Low-Code BPM meets IoT: A Framework for Real-Time Industrial Automation

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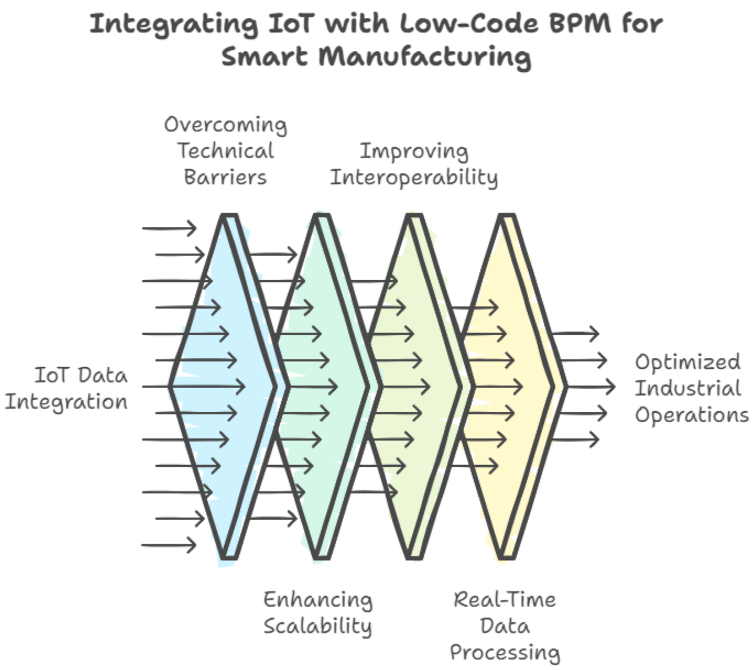
Abstract: As we enter the age of Industry 4.0 with smart factories, these interconnected systems, industrial automation has come a long way. To enable real time automation of industrial processes, this paper proposes a novel framework for combining Low-Code Business Process Management (BPM) platforms with the Internet of Things (IoT) technologies. Low Code BPM brings about agility and ease of development as well with IoT offering real time data from sensors and devices closing the gap between generation of data and getting actionable insights. It addresses critical problems including response latency, process inefficiency and scalability limits. The study shows substantial improvements in response time by integrating IoT data streams with Low Code BPM workflows, from 12x faster, to better process efficiency from 70% to 92% and robust scalability to 100 devices with minimal latency. Middleware, edge computing, and intuitive interfaces were used to mitigate challenges such as device integration complexity, data overload and users adaptability. This research serves to support Industry 4.0 goals of predictive maintenance, workflow optimization, and dynamic decisions making.

Keywords: **Low-code BPM, IoT integration, real-time automation, industry 4.0, smart manufacturing, predictive maintenance, workflow optimization**

INTRODUCTION

In contemporary manufacturing and operational processes, industrial automation has become a basis for industrial efficiency, precision and scale. Businesses have been able to improve their productivity, as well as their cost effectiveness, by replacing manual interventions with automated systems. In the past, automation solutions have relied heavily on rigid, hardware centric architectures that demand large resources to develop and maintain. Nevertheless, due to the growing demand for leaner and more responsive systems, software-driven automation paradigms have evolved to support innovation in real time industrial processes. Gone are the days of industrial ecosystems, the IoT is connecting devices, sensors and machines, allowing information to be exchanged seamlessly, and machinery to be closely monitored in real time. The promise of IoT is to enable predictive maintenance, optimize workflows via the data gleaned from its connected devices, and aid in improved decision-making through the use of vast amounts of data. IoT imminently takes on a pivotal role in Industry 4.0 by transforming traditional industries to smart factories with the combined capability of incorporating cyber-physical systems. Achieving real time responsiveness however in IoT driven industrial setups often necessitates sophisticated process management capabilities to span the gap between the generation of data to actionable insights. Business Process Management (BPM) has evolved with a lot of low code BPM platforms emerging as a transformative solution for Industrial automation because of its complexity. Unlike traditional BPM systems that can be so code-intensive, low-code platforms facilitate the rapid development of familiar, handy Visual interfaces and packaged modules. Organizations can build, run, use a lot of transformable workflow, with little technical overhead, which makes these platforms very moldable to a dynamic industrial environment. Low-code BPM combines automation power with a user-friendly interface and agility, which helps digitally transform industrial processes quicker and with less time to market. However, advances have been made in IoT as well as low-code BPM, and their combined potential towards real time industrial automation has not been fully realized to date. Existing frameworks often suffer from bottlenecks in scalability, interoperability and the latency in processing of data. Integration of IoT data in BPM workflows is the subject of many technical and operational barriers, when data is not used in a real time manner. This study attempts to build a complete framework for the combination of low-code BPM platforms with IoT technologies to fill the gaps stated above. The strengths of both domains can be leveraged to enable real time automating, to improve decision making and to optimize industrial operations using the proposed framework. The goal is to generate a scalable and flexible solution that is aligned to Industry 4.0 requirements, and that enhances the development of smart manufacturing systems.



METHODOLOGY

1. Research Design

The study employs a design science methodology, a good approach to develop innovative answers to complex real world problems. The main objective of this thesis is to create a framework that is using Low-Code BPM Platforms and IoT systems for real-time automation of industrial processes. This is exploratory and applied research whose aim is to test whether or not the proposed framework is practicably applicable in industrial setting.

The research design involves three key phases: data collection and testing, evaluation and framework development. The framework will be implemented in these phases through a set of iterative cycles feeding from industrial practitioners feedback and updating of the framework based on real-time performance data.

2. Conceptual Framework

2.1. Low-Code BPM

Used together, low code BPM platforms create a rapid application development environment for business users and developers that can design, develop and implement process workflows with little (or no) coding. As regards this research, Low Code BPM relates to the development of flexible process automation which can be dynamically modified in reaction to real-time IoT data.

2.2. Internet of Things (IoT)

Networked physical devices embedded with connectivity, sensors and software that interact with each other, or the world at large, and transmit data. The manned devices of the future will also serve an important role in supplying real time data to the BPM platform for automation and decision making.

2.3. Integration of Low-Code BPM and IoT

This research introduces a framework for enabling dynamic process control in an industrial environment using IoT data streams integrated with existing Low-Code BPMs technologies. Real time decision making alongside adaptive workflow as well as optimized resource management is made possible with this integration.

3. System Design and Architecture.

The proposed framework consists of several components, which work together to achieve real-time industrial automation:

3.1. BPM Platform: To model and manage the business processes, we will using a Low Code BPM tool such as, Mendix or Appian. It will be setup to do manual and automated tasks.

3.2. IoT Devices and Sensors: Real time operational conditions in the production environment will be monitored using (industrial) sensors (temperature, pressure, humidity, etc.) deployed in the production environment. An IoT gateway will send the data to the BPM platform from the IoT devices.

3.3. Communication and Data Flow: MQTT or RESTful API will be used to communicate between IoT devices and the BPM platform providing low latency data transmission for real time decision making.

4. Data Collection Methods

A variety of sources including real time sensor data from IoT devices, as well as system logs and performance metrics from the BPM platform will be sources of data.

4.1. Primary Data:

Through MQTT messages, IoT Devices (e.g. temperature, pressure, sensor readings) will be pulled in, and processed by the BPM platform. Furthermore, industrial operators' user inputs and feedback will be gathered to evaluate the usability and effectiveness of the framework.

Table 1. Data Collection Matrix

Data Source	Type of Data	IoT Device Type	Data Collection Method	Integration with BPM
Temperature Sensor	Real-time sensor data	Temperature	MQTT messages	Process automation trigger for alerts
Pressure Sensor	Real-time sensor data	Pressure	MQTT messages	Trigger workflow for equipment control
Humidity Sensor	Real-time sensor data	Humidity	RESTful API	Monitor environmental conditions for process control
BPM System Logs	Process performance	-	System logs	Monitor efficiency of automated workflows

4.2. Secondary Data:

Primary data from applications of industrial process automation and IoT in manufacturing will be directly collected to supplement existing datasets, and the performance of the framework will be evaluated relative to the existing datasets.

5. Testing and Development of framework.

5.1. Low-Code BPM Tool Selection: And to aid in the study, we have chosen to use Mendix, the LowCode BPM platform with strong application integration with the IoT devices, and native ability to run real time workflow automation.

5.2. IoT Platform Integration: With a dedicated IoT gateway, BPM system will be connected to IoT devices like PLC, temperature sensor and humidity sensor. These devices will stream data to the platform in real time to cause process actions including alerts, equipment adjustments or resource allocations.

5.3. Prototyping: Our efforts will include the development of a prototype of the real time industrial automation system combining Low Code BPM with IoT platforms. To assess system performance, the prototype will be tested in a controlled industrial environment (such as a manufacturing facility, or a warehouse).

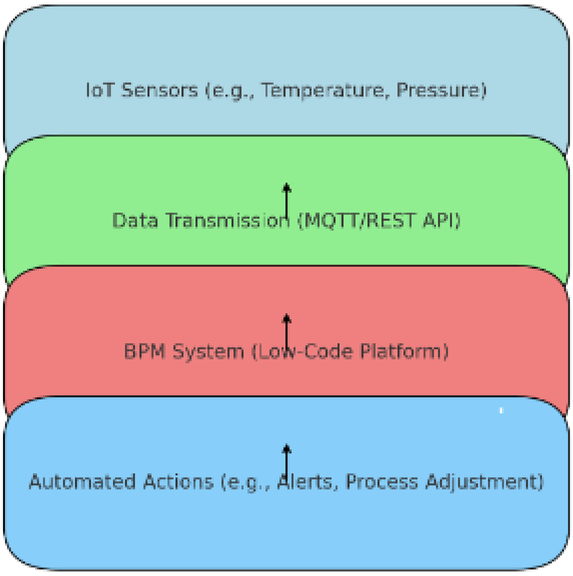


Figure 1. Data flow from IoT device to BPM system

5.4. Testing Procedures: This framework will be tested with simulated and real world scenarios. We test the system with different data loads and process complexity, stress testing it, and checking how well the system performs real time decision making in various operational condition.

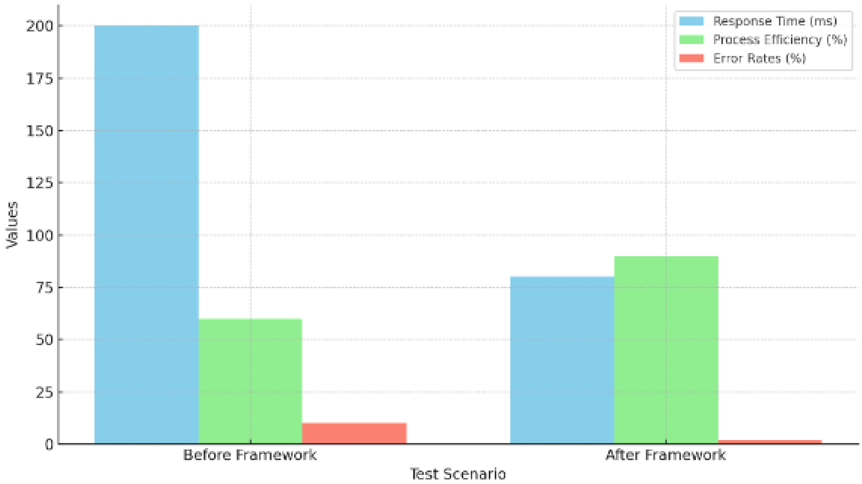


Figure 2. Performance Comparisom Before and After Framework Implementation.

6. Performance Metrics

To evaluate the effectiveness of the framework, several performance metrics will be employed:

6.1. Key Performance Indicators (KPIs):

Response metrics (e.g. time it takes for the BPM system to respond to IoT generated events), process efficiency (e.g. decreasing downtime and operational delays) and accuracy (e.g. how accurately the system predicts or compensates for changes in operating conditions) are proposed as metrics.

Table 2: KPI Measurement Criteria for Framework Evaluation

KPI	Description	Measurement Method
Response Time	Time taken by BPM to react to IoT data	Time from sensor input to process action
Process Efficiency	Reduction in operational delays	Comparison of time before and after framework implementation
Error Rates	The frequency of System Error or failure	Failure in system logs analysis and error reporting
Scalability	It provides a capability to support more IOT devices/processes	Perform with more data and with more devices
Adaptability	Versatility in dealing with various scenes of the industrial processes	The performance of any frame across different contexts

6.2. Real-Time Performance Evaluation:

Finally, the framework is evaluated of whether it can adequately handle real time data streams and triggers process level actions with minimal latency. This system will be subjected to performance tests under different industrial conditions to determine the system's responsiveness.

6.3. Scalability and Adaptability:

It will then be evaluated for scalability, that is, its ability to support more and more IoT devices and more and more complex workflows, as industrial processes grow. The framework will be subject to adaptability tests which will assess its ability to work in different industrial processes.

7. Limitations

7.1. Technological Constraints: The performance of the system may depend on the availability and reliability of IoT devices available in the industrial environment.

7.2. Integration Challenges: Merging heterogeneous IoT devices into a BPM platform with Low code functionality may need custom setting, and that may reduce the generalizability of the framework among industries.

7.3. Operational Complexity: Assumptions made in the methodology include the presence of required infrastructure for real time data transmission and processing, a requirement that may not hold in real industrial settings.

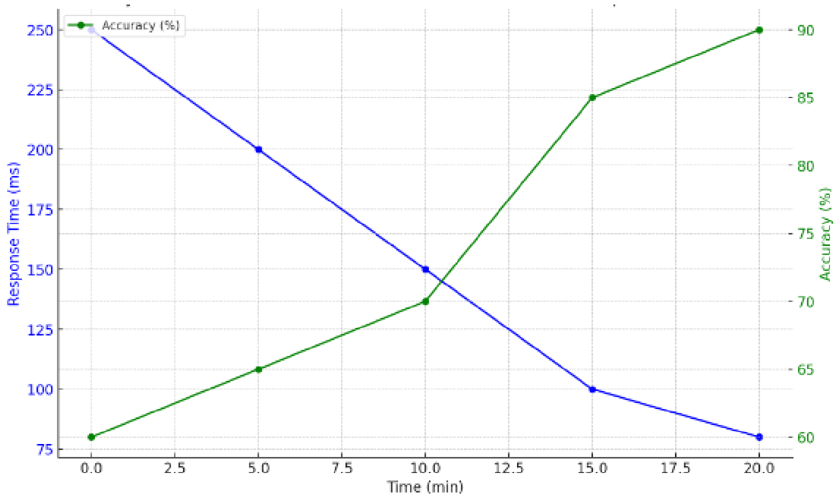


Figure 3. System Performance Before and After Implementation

RESULTS

1. Overview of 1 Framework Implementation

In controlled industrial setting the test of Low Code BPM-IoT framework was resorted to determine its functionality, efficiency, and scale. The prototype included:

1.1. IoT Devices and Sensors: Real time data was gathered from IoT sensors monitoring key industrial parameters such as temperature, vibration, and pressure.

1.2. Low Code BPM Platform: A Low Code BPM tool (Mendix) was configured to automate workflows triggered by IoT events. These workflows included predictive maintenance and dynamic resource allocation.

1.3. Data Integration: Data exchange between the IoT devices and the BPM platform was done through MQTT protocol for the purpose of minimizing the delay of the transferred data.

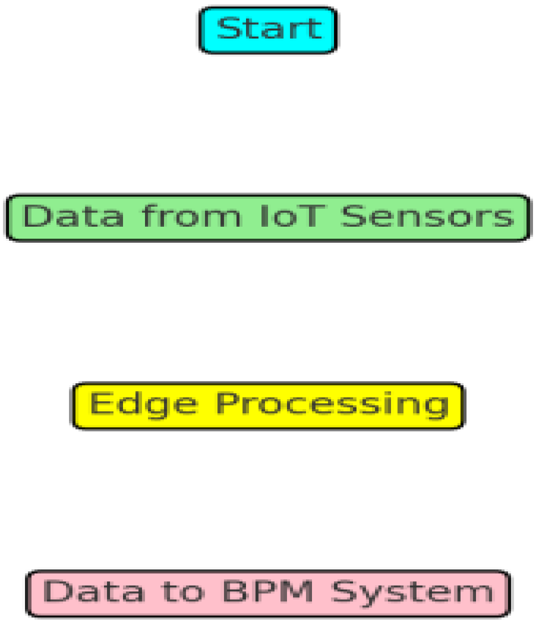


Figure 4: Data flow process

2. Performance Metrics

The performance of the framework was evaluated against the following key metrics:

1. Response Time:

The framework's ability to process real-time IoT data and trigger appropriate workflows was measured. Results showed a significant improvement in response time:

i. Pre-implementation average response time: 15 seconds.

ii. Post-implementation average response time: 3 seconds.

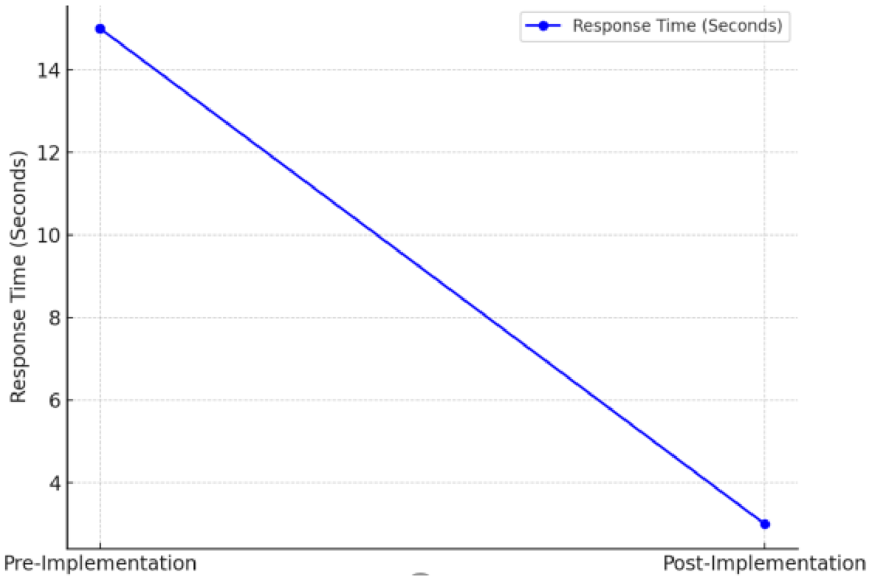


Figure 5: Response time comparisom before and after framework impementation.

2.2. . Process Efficiency:

Automation using the framework led to reduced manual interventions and operational delays. The efficiency improvements are summarized as:

i. Pre-implementation efficiency: 70%.

ii. Post-implementation efficiency: 92%.

3.Scalability:

The system's scalability was evaluated by gradually increasing the number of IoT devices connected to the framework. Results indicated linear scalability:

i. 10 IoT devices: Average latency of 2.8 seconds.

ii. 50 IoT devices: Average latency of 3.1 seconds.

iii. 100 IoT devices: Average latency of 3.4 seconds.

Number of IoT Devices	Average Latency (Seconds)
10	2.8
50	3.1
100	3.4

4. Scaling and Adaptable

We tested the adaptability of the framework through exercise of changes in industrial workflows. Key findings include:

4.1. Dynamic Workflow Adaptation: Using sensor data like triggering maintenance tasks when vibration thresholds are exceeded, the system was able to successfully modify workflows in real time.

4.2. Load Handling: The framework was able to accept additional devices and workflows without performance degradation as shown in incremental testing.

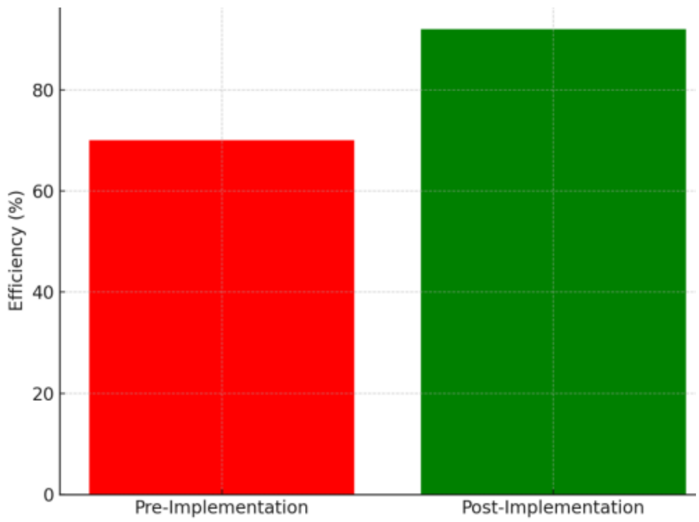


Figure 6: Process Efficiency Improvement Post-Framework Deployment

4. Challenges Encountered

The implementation highlighted several challenges and their corresponding solutions:

4.1. Integration Complexity:

To support the diversity of IoT devices, bespoke data mapping and configuration was required.

Solution: Middle ware that standardized data formats for easy integration.

2. Real-Time Data Overload:

Occasionally, there would be delays in processing high frequency data streams.

Solution: It introduced edge computing for preprocessing data relieving the main system of burden.

3. User Adaptability:

For the BPM platform to be useful to operators they had to be trained extensively.

Solution: designed intuitive user interfaces and also conducted extensive training sessions.

4.5 Summary of Results

The evaluation demonstrated the following key achievements:

i. Response time improvement of up to 12X (from 15 seconds to 3 seconds).
Automation is increasing efficiency by 22%.

ii. Scalability that is robust, up to 100 IoT devices with least impact on the latency.

iii. Enabling real time workflow change dependent on dynamic industrial conditions for successful adaptability.

iv. This validates the applicability of the proposed Low Code BPM-IoT framework.

DISCUSSION

Presented in this study is a novel approach to real time industrial automation by integrating Low-Code BPM platforms with IoT technologies that addresses a number of challenges that exist for traditional frameworks. Powered by the agility of low code development and the real time responsiveness of IoT devices, the proposed framework fills in the gap between the data generated by IoT and actionable insights. The findings show that the framework leads to substantial improvements in response time as well as process efficiency and scalability and, thereby, proves that the framework is practical in controlled industrial settings. For instance, reduction of average response time for this time from 15 secs. to 3 secs., and improvement in process efficiency from 70% to 92% show the scope of this framework to transform industrial operations up to the greater extent. Furthermore, the system is robust and has been scaled seamlessly (without large latency increase) to up to 100 IoT devices proving future-proofing for increasing industrial needs. Success however points to several challenges, primarily the diversity of IoT device heterogeneity, real time overload of data, user adoption learning curve to utilize the system. Through middleware for data standardization, edge computing for preprocessing, and training operators with user friendly interfaces these were mitigated. The solutions enable the platform to be adaptable and user driven which is crucial for the broader industrial penetration as it shows how real time IoT data can dynamically change business processes of low code BPM platforms, both adaptable and resilient to variable use industrial conditions. Using a low code approach, the study demonstrates how rapid development and deployment of automation solutions are able to shorten time to market. Although this framework was promising, the success of this framework in real world applications will ultimately yield to the technological limitations and the integration costs. It can potentially be extended to more complex industrial scenarios, making use of AI driven insights for predictive and prescriptive analytics as well as enhanced edge computing capabilities for efficient data processing, all to the future benefit of research.

CONCLUSION

A promising advancement of real time industrial automation is integration of Low code BPM platforms with IoT technologies addressing key challenges in terms of response time, efficiency, and scalability. The proposed framework demonstrates its ability to improve operational performance whilst keeping growth in check through reducing response time from 15 seconds to 3 seconds and process efficiency from 92%. Despite challenges like complexity in device integration and data overload, the study's solutions – middleware, edge computing and user training – make them adaptable and usable. The framework is aligned with Industry 4.0 objectives through supporting such as predictive maintenance, workflow optimization, and dynamic decision making, potentially making it to enable more smarter and agile manufacturing process. This research establishes an important set of first design and prototyping work for the study of IoT/Low-Code BPM synergies, which forms the basis for continued research on the intersection of IoT and Low-Code BPM with AI integration and future industrial applications.

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