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A Smart Solution Against Counterfeiting Using RFID and QR Code Technology Strengthening Product Integrity in Rwanda

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Abstract

Counterfeit products pose a significant challenge to both consumers and businesses in Rwanda, undermining product quality, consumer safety, and national economic development. Despite efforts to combat this issue, weak regulatory monitoring and a lack of robust authentication systems continue to exacerbate the problem. This research proposes the development and implementation of a Smart track and trace system that combines QR codes and RFID technology to enhance product authentication and supply chain transparency. By integrating these technologies, the system will allow consumers, businesses, and regulatory authorities to verify the authenticity of products in real time, creating a more secure environment for both local and international trade. The proposed solution aims to address existing gaps in regulatory oversight by providing a reliable, tamper-proof method of tracking products from manufacturing to the point of sale. The research evaluates the potential impact of this system on reducing counterfeit products, improving consumer trust, and strengthening Rwanda's regulatory framework. It is anticipated that the proposed Smart Track and Trace system will contribute to the fight against counterfeit goods, facilitating a more efficient and trustworthy market in Rwanda.

Keywords: *RFID, QR Code, Counterfeit, Track and Trace, Regulatory, Rwanda*

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1. Introduction

One of the biggest dangers to the global economy is counterfeiting (Choi et al., 2007) (Choi et al., 2007).The illegal act of replicating a real product and producing a counterfeit one is known as product counterfeiting. It presents serious risks to the world economy and manufacturing sectors (Choi et al., 2013). The global sector suffers significant losses due to counterfeiters. These losses involve social costs and harm the makers of genuine goods. Customers are the real victims of unfair competition. Governments pay hefty fees to enforce intellectual property rights and lose out on unpaid taxes (Rotunno et al., 2014). Traceability is a workable tactic to increase consumer confidence and ensure product safety (Xie & Tan, 2021).

The main goal of this study is to build on earlier research and generate fresh concepts by iden tifying and tracking fake goods "Made in Rwanda." starting with controlling the product's quality up to the point of sale to ensure that only authentic products are available to consumers.

By monitoring the entire lifecycle of a product from production through distribution to retail, this system would guarantee quality, prevent counterfeiting, and promote trust in Rwandan-made goods.

This work aims to develop a system for tracking and tracing counterfeiting of "Made in Rwanda" products. This system can ensure product authenticity, enhance consumer confidence, and protect local industries. The key idea behind this system would be to use QR codes and RFID technologies to check and trace the origin and movement of products from production to the final point of sale.

2. Background and motivation

“The Rwanda we want”, is the long-term strategy of Rwanda’s Vision 2050. Rwanda hopes to upgrade all Rwandans' lives and change its economy. Realizing that taking decisive and audacious action will be necessary to realize these goals. High quality and standards of life for Rwandans, as well as economic growth and prosperity, are the main objectives of Vision 2050 (*Republic of Rwanda (2015) Rwanda Vision 2050*, n.d.).

The industrial sector in Rwanda has expanded at an average annual rate of 9.4% since 2009. Industry's contribution to the GDP has increased substantially throughout the years, rising from 16% in 2009 to 19% in 2019. The actions outlined in the Vision are intended to create substantial job and business possibilities for Rwandans while reducing imports by up to $400 million by 2024, with further reductions anticipated in the following years. "Made in Rwanda" will be a well-known domestically and abroad brand by 2050 (*Republic of Rwanda (2015) Rwanda Vision 2050*, n.d.).

Rwanda's manufacturing industry has expanded gradually since the National Industrial Policy was adopted in 2011. During this time, several critical policy interventions and initiatives have been established, including the Made in Rwanda policy, the SMEs plan, the National Export plan, and others. The WTO's special and differential treatment clauses give Rwanda preferential access to several global markets (*Manufacturing - Official Rwanda Development Board (RDB) Website*, n.d.).

Rwanda's manufacturing sector experienced a significant growth of 8% in fiscal year 2017/18, compared to a 6% increase in the previous fiscal year. The NISR Annual Economic Report indicates that agriculture in 2022 grew by 2%, service by 12%, and industry saw a 5% increase. While the sector is currently small, its growth is steady. (*Manufacturing - Official Rwanda Development Board (RDB) Website*, n.d.).

The research will help protect products against counterfeiting using an innovative track-and-trace system with QR codes and RFID technologies. Meanwhile, consumers can scan and authenticate the products to ensure that their purchases are genuine.

3. Related works

Track and trace systems have proven to be a valuable tool in recent years for boosting engineering firms' competitiveness and ability to stop theft and counterfeiting while lowering recall frequency and costs (Choi et al., 2013). The Track and Trace system research community is interested in fighting counterfeit products. Juhan Kim, Dooho Choi, Inseop Kim and Howon Kim (Juhan et al., 2006). Moreover, Udhaya Nila, Abalin Luther, and Aathi Vignesh (Nila et al., 2021) developed a system for identifying fake products using MySQL and Python. This web application informs users about fake drugs. Fake products can be identified using QR codes. For every product, the manufacturer creates a QR code. The user can then use the QR

code to purchase the medicine via the website. It will produce a fake identification if the medicine is counterfeiting.

In (Shreekumar et al., 2022), the authors discuss massive emerging trends in wireless technology. Barcodes and QR (Quick Response) codes offer a reliable method to reduce the practice of counterfeiting products. A camera is used to identify fake goods, and the product's barcode or QR code is connected to a blockchain, which stores product information and each product's guaranteed unique code as blocks in the database.

An active Radio Frequency Identification (RFID) technology combined with a product seal is used in an authentication and anti-counterfeit method developed by Emil Nilsson, Björn Nilsson, and Eric Järpe (Nilsson et al., 2011). They presented a secure logistic chain using time-controlled numeric tokens (TCNT). A pharmaceutical anti-counterfeit system is used to demonstrate how the method is implemented. The system would consist of a pseudo-random (PN) ID code generator, terminal interrogators (PDA), a network connection (WAN), a secure database server with an internal standard clock, an RFID tag with an internal clock, and product sealing. In (Kim & Kim, 2005), with the help of future customers' mobile RFID devices, such as smartphones or PDAs with a mobile RFID reader, The authors suggested an application-level anti-counterfeiting solution that can track and trace a product during the entire lifecycle of EPC tag. Additionally, they proposed expanding the EPC-PAS to include the mobile RFID environment so that a product can be continuously tracked and traced using an EPC tag in relation to locations whenever a customer uses her mobile RFID device to seek product information.

Further, in (Choi et al., 2013), the authors proposed a system that does not require sophisticated technologies and is simple in architecture, targeting comparatively expensive consumer goods, it also helps safeguard authentic products by preserving the supply chain integrity and product pedigree. This mechanism prevents counterfeiters from copying the products or the tags for three reasons: 1. Businesses must pre-register before they can access the host company server to record product transactions, which prevents counterfeiters from trying to do so; 2. Suspicious transactions will be filtered out appropriately; and 3. Customers will not buy products without a credible history.

4. Proposed anti-counterfeiting solution

The research approach adopted to develop and implement a Smart tracking and tracing of counterfeit products with integrated RFID, Barcode, and QR code scanning capabilities. The system aims to streamline the tracking of product status, facilitate registration processes, and maintain comprehensive usage history logs. By providing hardware and software technologies, the solution offers a robust, user-friendly, and efficient mechanism for managing product information through a web-based interface.

4.1 Methods

To complete this task, barcodes and QR code scanners were used as the primary input devices to collect product data. Mobile devices with cameras, desktop computers with webcams, and optional dedicated barcode scanners served as the system's hardware components for scanning purposes. The data collected from these devices was processed using a web-based application, hosted on a centralized server, and stored in a database for future retrieval and analysis.

The system employed a multi-tier architecture combining front-end and back-end technologies. The Quaggas JS library and HTML5-QRCode were integrated for seamless scanning

functionality, while a RESTful API facilitated communication between the client-side and server-side components. The database stored product registration details, status updates, and usage history, ensuring robust data management and retrieval.

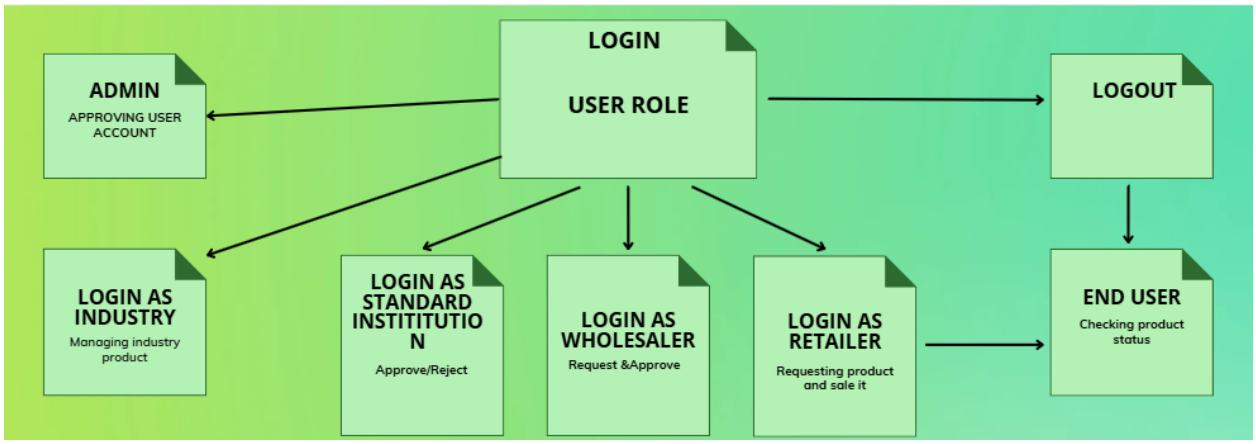

Figure 1: Smart Product Tracking System Analysis

4.2 Hardware Schematic Diagram

The Smart product tracking was assembled and configured using a combination of mobile devices, desktop computers, and optional dedicated hardware made of the RFID reader, and barcode scanners. The hardware setup included client devices equipped with cameras (smartphones, tablets, and webcams) for barcode and QR code scanning.

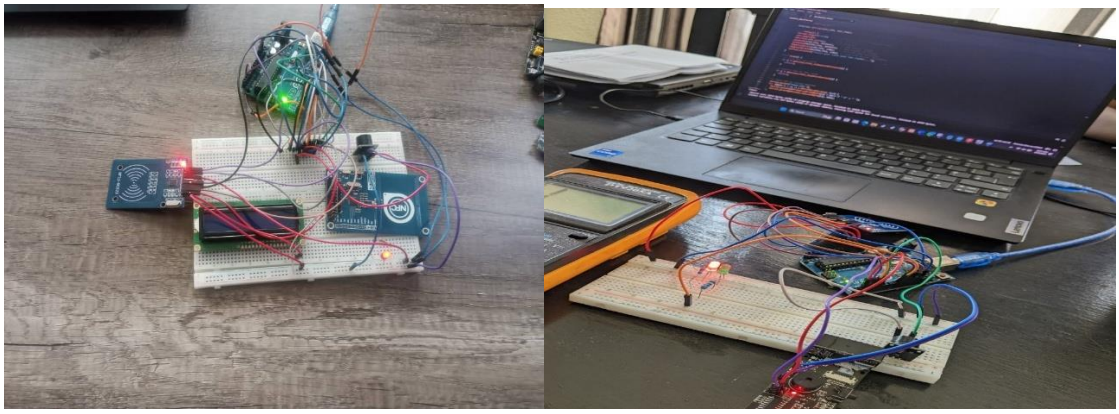

Figure 21: Hardware setup

4.3 Software Connection

The smart product tracking software component with Integrated Barcode and QR Code Scanning involves the programming and configuration required for the system to function seamlessly. Algorithms were meticulously developed to define how the system interacts with various input devices, such as cameras and barcode scanners, to ensure accurate code detection and data processing. The software also handles responses to specific scenarios, such as displaying product details upon scanning, updating product statuses, and logging usage history in the database.

For front-end development, a combination of HTML5, CSS3, and JavaScript was used to create an intuitive and responsive user interface. The integration of QuaggaJS and HTML5-QRCode libraries facilitates efficient barcode and QR code scanning directly through the web interface (*J. c. Adjanohoun, "Becoming a Frontend Developer: Mastering HTML5, CSS, and JavaScript," 2023, 26 August 203. [Online]. Available: Https://Medium.Com/@johnadjanohoun/Becoming-a-Frontend-Developer-Mastering-Html5-Css-and-Javascript-2b66adfc3320. [Accessed 23 July 2024] - Search*, n.d.). On the backend, PHP was utilized to manage server-side operations, including API endpoint handling, database queries, and user authentication. The database design, implemented using systems like MySQL, ensures structured storage and quick retrieval of product details, usage logs, and registration records.

4.4 Software Implementation

The software implementation of Smart Product Tracking with Integrated Barcode and QR Code Scanning involves the use of a combination of tools and technologies tailored to ensure seamless functionality and user experience. The core development was carried out using industry-standard tools like Visual Studio Code for code writing and debugging and a suite of libraries for front-end and back-end integration.

Frontend functionalities were implemented using JavaScript, incorporating libraries such as QuaggaJS for barcode scanning and HTML5-QRCode for QR code recognition. These libraries enabled the system to process real-time camera input, detect codes accurately, and parse the data for further processing. Additional JavaScript and CSS frameworks, like Bootstrap, were employed to enhance the responsiveness and visual appeal of the user interface.

4.5 Integration

Software and hardware integration in the Smart product tracking with Integrated Barcode and QR Code Scanning was achieved through seamless connectivity between input devices, processing units, and the backend system. The primary integration utilized client devices, such as mobile phones with cameras or desktop webcams, to serve as scanning interfaces. These devices worked in tandem with backend servers to ensure data processing and storage.

The PHP back-end server acted as the central controller for managing scanned data, communicating with the database, and providing real-time feedback to the user interface. Each client device processed camera feeds through the QuaggaJS and HTML5-QRCode libraries to extract barcode and QR code information. This extracted data was then transmitted to the backend for validation and further processing (*Android - How to Display the Query Result on the Php Page after the Server Receive QR Scan Result from Client Phone Which Acts as QR Scanner - Stack Overflow*, n.d.).

API endpoints streamlined communication and facilitated data integration between hardware components and the database. When a barcode or QR code was scanned, the system verified its details in the database, updated the product's status, and logged usage history. The backend algorithms determined whether the scanned product required status updates or triggered any alerts.

4.6 Working Mechanism

The Smart product track and trace system utilizes barcode and QR code scanning to seamlessly monitor and manage product inventory. The system ensures real-time updates by scanning product codes to capture essential data such as product identity, usage, and expiration date.

When a product's barcode or QR code is scanned using the integrated scanner, the system records the data and updates the inventory database. This information is processed to determine the current stock status, enabling users to track products efficiently without manual intervention. The scanned data is instantly synchronized with the central system and made available on a monitoring platform, providing users with insights into inventory levels and movement.

The system also supports notifications for product management. When the stock of a scanned item reaches a predefined threshold, alerts can be sent to the relevant personnel via email or SMS to prompt necessary actions, such as replenishment or redistribution. Additionally, the system can generate automated reports summarizing product tracking details for better decision-making.

The Smart Product Track System uses barcode and QR code technology to ensure precise inventory tracking, reduce errors, and streamline operations for enhanced productivity and efficiency.

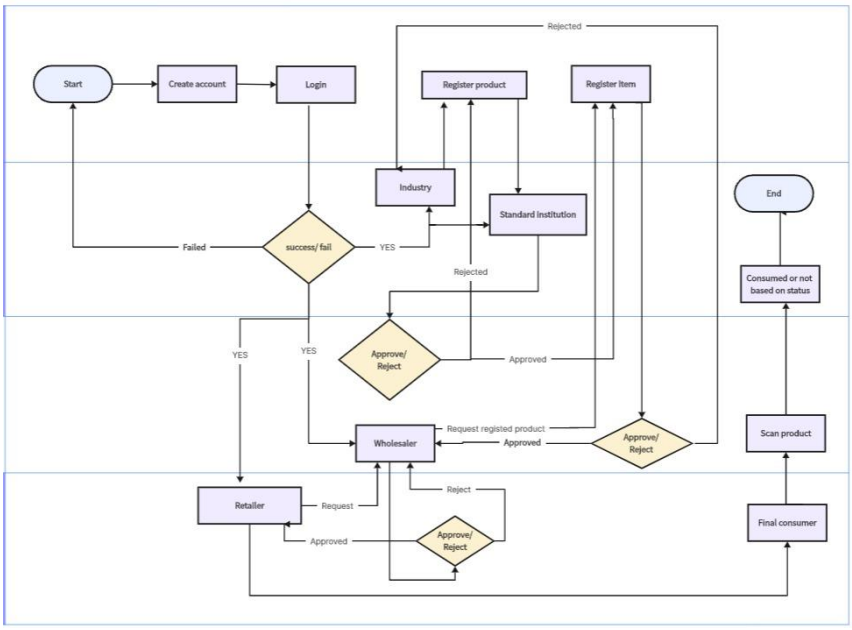

Figure 3: Flowchart diagram

The system lets users quickly retrieve detailed information about any product by scanning its QR code. This approach eliminates the need for manual searches or paperwork, making it an ideal solution for warehouses, retail businesses, and inventory management.

4.7 Product tracking design

It involves integrating hardware and software components to create a seamless product tracking experience. It is divided into two main sections: the hardware implementation and the software system.

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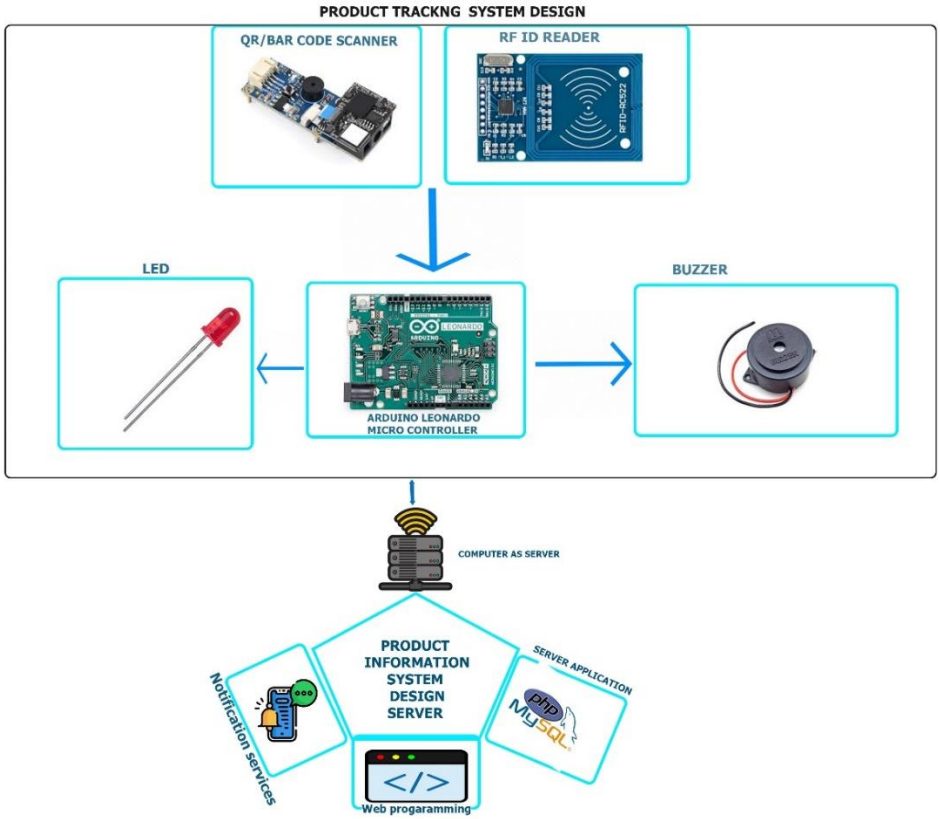

Figure 42: Product Tracing Design

The smart product tracking and tracing system is designed to address the inefficiencies of manual product tracking by leveraging modern scanning technologies to streamline operations in various business environments. The system enables real-time product tracking, registration, and status management by integrating hardware components and software systems.

Figure 3 illustrates the system workflow. The barcode, QR code scanner, and RFID reader are the primary input devices. These devices capture unique identifiers for each product and send the data to the Arduino Leonardo, which serves as the central processing unit. The Arduino processes the input data and updates the product status in a centralized database. The system maintains a comprehensive history log, allowing users to access real-time updates and audit trails (*J. c. Adjanohoun, "Becoming a Frontend Developer: Mastering HTML5, CSS, and JavaScript," 2023, 26 August 203. [Online]. Available: Https://Medium.Com/@johnadjanohoun/Becoming-a-Frontend-Developer-Mastering-Html5-Css-and-Javascript-2b66adfc3320. [Accessed 23 July 2024] - Search*, n.d.)

The system performs the following key functions:

- **Product Registration:** Scanning unique product identifiers (barcodes, QR codes, or RFID cards) for initial entry into the database.
- **Verification:** Comparing scanned data with the database to confirm product details.
- **Status Updates:** Automatically updating product status based on predefined criteria, such as movement or usage.
- **Usage History:** Logging all product-related activities for analysis and auditing purposes.

5. Summary and conclusion

The QR Code and RFID-based track and trace system allows consumers, wholesalers, and regulators to instantly verify product authenticity at different points in the supply chain. By scanning a QR code or using an RFID reader, users can confirm whether a product is genuine, reducing the circulation of counterfeit goods.

The proposed system enables real-time product monitoring, ensuring that only approved and legally compliant products reach the market. Integrating regulatory bodies into the system, it facilitates digital approvals, automated compliance checks, and faster interventions when counterfeit products are detected.

With this smart tracking solution, consumers can scan products before purchase to check their legitimacy. The system also provides alerts and prevents the reuse of QR codes and RFID tags, ensuring that once a product is consumed, its traceability code is invalidated. This increases consumer trust and awareness in verifying genuine products.

Implementing RFID (Radio Frequency Identification) and QR Code technologies offers a highly effective and modern solution for fighting counterfeit products, providing both businesses and consumers with a powerful tool to verify authenticity. These technologies enhance product traceability, improve supply chain transparency, and empower consumers to easily confirm the legitimacy of items they purchase.

The main objective of this study is to fight counterfeit products made in Rwanda using QR codes and RFID technologies. The combination of these two technologies was found to be the best technology for the counterfeiting system, with high accuracy, seeing that the compliance institution is incorporated.

References

android - How to display the query result on the php page after the server receives QR scan result from client phone which acts as QR Scanner - Stack Overflow. (n.d.). Retrieved February 3, 2025, from https://stackoverflow.com/questions/22555461/how-to-display-the-query-result-on-the-php-page-after-the-server-receive-qr-scan

Choi, S. H., Poon, C. H., & Spoofing, A. (2007). *An RFID-based Track-and-trace Anti-counterfeiting System*. *II*, 2–7.

Choi, S. H., Yang, B., Cheung, H. H., & Yang, Y. X. (2013). Data management of RFID-based track-and-trace anti-counterfeiting in apparel supply chain. *2013 8th International Conference for Internet Technology and Secured Transactions, ICITST 2013*, 265–269. https://doi.org/10.1109/ICITST.2013.6750203

J. c. adjanohoun, "Becoming a Frontend Developer: Mastering HTML5, CSS, and JavaScript," 2023, 26 August 203. [Online]. Available: https://medium.com/@johnadjanohoun/becoming-a-frontend-developer-mastering-html5-css-and-javascript-2b66adfc3320. [Accessed 23 July 2024] - Search. (n.d.). Retrieved January 30, 2025, from https://www.bing.com/search?pglt=297&q=J.+c.+adjanohoun%2C+%22Becoming+a+Frontend+Developer%3A+Mastering+HTML5%2C+CSS%2C+and+JavaScript%2C%22+2023%2C+26+August+203.+%5BOnline%5D.+Available%3A+https%3A%2F%2Fmedium.com%2F%40johnadjanohoun%2Fbecoming-a-frontend-developer-mastering-html5-css-and-javascript-2b66adfc3320.+%5BAccessed+23+July+2024%5D&cvid=3527d213dea944ebb144235

164560039&gs_lcrp=EgRlZGdlKgYIABBFGDkyBggAEEUYOdIBCDE1MjhqMGoxqAIIsAIB&FORM=ANSPA1&ucpdpc=UCPD&PC=U531

Juhan, K., Dooho, C., Inseop, K., & Howon, K. (2006). Product authentication service of consumer's mobile RFID device. *Proceedings of the International Symposium on Consumer Electronics, ISCE*, 660–665. https://doi.org/10.1109/isce.2006.1689423

Kim, J., & Kim, H. (2005). Anti-Counterfeiting Solution Employing Mobile RFID Environment. *Proceedings of World Academy of Science, Engineering and Technology, Vol 8*, *8*(8), 141–145.

Manufacturing - Official Rwanda Development Board (RDB) Website. (n.d.). Retrieved January 30, 2025, from https://rdb.rw/investment-opportunities/manufacturing/

Nila, U., Luther, A., & Vignesh, A. (2021). Block Chain in Fake Product Identification System Using QR Code. *International Journal on Cybernetics & Informatics*, *10*(2), 73–80. https://doi.org/10.5121/ijci.2021.100209

Nilsson, E., Nilsson, B., & Järpe, E. (2011). A pharmaceutical anti-counterfeiting method using time-controlled numeric tokens. *2011 IEEE International Conference on RFID-Technologies and Applications, RFID-TA 2011, March 2014*, 343–347. https://doi.org/10.1109/RFID-TA.2011.6068659

Republic of Rwanda (2015) Rwanda Vision 2050. (n.d.).

Rotunno, R., Cesarotti, V., Bellman, A., Introna, V., & Benedetti, M. (2014). Impact of track and trace integration on pharmaceutical production systems. *International Journal of Engineering Business Management*, *6*(1), 1–11. https://doi.org/10.5772/58934

Shreekumar, T., Mittal, P., Sharma, S., Kamath, R. N., Rajesh, S., & Ganapathy, B. N. (2022). Fake Product Detection Using Blockchain Technology. *JOURNAL OF ALGEBRAIC STATISTICS*, *13*(3), 2815–2821. https://publishoa.com

Xie, S., & Tan, H. Z. (2021). An anti-counterfeiting architecture for traceability system based on modified two-level quick response codes. *Electronics (Switzerland)*, *10*(3), 1–22. https://doi.org/10.3390/electronics10030320