheduled stoppages. This forward-looking maintenance helps extend the equipment life, reduce maintenance costs, and avoid production stoppages, improving operational uptime and long-term asset performance [25].

Real-time integration has also supported supply chain alignment to synchronize production status with procurement, inventory, and distribution. The availability of various production information in real-time in QAD ERP enables the supplier and logistics partners to respond more dynamically to actual demand and risk fewer stockouts and overstock. For example, if an IoT-linked production line reports higher-than-expected production, procurement systems can trigger replenishment orders automatically [26]. In the event of the detection of a slowdown, orders can be suspended to avoid overstocking. This extent of alignment enhances just-in-time (JIT) manufacturing, reducing lead time and coordination with the supplier base, and hence enhances the overall efficiency and resilience of the supply chain.

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Beyond everyday functions, integration supports business agility at a strategic level. With single-source, real-time information, business leaders have enterprise-level visibility into plant performance and can identify trends, forecast changes in the marketplace, and make informed decisions. The system supports data-driven forecasting, resource planning, and investing in priorities based on accurate operational knowledge. For example, visibility into recurring performance issues can necessitate procuring new technology or process redesign. The integration also positions manufacturers for new technologies, such as AI-driven optimization of manufacturing and autonomous systems [8]. Integrating IoT and QAD ERP positions manufacturers for success in an ever-changing Industry 4.0 environment.

V. CONCLUSION

5.1. Summary of key findings

When QAD ERP is combined with IoT, it significantly boosts regular manufacturing processes. By using the Bosch Production Line Performance dataset, the study highlighted the efficiency of sensors in interconnecting daily operations with company information systems [27]. Real-time monitoring of production ensured the ERP could be updated all the time. As a result, information was more accurate and timelier since decisions were based on real-time machine and process status instead of delayed reports. It was seen that IoT helps scale up ERP with its strategic role, allowing teams to adapt and react more quickly.

We significantly improved major production indexes by keeping machine events in sync with the ERP system. Operations became more efficient, with less time without work and higher usage of machines. The outcomes were accomplished using Node-RED as the middleware, MQTT, and OPC UA to handle communication and secure API endpoints in QAD ERP [6]. The Power BI visualizations reflected the improvements in a lively way. This system presented how live data pipelines might work, especially for QAD users in the manufacturing sector who aim to get into Industry 4.0 while keeping their current systems [4].

Additionally, seamless integration helped with continuous traceability, speedy alerts, and insightful monitoring across the production line. The focus shifted to include metrics like First Pass Yield (FPY), variations in cycle time, and active alerts for predictive maintenance. Using this approach, the factory could switch from acting after problems to anticipating and responding to issues before they occur [28]. Although the Bosch dataset was anonymous, it was still structured enough to model real-life factory behavior and test improvements in different ways. The study showed that integrating QAD ERP with IoT is technically possible and valuable in industry practice.

5.2. Strengths

One of the significant strengths of the proposed system is the seamless data flow between the production floor and QAD ERP [8]. Data from IoT sensors is sent to middleware platforms, which take care of data formatting, validation, and movement into QAD. Regularly sharing data reduces any delay in information, improves transparency, and allows for smoother adaptability to events happening on the work floor. As an alternative to entering data by hand or in batches, users now benefit from getting new data automatically when sensors are

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triggered. Such automation improves data accuracy, helps avoid duplicating work, and makes QAD ERP a real-time management center rather than a record-only system.

The system helps people make better decisions by delivering precise real-time data into the ERP system. For example, live information about a machine's cycle time or temperature allows operators to step in early to stop any possible issues [28]. In addition, supply chain managers and production planners can track lead times and revise schedules as needed, referencing the business's actual performance. Power BI dashboards helped managers see the trends of key metrics and spot any unusual events in operations. Because of this, information was now accessible to everyone in the company, from the lowest rank to the highest, even when it used to be delayed or unavailable. A good decision-making process results in sensible planning, wise resource management, and the best possible results for the company.

Scalability is also something unique about this integration. Extension to the system is possible through different protocols and middleware, all without modifying core ERP logic. It is possible to add a new machine, type of sensor, or line by modifying endpoints or adding them to the middleware. Factories at any stage of digital development can use the system since it is available on-site or on the cloud. The platform can be used with almost any type of IoT device from different companies. This flexibility enables QAD ERP to grow and adapt to production businesses' ever-changing character and growth.

Another strength is adjusting and combining different standards due to the system's design. Because the architecture relies on RESTful APIs and standards such as JSON and XML, integrating various systems is easy, and there are few compatibility issues. If devices are outdated, you can use IoT gateways; new equipment directly connects to the network. The middleware software helps manage network protocol changes and fixes errors that occur [20]. This way, multiple IT services and departments can share information as part of one integrated data ecosystem. Standard APIs help ensure that organizations comply with regulations, making audits of data and essential assets easier. His insight demonstrates how the field of manufacturing can evolve for tomorrow [4].

5.3. Future Work

Looking forward, AI should be used to look at more than just traditional KPIs. Using historical and current data together with machine learning, the system could help set the right production levels, find hidden areas where things are not as efficient, or predict when equipment will need more maintenance [29]. These insights would support manufacturers in starting to use prescriptive analytics. With AI modules on QAD ERP, users can see personalized reporting, stimulate scenarios in production, and adapt their planning to shift situations in the workplace. It helps learn and test the capabilities needed.

Edge computing is another prospective area that can significantly benefit future improvements. When the processing is carried out close to the sensors, the system can reduce delays, become more secure, and use less bandwidth. This becomes very useful in locations where internet access is slow or limited, and decisions must be made instantly. Edge nodes may perform predictions, set off alerts, or change parameters without waiting for the ERP to give the ok. Using QAD ERP with edge intelligence allows for tight control and flexibility to respond at different points.

Further improvements to the ERP-IoT ecosystem can be achieved by integrating machine learning into the middleware and analytics stack. Using the Bosch dataset to train anomaly detectors, new events could automatically be classified with only the most critical issues being flagged [19]. If algorithms learn failure patterns, they will only prompt maintenance when required, leading to better use of resources. Reinforcement learning may also be used to experiment with different settings for improved production. Having these abilities integrated into Node-RED or Power BI would help real-time analytics become systems that can learn and adjust automatically to the changing needs of the factory.

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