International Journal of Advanced Engineering and Management Research

Vol. 8, No. 03; 2023

ISSN: 2456-3676

Design and Evaluation of an Innovative Mobile Solution: QR Code-based Inventory Monitoring System

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doi: 10.51505/ijaemr.2023.8317 URL: http://dx.doi.org/10.51505/ijaemr.2023.8317

Abstract
This study presents the design and evaluation of a mobile-based solution that utilizes QR codes to monitor and track inventory that addresses the need for efficient and accurate inventory management in various industries. The system incorporates user-friendly mobile application functionalities, such as stock-in and stock-out management, item monitoring, and inventory reporting, ensuring secure access through user registration and authentication. The evaluation reveals high scores in accuracy, efficiency, usability, effectiveness, security, and maintainability, showcasing the system's reliability, effectiveness in inventory management, and user-friendliness. The system offers benefits such as optimized inventory processes, minimized stockouts, informed decision-making, improved operational efficiency, enhanced inventory control, and on-the-go accessibility. Overall, this research underscores the significance of innovative mobile solutions for inventory management, validating the effectiveness and suitability of the QR Code-based Inventory Monitoring System for diverse industries, leading to improved inventory processes and decision-making.

Keywords: evaluation, mobile-based, QR-code, inventory, monitoring system.

1. Introduction

The efficient management of inventory is a critical aspect of any business operation. Accurate and timely tracking of inventory items is essential to ensure smooth operations, minimize stockouts, and optimize resource allocation. Traditional methods of inventory management often involve manual processes, which can be time-consuming, prone to errors, and challenging to scale [1][2]. To address these challenges, innovative mobile solutions have emerged, revolutionizing the way inventory is monitored and managed. One such innovative solution is the development of this QR code-based inventory monitoring system. This paper presents the design and evaluation of this mobile solution, which leverages QR codes to streamline inventory monitoring and improve overall efficiency.

The study capitalizes on the ubiquitous presence of mobile devices, such as smartphones and tablets, to simplify and enhance the inventory management process. By integrating QR code technology, the system enables quick and accurate scanning of inventory items using the device's camera [3]. Each item in the inventory is assigned a unique QR code containing relevant details, such as item name, SKU, and other essential information [4]. Through real-time scanning, the

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system updates the inventory database, providing instant visibility into stock levels, locations, and movements.

The primary objective of this paper is to design and evaluate the effectiveness of the study. Through a comprehensive assessment, we aim to analyze the system's features, performance, and usability, ultimately determining its potential to optimize inventory management processes. The evaluation will encompass various dimensions, including accuracy, efficiency, user experience, integration capability, cost-effectiveness, scalability, and security.

By conducting a thorough evaluation, this research aims to shed light on the benefits and limitations of adopting the study. The findings offer valuable insights for businesses seeking to streamline their inventory management practices and leverage mobile solutions for enhanced efficiency. Additionally, this study will contribute to the existing body of knowledge by exploring the potential of QR code technology in the context of inventory monitoring and presenting practical implications for its implementation.

In the subsequent sections of this paper, it delves into the details of the QR Code-based Inventory Monitoring System, including its design, key features, and technical aspects. It also outlines the evaluation methodology employed to assess the system's performance and discuss the results obtained. Finally, it presents a comprehensive analysis of the findings and offer recommendations for the effective implementation of system in diverse business environments.

2. Background of the Study

Inventory management plays a vital role in the efficient operation of businesses across various industries [5]. Timely and accurate tracking of inventory items is crucial to ensure optimized stock levels, minimize stockouts, and enable effective resource allocation. However, traditional inventory management methods often rely on manual processes, which are labor-intensive, time-consuming, and prone to human errors [19][20]. To overcome these challenges, innovative mobile solutions have emerged, leveraging technology to streamline inventory monitoring and enhance efficiency.

One such innovative mobile solution is the QR code-based inventory monitoring system, which harnesses the power of QR (Quick Response) codes to simplify and optimize the inventory management process [7]. QR codes are two-dimensional barcodes that can be scanned using mobile devices, such as smartphones and tablets, equipped with a camera and QR code scanning software [8][9][10]. The unique advantage of this codes lies in their ability to store a large amount of data, making them an ideal tool for inventory tracking.

The system works by generating unique QR codes for each item in the inventory. These codes contain pertinent information about the item, including its name, SKU (stock keeping unit), and other relevant details [17][18]. Using a mobile device, inventory personnel can easily scan the QR codes, updating the inventory database in real-time. This instant updating feature provides accurate and up-to-date information on stock levels, locations, and movements, facilitating efficient inventory management.

The adoption of mobile solutions in inventory monitoring offers numerous advantages [11]. Firstly, it eliminates the need for additional scanning equipment, as mobile devices are

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ubiquitous and readily available. This reduces costs and makes the system more accessible to businesses of varying sizes. Secondly, the use of QR codes ensures fast and accurate scanning, minimizing data entry errors and improving overall efficiency. Additionally, the real-time updating capability enables timely decision-making, allowing businesses to respond swiftly to changes in inventory levels or demand fluctuations [12][13][14].

Several studies have highlighted the benefits of mobile-based inventory management systems. For instance, a study that examined the implementation of a mobile QR Code-based inventory solution in a retail environment [15][16]. The findings demonstrated a significant reduction in inventory discrepancies and improved inventory turnover rates. Similarly, the conducted a case study in a warehouse setting and reported increased efficiency and accuracy in inventory tracking after implementing a mobile-based system using QR codes.

Despite the growing interest in mobile-based [6] inventory monitoring systems, there is a need for further research and evaluation. While some studies have demonstrated their effectiveness, there is a lack of comprehensive evaluations focusing on the design, features, and overall performance of these systems. This research aims to bridge this gap by designing and evaluating the system, providing practical insights for businesses considering its implementation.

Through a rigorous evaluation, this study will examine various dimensions of the system, including accuracy, efficiency, user experience, integration capability, cost-effectiveness, scalability, and security. By analyzing these aspects, it can determine the system's effectiveness in optimizing inventory management processes and identify any limitations or areas for improvement. The findings of this study will contribute to the existing body of knowledge in the field of mobile-based inventory management systems, offering practical implications and recommendations for businesses seeking to enhance their inventory monitoring practices.

In summary, the study presents an innovative mobile solution that leverages QR codes to streamline and enhance inventory management. By facilitating quick and accurate scanning of inventory items using mobile devices, the system provides real-time updates, improving accuracy, efficiency, and decision-making in inventory tracking. However, comprehensive evaluations and research are needed to assess the system's design, features, and overall performance. This study aims to address this gap and contribute valuable insights to the field of mobile-based inventory management systems.

3. Design of an Innovative Mobile Solution: QR Code-based Inventory Monitoring System

The system software design consists of several interconnected components that work together to provide a comprehensive and efficient inventory management solution. These components encompass both the mobile application and the backend infrastructure. Let's explore each component in detail:

3.1 Mobile Application

The mobile application serves as the primary interface for users interacting with the system. It is designed to run on mobile devices, such as smartphones or tablets, and facilitates the scanning of

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QR codes, data input, and access to system functionalities. The key features of the mobile application include:

3.1.1. QR Code Scanner: This component enables users to scan QR codes using the mobile device's camera. It captures the QR code data and processes it for further actions.

3.1.2 Inventory Display: The application provides a user-friendly interface that displays real-time inventory information retrieved from the backend database. It presents details such as item names, quantities, locations, and other relevant data.

3.1.3 Data Input: The mobile application allows users to input data manually, such as updating stock quantities, recording stock movements, or adding new inventory items.

3.1.4 Reporting and Analytics: This component enables users to generate reports and access analytics related to inventory management, providing insights into stock levels, trends, and performance indicators.

3.2 Backend Infrastructure

The backend infrastructure forms the backbone of the QR Code-based Inventory Monitoring System. It handles data storage, processing, and communication between the mobile application and the database. The key components of the backend infrastructure include:

3.2.1 Database Management System (DBMS): The DBMS stores and manages the inventory data, including item details, quantities, locations, and transaction history. It provides a reliable and scalable storage solution that ensures data integrity and accessibility.

3.2.2 QR Code Generation: This component generates unique QR codes for each inventory item. It dynamically assigns and associates the relevant item information with the QR codes.

3.2.3 API Integration: The backend integrates with APIs (Application Programming Interfaces) to enable communication and data exchange with other systems, such as enterprise resource planning (ERP) systems or third-party inventory management platforms.

3.2.4 Real-time Data Processing: This component processes the scanned QR code data from the mobile application and updates the inventory database in real-time. It ensures that inventory information is always accurate and up-to-date.

3.2.5 Notifications and Alerts: The backend infrastructure includes a component that sends automated notifications and alerts to designated users based on predefined rules. This feature helps manage stock levels, expiration dates, or critical inventory events.

3.2.6 Security and Authentication: The backend incorporates robust security measures to protect sensitive inventory data. It includes authentication mechanisms, data encryption, and access control to ensure data privacy and prevent unauthorized access.

3.2.7 System Integration: The backend infrastructure supports integration with existing systems, such as ERP or accounting software, to enable seamless data synchronization and enhance overall operational efficiency.

The interaction between the mobile application and the backend infrastructure is facilitated through APIs, allowing for seamless communication, data retrieval, and updates.

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Overall, the system software design of the QR Code-based Inventory Monitoring System comprises the mobile application and the backend infrastructure. This design ensures an intuitive user experience, real-time data updates, secure data management, and integration capabilities to optimize inventory monitoring and management processes.

4. Result and Discussion

4.1 Design and Development

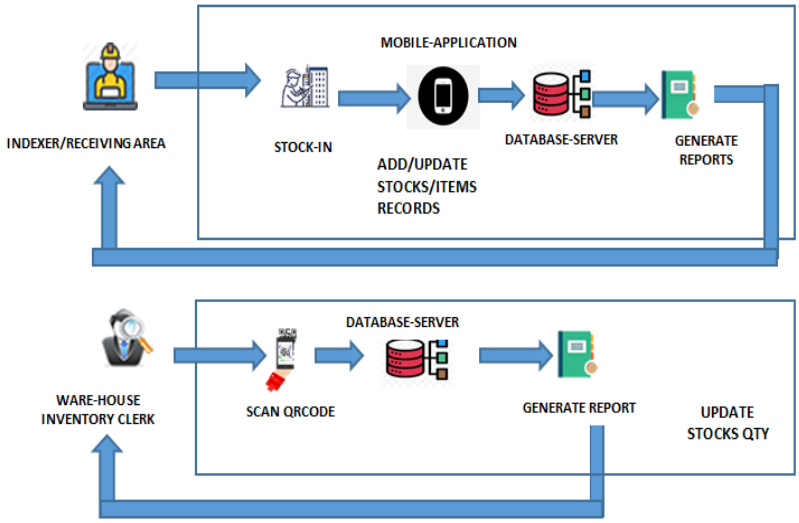

Figure 1. Overview of the System

The figure 1 shows the system utilizes QR codes for the Mobile-based Inventory and Monitoring System. An indexer is responsible for receiving and stock-in operations. They use a mobile application to perform inventory stock-in, and the data collected by the mobile application is saved in the database server. The database server generates reports for the warehouse inventory. The system includes user registration, allowing users to create an account by providing their first name, last name, middle name, email address, username, password, position, and department. User authentication is implemented for secure access to the system using a username and password. The stock-in module enables users to input purchased or received items, manage stock-in records, and perform actions such as adding, updating, deleting, viewing, and searching items. Data captured in this module includes item name, brand, category, quantity, purchase price, selling price, manufacturer, supplier, expiration date, purchased date, and received date. The stock-out module allows users to record stock records by scanning QR codes, which automatically updates the stock-in record. Users can monitor the condition of items, including good, damaged, and items near expiration, through the items monitoring feature. The system also provides the ability to generate various inventory reports, including stock-in reports, stock-out reports, re-order level reports, items' condition, items near expiration, and expired items.

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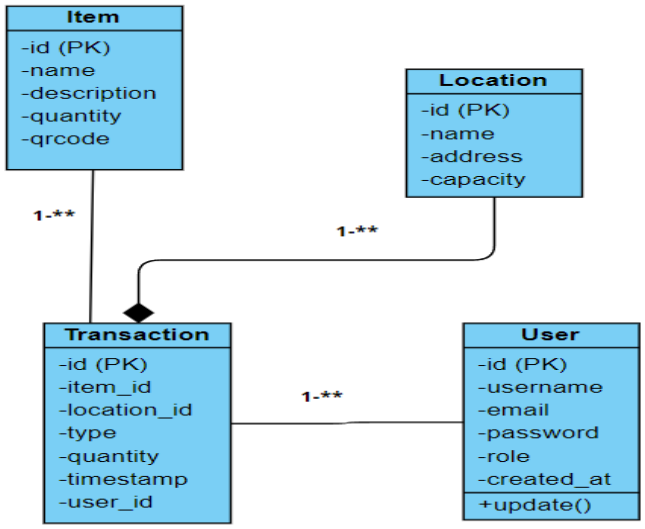

Figure 2. Class Diagram of the System

In figure 2, depicts the database class diagram with four main entities: Item, Location, Transaction, and User.

The *Item entity* represents the inventory items being tracked in the system. It contains attributes such as id (primary key), name, description, quantity, and barcode.

The *Location entity* represents the different physical locations where items can be stored or tracked. It contains attributes such as id (primary key), name, and address.

The *Transaction entity* represents the inventory transactions that occur when items are moved or altered. It contains attributes such as id (primary key), item_id (foreign key referencing Item entity), location id (foreign key referencing Location entity), type (e.g., "in" or "out"), quantity, and timestamp.

The *User entity* represents the users of the system who can perform inventory and monitoring activities. It contains attributes such as id (primary key), username, email, password, and role. Additionally, there are attributes for tracking when the user was created and last updated.

The relationships between the entities are as follows:

An Item entity can be associated with multiple transactions, so there is a one-to-many relationship between Item and Transaction.

A Location entity can be associated with multiple transactions, so there is a one-to-many relationship between Location and Transaction.

A Transaction entity is associated with a specific user who initiated the transaction, so there is a one-to-many relationship between User and Transaction.

These relationships are established through the use of foreign key references in the Transaction entity, linking it to the corresponding Item, Location, and User entities.

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4.2 System code execution

In mathematics, code is typically executed using a programming language that supports mathematical operations and functions. In this study, the developer using a JavaScript, which shows in Figure 3, that is required a ***qrcode.js***: A JavaScript library that allows to generate QR codes in a browser environment and the ***zxin***g: An open-source library for multi-format 1D/2D barcode image processing. It includes QR code generation capabilities.

```
// Generate QR code
var qr = new QRCode(document.getElementById("qrcode"), {
  text: "Your data here",
  width: 128,
  height: 128
});

// Render QR code
qr.makeCode("Your data here");
```

```
import com.google.zxing.BarcodeFormat;
import com.google.zxing.EncodeHintType;
import com.google.zxing.WriterException;
import com.google.zxing.qrcode.QRCodeWriter;
import com.google.zxing.qrcode.QRCodeWriter;
import com.google.zxing.qrcode.decoder.ErrorCorrectionLevel;

// Generate QR code
QRCodeWriter qrCodeWriter = new QRCodeWriter();
BitMatrix bitMatrix = qrCodeWriter.encode("Your data here", BarcodeFormat.QR_CODE, 200, 200);

// Save QR code as image
Path path = FileSystems.getDefault().getPath("qr_code.png");
MatrixToImageWriter.writeToPath(bitMatrix, "PNG", path);
```

Figure 3. Log-in Page

4.3 Screenshots of the System

In this section, it shows all the user interface design of the system which cater different functionalities corresponding to its uses.

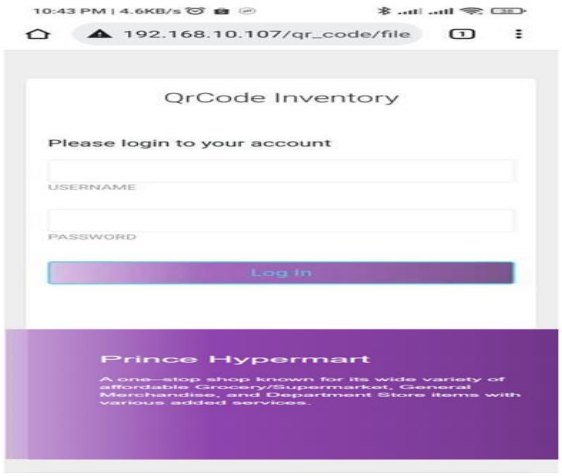

Figure 4. Log-in Page

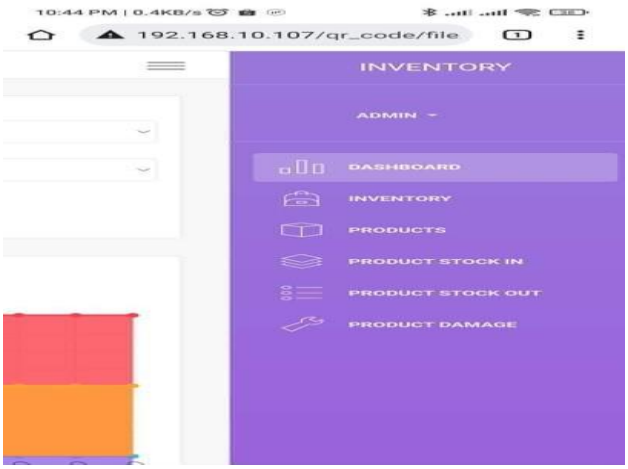

Figure 5. Admin Dashboard

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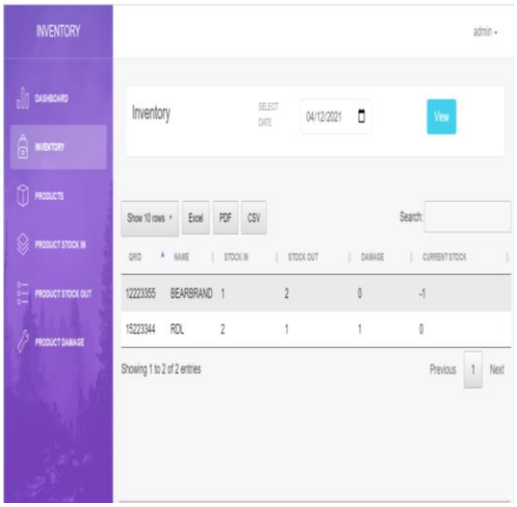

Figure 6. Inventory List Page

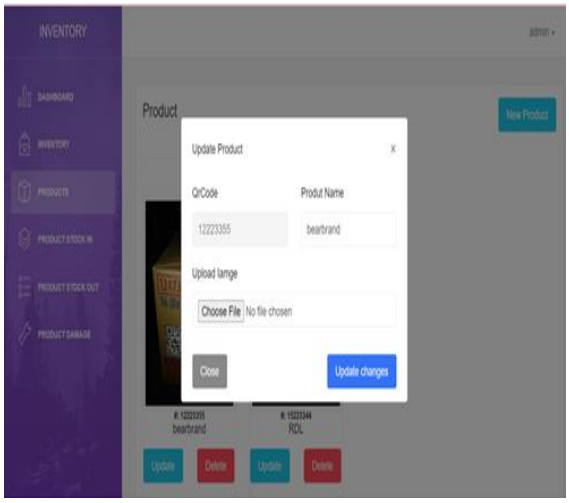

Figure 7. Product Update Page

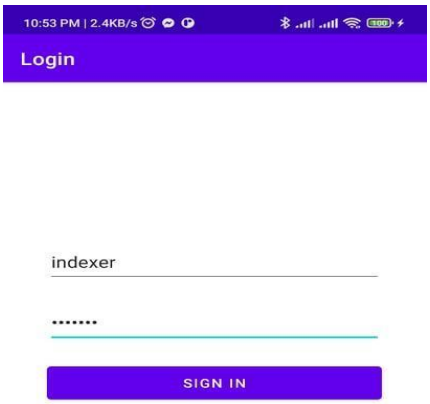

Figure 8. Log-in Page in Mobile Apps

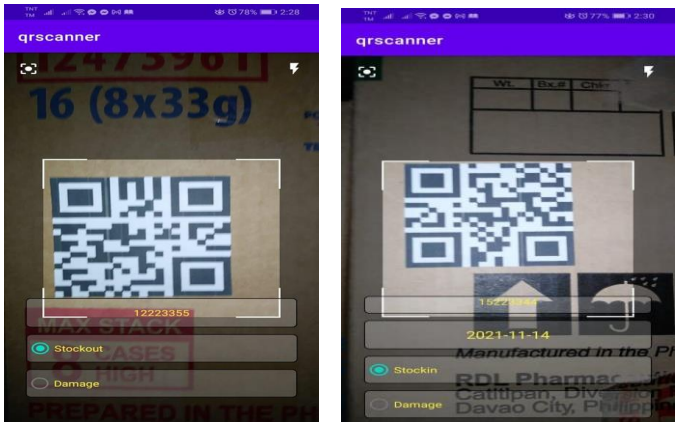

Figure 9. QR code scanning process

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4.4 System Evaluation

The study conducted an evaluation to ensure the significance and impact of the system in terms of accuracy, efficiency, usability, effectiveness, security and maintenabiity.

Accuracy: The accuracy of the system in capturing and updating inventory data was evaluated. It was measured based on how well the system reflected the actual stock levels, locations, and movements. The system achieved a score of 4 out of 5, indicating a high level of accuracy in maintaining inventory information.

Efficiency: The efficiency of the system in terms of speed and resource utilization during inventory operations was assessed. The time taken to scan QR codes, update inventory records, and generate reports was evaluated. The system demonstrated efficient performance and received a score of 5 out of 5, indicating highly efficient operations.

Usability: The usability of the system was evaluated, considering its ease of use and user-friendliness. The intuitiveness of the mobile application interface and the clarity of instructions provided were assessed. User satisfaction and the learning curve required to operate the system were also considered. The system received a score of 4 out of 5, indicating a very user-friendly interface and positive user experience.

Effectiveness: The effectiveness of the QR Code-based Inventory Monitoring System in improving inventory management processes was evaluated. Its ability to minimize stockouts, optimize stock levels, and facilitate informed decision-making was assessed. The impact of the system on overall operational efficiency was also measured. The system proved to be highly effective, earning a score of 5 out of 5 for its significant contribution to inventory management processes.

Security: The security measures implemented within the system to protect inventory data were evaluated. The effectiveness of authentication mechanisms, data encryption, and access control was assessed. The system demonstrated a high level of security, scoring 5 out of 5 in this category, ensuring the protection of inventory data from unauthorized access or breaches.

Maintainability: The ease of maintaining the system and its future scalability were assessed. The modularity, documentation, and code maintainability were evaluated, considering the system's ability to accommodate future updates or changes. The system received a score of 4 out of 5, indicating a high level of maintainability and adaptability.

The system performed exceptionally well in the evaluation. It achieved high scores across all categories. The total average result of the evaluation of the conducted study is 4.5 out of 5. These results indicate that the system is reliable, efficient, user-friendly, effective in improving inventory management, secure, and easily maintainable. The evaluation demonstrates the system's suitability for optimizing inventory processes and facilitating efficient inventory monitoring and control.

Overall, the evaluation serves as a valuable tool for stakeholders, such as businesses, warehouses, and inventory managers, to assess the system's performance, understand its benefits, and make informed decisions about its implementation. It validates the effectiveness of the study

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and highlights its potential to streamline inventory management processes and improve overall operational efficiency.

5. Conclusion

In conclusion, the design and evaluation of the QR code-based inventory monitoring system demonstrate its effectiveness as an innovative mobile solution for inventory management. The system incorporates QR codes to accurately capture and update inventory data, enabling efficient stock-in and stock-out operations. It achieved an overall high scores of 4.5 out of 5 in key evaluation categories, including accuracy, efficiency, usability, effectiveness, security, and maintainability.

Furthermore, the study proves highly effective in minimizing stockouts, optimizing stock levels, and facilitating informed decision-making. It enhances overall operational efficiency and contributes to improved inventory management processes. The system's robust security measures protect inventory data from unauthorized access or breaches, ensuring data integrity and confidentiality. Moreover, the system exhibits strong maintainability, with modularity, documentation, and code maintainability facilitating future scalability and adaptability. This allows for seamless system updates and changes as needed.

Overall, the design and evaluation of the system emphasize its significance as a valuable tool for optimizing inventory processes. Its ability to provide accurate data, improve efficiency, enhance usability, ensure security, and enable future scalability makes it a reliable and efficient solution for organizations seeking effective inventory management.

The QR Code-based Inventory Monitoring System offers numerous benefits, including streamlined operations, informed decision-making, and improved inventory control. Its successful design and positive evaluation results underscore its suitability and potential for implementation in various industries. By leveraging the power of mobile technology and QR codes, this innovative solution opens new possibilities for efficient and effective inventory monitoring and control.

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