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Optimizing inventory management in the textile industry: a comprehensive evaluation of UHF-RFID technology integration

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ABSTRACT

The integration of ultra-high frequency radio frequency identification (UHF-RFID) technology presents a transformative solution to inventory management challenges in the textile industry. This study examines the implementation of a web-based inventory management system incorporating UHF-RFID technology at AK-Tekstil Solo, focusing on its impact on inventory accuracy, operational efficiency, and product traceability. The developed system facilitates real-time tracking of yarn products, streamlines inventory audits, and minimizes manual errors, resulting in substantial improvements in inventory control and warehouse management processes. By enabling automated data capture and tracking, UHF-RFID technology supports the transition to smart warehousing by providing real-time insights into inventory movements. The findings demonstrate that UHF-RFID technology offers significant advantages, including enhanced inventory visibility, cost savings, and improved customer satisfaction through better product availability. Despite potential implementation challenges, the study shows that the long-term benefits of UHF-RFID integration outweigh the initial costs, proving it to be an effective solution for optimizing inventory management in the textile industry. Future research may explore the integration of complementary technologies such as the internet of things (IoT) and artificial intelligence (AI) to further enhance UHF-RFID enabled inventory management systems.

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1. INTRODUCTION

Inventory management in the textile industry presents significant challenges due to the intricate and dynamic nature of supply chains, characterized by diverse products and fluctuating demand patterns [1]–[4]. Traditional inventory methods, relying on manual tracking and barcode scanning, often result in inefficiencies, inaccuracies, and operational disruptions, leading to elevated labor costs, fulfillment delays, stockouts, and overstocking—ultimately compromising market competitiveness [5]–[8]. Consequently, the integration of advanced technologies has emerged as a viable solution [9]–[11].

Ultra-high frequency (UHF)-radio frequency identification (RFID) technology has gained prominence as an innovative tool for enhancing inventory management in textiles. By enabling real-time tracking, RFID significantly improves inventory accuracy and operational efficiency [12]. It optimizes audits, warehousing, and logistics, reducing time-consuming manual processes prone to human error [13]–[16]. These inefficiencies hinder manufacturers from maintaining optimal inventory levels, responding to market dynamics, and ensuring robust product traceability.

Integrating UHF-RFID with warehouse management systems offers distinct advantages, such as real-time item identification without direct line-of-sight scanning, mitigating labor-intensive operations, and enhancing data accuracy [17], [18] This study hypothesizes that UHF-RFID adoption in textiles will lead to superior inventory control, operational efficiency, and traceability improvements. RFID technology employs electromagnetic fields to track tagged items, facilitating automated data collection [8]. In textile applications, UHF-RFID tags affixed to garments, and fabric rolls inventory assets enable seamless tracking across production and distribution channels. Compared to barcode systems, RFID offers faster scanning speeds, greater data storage capacity, and enhanced operational efficiency, particularly in high-variability environments [12].

Literature indicates that RFID adoption fosters the development of smart warehouses, aligning with Industry 4.0 principles by leveraging digital automation for improved supply chain management [19], [20]. RFID enhances inventory audits, reduces labor costs, minimizes stock discrepancies, and increases supply chain transparency. Additionally, improved inventory visibility enhances customer satisfaction by providing accurate product availability information, ensuring responsive service levels crucial for competitiveness in the textile industry [1], [6], [15], [21], [22]. While RFID implementation entails challenges—such as high initial costs and integration complexities—the long-term benefits, including cost savings and efficiency gains, outweigh these concerns [1], [3], [8], [12], [21], [23].

Previous research has highlighted RFID's advantages across retail, manufacturing, and logistics, emphasizing its role in improving data accuracy, reducing labor costs, and enabling real-time tracking. However, its application in large-scale textile manufacturing remains underexplored. Existing studies predominantly address technical aspects, such as system design and hardware configuration, without comprehensive evaluations of its impact on operational efficiency and product traceability within textile supply chains. Furthermore, the role of user interaction and acceptance in RFID adoption within textile production environments has not been thoroughly examined, despite being critical to successful implementation. Understanding how employees engage with RFID, adapt to workflow changes, and utilize data for decision-making is vital for maximizing benefits.

This study aims to bridge these gaps by conducting a case study at AK-Tekstil Solo, evaluating the impact of UHF-RFID integration on inventory accuracy, operational efficiency, and traceability. Its novelty lies in examining the practical application of UHF-RFID in real-world textile production environments—moving beyond technical feasibility to consider operational, human, and supply chain dimensions. The study assesses system performance, user interaction, and RFID integration with other digital supply chain systems, offering valuable insights into its potential to revolutionize textile inventory management.

2. RESEARCH METHOD

The primary materials utilized in this study included UHF-RFID tags, RFID readers, and textile products from AK-Tekstil Solo. The RFID tags were specifically designed for attachment to various textile items, such as rolls of fabric and garments, enabling their identification and tracking throughout the inventory management process. These tags operate via electromagnetic fields to communicate with RFID readers, which were strategically positioned throughout the warehouse to capture data as items moved through different supply chain stages [8]. The textile products selected for this study represented a broad range of inventory typically found within a textile production environment, ensuring that the findings were relevant to real-world industry scenarios.

To implement UHF-RFID technology, RFID tags were attached to all textile products within AK-Tekstil Solo's inventory. Care was taken to position the tags in a manner that preserved their functionality and kept them unobtrusive throughout the inventory management process. RFID readers were then installed at critical points within the warehouse, such as entry and exit points, shelving units, and packaging areas, to enable comprehensive inventory tracking [8]. This configuration ensured that the RFID system could accurately capture data on inventory levels, movements, and product locations, facilitating a seamless transition from traditional to advanced, automated inventory management methods [12].

The experimental setup involved integrating the UHF RFID system into the existing warehouse management infrastructure at AK-Tekstil Solo. This integration required establishing a network of RFID readers connected to a central database, which processed and stored data from the RFID tags. The system enabled real-time inventory tracking, as the RFID readers automatically identified and recorded information

about each tagged item as it moved through the warehouse [8]. The warehouse management system's software interface was customized to display data from the RFID system, providing users with up-to-date information on stock levels, product locations, and transfer movements. This setup facilitated the seamless collection and analysis of inventory data, supporting more efficient inventory control and decision-making.

The study evaluated three key parameters: inventory accuracy, operational efficiency, and product traceability. Inventory accuracy was assessed by comparing RFID system data with manual inventory records to identify discrepancies and improvements in data accuracy [12]. Operational efficiency was measured by tracking the time required for inventory audits, product transfers, and order fulfillment before and after implementing the RFID system. Product traceability was evaluated based on the system's capability to monitor tagged items' movement throughout the warehouse, ensuring that each product's location could be identified in real-time. Collectively, these parameters provided a comprehensive assessment of UHF-RFID technology's impact on inventory management in the textile industry.

3. RESULTS AND DISCUSSION

In this study, a web-based application was developed to manage yarn inventory at the AK-Tekstil Solo workshop, integrating UHF-RFID technology to enhance inventory control as shown in Figure 1. This application functions as an inventory management system that enables real-time tracking of yarn stock, facilitating efficient data entry and monitoring. Key features of the system include a master data module for managing product information and warehouse locations, an inventory tracking module for monitoring items, and a reporting module for tracking inbound, outbound, and transfer movements.

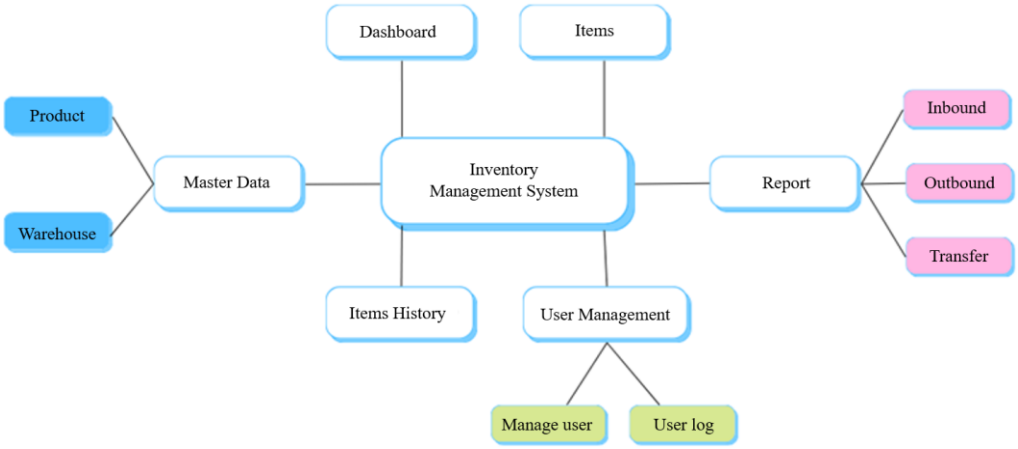

Figure 1. Working system of website application

The integration of UHF-RFID technology within the application supports seamless inventory audits by automatically capturing data from RFID tags attached to yarn products. This automation minimizes the need for manual data entry, reducing the risk of human error and resulting in accurate and up-to-date inventory records. The use of RFID readers allows for real-time tracking of each movement of yarn within the warehouse, providing detailed insights into stock levels, locations, and movements, which optimizes inventory management processes.

The findings from this study align with existing literature, which underscores the benefits of UHF-RFID technology in enhancing inventory management within the textile industry [8]. The study corroborates prior research that highlights how RFID technology streamlines inventory control, warehousing, and logistics processes [24], [25], as observed in the current implementation at AK-Tekstil Solo. Similar to observations made by [23], the web-based application facilitated rapid data collection and processing, leading to a reduction in labor costs and operational inefficiencies. Additionally, the system's responsive inventory management capabilities align with findings by [12], who emphasized RFID's capacity to support real-time adjustments in response to fluctuating demand, a particularly relevant feature in fast-paced sectors like textiles.

Moreover, the integration of RFID technology in this study contributes to the Industry 4.0 digital transformation trend within the textile sector, as noted by [12]. The RFID-enabled system at AK-Tekstil Solo exemplifies a move towards smart warehousing by leveraging data analytics and automation to optimize inventory processes. This implementation not only improved operational efficiency but also supported

sustainability objectives by reducing waste and promoting optimal resource utilization, echoing sustainability initiatives described in the literature [12].

The implementation of a web-based application with integrated UHF-RFID technology at AK-Tekstil Solo showcases the significant potential for enhancing inventory management within the textile industry. By enabling real-time tracking and automating inventory processes, the system has led to increased operational efficiency, reduced labor costs, and minimized errors [25], [26]. These outcomes highlight RFID technology as a viable solution for addressing the complexities of inventory management in the textile sector, ultimately supporting the industry's need for greater agility and responsiveness to market demands [27].

This study's scientific implications contribute to the expanding body of research on the role of RFID technology in advancing inventory management practices, particularly within textile production environments. From a practical perspective, the integration of RFID technology enhances inventory visibility and control, enabling textile manufacturers to make data-driven decisions and adapt more effectively to demand fluctuations. Additionally, the transparency and traceability provided by RFID systems can help textile companies meet consumer expectations for sustainable and ethically sourced products, aligning with broader industry trends [28], [29]. Consequently, this study underscores the transformative potential of RFID technology in revolutionizing inventory management practices—not only within the textile industry but also in other sectors facing similar inventory control and supply chain challenges.

The web-based inventory management application developed for AK-Tekstil Solo features a secure login page as the initial interface as shown in Figure 2, requiring users to enter their email and password. This login mechanism serves as the first layer of security, ensuring that only authorized personnel can access the system, and it supports role-based access to different functionalities within the web application. By integrating this login page, the application provides better control over data access, ensuring that inventory management activities are conducted securely and in a structured manner.

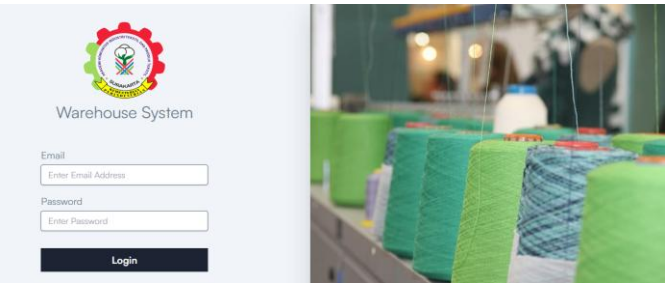

Figure 2. Login page

Combined with UHF-RFID technology, the web application allows authorized users to monitor inventory in real-time, conduct stock audits, and manage the flow of goods with high precision [30]–[32]. This setup eliminates the need for manual record-keeping, significantly reduces the potential for human error, and creates a robust system for maintaining accurate inventory levels. The integration of a secure, login-based web application aligns with current trends in inventory management systems, which emphasize data security, access control, and real-time tracking. According to Nayak [27], combining RFID technology with digital platforms enhances inventory control efficiency, resulting in more streamlined operations.

The secure login feature is essential in safeguarding the integrity and confidentiality of inventory data, as only authorized personnel can access it. This aspect is crucial for the textile industry, where the handling of large volumes of dynamic inventory data requires robust security measures. The implementation also reflects broader digital transformation trends within the textile industry, as noted by [12], with the adoption of smart technologies such as RFID and web-based systems to develop smart warehouses. Traditional inventory systems, often vulnerable to unauthorized access and data manipulation [33], benefit from the security provided by a login-based interface, ensuring data integrity throughout the inventory management process [34].

Incorporating a secure login interface into the RFID-enabled web application marks a significant advancement in optimizing inventory control processes in the textile industry. By limiting access to authorized users, the system enhances data security, minimizes the risk of unauthorized data manipulation, and ensures efficient, accurate inventory management. Additionally, this feature promotes user accountability, as specific actions within the system can be traced back to individual users, enhancing transparency and traceability [35], [36].

The practical implications of this system are considerable, as it illustrates the feasibility of integrating advanced technologies such as RFID with secure, web-based applications to improve inventory management in real-world textile production settings. This integration not only boosts operational efficiency but also supports the industry's shift towards more digitized, data-driven inventory management practices. Scientifically, this study demonstrates how the combination of RFID technology with secure web applications can address the complexities of inventory management, providing a scalable model that can be adapted to other sectors with similar challenges.

The homepage of the web-based inventory management system at AK-Tekstil Solo presents users with an intuitive, comprehensive dashboard upon logging in Figure 3. This dashboard offers a clear overview of essential inventory data, including inbound and outbound stock movements, as well as a visual breakdown of stock products and non-product items. The real-time data displayed on the dashboard ensures that users have immediate access to key inventory metrics, allowing for efficient monitoring of inventory levels, tracking of product movements, and a holistic view of warehouse performance.

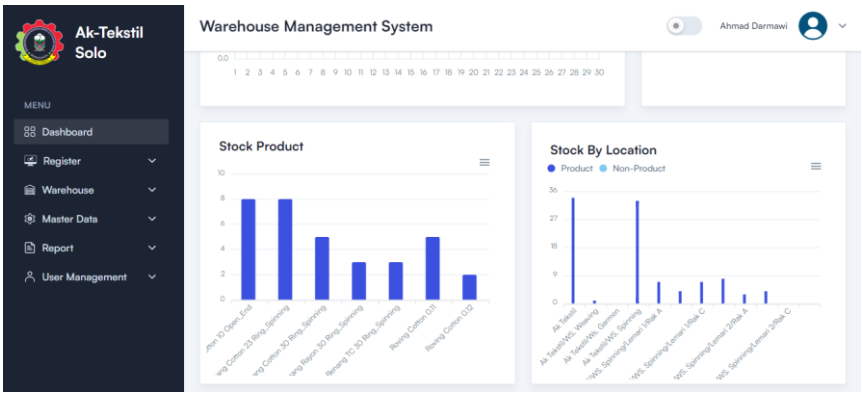

Figure 3. Dashboard product inventory management system

The integration of UHF-RFID technology automates data collection, feeding accurate and current information directly into the dashboard. This automation significantly reduces the need for manual data entry, minimizes the potential for errors, and provides users with real-time insights necessary for informed stock management decisions. As a result, users can swiftly assess and respond to inventory needs, optimizing operational efficiency and ensuring inventory data remains consistently up-to-date.

The integration of a dashboard within the RFID-enabled inventory management system aligns with the literature's emphasis on the importance of real-time data visibility for effective inventory control. Nayak [27] highlighted RFID technology enables rapid data collection and processing, which is reflected in this system's capacity to present real-time data on the dashboard. This capability streamlines inventory management processes and enhances operational efficiency, allowing users to quickly access and interpret inventory data without the delays associated with manual data entry.

Moreover, Pınar *et al.* [12] emphasizes the need for responsive and accurate inventory management systems that can adjust to demand fluctuations, particularly in sectors like textiles, where demand is often unpredictable. The dashboard's real-time display capabilities allow AK-Tekstil Solo to swiftly adapt to changing inventory needs, aligning with the broader industry trend towards developing smart warehouses that leverage data analytics for informed decision-making, as suggested by [12]. This integration not only enhances operational efficiency but also underscores the role of RFID technology in supporting digital transformation within the textile industry. By providing immediate visibility into inventory dynamics, the system empowers AK-Tekstil Solo to make timely adjustments and maintain inventory levels that align with fluctuating market demands, reinforcing the industry's move towards more data-driven, agile operations.

The introduction of a user-friendly dashboard that delivers real-time inventory data marks a significant advancement in inventory management practices within the textile industry. This feature empowers textile manufacturers to effectively monitor stock levels, track product movements, and swiftly respond to inventory fluctuations, thereby reducing the risks of stockouts or overstocking. The incorporation of UHF-RFID technology optimizes inventory accuracy and supports more informed decision-making based on reliable, real-time data.

Scientifically, this study illustrates the practical application of combining RFID technology with a web-based interface to enhance inventory management. The visualization of inventory data through a

dashboard aligns with Industry 4.0 trends, promoting the adoption of smart technologies and contributing to the digital transformation of the textile industry. The practical implications are extensive, as this system can be adapted to other sectors facing similar inventory management challenges, providing a scalable model for leveraging RFID technology to increase efficiency, reduce errors, and improve supply chain transparency.

The transfer report page within the RFID-enabled warehouse management system at AK-Tekstil Solo is another pivotal feature, specifically designed for managing product and non-product transfers between warehouse locations as shown in Figure 4. This page allows users to monitor and control inventory transfers, displaying details such as receipt numbers, origin and destination warehouses, transfer items, and the personnel involved. The system's capability to generate reports in PDF and Excel formats enables efficient documentation and tracking of inventory movements.

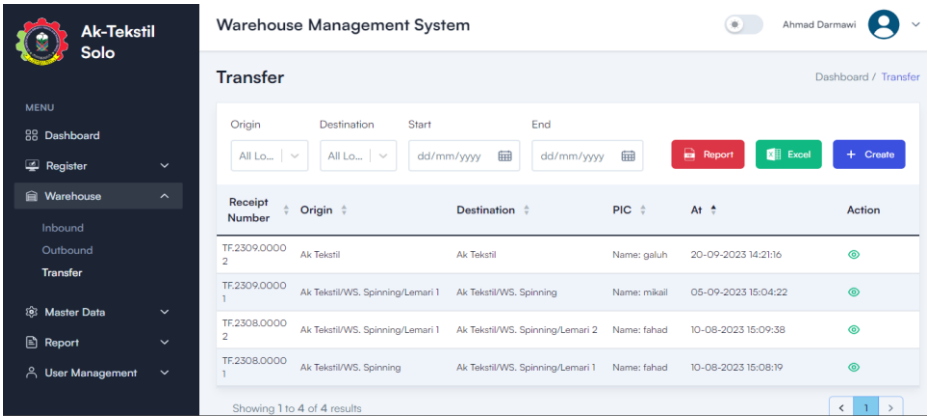

Figure 4. Transfer report page

The integration of UHF-RFID technology allows for the automatic tracking of products during transfers, ensuring each movement is accurately recorded and updated in real time. This automation minimizes the possibility of manual errors, improves inventory accuracy, and provides complete traceability within the warehouse management system, thereby enhancing operational efficiency. The functionality provided by the transfer report page aligns with the literature on UHF-RFID technology, particularly its benefits in streamlining inventory management processes and maintaining real-time stock visibility. As noted by [8], [27] RFID technology can significantly enhance warehousing and logistics efficiency by facilitating automated data capture, which is effectively demonstrated through this transfer report feature.

Furthermore, the ability to track inventory transfers in real time aligns with findings by [12], which emphasize the importance of accurate inventory tracking for optimizing supply chain efficiency and minimizing manual data entry errors. By offering real-time visibility into product transfers, the RFID-enabled system supports the development of smart warehouses, as suggested by [12], and allows AK-Tekstil Solo to efficiently manage inventory while adapting to changing demands. This capability underscores the value of RFID technology in supporting agile, data-driven operations within the textile industry and beyond.

The transfer report page exemplifies the practical advantages of integrating UHF-RFID technology into inventory management systems in the textile industry. By enhancing the accuracy and traceability of inventory transfers, it significantly improves operational efficiency through reduced reliance on manual data entry and minimized error rates. This capability is particularly valuable for textile manufacturers like AK-Tekstil Solo, where accurate, real-time tracking of inventory movements is essential for maintaining optimal stock levels and ensuring timely order fulfillment.

From a scientific perspective, this study demonstrates RFID technology's potential to revolutionize traditional inventory management practices by introducing automated, data-driven solutions that improve both efficiency and accuracy. The practical implications extend well beyond the textile industry, as the successful deployment of this system can serve as a model for other sectors aiming to optimize their inventory management processes. In conclusion, the transfer report page illustrates how RFID technology can foster a more responsive, transparent, and efficient inventory management system. This advancement aligns with broader digital transformation goals and supply chain optimization efforts in the textile industry, providing a scalable approach to meeting evolving market demands and supporting a data-driven, agile operational framework.

4. CONCLUSION

The integration of UHF-RFID technology into the inventory management system at AK-Tekstil Solo has yielded substantial improvements in operational efficiency, inventory accuracy, and traceability. The web-based application developed in this study enabled real-time tracking of inventory movements, minimized manual errors, and provided comprehensive data to support informed decision-making. These advancements align with the broader trend of RFID technology adoption within the textile industry, underscoring its potential to streamline inventory control processes, optimize warehouse management, and support the digital transformation towards smart warehousing practices. The findings also demonstrate how RFID integration can enhance customer satisfaction by improving product availability and supply chain transparency. Despite initial investment and implementation challenges, the long-term benefits—such as cost savings, operational efficiency, and improved responsiveness to market demands—highlight RFID technology's transformative potential in revolutionizing inventory management in the textile sector. Future research should explore the integration of RFID with complementary technologies, such as the internet of things (IoT) and artificial intelligence (AI), to further expand inventory management capabilities. Such integration could also support more sustainable industry practices, offering new avenues for optimizing supply chain processes and enhancing the overall resilience and agility of the textile industry.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

INFORMED CONSENT

Informed consent is not applicable to this study as the research focuses on technical system implementation and inventory management, and does not involve human participants or the collection of personally identifiable information.

ETHICAL APPROVAL

Ethical approval is not applicable to this paper as the research involved the technical deployment of an inventory management system and did not involve human participants or animals.

DATA AVAILABILITY

The data that support the findings of this study, which include case study observations and performance metrics from AK-Tekstil Solo, are available upon reasonable request from the corresponding author [AD].

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