SEVEN
publicações acadêmicas

A REAL-TIME PRODUCTION CONTROL SYSTEM

UM SISTEMA DE CONTROLE DE PRODUÇÃO EM TEMPO REAL

UN SISTEMA DE CONTROL DE PRODUCCIÓN EN TIEMPO REAL

https://doi.org/10.56238/sevened2025.036-164

Adriano Camargo De Luca[1], André Albuquerque Nunes Ribeiro[2], Roberto Luiz Ciuccio[3], Ricardo Luiz Ciuccio[4]

ABSTRACT

This article presents the development and application of a real-time production control system, integrating hardware and software for continuous monitoring of industrial operations and costs. The proposal aims to promote greater operational efficiency and agility in decision-making. The main objective is to present a proposal for applying the concept of paperless manufacturing, here referred to as “right time,” in a production line of medical and hospital products, in order to identify and quantify the benefits generated by the proposed environment. The adopted methodology was action research, encompassing the system design, its technological architecture, and its application in a simulated manufacturing environment. The results demonstrate significant gains in operational visibility, waste reduction, and improvement in cost control. With the implementation of the developed improvement proposal, a reduction of 32% in document-filling time on the assembly line is estimated, in addition to a 5% decrease in annual paper consumption. Other observed benefits include improvements in internal communication, document control, workplace organization, and the execution of routine activities. Additionally, the study contributes to digital transformation in industry, aligning with the principles of Industry 4.0 and reinforcing the importance of digitalization as a strategic tool for the modernization of production processes.

Keywords: Process Optimization. Digital Transformation. Real-Time Production Control. Industry 4.0. Lean Manufacturing.

RESUMO

Este artigo apresenta o desenvolvimento e a aplicação de um sistema de controle de produção em tempo real, integrando hardware e software para o monitoramento contínuo das operações e dos custos industriais. A proposta visa promover maior eficiência operacional e agilidade na tomada de decisões. O objetivo principal é apresentar uma proposta de aplicação do conceito de manufatura paperless, aqui denominado tempo certo, em uma linha de produção de produtos médicos hospitalares, com o intuito de identificar e quantificar os benefícios gerados pelo ambiente proposto. A metodologia adotada foi a pesquisa-ação, abrangendo a concepção do sistema, sua arquitetura tecnológica e a

[1] Specialization in Architecture and Sustainable Design Projects. Strattexia Inovação.
E-mail: adriano@strattexia.com.br
[2] Specialization in Software Architecture. Strattexia Inovação. E-mail: andre@strattexia.com.br
[3] Specialization in Big-Data and Data Science. Strattexia Inovação. E-mail: roberto@strattexia.com.br
[4] Master's Degree in Mechanical Engineering. Centro Universitário Senac.
E-mail: ricardo.lciuccio@sp.senac.br

aplicação em um ambiente fabril simulado. Os resultados demonstram ganhos significativos em visibilidade operacional, redução de desperdícios e melhoria no controle de custos. Com a implantação da proposta de melhoria desenvolvida, estima-se uma redução de 32% no tempo de preenchimento de documentos na linha de montagem, além de uma diminuição de 5% no consumo anual de papel. Outros benefícios observados incluem avanços na comunicação interna, no controle de documentos, na organização do ambiente de trabalho e na execução das atividades rotineiras. Adicionalmente, o estudo contribui para a transformação digital na indústria, alinhando-se aos princípios da Indústria 4.0 e reforçando a importância da digitalização como ferramenta estratégica para a modernização dos processos produtivos.

Palavras-chave: Otimização de Processos. Transformação Digital. Controle de Produção em Tempo Real. Indústria 4.0. Lean Manufacturing.

RESUMEN

Este artículo presenta el desarrollo y la aplicación de un sistema de control de producción en tiempo real, integrando hardware y software para el monitoreo continuo de las operaciones y de los costos industriales. La propuesta tiene como objetivo promover una mayor eficiencia operativa y agilidad en la toma de decisiones. El objetivo principal es presentar una propuesta de aplicación del concepto de manufactura sin papel, denominado aquí “tiempo correcto”, en una línea de producción de productos médicos hospitalarios, con el fin de identificar y cuantificar los beneficios generados por el entorno propuesto. La metodología adoptada fue la investigación-acción, abarcando el diseño del sistema, su arquitectura tecnológica y la aplicación en un entorno fabril simulado. Los resultados demuestran avances significativos en visibilidad operativa, reducción de desperdicios y mejora en el control de costos. Con la implementación de la propuesta de mejora desarrollada, se estima una reducción del 32% en el tiempo de llenado de documentos en la línea de montaje, además de una disminución del 5% en el consumo anual de papel. Otros beneficios observados incluyen mejoras en la comunicación interna, en el control de documentos, en la organización del entorno de trabajo y en la ejecución de las actividades rutinarias. Adicionalmente, el estudio contribuye a la transformación digital en la industria, alineándose con los principios de la Industria 4.0 y reforzando la importancia de la digitalización como herramienta estratégica para la modernización de los procesos productivos.

Palabras clave: Optimización de Procesos. Transformación Digital. Control de Producción en Tiempo Real. Industria 4.0. Lean Manufacturing.

1 INTRODUCTION

Digital transformation has driven significant changes in the way industries operate. In this context, real-time production control becomes essential to ensure competitiveness, efficiency, and quality. The concept of "right time" proposes that operations take place at the right time, with adequate resources and without waste. This article proposes a system that integrates hardware and software to monitor and control production in real time, promoting greater visibility and control over production processes.

The concept of Industry 4.0, which emerged in 2011, goes beyond the digitalization and automation of production processes. It encompasses the integration between information technologies and industrial automation, with the aim of reducing latency in managerial decision-making and facilitating access to reliable data from the industrial operation, maximizing business value (Becker et al., 2017).

The global market is increasingly competitive, demanding greater productivity and quality from organizations, reduced production time, and the ability to meet demands with shorter deadlines and more complex products. These products require traceability of both the process and the product, as a way to ensure reliability (Conceição et al., 2009).

To ensure this traceability, companies develop and regulate their manufacturing processes based on internal and external standards. These documents, defined as operational procedures, are fundamental for the standardization of processes and for the prevention of failures and waste, in addition to facilitating the understanding of activities (Freitas et al., 2012).

An approach that contributes to the standardization and integration of these procedures is Virtual Manufacturing, which allows the connection between all sectors involved in the planning, design, updating and documentation of information and specifications of the process and the manufacture of the product on a computational basis (Banerjee and Zetu, 2001; Conceição et al., 2009; Groover, 2011).

Digital Transformation (DT) is a process driven by digital technologies, whose impacts affect the mechanisms of value creation, strategy, and organizational structure (Vial, 2019). It transforms products, processes, structures, and organizational aspects (Matt, 2015). For Feroz et al. (2021), DT goes further, creating opportunities both for business competitiveness and for the remodeling of business performance and its environmental impact.

The concept of electronic documentation (paperless) emerged more than 30 years ago and aims to eliminate or reduce the use of paper in the administrative routine, using

technology to optimize processes, facilitate access to information, save resources and contribute to sustainability (Ortega, 2004). This practice can be applied to companies of all sizes and segments, promoting resource savings, agility, information security, and sustainability. According to Indolfo et al. (1995), documents are material records of information that prove facts and thoughts in a given time and space. Freitas and Guarechi (2011) highlight that electronic documents provide convenience, speed, security and reliability, in addition to reducing the volume of printed material, becoming instruments of great relevance for organizations.

Thus, the main objective of the present work is to present a proposal for the application of the concept of paperless manufacturing, here called right time, in a production line of hospital medical products, aiming to identify and quantify the benefits generated with the proposed environment.

2 INTEGRATED INFORMATION SYSTEM

Efficient data sharing between and within an organization's functional areas directly contributes to more effective business processes and businesses. Information systems designed to enable this sharing are known as integrated information systems. Companies receive resources — such as materials, people, or equipment — and turn them into goods and services for customers. For this transformation to occur efficiently, it is essential to have accurate and up-to-date information.

For example, when receiving a purchase order, the sales team activates production, which schedules manufacturing. If raw materials are required, production notifies the purchasing department, which carries out the purchase. The logistics sector, in turn, receives and accounts for the materials, updates the records and forwards the inputs to production. This flow is only possible with the integration of information systems, which results in a more efficient organization and optimized processes (Monk and Wagner, 2006 1).

According to no et al. (2015 2), the integration of systems facilitates the flow of information and communication between organizational sectors. Rich and Dibbern (20123) add that this optimization allows identifying bottlenecks in data entry and implementing corrective measures. As a result, internal communication improves, productivity increases, and costs are reduced.

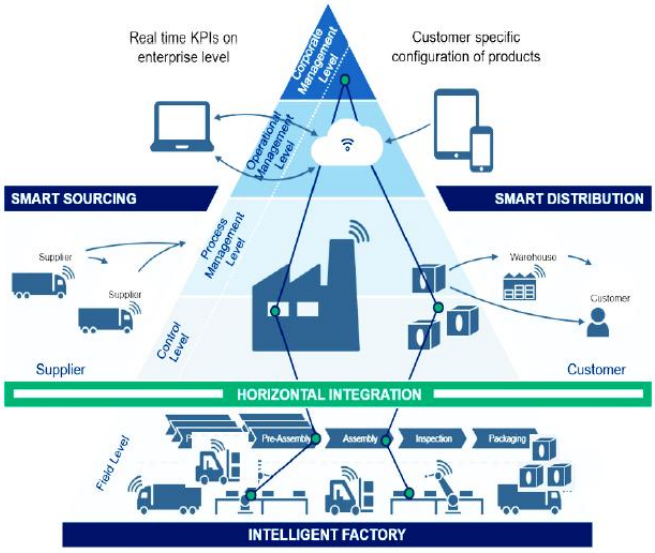
In manufacturing environments, where several departments and employees work simultaneously, the efficient circulation of information is essential. For this, integration between systems and data is necessary (Chao, 2016).

Two fundamental concepts in this context are Horizontal Integration and Vertical Integration. Horizontal Integration connects the sectors of the production chain, allowing quick responses and optimized use of resources — such as, for example, inventory connected to the supplier for automatic replenishment. Vertical Integration, on the other hand, connects all hierarchical levels of the company, from the operation to the board of directors, promoting agility in communication and assertiveness in decision-making (Albertin, 2021).

In this work, the proposal is based on Vertical Integration, allowing the exchange of information in real time between sectors, which generates value for the organization through faster and more accurate decisions. Figure 1 presents the Industry 4.0 pyramid and the concepts of integration and Smart Industry.

Figure 1

Industry 4.0 Pyramid Concepts of Integration and Smart Industry



Source: Pinterest (2022).

2.1 DIGITAL TRANSFORMATION

The term "digital" has been widely used since 2010, and the expression "digital transformation" (DT) has gained prominence in various media, such as newspapers, TV programs, books, and academic articles (Krimpmann, 2015; Andriole, 2020; Imran et al., 2021). Krimpmann (2015, p. 1209) defines DT as the "sum of technologies that transform

previously physical processes into processes that are partial or fully activated by technology". Thus, DT occurs when new structures — such as business models, practices, values, and beliefs — emerge from the consolidation of digital innovations.

Hinings, Gegenhuber and Greenwood (2018, p. 53) add that DT results from the combined effects of multiple digital innovations, creating new actors, structures and practices that challenge or replace existing organizational rules. Vial (2019, p. 3) defines DT as a process that aims to improve institutions through the combination of information, computing, communication and connectivity technologies, promoting new forms of collaboration and innovation.

The structural change promoted by DT requires cultural and behavioral transformations, and leadership is an essential factor in this process (Shaughnessy, 2018). Organizations look to TD to improve the quality of their products and services (Fachrunnisa et al., 2020), as well as to meet environmental sustainability demands (Feroz, Zo, and Chiravuri, 2021).

Digital technologies are reshaping the way sustainability is measured and controlled, especially in areas such as waste management, pollution control, and sustainable production. However, there are still gaps in the literature on how organizations should adapt to these disruptions (Feroz, Zo, and Chiravuri, 2021). Jones and Wynn (2021) note that while "digital" and "sustainability" are dominant trends, their intersection is still underexplored.

Lokuge et al. (2021) highlight that the environmental impact of digital technologies requires global coordination, aligned at the local, organizational, and individual levels, with a focus on awareness, incentives, and overcoming barriers. Sartal et al. (2020) reinforce that today's society recognizes the need for a new model of production and consumption, which considers environmental and social impacts.

In this context, digital technologies offer opportunities to develop sustainable business models or adapt existing ones with environmentally responsible practices. Incorporating sustainability into DT and organizational strategy is still a challenge that requires further study. Feroz and Chiravuri (2021) point out that the development of sustainable digital capabilities positively impacts organizational performance, customer loyalty, and brand value.

Finally, Hausberg et al. (2019) identify gaps in DT research, especially with regard to the sustainability and societal effects of digital technologies. The authors warn of the risks of digital exclusion, especially in economically vulnerable societies, reinforcing the need for a critical and inclusive approach to digital transformation.

2.2 PAPERLESS

According to Granieri (2016), the concept of paperless, that is, the elimination or reduction of the use of paper, is a policy adopted by organizations that, with the help of technology — such as software, applications, and online resources — allows the management and storage of documents in order to optimize processes and increase operational efficiency.

Arney, Jone and Wolf (2009) point out that, in addition to the technology offering new alternatives for reducing the use of paper, it also provides significant cost savings. However, this concept still faces resistance in some companies, due to the difficulty of adapting management and organizational culture, as well as the increase in the flow of information throughout the value chain, which intensifies paper consumption.

With the reduction of the obligation to physically print documents and the advancement of technologies, the market already offers affordable solutions for organizations that wish to adopt the paperless model (Granieri, 2016).

For an effective transition to the digital environment, strategic planning is necessary, which involves investments in high-capacity storage software, such as OCR (Optical Character Recognition), which converts scanned documents into searchable text, as well as applications and devices for creating and maintaining documents. Investments in team training and digital security are also essential (Chuck, 2014).

Johnson (2012) and Granieri (2016) suggest strategic goals for the adoption of paperless systems, such as: reduction of operation time, document traceability, improvement in report generation, optimization of processes and promotion of sustainable practices.

2.3 INFORMATION MANAGEMENT

Information management, as defined by Marcondes (2020), is essential for organizations, as it seeks to identify, organize, and maximize available informational resources. This is fundamental, since information is considered a strategic resource, capable of driving knowledge generation, innovation, and competitive advantage. Information management covers all stages of the information cycle — from collection to use — including the storage, organization, analysis, and distribution of data. For this, it is essential to use technological tools that facilitate access and sharing of information between users.

At the same time, the ISO 9000 standards establish guidelines for the creation and maintenance of a quality management system. These standards define quality principles

applicable to any organization that seeks sustained success through standardization and continuous improvement of its processes. Among them, ISO 9001 stands out, which specifies the requirements to demonstrate the ability to provide products and services that meet customer requirements and legal requirements. ISO 9004 offers guidelines to improve the performance of the quality management system, while ISO 19011 deals with guidelines for internal and external audits (ABNT, 2015).

Therefore, both information management and the adoption of ISO 9000 standards are determining factors for organizational success, contributing to process efficiency, continuous improvement and competitiveness in the market.

3 METHODOLOGY

The present research has a quantitative and qualitative approach and an explanatory character and was applied in a medical products company, manufacturer of dental implants, located in the interior of the state of São Paulo.

For this study, the action research procedure was used, which, as defined by Thiollent (1985) and Gil (2010), is a methodology of experimental verification in a participatory or cooperative way that provides the development and change of the environment/object studied.

Mello et al., (2012), Coughlan and Coghlan (2002) and Thiollent (2007) establish the following stages for the construction of an action research: Exploratory phase; Formulation of the problem; Construction of hypotheses; Hold seminars; Select samples; Collect data; Analyze data; Prepare an action plan; Implement and evaluate the results.

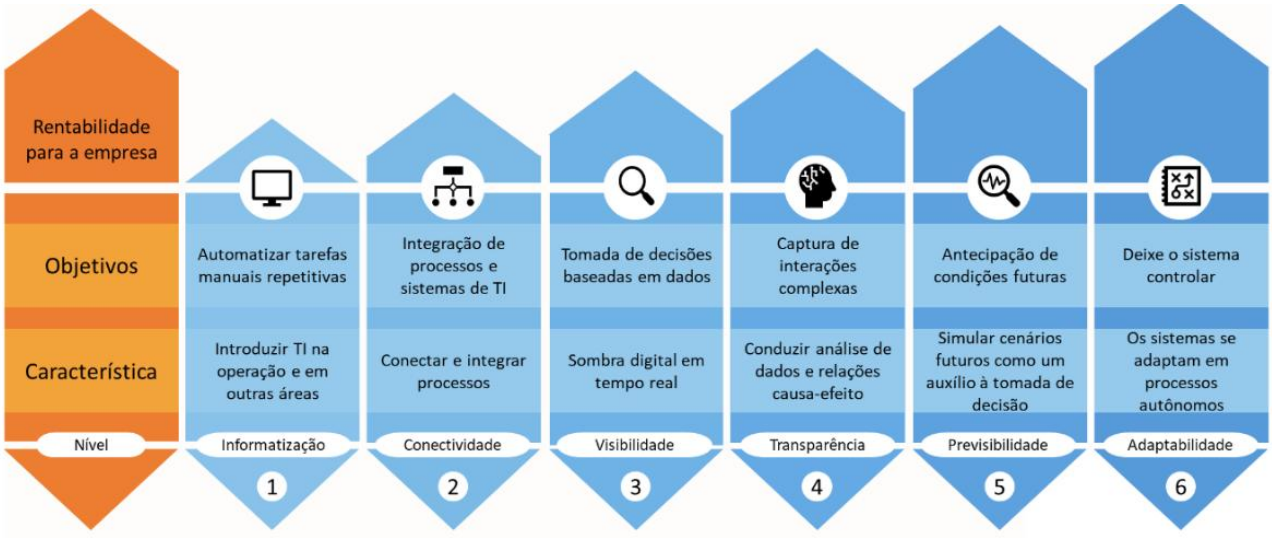
The methodology proposed by the German Academy of Sciences and Engineering (Acatech) allows companies to assess their maturity in relation to industry 4.0 and develop strategies to increase it, aiming to maximize the economic benefits of digital transformation (Beckeret al., 2017). This maturity index helps organizations understand their progress in digital transformation and plan their next steps. Acatech describes six levels: a) computerization; b) connectivity; c) visibility; d) transparency; e) prediction capacity; and f) adaptability. Starting with basic automation at the compute level, organizations move on to systems integration at the connectivity level, followed by the ability to monitor operations in real time at the visibility level. Transparency is achieved through detailed understanding of the plant's state, while predictive ability allows you to predict future trends. The apex of maturity is reached at the level of adaptability, where organizations can quickly adjust their

operations and strategies according to changes in the business environment or unexpected problems, however, it has proven to be a challenging task (Beckeret al., 2017).

When it comes to the maturity of a process in relation to Industry 4.0, there are several models that represent the stages of a digital transformation. In the case studied in this article, the company is in a process of computerization, that is, the introduction of systems in an operation. Figure 2 shows the stages of evolution that a company must follow to ensure the digitalization of processes and belong to the Industry 4.0 level.

Figure 2

Stages of the development path of industry 4.0

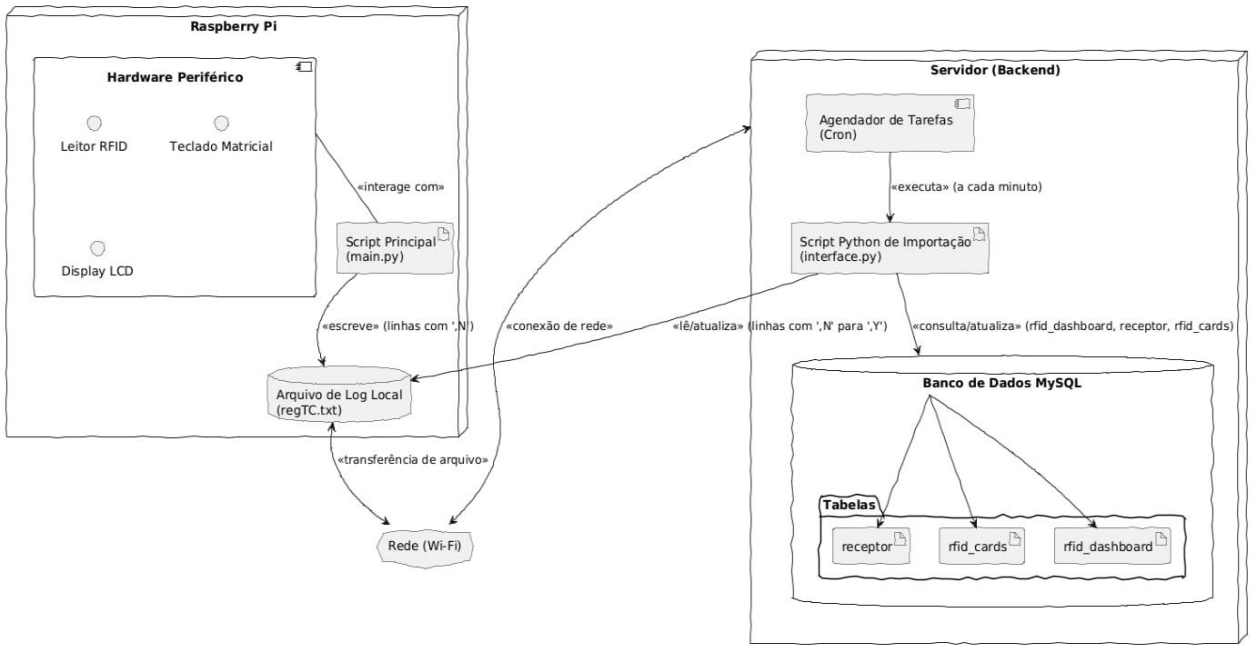


Source: Prepared by the author adapted from Schuh et al. (2020).

Figure 3 shows the flowchart that represents the operation of the system with Raspberry Pi, backend server integrated with its peripherals and MySQL database. It clearly shows the flow of data between the components and scripts involved.

Figure 3

Schematic drawing of the software architecture



Source: Prepared by the author (2025).

4 RESULTS AND DISCUSSION

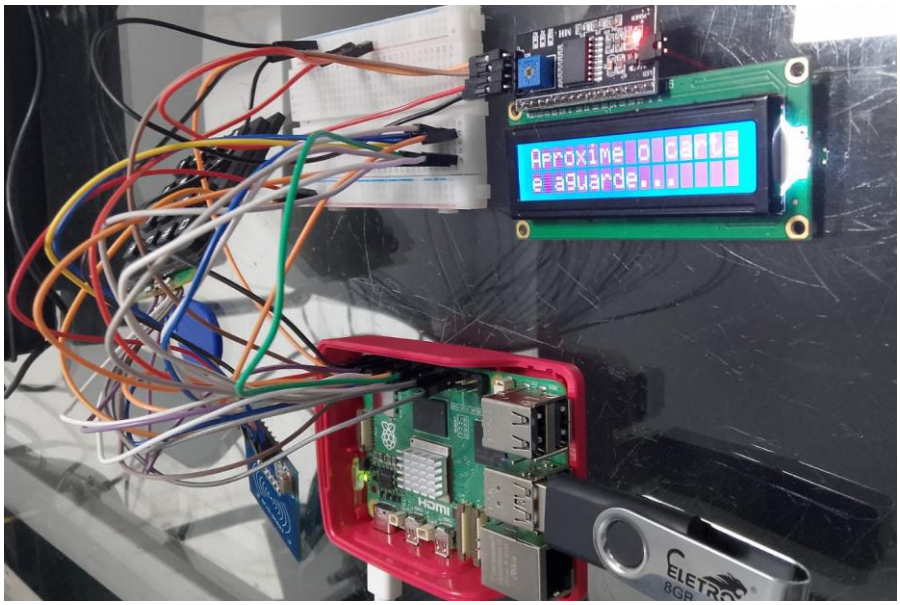
The project developed aims to apply RFID (Radio Frequency Identification) technology to optimize time and cost control in operational and academic environments. Using a Raspberry Pi board integrated with an LCD display and RFID sensors, it was possible to create a functional and accessible system for monitoring attendance and activities.

The message displayed on the display — "Bring the card close and wait..." — indicates the simplicity and efficiency of the identification process, which can be used to register the entry and exit of employees, students or event participants. The collected data is stored locally on an 8GB USB stick, ensuring security and portability.

The photographic record in figure 4 presents the prototyping of the product developed for real-time time and cost control.

Figure 4

Prototyping the Timing hardware



Source: Prepared by the author (2025).

The photographic record in figure 5 shows the device developed in an acrylic case to protect the electronic circuit and easy access to the card reader and for data input using the keyboard.

The device called "Tempo Certo" was tested in a medical device industry, with the aim of controlling production operations in real time. Before the implementation, an employee was responsible for manually collecting the data from the previous day to make the production notes and send the status of the manufacturing system to management. This process was time-consuming and subject to errors and delays.

With the application of the developed technology, based on RFID and embedded computing, the data began to be presented in real time. This allowed the employee to redirect their time to more value-added activities, such as performance analysis and continuous improvement of processes.

According to Wanderley, Holanda and Oliveira (2014), RFID "has been presenting itself as an important tool in the search for quality in the flow of information, presenting great potential for application in various segments". This wireless technology allows the automation of product identification, integrating the physical and technological sectors and providing real-time monitoring of stock levels and movements.

In addition, Salgado (2013) highlights that the integration between technology and logistics allows for a more accurate and efficient information chain, reducing errors and increasing the reliability of processes. Almeida (2010) reinforces that inventories represent about 2% of the net revenue of companies, and effective management is essential to avoid losses and improve operational performance.

Figure 5

Right Time in Operation

Source: Prepared by the author (2025).

Among the main results obtained with the project, the following stand out:

- Reduction of operating costs with manual processes of time and production control.
- Increased accuracy in the collection of time and movement data.
- Process automation, with less human interaction and greater reliability.
- Ease of integration with existing systems, thanks to the use of accessible and open-source components.
- Portability and scalability, allowing system replication in different environments with minimal adaptation.
- Technological engagement of students and entrepreneurs, who actively participated in the assembly and programming of the system.

Figure 6 features an open hand in the foreground, symbolizing human control over digital systems. Floating above the hand, various graphical and user interface elements represent a real-time data processing environment.

Visual composition conveys the idea of interaction between humans and technology, with a focus on monitoring, performance, and control of complex systems. It can be used to illustrate topics such as industry 4.0, intelligent automation, real-time data analysis or human-machine interfaces.

The application of this solution presented several dashboards to facilitate real-time decision-making for management. The results obtained indicate that the implementation of the improvement will allow a 32% reduction in the time to fill out documents on the assembly line of hospital medical products, in addition to a 5% decrease in the company's annual paper consumption. Other benefits include improvements in internal communication, document control, the work environment, and routine activities.

Figure 6

Presentation of results in real time

Source: Prepared by the author (2025).

This work demonstrates how emerging technologies, such as RFID and embedded computing, can be applied in a practical and efficient way to solve real problems, promoting innovation, productivity, and interdisciplinary learning.

5 FINAL THOUGHTS

The present research proposed the application of the concept of paperless manufacturing in a production line of medical products, with the objective of identifying and quantifying the benefits generated by this new environment.

Based on the research carried out, the concepts presented and the analysis of the reality of the company studied, quantitative and qualitative benefits resulting from the implementation of the proposal were identified and quantified.

The results obtained indicate that the implementation of the improvement will allow a 32% reduction in the time to fill out documents on the assembly line of hospital medical products, in addition to a 5% decrease in the company's annual paper consumption. Other benefits include improvements in internal communication, document control, the work environment, and routine activities.

In addition, the study contributes to the digital transformation in the industry, aligning with the principles of Industry 4.0.

REFERENCES

Banerjee, P., & Zetu, D. (2001). Virtual manufacturing. John Wiley & Sons.

Becker, T., et al. (2017). Industrie 4.0 maturity index: Managing the digital transformation of companies. Herbert Utz Verlag.

Conceição, S. V., et al. (2009). Desenvolvimento e implementação de uma metodologia para troca rápida de ferramentas em ambientes de manufatura contratada. Gestão & Produção, 16(3), 357–369.

Feroz, A. K., Zo, H., & Chiravuri, A. (2021). Digital transformation and environmental sustainability: A review and research agenda. Sustainability, 13(3), Article 1530. https://doi.org/10.3390/su13031530

Freitas, S. L., & Guarechi, H. M. (2012). A padronização de processos no serviço público através do uso de manuais: A viabilidade do manual de eventos da UTFPR – Campos de Francisco Beltrão. Revista Organização Sistêmica, 2(1).

Groover, M. P. (2011). Automação industrial e sistemas de manufatura (3a ed.). Pearson Prentice Hall.

Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. Business & Information Systems Engineering, 57(5), 339–343. https://doi.org/10.1007/s12599-015-0401-5

Ortega, C. D. (2009). A documentação como uma das origens da ciência da informação e base fértil para sua fundamentação. Brazilian Journal of Information Science: Research Trends, 3(1), 3–35. https://doi.org/10.36311/1981-1640.2009.v3n1.02

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. The Journal of Strategic Information Systems, 28(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003