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An Innovative Approach to Yard Management Using QR Code-Based Technology

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Abstract

Traditional yard and warehouse management systems are often prone to human errors which result in misplaced materials and products, operational disruptions and delays. To address these challenges, we propose a novel QR-based Yard Management System mobile application that leverages the ubiquity of QR codes to digitalize the process of material identification and placement verification. Upon receiving a material, dedicated QR codes placed on the material and the bins are scanned to automatically keep track of which bin the material is being placed in along with a validation process that ensures that the material is being placed in the right bin. This reduces the likelihood of misplacement of products, minimizes inventory discrepancies and any associated disruptions. Additionally, the system also provides real-time visibility into the product and bin statuses, enabling the yard managers to effectively track material locations and ensure their timely availability. By streamlining the material handling process, the Yard Management System enhances overall yard operation efficiency, thereby improving productivity and cost savings.

Keywords: *Yard Management System, QR codes, Mobile Application, Real-time, Digitalization*

1. Introduction

An effective inventory management system for any warehouse or yard is the cornerstone of an efficient and streamlined industrial and manufacting operations processes. However, many organizations tend to leave a huge scope for improvement in their yard management system. Many organizations use a simple excel sheet for keeping track of their yard or warehouse inventory [7]. This might be sufficient for small scale industries and manufacturers which produce fewer materials; however, continuing to use Excel sheets as the production capability scales is simply inefficient, cumbersome, and error-prone [2]. There are many ways to combat this issue such as using RFID tags [1], Barcodes [14], QR codes [13], Artificial intelligence, Computer Vision, Geotagging [3] And even UAVs [12]. However, organizations prefer to minimize cost while maximizing productivity. So, an expensive solution would only encourage them to continue using traditional systems such as Excel sheets and physical registers to keep track of items in their yards. So, it is important that the solution is as cheap as possible while being as efficient and productive as possible. A yard management system is ideally expected to (i) keep track of any products that enters the yard to be stored, (ii) keep track of where the product that has arrived at the yard has been stored, (iii) make sure that the data pertaining to its location is accurate, (iv) keep track of products being dispatched from the yard and where it is being dispatched, and (v) provide a real-time view of the status of all products and storage bins within the yard at any given point of them. So, our proposed method handles these five expectations with a QR

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based approach by assigning unique IDs to products and bins. A similar strategy was used by Tsai ET. al. 2021 [6] in an intelligent tracking system for clothing manufacturers. This method can be further improved by incorporating warehouse robots to reduce errors and increase efficiency [4]. Smart warehouses are becoming increasingly trendy [5]. This means choosing how to make any warehouse smart is also an extremely important decision.

2. Literature review and related word on yard management system

Many papers have studied and worked on improving the management of different organizations' inventory, warehouses, and yards. From these papers, it is evident that a lot of organizations tend to use a simple Excel sheet to maintain and manage their inventory. Chao Li et al. 2022 [2] mention how for warehouses that deal with only a small number of goods, Excel or simple manual notes are sufficient but when the number of goods increases, this method ends up with a lot of flaws. Despite Sthis, many companies continue to use simple spreadsheet software due to its ease of use and cheaper cost. Ning Ling et al. 2015 [7] highlight the situation at Hongxing Logistics before the implementation of their system wherein the company was using Excel to manually keep track of all the goods entering the warehouse, their quantity, and their location within the warehouse. Many papers have been written to suggest methods to better improve the management and tracking of warehouses and yards more efficiently. Chao Li et al. 2022 [2] have implemented a system that makes use of the Vuetify 3.0 framework to perform various warehouse management-related tasks such as viewing, searching, creating, and modifying cargo details through a web interface. There have been multiple papers that make use of Radio Frequency Identification (RFID) technology for an automated inventory management. Mark L. McKelvin, Jr. et al. 2005 [8] propose a detailed implementation that makes use of a distributed network of wireless sensor nodes and RFID readers to keep track of the inventory. Similarly, Yong Liang et al. 2010 [9] propose an architecture of placing RFID tags on different containers in a yard to keep track of them. Ananthi K et al. 2021 [10] propose a system that makes use of IoT with the help of passive RFID tags, Thing Speak platform, and a Raspberry Pi for inventory management. The application of this inventory management is also seen in the Oil and Gas sector as mentioned by Shanthi Vallingiri et al. [11] 2013 where the integration of steel structures called pallets and RFID tags together helps in performing various management operations. Another innovative solution proposed by Sung Moon Bae et al. [12] 2016 makes use of UAV and RFID together to manage inventory checking in open storage yards. Another paper by Bohan Yoon et al. 2021 [13] suggests making use of drones and QR technology for inventory management automation. The system makes use of different QR codes placed on the ground to help the drone reach the desired product by predicting its location. Then, the drone scans the QR code placed on the product itself (and not the ones on the ground) to find the location of any product present anywhere in the yard or warehouse. Another solution to this problem, as pointed out by Nadya Amanda et al. 2020 [14], uses barcodes and scanners to track inventory in the warehouse and improve warehouse efficiency. Suwarni ET. al. 2018 [15] proposed a solution in their Warehouse Receipt System which is designed for agricultural processes. The system works by providing warehouse receipts to those who come to the warehouse to get their products quality checked. This receipt generation system is a unique system that has inspired our proposed method for a solution to the yard management solution as well.

3. User Requirements

After reviewing various related work, we decided to club the best functionalities from different works and put them in one singular system to provide an improved solution. The application will make use of QR technology, inspired from the work of Bohan Yoon et al. [13] and Nadya Amanda et al [14]. This was combined with the modular design structure inspired by the work of Ning Ling et al [7]. So, before proposing a solution, the users of the system were identified, and their requirements were gathered. Below are the findings.

3.1 Workers responsible for handling the finished product at the Factory

This user works at the manufacturing site where the product which is to be stored in the yard is produced. The factory worker should be able to:

- Generate a QR code for each product based on its unique product ID.
- View the generated QR code.
- Save and share the QR code.
- Print the QR code.

3.2 Workers responsible for handling the product at the yard

This user works at the yard and is responsible for receiving the product into the yard and placing them in storage bins and also dispatching them out of the yard. The yard worker should be able to:

- Generate a QR code and view it for each bin based on its unique bin number.
- Share and print the generated QR code.
- Scan the QR code on the material to get all the required material data without having to enter it manually.
- Scan the bin in which the product is being placed so that the details of the bin in which the material has been placed are automatically reflected.
- See a receipt at the end to confirm successful material placement.
- Scan either the product itself or the bin in which the product has been in order to get all the details pertaining to the product that is being dispatched to the customer.
- See a receipt at the end to confirm successful material dispatch.

3.3 Yard Manager

This user works at the yard and is responsible for supervising the yard worker and being able to keep track of all the products present in the yard. The manager should be able to:

- Do everything a factory worker can do.
- Do everything a yard worker can do.
- Enter product status or bin status to see the status of any product or any bin.

4. Proposed method

Based on the requirements of the various users, the application has been divided into five different modules, each responsible for handling different tasks related to different users. The different storage areas or the slabs where the products will be physically placed are called bins and each bin is given its own unique ID called Bin ID to differentiate it from the other bins. Similarly, each product produced that enters the yard has its own unique Material ID. Based on the IDs of the material and the bins, they are given their own QR code which is used to keep track of the status of the product and the bin in a database. The bin is assumed to be capable of handling only a single item at any given time. So, the five modules are listed below:

1. **User Authentication-** This module authenticates the different workers and provides them with an appropriate view.
2. **QR generation-** This allows the various users to generate a QR code as per their requirement. The factory worker can generate a QR code for the material while the yard worker can generate a QR code for the bin.
3. **Products receive-** This module is responsible for handling the intake of products into the yard. The system scans the QR code on the material received and the bin it was placed in. From these two QR codes being scanned, the system now knows which material has been received by the yard and in which bin it has been placed in.
4. **Product dispatch-** This module is responsible for handling the dispatch of products out of the yard. The system scans the QR code on either the material or the bin in which it has been placed as both are now interconnected with each other and will return the same data. From either of these two QR codes being scanned, the system now knows which material is being dispatched from the yard.
5. **Product status-** This module provides a real-time update on the status of any product or any bin. Product status shows all the details related

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to a product and which bin it has been placed in. Bin status shows whether a specific bin is occupied or not and if it is, then by which product.

The next few figures show the component diagram of each of the four modules described above and gives an idea of the functionality of them all at an abstract level. Figure 1 shows the generate QR section consisting of Bin QR generator and Material QR generator with each being capable of generating a QR code and saving or printing the generated QR code.

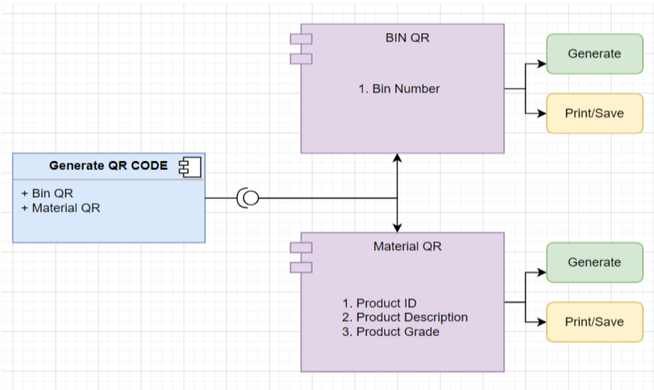

Figure 1 Component Diagram for QR Generation Module

Figure 2 shows the component diagram for the Product receive module. The module consists of a Material scanner and Bin scanner. The material scanning is used to get various data pertaining to the product such as its Product ID, the date at which the product was placed at the yard, the quantity of the product, its mode of transport used to reach the yard and any remarks required while placing the product in the bins.

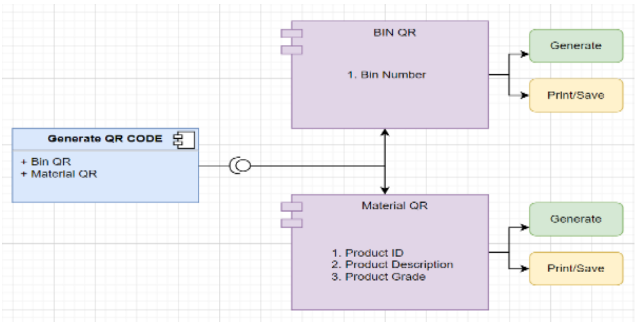

Figure 2 Component Diagram for Product Receive Module

Similarly, the bin scanner keeps track of the product ID of the product that it is storing, the date at which the material was placed in the bin and so on. Once these data are successfully collected, a receipt is generated to show successful receiving of the product at the yard. This receipt will contain a unique Receipt ID, the product ID of the product stored, the date, quantity and so on. Figure 3 shows the various components of the product dispatch module. Quite like the product receive module, the product dispatch module also consists of a material scanner and a bin scanner through which various data of the product that is being dispatched such as The product ID, date, quantity and so on are retrieved.

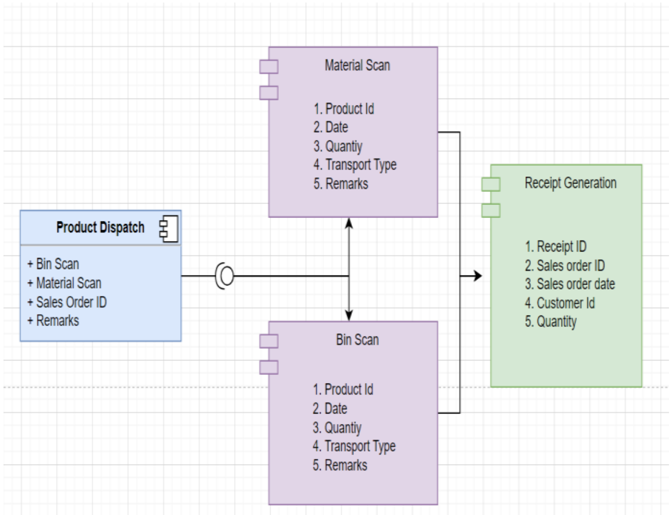

Figure 3 Component Diagram for Product Dispatch Module

The product dispatch module, like the product receive module, will contain data such as the product ID, quantity, and transport type and so on. Along with this data, the receipt in product dispatch will also contain a unique Sales Order ID belonging to the person requesting the dispatch of the product and a customer ID of the customer who wants the product dispatched. Figure 4 shows the component diagram for the status module which shows the product details and bin details and their current status.

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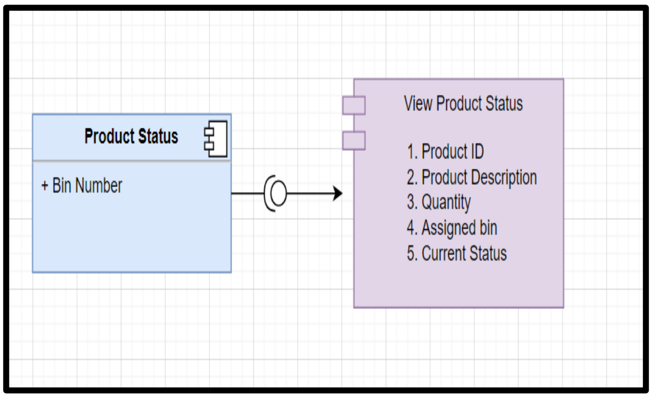

Figure 4 Component Diagram for Product Status

Figure 5 shows the use case diagram comprising of the three main users described earlier: factory worker, yard worker and yard manager. The factory worker has access to material QR generation while the yard worker has access to Bin QR generation, Product receive and dispatch.

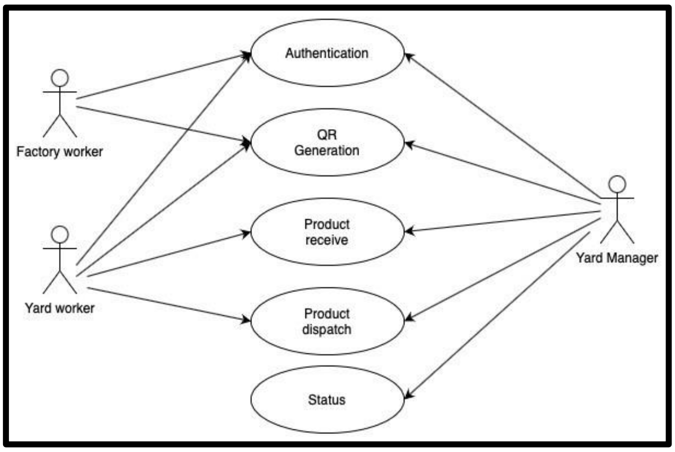

Figure 5 Use Case Diagram

Yard manager has access to everything the factory and yard workers have access to: QR generation, Product receive and Product dispatch. On top of this, they also have access to view the real-time status of any product or bin through the status module. Figure 6 contains the activity diagram illustrating the flow of different activities in the application. The application starts with an authentication of the user followed by a view specific type of user. The factory worker and yard worker can generate QR codes once they are authenticated in.

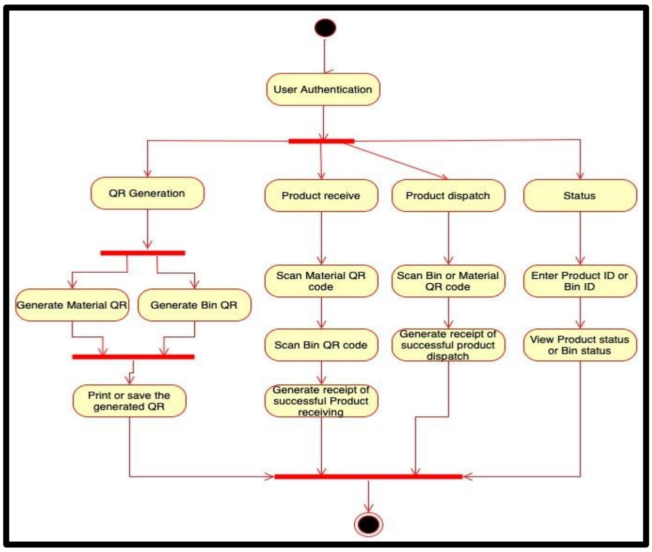

Figure 6 Activity Diagram

Yard workers, after being authenticated in can also perform product receive and product dispatch functionalities. Yard managers, on top of being able to do all this, can also view the status of each product and bin.

5. Comparative study

5.1 RFID enabled Container Yard Management System, 2010 by Yong Liang and Xiao-bo Bai [9]

Proposed solution: The solution proposes the use of RFID tags to keep track of products in a yard. RFID tags are placed on all product containers in the yard and these RFID tags transmit data related to the product which include product container location, product information and even product container history data.

Benefits: The solution is cheap and provides a reliable way to keep track of product containers within the yard. A simple search in the search engine provides an accurate location of product in the yard along with any information related to it.

Flaws: The solution requires the implementation of a complex network of RFID tags transmitting data to the application layer which can be difficult to set up and maintain. The maintenance of the RFID tags can also be quite costly if damaged. RFID tags can cost at the minimum ₹1, 00,000 (or $1200) for just 1000 units. So, replacing the tags can be a costly affair.

5.2 Web based application based on Design and Implementation of Warehouse Management System, 2022 by Chao Li et al. [2]

Proposed solution: This design creates a web-based application using the Verify 3.0 framework. It includes a front end as well as a back end consisting of a 5T large capacity database to keep track of warehouse inventory.

Benefits: This system is very cheap to implement and is also quite easy to learn and use. It is also scalable and can continue working efficiently even as more products come into the warehouse, unlike using excel sheets.

Flaws: The web-based application still relies on manual input of data from the user, which means it is prone to human error during data entry which can lead to a cascading series of errors bringing down overall productivity and increasing costs.

5.3 UAV based approach based on 3D position estimation of drone and object based on QR code segmentation model for inventory management automation, 2021 by Bohan Yoon ET. al. [13]

Proposed solution: This approach makes use of QR codes and UAV drones to keep track of products in a warehouse.

Benefits: The approach provides complete automation of product tracking and inventory management in a warehouse with a good amount of reliability. It also reduces the need for labor, thereby bringing down operational costs of the warehouse.

Flaws: The UAV approaches only achieve recognition rate of 80%-95% [9] when it comes to using image processing and pattern recognition. Also, this method is expensive as UAVs tend to be expensive to purchase and maintain. This method can also be complex and not as easily scalable if the warehouse size increases.

5.4 Wi-Fi signal strength-based approach to keep track of product location based on Automatic Asset Location Determination for Warehouse Management System Based on Wi-Fi Signal Strength, 2020 by Rudy Gunawan et al. [16]

Proposed solution: This design proposes the use of Wi-Fi tags and the strength of the signal emitted by them to keep track of a product's location in a warehouse.

Benefits: This system is much faster in terms of helping the user locate the position of a particular product within the warehouse. Also, since the solution only requires Wi-Fi tags for implementation, this solution is quite cheap as well.

Flaws: Just like the solution making use of RFID tags, this solution also requires individual Wi-Fi tags for each product. This means that the cost and effort of maintaining and replacing damaged tags will be very high. The accuracy of these system, as mentioned by the authors themselves is also on the lower side. Also, the implementation of this system can be quite a complex task.

6. Results and Discussion

In a yard, a cheap and efficient system is required to handle the flow of products in and out of the yard. The QR-based Yard Management system handles this perfectly by giving us the right amount of compromise between cost and productivity. The QR technology is cheap to implement as it only requires printouts of QR codes to be attached to products and bins. This is a much cheaper alternative when compared to RFID or UAV based methods. The only cost involved with this method is the cost of setting up and maintaining a database. This cost can be reduced by choosing between on premise and cloud-based databases based on the requirements of the organization. For a cloud-based approach, using AWS RDS m4 large instance would cost approximately $1600 per year. This also converts capital costs associated with the other methods discussed in this paper into operational costs.

7. Performance analysis

The performance of the two major functionalities of the application: QR scanning and database entry, were studied and the results were noted. The results of the analysis are shown in Table 1 and 2. Table 1 shows the results of the performance analysis of the QR scanning process while Table 2

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shows the results of inserting entries into the database.

Table 1 Performance Analysis of QR Scanning

S. no.	Time Stamp	Response time	Status
1	0:00:00	361	Success
2	0:10:08	65	Success
3	0:21:06	441	Success
4	0:32:04	567	Success
5	0:43:02	465	Success
46	8:06:00	-	Failure
47	8:16:08	-	Failure
48	8:27:06	-	Failure
49	8:38:04	616	Success
50	8:49:02	351	Success

Table 2 Performance Analysis of Product Receive

S. no.	Time Stamp	Response time	Status
1	27-11-23 0:00	80	Success
2	27-11-23 0:01	949	Success
3	27-11-23 0:02	219	Success
4	27-11-23 0:03	-	Failure
5	27-11-23 0:04	-	Failure
46	27-11-23 0:45	4865	Success
47	27-11-23 0:46	7805	Success
48	27-11-23 0:47	-	Failure
49	27-11-23 0:48	-	Failure
50	27-11-23 0:49	-	Failure

A series of 50 tests were conducted, each for

i. QR Scanning
ii. Recording the data into the database

Out of the 50 tests conducted for QR Scanning, each with a time interval of 10 seconds between the scans, the average response time was clocked at 487.34 milliseconds. This metric was measured in milliseconds to indicate the system's responsiveness. The accuracy of the tests stands at 94% with 47 out of the 50 resulting in successful outcomes. The test cases which led to a failure were assuming that the device which was used for scanning was highly unsteady or wobbly. As for the tests which involved recording the data into the database, the time interval was further increased to 2 minutes between each scan. This was done to consider the time spent by the worker to generate the QR, scan the respective QR, and input the required information via the application. With all other metrics and conditions remaining the same, the average response time was clocked at 467.28 milliseconds. The cases where the system took longer to respond were under extreme conditions of poor to very low internet connectivity, in which case it took around 5 seconds to record the data into the database. These findings indicate the efficiency and the reliability of the system.

Conclusion and future scope

The Yard Management System simplifies the process of keeping track of the yard inventory for an organization of any size by reducing the costs involved and improving the overall efficiency and productivity of the whole process. Compared to the other proposed methods we discussed in section 5; our method tries to reduce their flaws while embracing their benefits. Compared to the traditional Excel sheets solution, our solution is far more efficient and less prone to error. Compared to the RFID solution proposed by Yong Liang and Xiao-bo Bai [9], our solution is much easier and easier to maintain and scale while being just as accurate. Even though the UAV approach proposed by Bohan Yoon ET. al. [13] reduces the need for labour, it is still complex to implement and provides an accuracy of just 80-95%, compared to which, the accuracy of our solution stands at 94%. Our solution is also far easier to implement and more scalable than the UAV solution. The WiFi signal-based solution proposed by Rudy Gunawan et al. [16] is cheap and is faster in helping the worker locate the exact location of a bin, it is still not as accurate and more complex to implement when compared to a QR based solution. So, based on this, our proposed method tries to improve on the benefits of all the existing solutions by making the system cheap, scalable, and easy to use while reducing their flaws by making the system easy to implement and scale.

The future scope for this includes:

1. Mobile app refinement and user interface improvement
2. Integrating the app with the organization's existing ERP systems to consolidate the data.
3. Integration with sensors to improve tracking of products on bins and reduce chances for error even more.
4. Implementation of another view for customers who wish to buy from the products stored in the yard. This process would come between the yard receipts and yard dispatch process and after the yard dispatch process.

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