

DEVELOPMENT OF A FRONT-END INTERFACE FOR REAL-TIME SMART PRODUCTION MONITORING IN THE CONTEXT OF INDUSTRY 4.0

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ABSTRACT

The advancement of Industry 4.0 has driven the integration of smart systems, the Internet of Things (IoT), and Artificial Intelligence (AI), promoting greater automation and efficiency in manufacturing environments. In this context, real-time production monitoring has become essential for supporting decision-making, reducing operational failures, and increasing industrial productivity. Given this scenario, this work aims to develop a frontend interface for intelligent real-time production monitoring, enabling centralized visualization of production indicators, operational events, and AI-based analyses. The methodology involved a literature review on Industry 4.0, definition of the application's functional requirements, modeling of the system architecture, and implementation of the interface using modern web technologies. The solution was integrated with backend services responsible for collecting data from industrial machines and sensors, as well as applying Artificial Intelligence algorithms for pattern analysis and the generation of smart alerts. The results obtained demonstrated that the developed interface enabled greater visibility of production processes, quick access to critical information, and better monitoring of indicators in real time. The use of interactive visual tools and intelligent mechanisms has helped optimize production monitoring and support preventive measures. It can be concluded that the proposed application has the potential to assist companies in the context of Industry 4.0 by promoting greater operational efficiency on the production line of a factory in the tape industry, faster decision-making, and intelligent integration of production data. Frontend Interface, Intelligent Production Monitoring, Industry 4.0, Artificial Intelligence.



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I. INTRODUCTION

The digital transformation driven by Industry 4.0 has revolutionized production processes through the integration of cyber-physical systems, the Internet of Things (IoT), cloud computing, and Artificial Intelligence (AI). In this context, the need for continuous and intelligent production monitoring has become a strategic factor for companies seeking greater competitiveness, operational efficiency, and real-time decision-making capabilities [1], [2]. The growing volume of data generated by machines, sensors, and industrial devices demands technological solutions capable of collecting, processing, and presenting information in a clear, dynamic, and accessible manner to managers and operators. In this context, the development of front-end interfaces designed for intelligent production monitoring represents a significant contribution to the modern industrial environment. A well-designed interface makes it possible to transform large volumes of data into understandable visual information, facilitating the identification of faults, production bottlenecks, waste, and opportunities for optimization.

Furthermore, the use of interactive dashboards and real-time indicators contributes to more efficient production management, reducing response time to critical events and increasing the productivity of industrial processes [3], [4]. The relevance of this research is related to the growing demand for intelligent systems that integrate data visualization, automation, and predictive analytics in the context of Industry 4.0. Many companies still face difficulties in centralizing and interpreting data from different industrial devices, which compromises operational efficiency and strategic decision-making. Thus, the development of an intelligent front-end interface emerges as an alternative to promote greater integration between production data and system users, enabling more precise and proactive production supervision. The innovation of this paper lies in the integration of modern front-end development technologies with artificial intelligence capabilities applied to real-time industrial monitoring. The solution aims to provide not only the visualization of production indicators but also intelligent features, such as automatic alert generation, identification of operational patterns, and support for preventive maintenance. In this way, the system contributes to the modernization of industrial processes, promoting greater connectivity, efficiency, and operational intelligence—essential characteristics for companies operating within the Industry 4.0 paradigm [5], [6].

II. LITERATURE REVIEW

II.1 INDUSTRY 4.0 AND ITS APPLICATIONS

Industry 4.0 represents the fourth industrial revolution and is characterized by the integration of digital technologies into industrial processes. Unlike previous industrial revolutions, which focused on mechanization, mass production, and automation, Industry 4.0 combines advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, Cloud Computing, robotics, and cyber-physical systems to create smart, interconnected production environments. These technologies enable machines, devices, and systems to communicate and exchange data in real time, improving efficiency, productivity, and decision-making in industries [7-9]. One of the key features of Industry 4.0 is the use of IoT devices and sensors in manufacturing environments. Machines equipped with sensors can collect operational data, such as temperature, pressure, energy consumption, and production speed. This information is transmitted to centralized systems, where it can be analyzed to continuously monitor production processes. As a result, industries are able to identify failures early, reduce downtime, and optimize operational performance. Predictive maintenance is one of the most significant applications of this technology, enabling companies to predict equipment failures before they occur, thereby reducing maintenance costs and extending the service life of machines [10], [11]. Artificial Intelligence also plays a key role in Industry 4.0 applications. AI algorithms can analyze large volumes of industrial data to identify patterns, generate insights, and support strategic decisions. In manufacturing, AI is used for quality control, process optimization, demand forecasting, and intelligent automation. Computer vision systems, for example, can automatically inspect products and detect defects with high precision, improving product quality and reducing waste. Another important application of Industry 4.0 is the use of smart factories.

In these factories, production systems are highly automated and interconnected, enabling real-time monitoring and decentralized decision-making. These factories can quickly adapt to changes in production demand, customize products according to customer preferences, and improve resource utilization. Automation technologies, including collaborative robots known as cobots, work alongside human operators to increase productivity and workplace safety. Cloud computing and big data technologies further strengthen Industry 4.0 by enabling the storage and processing of large amounts of data generated by industrial operations. Cloud platforms provide scalable infrastructure for data analysis and remote access to production systems. Managers and engineers can monitor industrial performance through dashboards and visualization systems from any location, facilitating faster and more efficient decision-making [12], [13]. The applications of Industry 4.0 extend beyond manufacturing and can also be found in the logistics, healthcare, agriculture, and energy sectors. In logistics, intelligent systems optimize inventory management and supply chain operations. In agriculture, sensors and AI support precision farming by monitoring soil conditions and crop health. In the energy sector, smart grids improve energy distribution and consumption efficiency. In summary, Industry 4.0 is transforming industries by promoting automation, connectivity, and intelligent decision-making. Its applications improve operational efficiency, reduce costs, increase flexibility, and drive innovation across various sectors. As the digital transformation continues to evolve, Industry 4.0 technologies are expected to become even more essential for organizations seeking competitiveness and sustainability in the modern industrial landscape.

II.2 FRONT-END INTERFACE FOR INTELLIGENT PRODUCTION MONITORING

The Frontend Interface for Intelligent Production Monitoring plays a fundamental role in the context of industrial digital transformation and Industry 4.0. With advances in automation technologies, the Internet of Things (IoT), Artificial Intelligence (AI), and cyber-physical systems, industries have begun to generate large volumes of data from machines, sensors, and production processes. In this scenario, it is essential to develop interfaces capable of presenting this information in a clear, dynamic, and accessible manner, allowing operators, engineers, and managers to monitor production in real time and make faster and more efficient decisions. The frontend represents the visual and interactive layer of a system, responsible for communication between the user and the data processed in the backend. In intelligent production monitoring systems, this interface must be intuitive, responsive, and efficient in displaying industrial indicators. Interactive dashboards, real-time graphs, automatic alerts, and performance dashboards are some of the key features used to facilitate the supervision of industrial operations. These tools enable the rapid identification of failures, production bottlenecks, waste, and operational anomalies, contributing to increased productivity and process quality. One of the main objectives of a front-end interface for smart monitoring is to transform complex data into understandable information. In modern industrial environments, thousands of data points can be continuously generated by IoT sensors installed on machines and equipment. Without a suitable interface, interpreting this information becomes difficult and inefficient. Thus, the frontend acts as a facilitator of operational analysis, organizing data into graphs, visual indicators, and reports that help monitor production performance in real time. Integration with Artificial Intelligence technologies also significantly expands the capabilities of these interfaces. Intelligent systems can analyze production patterns, predict equipment failures, and generate automatic alerts for preventive maintenance. In addition, machine learning algorithms can identify trends and suggest operational improvements based on collected historical data.

Presenting these results through visual interfaces makes it easier to understand the analyses performed by AI, making the decision-making process more efficient and strategic. Another important aspect is the responsiveness and accessibility of the frontend interface. Today, managers and operators need to access industrial information on various devices, such as computers, tablets, and smartphones. Therefore, developing responsive interfaces ensures that data can be viewed in any environment and in real time, promoting greater mobility and operational flexibility. Modern web development technologies, such as React, Angular, and Vue.js, are widely used to create fast, scalable, and interactive frontend applications. In summary, the Frontend Interface for Intelligent Production Monitoring is an essential solution for companies operating within the Industry 4.0 context. Its implementation contributes to the integration of industrial data, the optimization of production processes, and the improvement of real-time decision-making. By combining data visualization, automation, and Artificial Intelligence, these interfaces promote greater operational efficiency, cost reduction, and increased industrial competitiveness, making them a strategic element for the future of smart manufacturing.

II.3 MAPPING INDUSTRY 4.0 TECHNOLOGIES: FROM CYBER-PHYSICAL SYSTEMS TO ARTIFICIAL INTELLIGENCE

This mapping provides a comprehensive analysis of the key technologies that make up Industry 4.0 and their importance for the digital transformation of industrial processes. The concept of Industry 4.0 refers to the fourth industrial revolution, characterized by the integration of physical and digital systems, enabling greater automation, connectivity, and intelligence in production environments [14], [15]. One of the central elements addressed in the text is Cyber-Physical Systems (CPS). These systems combine physical components with computational technologies and communication networks, enabling machines, sensors, and devices to exchange information in real time. This interaction allows for more efficient monitoring of industrial processes, reducing failures and increasing productivity. CPS are considered the foundation of Industry 4.0, as they connect the physical world to the digital world [16-18]. Another key technology is the Internet of Things (IoT), which enhances connectivity between equipment and systems. The IoT enables industrial devices to continuously collect and share data, facilitating rapid and accurate decision-making. As a result, companies can predict maintenance issues, optimize resources, and improve operational performance [19-21]. The text also emphasizes the importance of Big Data and data analysis. The vast amount of information generated by intelligent systems requires tools capable of storing, processing, and interpreting data on a large scale. In this context, data analysis becomes essential for identifying patterns, predicting trends, and supporting more efficient business strategies. In addition, cloud computing contributes to the secure and accessible storage of this information, enabling greater flexibility and integration across sectors [22-24]. Artificial Intelligence (AI) stands out as one of the most revolutionary technologies of Industry 4.0. Through advanced algorithms and machine learning, AI enables automated systems to learn from data and make decisions autonomously. This increases the efficiency of industrial processes, reduces costs, and improves product quality. AI is also applied in intelligent robots, predictive maintenance, and automated control systems [25-27]. In summary, the text demonstrates that the integration of these technologies creates smart factories that are more connected and adaptable to market demands. However, it also highlights challenges related to information security, professional training, and high technological investments. Thus, Industry 4.0 represents not only a technological evolution but also an economic and social transformation that requires constant adaptation by companies and workers.

III. MATERIALS AND METHODS

The study was conducted as applied research, focusing on the development of a front-end interface for intelligent real-time production monitoring in the context of Industry 4.0. The proposal was directed at the system's production control module, taking into account the need to present data from machines, production orders, operational events, and industrial performance indicators in a visual, dynamic, and accessible manner. Applied research was adopted because it is directly related to solving a practical problem observed in the manufacturing environment: the difficulty of monitoring, in a centralized and real-time manner, the status of machines, production progress, operational deviations, and critical process alerts. Thus, the development of the frontend aimed to transform operational data into visual information useful for operators, supervisors, managers, and technical staff. Initially, the requirements of the production control module were analyzed, considering the main elements that should comprise the interface. Among these elements, the following stand out: an overview of the machines, monitoring of operational status, display of targets and daily production, calculation and presentation of indicators such as productivity, availability, quality, OEE, FPY, unplanned downtime, and real-time visibility, as well as the display of notifications and alerts based on criticality. Development was carried out incrementally, allowing features to be built, integrated, tested, and refined progressively. This approach enabled the gradual evolution of the system's screens, such as the main machine dashboard, the equipment metrics modal, the full-screen dashboard designed for display on TV, the notifications panel, and the email alert configuration interface. The use of incremental cycles facilitated continuous validation of components, the correction of visual inconsistencies, and the adaptation of the interface to the needs of the production environment. As with the overall system development, project management and incremental development principles already defined for the project were followed, including requirements gathering, software design, implementation, validation, testing, and evolutionary maintenance. In the specific case of the frontend, these stages were applied with an emphasis on the visual organization of screens, component layout, clarity of indicators, responsiveness, usability, and integration with the services provided by the backend.

III.1 METHODOLOGICAL PROCEDURES

As with the overall development of the system, we followed the project management and incremental development principles already established for the project, including requirements gathering, software design, implementation, validation, testing, and evolutionary maintenance. In the specific case of the frontend, these stages were applied with an emphasis on the visual organization of screens, component layout, clarity of indicators, responsiveness, usability, and integration with the services provided by the backend.

III.2 FRONTEND INTERFACE ARCHITECTURE

The frontend interface was designed as the presentation and interaction layer of the intelligent production system. Its function is to receive data processed by the backend and present it in a visually understandable way to end users. Thus, the frontend acts as a bridge between the industrial data processing layer and the users responsible for decision-making in the manufacturing environment. The interface architecture is organized into visual components, navigation pages, API communication services, and real-time update features. The visual components include indicator cards, tables, buttons, status badges, charts, gauges, event panels, modals, and configuration forms. The navigation pages organize these components into specific screens, such as the machine dashboard, the detailed view by equipment, the full-screen dashboard, and the notifications panel. Communication with the backend allows the interface to display up-to-date data on machine status, production orders, recent events, and operational indicators. This integration is essential so that the frontend functions not merely as a static display, but as a dynamic tool for monitoring and decision support. In industrial environments, this feature is important because production events can occur continuously and require a rapid response from the team. Figure 1 shows the general organization of the proposed frontend architecture for the production control module.

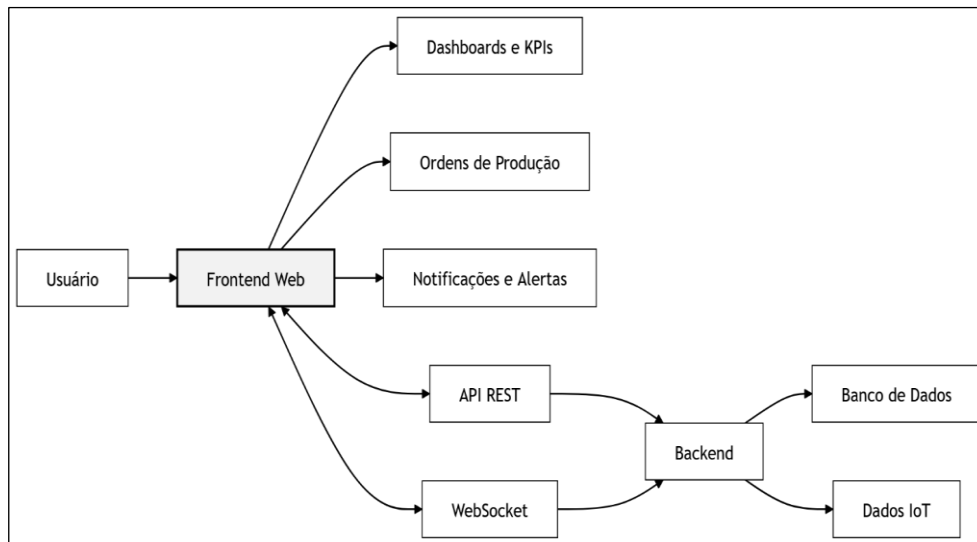


Figure 1: Architecture of the production control module's front-end interface.

Source: Authors, (2026).

III.3 TOOLS USED IN DEVELOPMENT

For the development of the front-end interface, tools were used to support coding, version control, task organization, and visual modeling. These tools made it possible to structure the development process, track the progress of features, and maintain control over changes made to the source code.

Table 1: Tools used in the development of the front-end interface.

Tool	Concept	Application in the project
Visual Studio Code	Source code editor with support for extensions, debugging, syntax highlighting, and version control integration.	Used as the primary development environment for the front-end interface, enabling the coding of components, screens, and communication services.
Git	A distributed version control system used to track changes to source code.	Used for code versioning, tracking development history, and facilitating collaboration among team members.
Draw.io	Tool for creating diagrams, flowcharts, and architectural models.	Used to create architectural diagrams, navigation flows, and visual representations of the system structure.
Trello	A task management tool based on grids and cards.	Used to track development tasks, interface adjustments, testing, and validation.
Navegador Web	An environment for running and viewing web applications.	Used to test the interface at different resolutions, validate responsiveness, navigation, data updates, and the visual behavior of components.

Source: Authors, (2026).

III.4 TECHNOLOGIES USED IN THE FRONTEND

The technologies used in frontend development were selected based on requirements for responsiveness, interactivity, API communication, real-time updates, and the visual presentation of industrial indicators. These technologies were chosen to enable the creation of a modular, scalable interface suitable for continuous production monitoring.

Table 2: Technologies used in the development of the frontend interface.

Tool	Concept	Application in the project
Vue.js	A JavaScript framework used to build reactive interfaces and single-page web applications.	Used in the development of screens for the production control module, including dashboards, tables, modals, notification panels, and interactive components.
TypeScript	A JavaScript superset that adds static typing to development.	Used to improve code organization, standardize data structures received from the backend, and reduce errors during integration between components.
Vue Router	The official routing library for Vue.js applications.	Used to organize navigation between the system's pages, such as machine dashboards, reports, management, and operational screens.
Axios	A JavaScript library used to make HTTP requests.	Used to communicate with backend APIs, enabling the retrieval of data on machines, metrics, production orders, events, and settings.
WebSocket	Real-time bidirectional communication protocol between client and server.	Used to receive automatic updates on machines, production, operational events, notifications, and alerts without having to manually refresh the page.
ECharts	JavaScript library for creating charts and data visualizations.	Used to display production metrics through charts and visual indicators, such as gauges for productivity, quality, availability, and OEE.
HTML5	A markup language used to structure web pages and applications.	Used to structure the visual elements of the interface, such as tables, buttons, forms, panels, and dashboard sections.

Source: Authors, (2026).

III.5 DEVELOPMENT OF THE PRODUCTION CONTROL MODULE SCREENS

The development of the screens was focused on creating a visual experience suitable for monitoring production in real time. To this end, the interface was organized into different levels of information, allowing users to view both an overview of the process and specific details about a machine or production order. The first level corresponds to the main machine dashboard. This screen displays cards with general indicators, a machine table, and a recent events panel. The top cards show information such as the number of active machines, average run time, average OEE, and total downtime. The central table presents operational data by machine, including production line, operator, status, daily target, parts produced, OEE, and available actions. This structure allows the user to quickly identify the overall status of the production process. The second level corresponds to the detailed view by equipment. By selecting a machine, the user has access to a metrics modal containing information such as runtime, notes, and performance indicators. The indicators are displayed via gauges, allowing for a quick readout of productivity, unplanned downtime, FPY, and real-time visibility. This approach facilitates individual analysis of each machine's performance. The third level corresponds to the full-screen dashboard, designed for display on televisions or monitors in a manufacturing environment. On this screen, the visual elements have been enlarged to make them easier to read from a distance. The dashboard displays information such as the machine being monitored, the production order, daily gross production, hourly target, percentage of target achieved, defects, hourly production, and side indicators for productivity, quality, availability, and OEE. The Production Order visualization interface was also developed, with a focus on tracking the production flow by machine and displaying the parameters associated with the execution of the PO.

This screen allows users to view information such as the order code, product to be manufactured, planned quantity, destination inventory, creation date, and completion status. In addition, the PO flow section displays the associated production process, the total order quantity, the cumulative official write-off points, the completion percentage, and operational alerts related to production progress. The interface also includes individual breakdowns by machine within the Production Order. In this feature, the user can view machine-specific parameters, such as PO quantity, total gross production, progress percentage, last closure, official release point indication, and production history by time. The hourly table displays gross production, actual cumulative total, cumulative total against the target, and the corresponding percentage of the PO. This functionality was incorporated into the frontend to enhance production traceability and allow operators and managers to track the order's progress not only in aggregate but also by machine and by execution period. The adjustments made to this interface were intended to improve the clarity of information related to production closure, surplus after the target is met, and the comparison between actual progress and the official progress of the production order. As a result, the frontend now provides visual support not only for monitoring general indicators but also for interpreting the production flow and the operational rules applied during order execution. In addition to the monitoring screens, notification and alert features were developed. The notifications panel displays recent system events, such as the automatic completion of production orders and alerts related to specific machines. Alerts are classified by severity level, using colors and icons to facilitate visual identification. A screen for configuring email alerts was also implemented, allowing users to define recipients and sending intervals based on the severity of the event.

III.6 INTERFACE VALIDATION CRITERIA

The front-end interface was validated based on functional, visual, and operational criteria. Functional tests were conducted to verify that the application components performed their actions correctly, including opening modals, loading data, changing filters, displaying notifications, navigating between screens, and updating indicators. The visual criteria considered the readability of information, the hierarchy of elements, color consistency, the appropriate use of icons, the distribution of components on the screen, and the differentiation between operational states.

In industrial dashboards, these aspects are fundamental for the user to quickly interpret the production status and identify events that require attention. The interface's responsiveness was also evaluated, considering its use on different screen sizes, including conventional monitors, laptops, and televisions used for full-screen display. In the case of the TV-based dashboard, readability from a distance was prioritized, with larger elements, centralized information, and visual indicators that are easy to interpret. Another criterion evaluated was the real-time updating of information. The interface was assessed for its ability to reflect changes in operational data, such as updates to indicators, completion of production orders, changes in machine status, and the generation of alerts. This criterion was considered essential for validating the application's behavior in a continuous monitoring scenario. Finally, usability aspects were analyzed, such as ease of navigation, clarity of labels, button organization, ease of access to detailed information, and comprehensibility of alerts. The validation demonstrated that the developed interface is well-suited to support real-time production monitoring, providing organized and visually accessible information to system users.

IV. RESULTS AND DISCUSSIONS

The development of the front-end interface resulted in a functional production control module, consisting of dashboards, operational tables, visual indicators, screens for tracking production orders, notification panels, and alert configuration features. The developed solution enabled the centralization of relevant production process information within a web application, facilitating real-time monitoring of machines, order progress, and key industrial indicators. The interface was designed to transform operational data into visual information accessible to system users. Thus, the frontend began to act as a layer for interpreting and presenting the data processed by the application, allowing operators, supervisors, and managers to monitor production in a clearer, more dynamic, and organized manner. The results obtained are presented in the following subsections, according to the main functionalities developed.

IV.1 MAIN MACHINE DASHBOARD

Figure 2 shows the main machine dashboard of the production control module. This screen provides an overview of operations, displaying key metrics related to the number of active machines, average cycle time, average OEE, and total downtime. Below these indicators, the interface displays a table of registered machines, containing information such as production line, operator, operational status, daily target, parts produced, OEE, and actions available for detailed viewing.

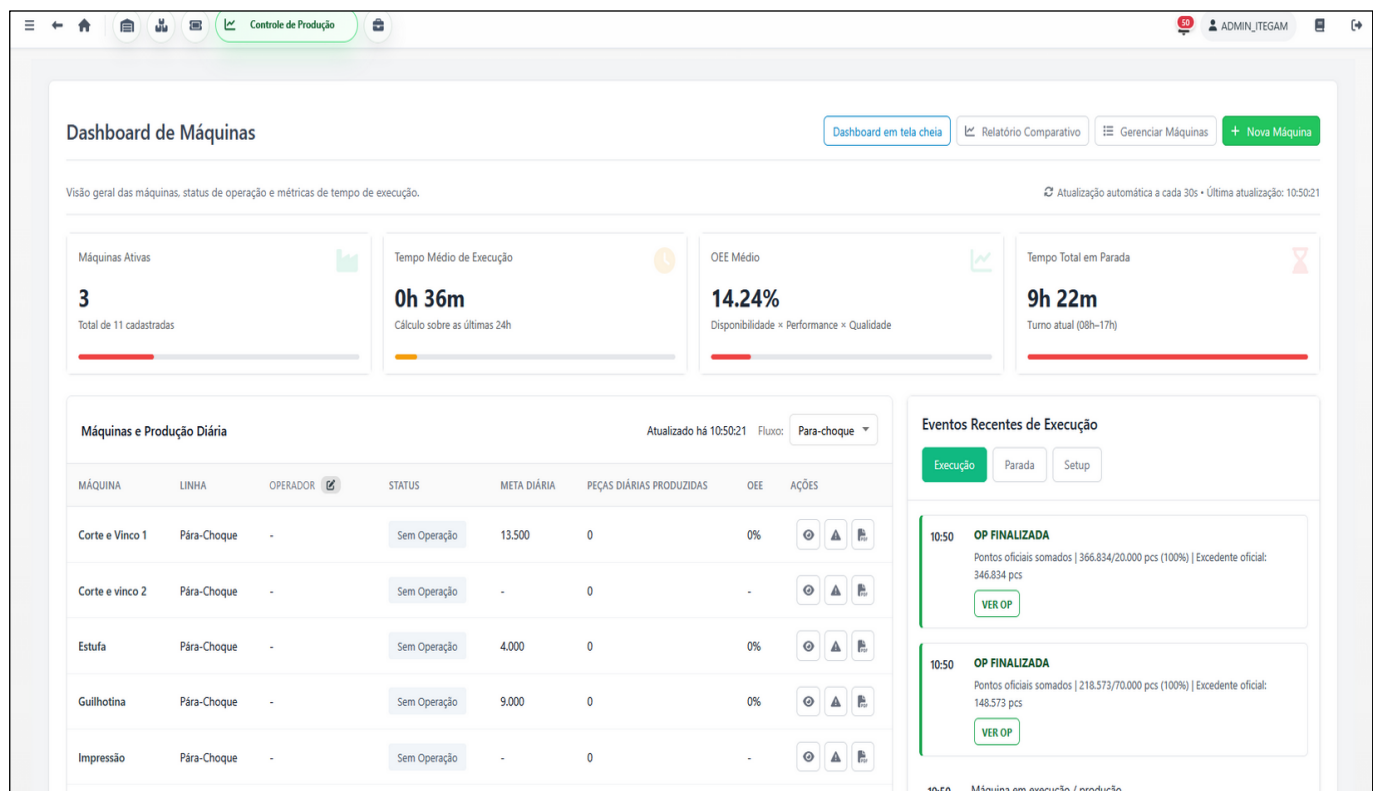


Figure 2: Main dashboard of the production control module, featuring general metrics, a machine table, and recent events.

Source: Authors, (2026).

The layout of the main dashboard has helped consolidate, on a single screen, information that was previously scattered across different queries or operational records. The top cards facilitate a quick overview of key indicators, while the table allows for an individual analysis of registered machines. The presence of filters by production flow also makes it possible to restrict the view to a specific process, making the query more appropriate to the context of use for the operator, supervisor, or manager. The use of colors, status badges, and visual bars helped differentiate operational states. Machines not in operation, machines in operation, and alert situations became easier for the user to identify. This feature is relevant in production environments, where the rapid interpretation of machine status can reduce response time in the face of downtime, failures, or production deviations.

In addition, the main dashboard features a recent events area, allowing users to track occurrences related to execution, downtime, and setup. This functionality helps increase the traceability of actions and facilitates the identification of relevant events within the production flow.

IV.2 INDIVIDUAL MACHINE METRICS

Figure 3 shows the individual machine performance metrics screen. This feature was developed to enable a more detailed analysis of a piece of equipment selected on the main dashboard. The screen displays information such as the operator, runtime, notes, and machine-specific indicators.

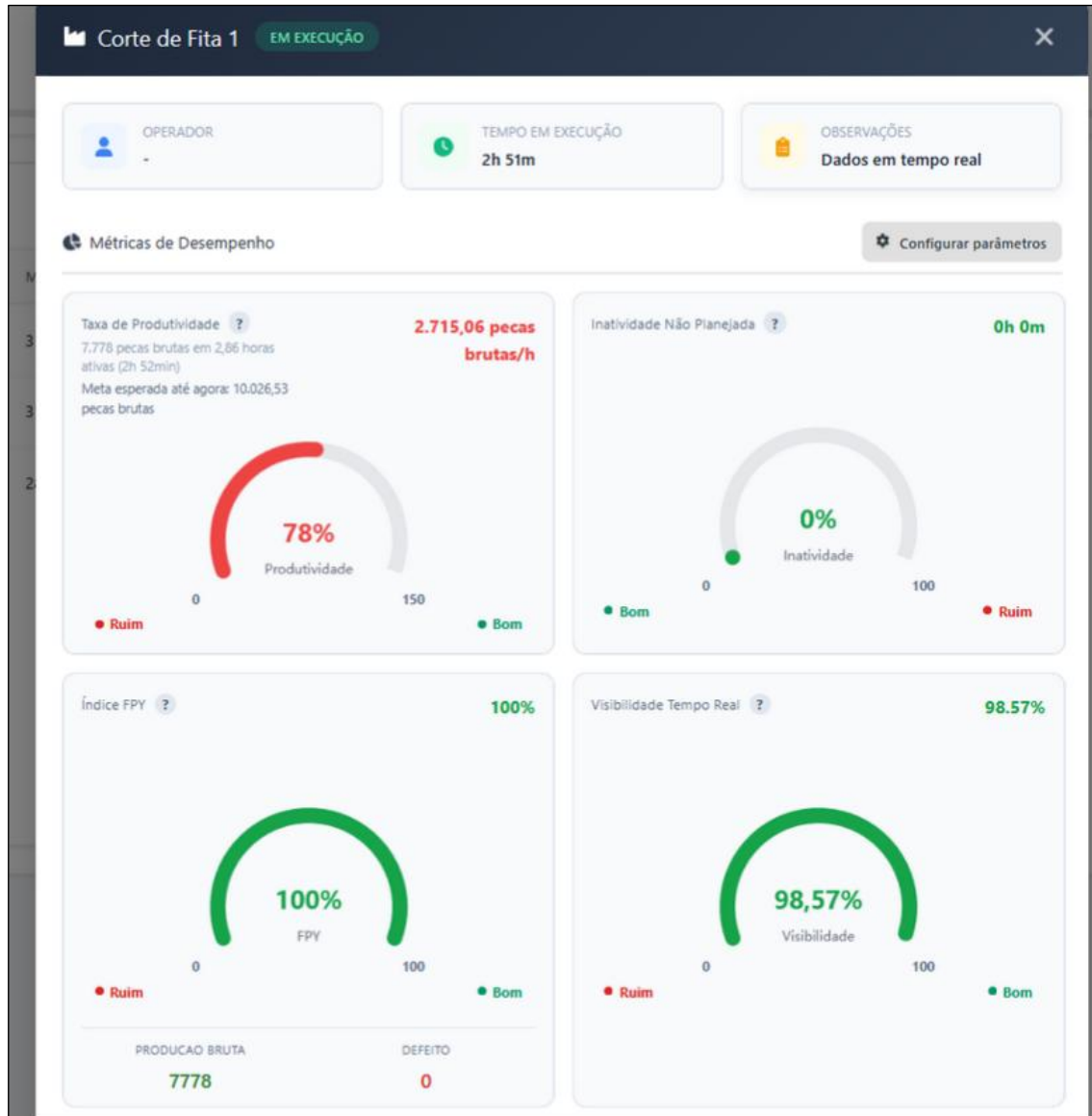


Figure 3: Individual machine performance dashboard showing real-time indicators for productivity, downtime, FPY, and visibility.
Source: Authors, (2026).

The indicators were presented using gauge-style visual meters, including productivity rate, unplanned downtime, FPY index, and real-time visibility. This format proved suitable for displaying percentage and operational indicators, as it allows users to quickly determine whether a given value falls within or outside the expected range. In the example shown, the interface displays productivity, downtime, FPY, and real-time visibility on separate cards, allowing each indicator to be analyzed individually. This visual separation prevents information overload and facilitates the identification of critical points. While the main dashboard offers an overview of production, the individual breakdown allows for observing the specific performance of each piece of equipment, enabling more targeted analyses. In this way, the metrics modal has helped make the interface more analytical, allowing the user to switch from a general view of the process to a specific machine view. This strengthens the role of the frontend as a tool to support operational supervision and not merely as a data display panel.

IV.3 FULL-SCREEN DASHBOARD FOR MANUFACTURING ENVIRONMENTS

Figure 4 shows the full-screen dashboard, developed for display on televisions or industrial monitors. This screen was designed for use on the factory floor, prioritizing larger elements, high visual contrast, and readability from a distance.

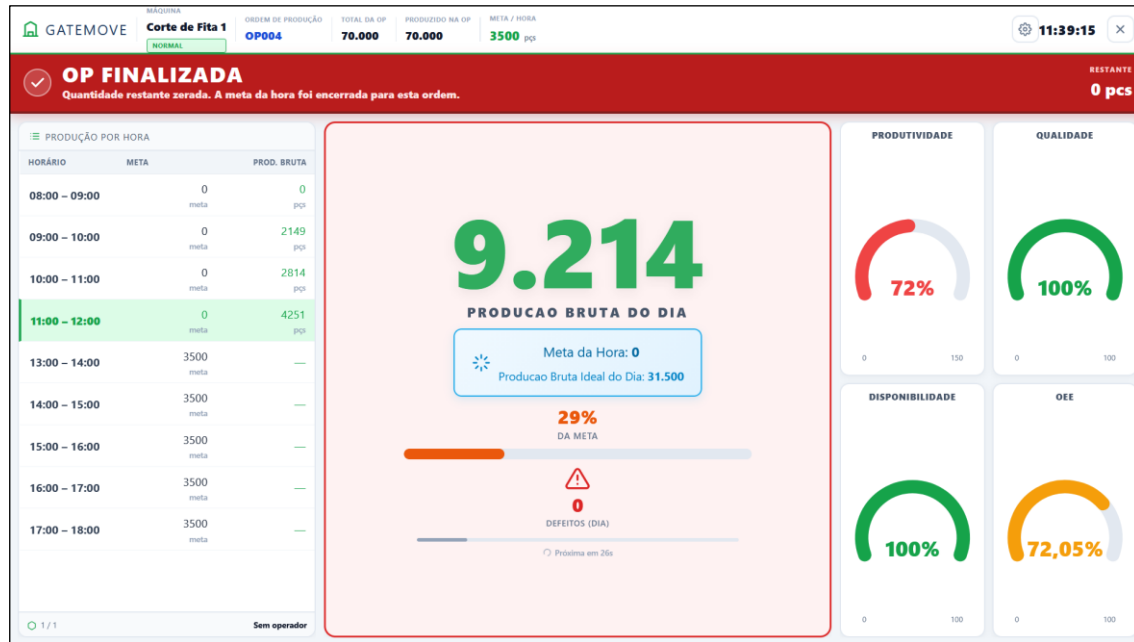


Figure 4: Full-screen dashboard for monitoring production in a manufacturing environment.
Source: Authors, (2026).

The dashboard displays information such as the monitored machine, production order, total planned quantity, gross daily production, target achievement percentage, number of defects, hourly production, and side indicators for productivity, quality, availability, and OEE. This organization allows operators and supervisors to monitor production progress without relying on manual reports or consulting more detailed screens. The full-screen mode represents one of the main outcomes of the interface, as it allows critical information to be continuously displayed within the production environment. The screen centralizes the gross daily production value, highlighting it as the primary information. Around this indicator, complementary elements are organized, such as hourly production, hourly target, percentage of target achieved, and performance indicators. The hourly production table makes it possible to identify periods with production, absence of production, or variations in relation to the target. Meanwhile, the side indicators provide a summarized view of productivity, quality, availability, and OEE. Thus, the full-screen dashboard contributes to increasing the visibility of the production process, making information accessible in real time to users present in the manufacturing environment.

IV.4 PRODUCTION ORDER MONITORING

Another relevant result was the implementation of the Production Order visualization screen. Figure 5 presents the interface developed for consulting the general PO data and monitoring the production flow.

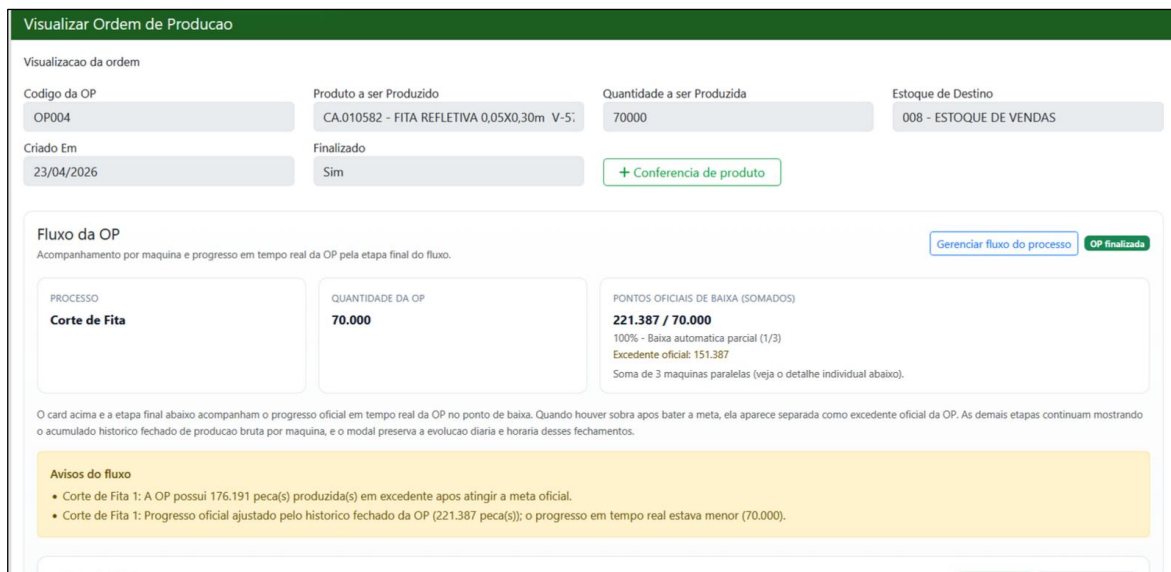


Figure 5: Production Order visualization interface with production flow monitoring.
Source: Authors, (2026).

This screen displays information such as the order code, product to be manufactured, planned quantity, destination stock, creation date, and completion status. In the PO flow section, the associated production process, total order quantity, summed official reporting points, completion percentage, and operational warnings related to production progress are presented.

The Production Order screen expanded the frontend's traceability capabilities, as it allowed production progress to be monitored not only from the machine perspective but also from the perspective of the executed order. This feature is important because the PO represents a central control unit in the production process, connecting the product, planned quantity, involved machines, production reporting, and stage completion. The PO flow section proved especially relevant for interpreting the order's progress. The interface displays the official reporting points, indicates when the PO has been completed, and shows warnings related to excess production or adjustments in official progress. These warnings help the user understand situations in which the recorded production exceeds the planned target or when official progress is adjusted based on closed historical records. Thus, the interface no longer displays only numerical values but also contextualizes the data according to the applied operational rules. This functionality makes the visualization more understandable for the user and reduces the need for manual interpretation of production records.

IV.5 PRODUCTION PARAMETERS BY MACHINE

Figure 6 presents the machine production detail modal within the Production Order. This screen displays machine-specific parameters in the context of the PO, such as order quantity, total gross production, PO percentage, last closing, and indication of the official reporting point.

Corte de Fita 1					
OP OP004 - Corte de Fita					
ORDEM NO FLUXO -	QUANTIDADE DA OP 70.000	PRODUCAO BRUTA TOTAL 221.387	PERCENTUAL DA OP 100%	ULTIMO FECHAMENTO 13/05/2026 10:00	PONTO OFICIAL DE BAIXA Sim
23/04/2026 Producao do dia: 14.140		Acumulado real: 14.140 Acumulado na meta: 14.140 % da OP: 20,20%			
HORA	PRODUCAO BRUTA	ACUMULADO REAL	ACUMULADO NA META	% DA OP	
11:00	0	0	0	0%	
12:00	0	0	0	0%	
13:00	0	0	0	0%	
14:00	10.374	10.374	10.374	14,82%	
15:00	1.990	12.364	12.364	17,66%	
16:00	1.776	14.140	14.140	20,20%	
17:00	0	14.140	14.140	20,20%	

Figure 6: Machine production detail modal with Production Order parameters and hourly history.

Source: Authors, (2026).

In addition to the general parameters, the interface presents an hourly history table containing gross production, actual accumulated production, accumulated production considered toward the target, and the corresponding percentage of the order. This machine-level detail was an important result for monitoring PO execution, as it allows analysis of how each piece of equipment contributed to the order's progress over time. The hourly table makes it possible to observe production evolution during different periods of the shift, identifying hours with higher or lower production. It also allows comparison between the actual accumulated production and the accumulated production considered for the target, supporting data verification and the analysis of possible discrepancies between recorded production, valid production, and the official progress of the PO. The display of the last closing and the official reporting point contributes to production traceability. These fields help clarify which records were considered in the official PO progress and which values correspond to accumulated production. In this way, the frontend provides a more transparent visualization of production closing and reporting rules, supporting operational analysis and result verification. This functionality also reinforces the importance of the frontend as a support layer for production control. By enabling visualization of PO parameters by machine, the interface brings technical production process data closer to the users' daily monitoring routine, making it easier to identify inconsistencies, excess production, and actual production progress.

IV.6 NOTIFICATION PANEL AND RECENT EVENTS

In addition to the dashboards and monitoring screens, a notification panel was developed to display recent system events. Figure 7 presents this feature, where notifications of completed POs, critical alerts, and medium-level alerts associated with specific machines are displayed.

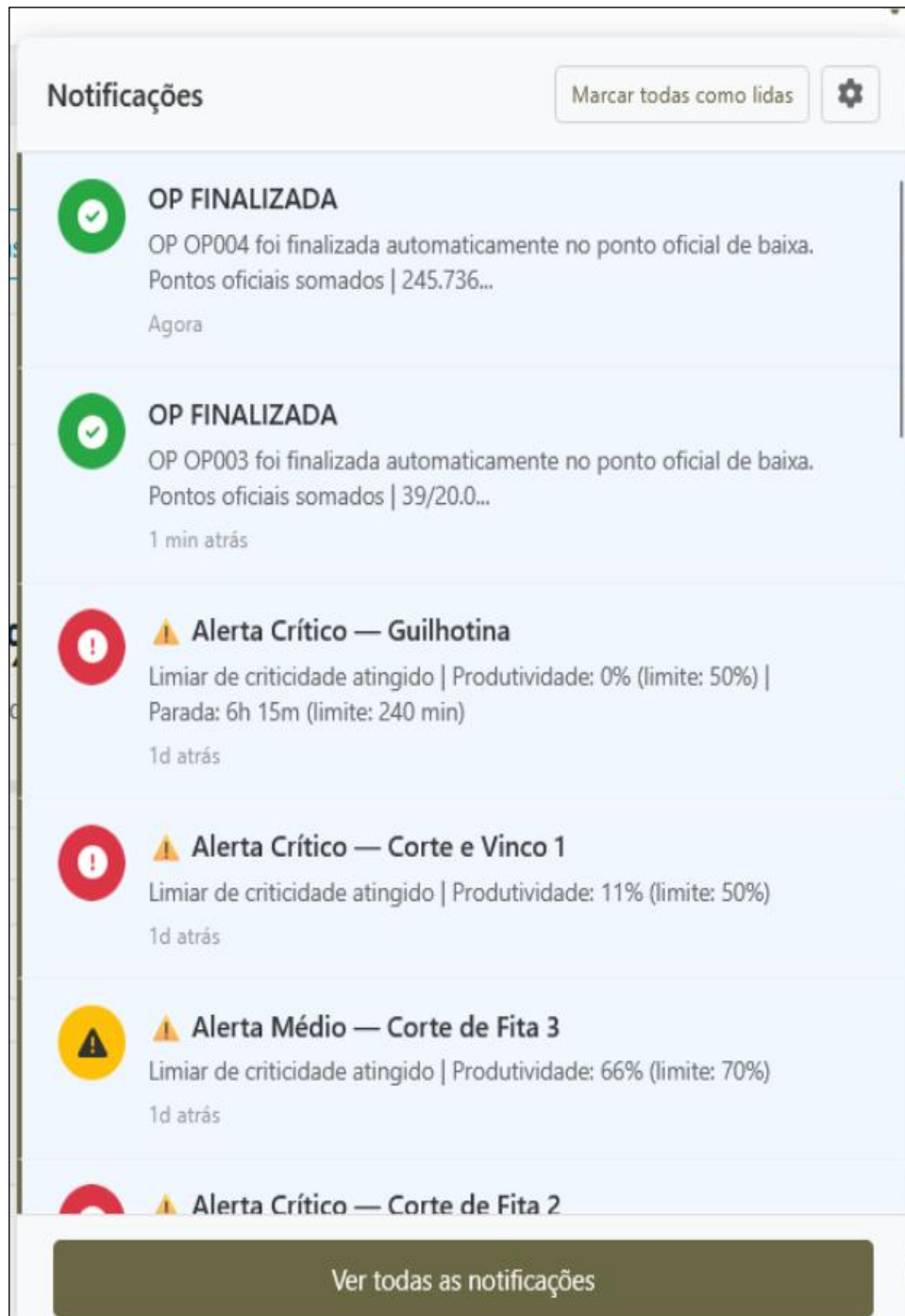


Figure 7: Notification panel with recent events and operational alerts.
Source: Authors, (2026).

The notifications are organized with icons, colors, and descriptive messages, allowing differentiation between positive events, warning situations, and critical occurrences. This feature contributed to making the frontend more active in production supervision. Instead of being limited to the presentation of static indicators, the interface began highlighting relevant events generated by the system. Among the displayed events are notifications of automatic completion of production orders, alerts related to criticality thresholds, and warnings associated with specific machines. This behavior supports rapid team response to situations requiring attention, such as low productivity, excessive downtime, or events related to the production flow. The use of different visual alert levels facilitates the prioritization of occurrences. Critical alerts are highlighted with greater visual intensity, while completed PO notifications are displayed with a positive indication. This differentiation helps users quickly understand the nature and urgency of the event, contributing to more efficient supervision.

IV.7 E-MAIL ALERT CONFIGURATION

Figure 8 presents the e-mail alert configuration interface. This feature allows recipients to be defined for different criticality levels, such as critical, high, medium, and low, in addition to configuring the cooldown interval for each type of alert.

Alertas por Email

Crítico Cooldown: 120 min
Nenhum destinatário configurado
ex: fulano@empresa.com +

Alto Cooldown: 60 min
Nenhum destinatário configurado
ex: fulano@empresa.com +

Médio Cooldown: 60 min
Nenhum destinatário configurado
ex: fulano@empresa.com +

Baixo Cooldown: 120 min
Nenhum destinatário configurado
ex: fulano@empresa.com +

Figure 8: E-mail alert configuration interface according to criticality level.

Source: Authors, (2026).

The e-mail alert configuration expanded the operational reach of the frontend, as it enabled critical events to be communicated even outside the direct visualization of the dashboard. Defining recipients according to criticality level makes communication more organized, allowing higher-severity alerts to be forwarded to those responsible for decision-making or technical intervention. The cooldown feature helps reduce operational noise by preventing multiple notifications from being sent within a short period for the same condition. This adjustment is important in industrial environments, where repetitive events may generate excessive notifications and make it more difficult to prioritize truly critical occurrences. With this functionality, the interface came to encompass not only data visualization but also the configuration of operational communication rules. This demonstrates that the developed frontend acts as a layer of interaction and system parameterization, allowing users to adapt alert behavior according to operational needs.

IV.8 GENERAL ANALYSIS OF THE RESULTS

Overall, the results demonstrated that the developed frontend interface achieved the objective of transforming industrial data into useful visual information for monitoring and decision-making. The combination of cards, tables, gauges, full-screen dashboards, Production Order screens, machine parameters, notifications, and alert configuration made it possible to address different levels of analysis: overall production overview, equipment-level detail, PO monitoring, TV-based supervision, and event management. The solution also demonstrated adherence to Industry 4.0 principles, especially regarding connectivity, process digitalization, system integration, and real-time monitoring. The developed frontend materializes this proposal by providing interfaces capable of representing machines, orders, indicators, and events in a centralized and understandable manner. Another observed aspect was the interface's contribution to system usability. Dividing the information into specific screens reduced the complexity of analysis and facilitated the interpretation of production data. The main dashboard provides a summarized production overview; the modals enable detailed analysis; the full-screen dashboard supports shop-floor usage; the Production Order screens enhance traceability; and the alerts support responses to critical events. Finally, the developed module contributed to increasing operational visibility of production, allowing operators, managers, and technical teams to monitor machine performance, order progress, recent events, and criticality alerts. The interface also proved suitable for different usage contexts, including workstation consultation, detailed modal analysis, and full-screen monitoring in the manufacturing environment. Therefore, the developed frontend does not act merely as a display layer, but as a strategic component for supervision, traceability, and decision-making support within the intelligent manufacturing system.

V. CONCLUSIONS

The development of the frontend interface for intelligent real-time production monitoring demonstrated the importance of the visual and interactive layer in industrial systems within the context of Industry 4.0. The developed solution enabled the centralization of relevant operational information, such as machine status, performance indicators, Production Order progress, production parameters by equipment, recent events, and critical alerts, making industrial data more accessible and understandable for operators, supervisors, and managers. The presented results showed that the dashboards, tables, gauges, Production Order monitoring screens, notification panel, and e-mail alert configuration contributed to increasing the visibility of the production process and supporting real-time decision-making. The full-screen dashboard, intended for use in the manufacturing environment, also proved relevant by facilitating continuous production monitoring through objective and easy-to-read information. Thus, it can be concluded that the developed frontend does not act merely as a data presentation layer, but as a strategic component for production supervision, traceability, and operational control. The proposed interface strengthens the integration between users and the intelligent system, contributing to greater agility in identifying deviations, improving operational communication, and advancing digital transformation in the industrial environment.

VI. AUTHOR'S CONTRIBUTION

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VIII. REFERÊNCIAS

- [1] Spadinger, R. (2024). Internet of Things (IoT), digital transformation, and Industry 4.0.
- [2] Rocha, P. M. (2025). Opportunities and challenges arising from the implementation of Industry 4.0: a study on digital transformation in the electronics sector in the Manaus Industrial Pole.
- [3] Damasceno, A. H., Leite, J. C., Junior, J. D. A. B., & de Queiroz Júnior, F. C. (2024). Digital transformation in the Manaus Industrial Pole: increasing efficiency in lithium battery production through Industry 4.0. *ARACÊ, 6*(4), 15458–15470.
- [4] Radanliev, P., De Roure, D., Nicolescu, R., Huth, M., & Santos, O. (2022). Digital twins: artificial intelligence and IoT cyber-physical systems in Industry 4.0. *International Journal of Intelligent Robotics and Applications, 6*(1), 171–185.
- [5] Haldorai, A. (2023). A review on artificial intelligence in the Internet of Things and cyber-physical systems. *Journal of Computing and Natural Science, 3*(1), 012–023.
- [6] Tran-Dang, H., & Kim, D. S. (2021). The physical internet in the era of digital transformation: perspectives and open issues. *IEEE Access, 9*, 164613–164631.
- [7] Qadir, A. (2025). The future of cyber-physical systems: integration of AI, IoT, and cloud computing for the Industrial Revolution 5.0. *Frontiers in Multidisciplinary Studies, 2*(01), 43–53.
- [8] Radanliev, P., De Roure, D., Nicolescu, R., Huth, M., & Santos, O. (2021). Artificial intelligence and the Internet of Things in Industry 4.0. *CCF Transactions on Pervasive Computing and Interaction, 3*(3), 329–338.
- [9] Borangiu, T., Morariu, O., Răileanu, S., Trentesaux, D., Leitão, P., & Barata, J. (2020). Digital transformation of manufacturing: Industry of the Future with cyber-physical production systems. *Romanian Journal of Information Science and Technology, 23*(1), 3–37.
- [10] Lăzăroiu, G., Klietk, T., & Novak, A. (2021). Smart Internet of Things devices, industrial artificial intelligence, and real-time sensor networks in sustainable cyber-physical production systems. *Journal of Self-Governance and Management Economics, 9*(1), 20–30.
- [11] Ryalat, M., ElMoaqet, H., & AlFaouri, M. (2023). Design of a smart factory based on cyber-physical systems and the Internet of Things toward Industry 4.0. *Applied Sciences, 13*(4), 2156.

- [12] Meindl, B., & Mendonça, J. (2021). Mapping Industry 4.0 technologies: from cyber-physical systems to artificial intelligence. *arXiv preprint arXiv:2111.14168*.
- [13] Radanliev, P., De Roure, D., Van Kleek, M., Santos, O., & Ani, U. (2021). Artificial intelligence in cyber-physical systems. *AI & Society, 36*(3), 783–796.
- [14] Lachvajderová, L., & Kádárová, J. (2022). Industry 4.0 implementation and readiness for Industry 5.0 in industrial enterprises. *Management and Production Engineering Review, 13*.
- [15] Ulewicz, R., KRSTIĆ, B., & Ingaldi, M. (2022). Mining Industry 4.0 – Opportunities and barriers. *Acta Montanistica Slovaca, 27*(2).
- [16] Karnouskos, S. (July 2011). Cyber-physical systems in the smart grid. In *2011 9th IEEE International Conference on Industrial Informatics* (pp. 20–23). IEEE.
- [17] Keerthi, C. K., Jabbar, M. A., & Seetharamulu, B. (December 2017). Cyber-physical systems (CPS): security issues, challenges, and solutions. In *2017 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)* (pp. 1–4). IEEE.
- [18] Jamaludin, J., & Rohani, J. M. (November 2018). Cyber-physical system (CPS): state of the art. In *2018 International Conference on Computing, Electronics & Communications Engineering (ICCECE)* (pp. 1–5). IEEE.
- [19] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): a vision, architectural elements, and future directions. *Future Generation Computer Systems, 29*(7), 1645–1660.
- [20] Abdul-Qawy, A. S., Pramod, P. J., Magesh, E., & Srinivasulu, T. (2015). The Internet of Things (IoT): an overview. *International Journal of Engineering Research and Applications, 5*(12), 71–82.
- [21] Gupta, B. B., & Quamara, M. (2020). An overview of Internet of Things (IoT): architectural aspects, challenges, and protocols. *Concurrency and Computation: Practice and Experience, 32*(21), e4946.
- [22] Rawat, R., & Yadav, R. (January 2021). Big data: big data analytics, issues, challenges, and technologies. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1022, No. 1, p. 012014). IOP Publishing.
- [23] Kitchin, R. (2021). *The Data Revolution: A Critical Analysis of Big Data, Open Data, and Data Infrastructures.*
- [24] Nadikattu, R. R. (2020). Research on data science, data analytics, and big data. *International Journal of Engineering, Science and, 9*(5), 99–105.
- [25] Christou, P. A. (2024). Thematic analysis through artificial intelligence (AI). *The Qualitative Report, 29*(2), 560–576.
- [26] Zhai, X., Chu, X., Chai, C. S., Jong, M. S. Y., Istenic, A., Spector, M., ... & Li, Y. (2021). A review of artificial intelligence (AI) in education from 2010 to 2020. *Complexity, 2021*(1), 8812542.
- [27] Ahmed, I., Jeon, G., & Piccialli, F. (2022). From artificial intelligence to explainable artificial intelligence in Industry 4.0: a survey on what, how, and where. *IEEE Transactions on Industrial Informatics, 18*(8), 5031–5042.