

Development of an NFC-Based Tracking System for Production, Inventory, and Maintenance in Manufacturing

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Abstract— This paper presents the development, implementation, and evaluation of a computational system for integrating production control, inventory management, and maintenance operations in a manufacturing company using Near Field Communication (NFC) technology. The proposed solution leverages NFC tags as a core element to ensure real-time tracking of products and components throughout the manufacturing process. The system architecture consists of NFC tags for product identification, a custom mobile application for data acquisition, and a centralized database for storage and analysis. The system workflow enables operators to register, monitor, and update the status of products using mobile devices, enhancing traceability, efficiency, and data accuracy. The solution was validated in a real-world manufacturing environment through functional tests and a System Usability Scale (SUS) questionnaire, which yielded an average usability score of 72.08, indicating a good level of user satisfaction. These results demonstrate the feasibility, usability, and practical benefits of the proposed system, which contributes to the digital transformation of industrial operations and aligns with Industry 4.0 principles.

Keywords- NFC; Production Control; Inventory Management; Industry 4.0; Circular Economy

I. INTRODUCTION

The digital transformation of manufacturing industries has been intensified by the advent of Industry 4.0, which promotes the integration of advanced digital technologies to optimize production processes, inventory management, and maintenance operations [1]. Among these technologies, Near Field Communication (NFC) stands out as a promising solution for industrial traceability and automation, enabling secure, fast, and wireless data exchange without the need for complex infrastructure [2].

The application of NFC tags in industrial contexts has significantly advanced in areas such as smart packaging [3], material integrity monitoring [4], healthcare [5], and asset management [1]. The potential of this technology is evident in its ability to integrate real-time data into industrial processes, contributing to more efficient and sustainable management. In

the packaging sector, for instance, NFC tags are used to enhance the consumer experience and authenticate products, while in industrial environments, they can be employed to track materials and manage inventory automatically [3], [6].

Moreover, the literature highlights the role of Information and Communication Technologies (ICT) in supporting the Circular Economy (CE), particularly in the construction sector, where efficient resource management and waste reduction are central challenges [7]. The use of digital tools, such as sensors and ICT-based platforms, helps optimize the material lifecycle, improve traceability, and support decision-making at different stages of production [7].

In the field of industrial data management, there has been a significant increase in the adoption of concepts such as Big Data, the Internet of Things (IoT), and cloud computing systems, which are essential for handling the large volume of information generated in industrial environments [1]. However, despite these advances, gaps still exist, particularly in the integration of real-time tracking and monitoring systems capable of effectively aligning production, inventory, and maintenance operations [1].

In this context, the present study proposes the development of an innovative computational system for a manufacturing company that integrates production control, inventory management, and product maintenance through the use of NFC tags. The proposed solution aims not only to modernize the company's operational control but also to reduce costs, enhance traceability, and promote sustainability in industrial processes, aligning with the trends of Industry 4.0 and the Circular Economy.

NFC technology also demonstrates significant potential beyond the industrial environment, with growing adoption across various sectors. Du [8] highlights its growing adoption in mobile commerce (m-commerce), including contactless payments, peer-to-peer transactions, and mobile coupons. Lathiya and Wang [9] emphasize its application in wireless power transfer (WPT), particularly in wearable and embedded

devices, where NFC can efficiently transmit energy at 13.56 MHz using inductive coupling. Furthermore, Rodrigues et al. [10] explore a wide range of NFC use cases in contexts such as transportation, hospitality, smart homes, and social networks, reinforcing the technology's versatility and its increasing relevance in digital transformation across multiple domains.

II. METHODOLOGY

The proposed system was developed to integrate production control, inventory management, and maintenance operations in a manufacturing company using Near Field Communication (NFC) tags. The system leverages NFC technology for real-time tracking of products and components throughout the production cycle, enabling efficient monitoring, registration, and traceability of manufacturing processes.

A. System Architecture

The solution is composed of three main components:

NFC Tags: Each product or package is associated with a unique NFC tag containing a globally unique identifier (GUID). These tags enable the tracking of products at different stages of production, storage, and maintenance.

Mobile Application: A custom mobile application was developed for Android devices, enabling operators to read and write data from NFC tags using built-in NFC readers. The app provides functionalities for registering new packages, updating status, and retrieving information about products and components.

Backend Database: A centralized database stores all the records of NFC interactions, including tag identifiers, product information, timestamps, and status updates. This enables comprehensive data analysis and historical tracking.

B. System Workflow

The system workflow is illustrated in Figures 1–4. The process begins with the assignment of an NFC tag to a product or package. Operators use the mobile application to scan the tag, which retrieves the corresponding data from the database and updates the system with new information as needed. The main stages of the workflow include:

Tag Registration: Each product is tagged using a unique NFC identifier. Operators can scan the tag to register the product in the system, associating it with production orders and component details.

Product Tracking: As the product moves through different stages (e.g., assembly, storage, shipping), operators scan the tag to update the status. The app displays relevant information such as product type, client name, material used, and comments.

Maintenance and Updates: The system allows operators to update product information, such as component replacements, maintenance actions, or changes in descriptions and quantities.

Traceability: The entire history of a product can be accessed by scanning its NFC tag, providing a full trace of its lifecycle.

C. User Interface

The user interface was designed for ease of use in industrial environments. Figures 2 and 3 present examples of the mobile application screens, showing tag scanning, product information retrieval, and status updates. The system provides visual feedback, such as confirmation messages for successful scans ("Tag Approved!") and error messages for invalid tags or unregistered items.

D. Testing and Validation

The system was tested in a real manufacturing environment. Operators performed a series of scans, registrations, and updates on products such as musical instrument components. The test demonstrated the feasibility and reliability of using NFC tags for real-time tracking, with accurate data retrieval and minimal errors during the scanning process.

III. RESULTS

A. System Interface and Functionalities

The system's interface and workflow are demonstrated through a series of figures that illustrate its key functionalities. Figure 1 presents the interface for reading NFC tags, where operators are prompted to scan a tag and receive confirmation messages such as "Tag Approved!" or error notifications in case of invalid tags. This screen ensures that the correct tag is read and associated with the corresponding product in the system.

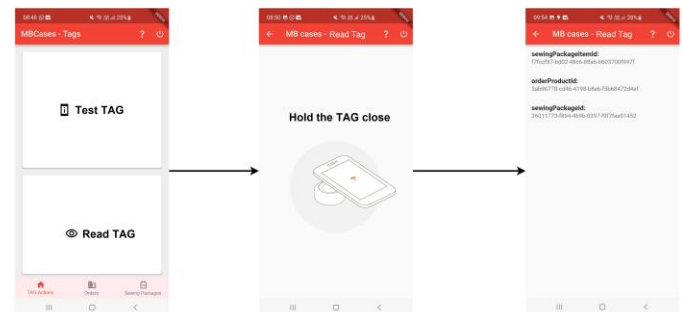


Figure 1: Example of tag scanning interface.

Figure 2 shows the product tracking screen, where detailed information about the product is displayed. This includes the product type, client name, material used (e.g., "Bovine Leather"), and additional comments that can be added or modified by the operator during the production process.

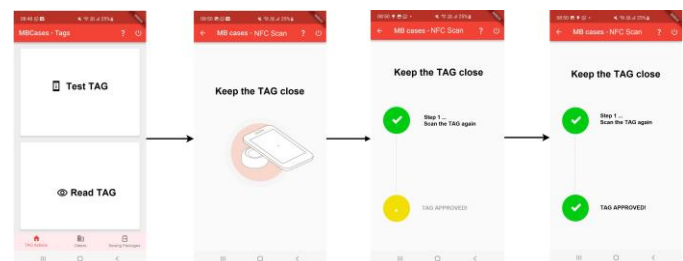


Figure 2: Product tracking screen showing product details and status updates

In Figure 3, the product lifecycle tracking screen is presented. This interface enables operators to manage maintenance actions, such as registering replacements of components, recording maintenance procedures, or modifying product descriptions and quantities. This feature is essential for maintaining traceability and ensuring that all modifications are properly logged throughout the product's lifecycle.

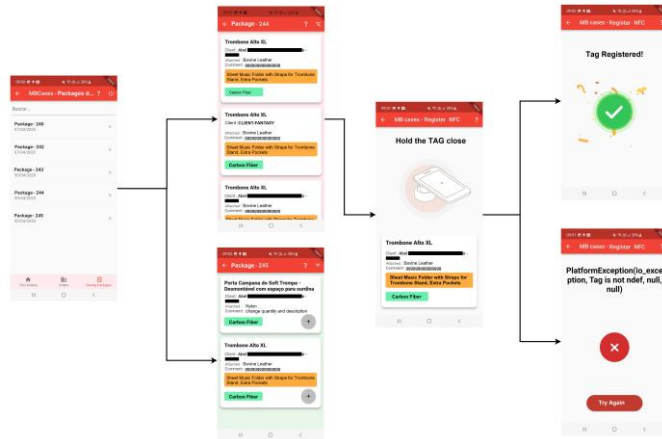


Figure 3: Product lifecycle tracking and maintenance screen

Finally, Figure 4 illustrates the package management and product grouping interface. This screen allows users to view and organize packages that contain multiple products, enabling better control over grouped items and their associated NFC tags. The interface also supports operations such as searching for specific products, viewing package details, and managing inventory in an intuitive manner.

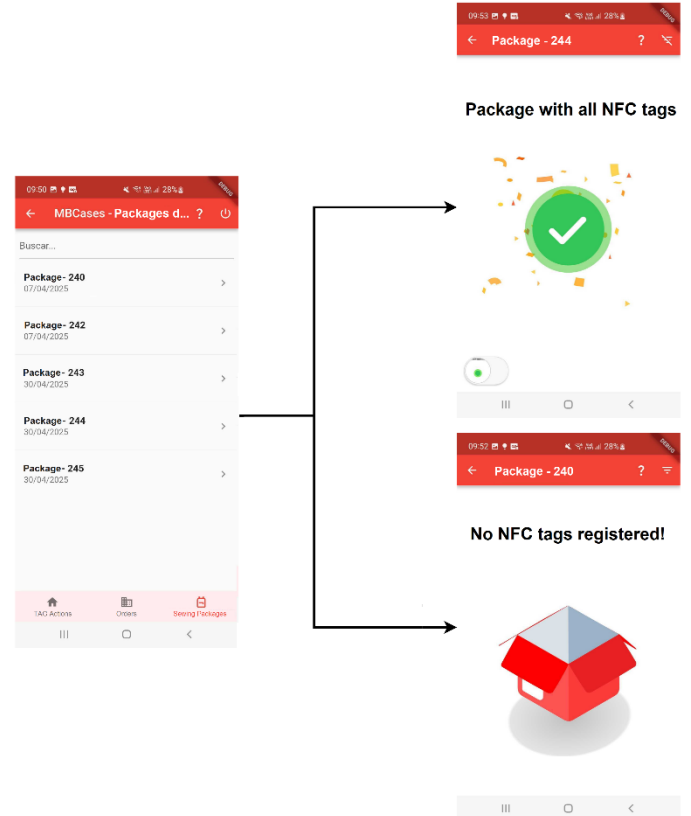


Figure 4: Package management and product grouping interface. Together, these figures provide a comprehensive overview of the system's capabilities, highlighting how the integration of NFC technology supports real-time tracking, efficient management of production processes, and enhanced traceability in the manufacturing environment.

B. Usability Test – System Usability Scale (SUS)

To evaluate the usability of the system, a SUS questionnaire was applied to six users. Table 1 presents the responses of six users to the ten questions of the System Usability Scale (SUS), along with their respective final scores.

Table 1 – Results of the Usability Test (SUS)

V	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	P
1	4	2	4	3	4	3	4	3	4	3	65,00
2	5	2	5	2	5	2	5	3	5	4	80,00
3	5	1	4	3	4	2	4	2	5	2	80,00
4	4	2	5	3	4	3	4	3	4	2	70,00
5	4	3	4	3	4	4	3	4	3	4	50,00
6	5	2	5	2	5	2	5	2	5	2	87,50
Average											72,08

Where, V are the volunteers and Q# are the applied questions.

The average SUS score was 72.08, which, according to standard SUS interpretation guidelines, indicates a good level of usability. This suggests that users found the system easy to use and effective in supporting their tasks.

IV. DISCUSSION

Recent studies have demonstrated the versatility of Near Field Communication (NFC) in different Industry 4.0 domains. Oliveri et al. [11] proposed an NFC-based toolkit for process mapping automation in small and medium enterprises, providing a cost-effective solution for business process reengineering. Lazaro et al. [12] surveyed NFC sensors with energy-harvesting capabilities, emphasizing their role in sustainable Internet of Things (IoT) applications, such as cold-chain traceability and wearable devices. These contributions highlight NFC's potential for efficiency and sustainability, but they do not integrate production, inventory, and maintenance in a unified manner. The present work addresses this gap by proposing and validating a system that combines these three dimensions in a real industrial environment.

Other works emphasize user interaction and adoption. Fernández-Caramés and Fraga-Lamas [13] reviewed the evolution of IoT-connected smart labels, pointing out their relevance for real-time connectivity and human-centered design in smart factories. Karpavičė et al. [14] experimentally analyzed NFC-enabled packaging, identifying user acceptance barriers through the Technology Acceptance Model (TAM). Differently, our proposal demonstrates not only technical feasibility but also practical usability by applying the System Usability Scale (SUS) in a manufacturing context, ensuring both reliability and acceptance among operators.

In addition, previous studies already cited in this work reinforce the broader applicability of NFC. Du [10] emphasized its growing adoption in mobile commerce and transport, while Lathiya and Wang [9] highlighted NFC's potential in wireless power transfer for embedded and wearable systems. Yu et al. [7] discussed the importance of ICT tools for supporting the Circular Economy, particularly through improved resource management and traceability. Our system aligns with these perspectives by contributing to operational sustainability and by enabling transparent tracking of products throughout their lifecycle.

Taken together, these comparisons show that the proposed solution extends beyond isolated NFC applications. By integrating production control, inventory management, and maintenance processes in a single platform, the system strengthens industrial traceability, reduces costs, and fosters sustainable practices, thereby consolidating NFC as a key enabler of Industry 4.0 and digital transformation.

V. CONCLUSIONS

This work described the design and validation of an NFC-based system that brings together production control, inventory management, and maintenance in a manufacturing context. The proposed architecture, which integrates NFC tags, a mobile application, and a centralized database, allowed real-time tracking and accurate information management. In practice, the solution contributed to greater traceability and efficiency while reducing operational costs. Usability tests using the SUS method resulted in an average score of 72.08, which indicates a positive perception by the operators involved.

When compared with related studies, the contribution of this work becomes clearer. While Oliveri et al. [11] emphasized the role of NFC in mapping processes within SMEs, while Lazaro et al. [12] presented advances in NFC sensors with energy-harvesting for IoT applications. In another direction, Fernández-Caramés and Fraga-Lamas [13] discussed the potential of smart labels in Industry 4.0, and Karpavičė et al. [14] explored the adoption of NFC packaging from the user's perspective. Although relevant, none of these studies addressed the simultaneous integration of production, inventory, and maintenance under industrial testing conditions, which is the distinctive element of our proposal.

In line with the principles of Industry 4.0 and the Circular Economy, the system presented here demonstrates that NFC can effectively support digital transformation in manufacturing. One limitation of the current research is the restricted number of participants in the usability test. Future investigations should therefore include broader user groups, across different industrial domains, to strengthen the generalizability of the findings. Furthermore, practical extensions such as automated maintenance alerts and integration with ERP systems represent promising directions for further development.

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