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Original Article

Optimizing Port Logistics: Empowering Mogadishu Port with RFID Technology in Somalia

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***Abstract -** Innovative solutions are pivotal in pursuing sustainable development in Somalia, and Radio Frequency Identification (RFID) technology stands out as a transformative enabler. The challenges posed by growing cargo volumes and the imperative of efficient supply chain management have catalyzed the need for inventive approaches in port logistics. RFID technology creates a dependable and automated mechanism for identifying, monitoring, and orchestrating cargo, containers, and assets across the port ecosystem. This paper delivers a comprehensive overview of the applications of RFID within port logistics, encompassing container tracking, real-time inventory oversight, autonomous cargo manipulation, and elevated security with amplified visibility. Exploiting the potential of RFID empowers ports to unlock heightened operational efficiency, cost reduction, error mitigation, and an overarching performance enhancement. The research underscores the advantages, obstacles, and future potentials of RFID assimilation in port logistics, charting a course toward more robust, responsive, and sustainable maritime trading systems in Somalia.*

***Keywords -** RFID technology, Logistics, Sustainability, Cargo tracking, Maritime.*

1. Introduction

At the core of Somalia's drive for sustainable development lies the Mogadishu Port-a crucial trade gateway that grapples with significant operational challenges spanning cargo tracking, inventory control, security, and procedural efficiency. The lack of an effective cargo tracking mechanism leads to delays, increased costs, and customer dissatisfaction. Meanwhile, manual inventory management processes result in inaccuracies, excess stock, and shortages, disrupting demand projection and impairing overall productivity.

The port's geographical location and the current political instability exacerbate security issues, including theft, unauthorized entry, financial losses, and discouragement of potential investors [1, 2]. Furthermore, the inefficiencies from manual labor, coordination difficulties, and limited technological integration contribute to setbacks and additional costs for importers and exporters. The need to fully harness the port's potential and foster sustainable development is paramount [3, 4].

Within this context, Radio Frequency Identification (RFID) technology emerges as a beacon of promise to surmount the multifaceted obstacles confronting Mogadishu Port logistics. Real-time tracking augments visibility by affixing RFID tags to containers, empowering proactive management of potential delays. Furthermore, the automation furnished by RFID seamlessly streamlines inventory tracking, ameliorating stock-related issues and elevating the effectiveness of the supply chain. This technology fortifies security through access regulation and tamper detection, assuring cargo integrity and curtailing risks. Moreover, RFID expedites operational procedures and augments throughput capacity, bolstering operational efficiency. As Mogadishu Port embraces RFID innovation, it embarks on becoming a competitive trade nucleus. The bolstered cargo tracking, inventory management, security fortification, and overall efficiency catalyze economic expansion, magnetizing investment prospects [5, 6].

2. Related Work

RFID technology uses radio waves to exchange data between a reader and an electronic tag attached to an object for identification and tracking purposes[1-6]. It allows machines or computers to identify objects, record metadata, or control individual focus through radio waves [7, 8]. Technology is applied in various industries, such as healthcare, textiles, and manufacturing [9, 10].

RFID systems have three main components: tags, readers, and antennas. Tags are attached to objects and transmit data to the reader when activated by the reader's electromagnetic field. The reader gathers information from the tags and can track individual objects. RFID technology offers real-time traceability, improved operations efficiency, and reduced inventory levels. It is also used for automatic toll collection, animal tracking, and counterfeit prevention.

RFID technology offers several benefits in logistics. It can significantly increase the efficiency of logistics processes [11]. By using RFID technology, the agricultural products logistics system can improve efficiency, reduce losses, and ensure the safe consumption of consumers [12]. In the animal husbandry industry, RFID technology can establish an intelligent logistics management system that fundamentally controls and eliminates animal diseases, improving efficiency and reducing costs [13]. In traditional logistics management, RFID technology can solve visual tracking problems and complicated operations, while blockchain technology can enhance transparency and security in the logistics industry [14]. Additionally, RFID technology can be used to integrate and analyze large datasets in logistics, increasing information quality and reducing data volume [15].

RFID technology has various applications in different fields. It is used in supply chain management, healthcare and medical fields, agriculture management, food processing, library management, highway toll systems, and the construction industry [16]. RFID technology is also used in shop-floor industrial settings, smart home architecture, and as a replacement for UPC barcodes [17]. In the context of smart cities, RFID is utilized in applications such as smart parking, traffic management, human tracking, and healthcare [18]. In logistics and management, RFID is crucial for tracking and managing items and improving hospital efficiency and safety [19]. Additionally, RFID technology is used for vehicle security systems, tracking products, and supporting automated checkout [20].

RFID technology has a wide range of applications in logistics. It can be used in various aspects of the supply chain, including warehouse management, inventory management, freight transportation, manufacturing, and retailing [21]. By utilizing RFID technology, logistics operations can achieve enhanced efficiency and automation management [22]. The technology enables data collection, processing, automated identification, and storage, which are crucial factors in logistics information systems [23]. RFID technology also plays a significant role in military logistics, allowing for monitoring and documenting changes in business processes within the supply chain [24]. The introduction of RFID technology in transport and warehouse logistics has significantly increased the efficiency of logistics processes [25]. RFID technology can positively impact all logistics supply chain management aspects, facilitating information sharing and security protocols for optimized synergy.

RFID technology has the potential to improve efficiency in seaport logistics [24] significantly. It can be used in various aspects of the shipping industry, such as cargo security, handling, and tracking of crew members [26]. In the context of port worker safety, RFID can be combined with ZigBee communication technology to create cost-effective and reliable solutions [27]. Additionally, the application of RFID technology in logistics warehousing management can enhance the efficiency of warehouse operations [28]. A specific example is the use of RFID technology in a logistics transportation system, which improves sorting efficiency and accuracy [11]. RFID technology integration in seaport logistics can provide real-time information, reduce waiting times, prevent bottlenecks, and enhance overall efficiency in various aspects of the shipping industry.

3. Methodology

This study uses a Systems Analysis and Design (SAD) methodology to create the RFID optimization system tailored to the Mogadishu Port. This methodology offers a systematic and structured framework ideal for improving cargo tracking, security, and logistical efficiency within a port environment. The study begins with a preliminary investigation phase involving comprehensive data collection through interviews and document analysis to understand the existing logistics processes, challenges, and inefficiencies.

Subsequently, identified challenges are defined, and a feasibility analysis is conducted to assess the practicality of implementing the system. Detailed system requirements are gathered through stakeholder engagement, leading to the design and development phase, where the system's structure and functionality are delineated. Hardware and software components are procured and configured, and implementation is meticulously carried out while considering operational constraints. This methodological approach ensures a systematic and effective development process tailored to the unique challenges and requirements of Mogadishu Port's logistics operations.

3.1. Hardware Component

The system architecture devised to enhance port logistics through RFID optimization is paramount in modernizing cargo tracking and management within port facilities. This section expounds upon the intricacies of this architecture, delineating the key components in which we used them as hardware components of the system and their roles in facilitating automated and error-reduced operations.

3.2. Arduino UNO

The Arduino UNO represents an open-source platform that offers the versatility to construct customized frameworks capable of controlling physical and digital domains. This microcontroller board has 14 digital pins, encompassing input-output functionality. The Arduino UNO relies on the Arduino Integrated Development Environment (IDE) software for programming to facilitate its operation. It derives power through two distinct means: the USB interface and an external power supply. With a memory capacity of 32 kilobytes, coupled with 2 kilobytes of Static Random-Access Memory (SRAM) and 1 kilobyte of Electrically Erasable Programmable Read-Only Memory (EEPROM), it serves as a communication conduit with computers, other Arduino boards, or various microcontrollers. Additionally, it incorporates a reset button to facilitate user interaction (Figure 1).

Fig. 1 Arduino Uno

3.3. Node MCU

The Node MCU, conversely, is a development board housing the ESP8266 microcontroller, and its nomenclature mirrors that of its firmware. In parallel with the Arduino UNO, the Node MCU adopts an 8-bit ATmega328P microcontroller at its core. Apart from this central component, it encompasses additional elements such as a crystal oscillator, serial communication interfaces, and voltage regulation mechanisms to bolster the microcontroller's functionality. The Node MCU's suite of features includes 14 digital input-output pins, of which 6 are adaptable for Pulse Width Modulation (PWM) outputs. Additionally, it incorporates 6 analog input pins, a USB connection interface, a Power barrel jack, an In-Circuit Serial Programming (ICSP) header, and a reset button (Figure 2).

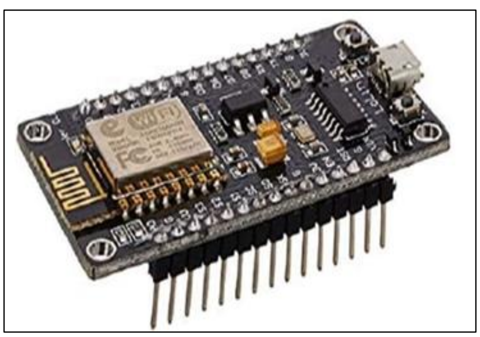

Fig. 2 Node MCU

3.4. RFID Module RC522

The RFID Module RC522 stands out as an economically viable RFID reader/writer module underpinned by the MFRC522 Integrated Circuit (IC). Its primary utility lies in the reading and writing of data onto RFID tags, diminutive electronic devices proficient in wirelessly transmitting and storing information through radio frequency waves. Operating at a frequency of 13.56 MHz, this module engages diverse protocols, including ISO/IEC 14443 Type A and B, MIFARE, and FeliCa, for communication with RFID tags. Depending on the tag type and associated antenna, it can detect tags at varying distances, ranging from mere centimeters to several meters.

The RC522 module typically comprises an integrated antenna, power supply circuitry, and an SPI (Serial Peripheral Interface) interface tailored for seamless communication with microcontrollers like the Arduino. Furthermore, it incorporates various security features, including authentication and encryption, to safeguard against unauthorized access to RFID tags. As a versatile component, the RC522 module finds extensive application in access control systems, asset tracking, inventory management, and payment systems (Figure 3).

Fig. 3 RFID module RC522

3.5. ISO/IEC 14443 Tag

An RFID tag operating at a frequency of 13.56 MHz and adhering to the ISO/IEC 14443 Type A standard is an example of a contactless smart card or RFID tag. These tags rely on a communication protocol rooted in load modulation, facilitating contactless data transfer. Typically, they exhibit a maximum communication range extending only a few centimeters, boasting up to 106 kilobits per second data transfer rates.

The ISO/IEC 14443 Type A compliant RFID tags find ubiquitous application in domains such as access control systems, public transportation, and payment systems. This standard delineates the physical characteristics and communication protocols that underpin contactless smart cards and RFID tags operating at the 13.56 MHz frequency band. Various examples of such tags include the MIFARE Classic, MIFARE Ultralight, and MIFARE DESFire EV1.

These tags incorporate essential components, including an antenna coil for communication, a microcontroller for data processing, and memory for data storage. Their design emphasizes compactness, durability, and user-friendliness, making them suitable for various applications necessitating contactless communication. Accessing or modifying data on ISO/IEC 14443 Type A compliant RFID tags typically necessitates a compatible RFID reader/writer, such as the RC522 module, and corresponding software for data interpretation. This reader interfaces with the tag through the

ISO/IEC 14443 Type A protocol, leveraging interfaces such as SPI or I2C for data transfer (Figure 4).

Fig. 4 ISO/IEC 14443 tag

3.6. LCD Display

Character-based LCDs are pervasive and are frequently underpinned by controllers such as Hitachi's HD44780 or compatible alternatives like HD44580. These LCDs find extensive applicability, interfacing seamlessly with various microcontrollers through diverse interfaces, including 8-bit and 4-bit configurations. This versatility extends to programming, affording opportunities for innovative customizations and capabilities. Character-based LCDs add an aesthetic dimension to applications, providing a novel outlook and enhancing user engagement (Figure 5).

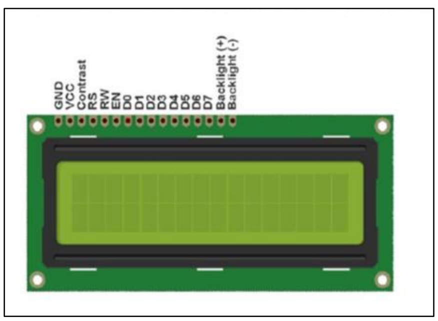

Fig. 5 LCD display

3.7. Cable and Connectors

Jumper wires, a staple of electrical connectivity, consist of wires with connectors at both ends, coming in male-to-male, female-to-male, and female-to-female variants. These connectors are indispensable in facilitating the interconnection of various electronic components, enabling seamless communication and data exchange (Figure 6).

Fig. 6 Connectors

3.8. Software Component

In implementing the prototype system, a combination of different software platforms was utilized to achieve the desired functionality and features. These software tools encompassed the Arduino IDE and C/C++ for the hardware integration and RFID readers, as well as PHP and MySQL for developing the system's backend and database. The integration of these diverse software platforms facilitated the creation of a comprehensive RFID Optimization System tailored for Mogadishu Port.

The Arduino IDE and C/C++ were instrumental in configuring and interfacing with RFID readers and hardware components. At the same time, PHP and MySQL were employed to develop the backend logic and manage the database, ensuring seamless data integration and retrieval. This multifaceted software approach was pivotal in achieving the system's objectives and addressing the unique challenges of the port's logistics operations, as outlined in the methodology section.

4. Results

Implementing the RFID Optimization System, following the Systems Analysis and Design (SAD) methodology, and utilizing hardware and software components brought notable improvements within Mogadishu Port's logistics operations. Cargo tracking and management witnessed a significant transformation as RFID technology enabled real-time tracking and precise identification of cargo containers Figure 7, reducing manual efforts and errors.

Security measures were bolstered through RFID-based access control systems, enhancing overall port security. Moreover, logistics operations were streamlined, leading to optimized container placement, reduced waiting times, and improved operational efficiency. Incorporating an intuitive LCD Display offered a user-friendly interface, aiding port personnel in decision-making and communication Figure 8. The data centralization through PHP and MySQL facilitated efficient data integration, storage, and analysis, supporting process optimization and decision support.

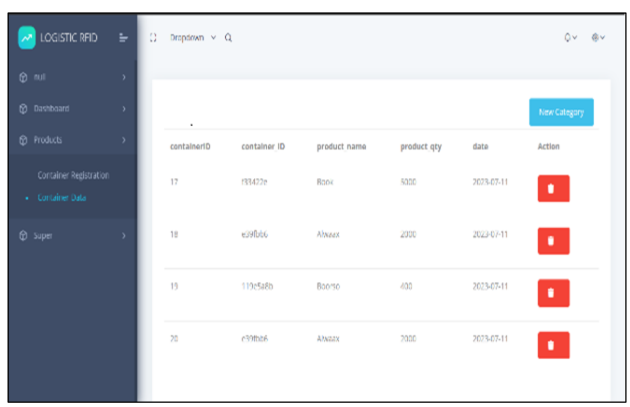

Fig. 7 Container data

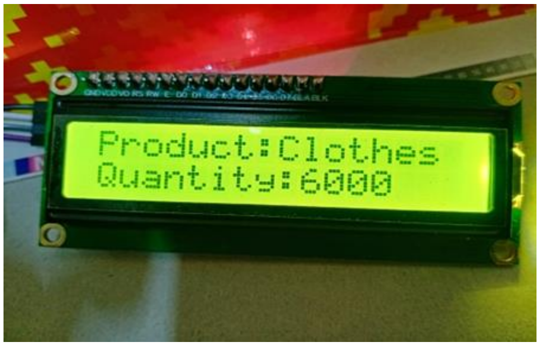

Fig. 8 Scanning item

These results highlight the potential of RFID technology to revolutionize port logistics. The systematic approach of the SAD methodology ensured that the system was tailored to Mogadishu Port's unique challenges, setting the foundation for scalability and continuous improvements.

However, the success of such a system also relies on factors like personnel training and system maintenance. Therefore, the RFID Optimization System has proven its value by enhancing cargo tracking, security, and logistical efficiency within Mogadishu Port, positioning the port for competitiveness in the global logistics landscape with room for further research and refinement.

5. Conclusion

The successful implementation of the RFID Optimization System at Mogadishu Port is a powerful example of how innovative technology can pave the way for sustainable progress. By following the Systems Analysis and Design (SAD) methodology and harnessing a blend of hardware and software components, this study has demonstrated the transformative potential of RFID technology in the context of port operations. This innovation can be pivotal in enhancing cargo tracking precision, bolstering security measures, streamlining logistics, and contributing to the region's sustainable development. The system's capacity to reduce operational costs and increase revenue aligns with the broader goals of economic sustainability in Somalia.

Furthermore, the inclusion of user-friendly interfaces and data-driven decision-making processes underscores the importance of human-centric technology solutions as catalysts for sustainable development. This study is a beacon, showcasing how Somalia and other regions can harness innovation to build resilient, efficient, and secure infrastructure. As we navigate the ever-evolving global logistics landscape, the lessons drawn from this endeavor resonate within port operations and various industries striving for sustainable growth through innovation and technological advancement.

RFID technology has been successfully integrated into the logistics operations of several global ports. These ports include the Shanghai Yangshan Deep-Water Port in China, the Port of Rotterdam in the Netherlands, the Port of Singapore, and the Port of Hamburg in Germany. The overall RFID market in ports is nearly $100m, with wide usage in port gate automation and yard processes like tracking container location and asset tracking [29]. The ports and terminals sector represents a proven, growing market for RFID. The RFID Optimization System at Mogadishu Port embodies the potential of technology to empower innovation for the enduring benefit of Somalia's sustainable development journey.

This implementation of the RFID Optimization System at Mogadishu Port promises economic advancement, infrastructure modernization, and technology transfer. It advocates for data-driven governance, enhances security and stability, and positions Somalia for global engagement. This study serves as a beacon of hope, showcasing the transformative potential of innovative technology in propelling Somalia's sustainable development journey while offering valuable insights for other regions pursuing similar objectives.

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