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Revitalizing Warehouse Management: A Study of DBL Ceramics LTD's AS/RS Implementation for Capacity and Performance

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Abstract

The implementation of an optimized intelligent warehouse management system utilizing the Industrial Internet of Things (IoT) and an Automatic Storage and Retrieval System (AS/RS) has demonstrated promising results in enhancing the productivity and efficiency of logistics departments in ceramic industries. The proposed system layout, which uses RFID technology and Petri Net simulation, resulted in increased storage capacity, improved inventory management, and faster order processing speed for DBL Ceramics LTD. Compared to the traditional manual recording of logistics operations, the AS/RS system provides benefits such as real-time inventory tracking, a controlled environment for storage and retrieval, optimized warehouse operations and reduced costs. The suggested AS/RS model uses advanced technologies like TGVs, RFID tags, checkers, rotors, stackers, and conveyor rollers to minimize human interaction and maximize efficiency. The use of advanced technologies in warehouse management systems will result in higher efficiency and production for ceramic industries seeking to improve their logistics processes.

Keywords: AS/RS, RFID, IoT, Optimized Warehouse

1. Introduction

Ceramic companies are facing significant challenges in managing their logistics systems due to the complexity of their production processes and the need for strict storage requirements. Traditional manual recording of logistics operations is inefficient, resulting in a decline in the rate of high-quality products. To address these challenges, ceramic and logistics industry experts are researching and applying technology to upgrade and integrate supply chain management platforms [1]. One promising technology is the Industrial Internet of Things (IoT), which combines various technologies such as bar code technology, RFID technology, GPS/GTS technology, and internet technology. By using the IoT, ceramic companies can intelligently transform their original warehousing systems and improve their logistics operations [2].

DBL Ceramic LTD, a leading ceramic company, recognizes the need to improve its logistics system to meet customer requirements and enhance the mechanization and automation of storage. As such, this research paper aims to propose a system architecture to increase the capacity of DBL Ceramic LTD's warehouse, build intelligent warehousing, and connect upstream and downstream enterprises effectively. The use of RFID technology will create an automated storage and retrieval system (AS/RS) that can enhance the system's efficiency and make operations more rational. This AS/RS system uses computer-controlled material handling equipment such as robotic arms and conveyors to store and retrieve products from the warehouse, providing a controlled environment to maintain product quality. It also enables tracking of product locations and movements, helping warehouse staff monitor and ensure quality [3]. By reducing the time and effort required for storage and retrieval, the system can handle large volumes accurately, minimizing manual labor and errors, thereby helping warehouse managers optimize operations, reduce costs, and boost productivity.

The proposed system architecture is designed to enhance warehouse automation, optimize scheduling strategies, improve operational efficiency, and establish seamless integration with supply chain partners, ultimately increasing DBL Ceramic LTD's warehouse capacity and productivity. The primary objectives of this study are to

design and implement an advanced warehouse management system that improves automation, optimizes scheduling strategies, and boosts operational efficiency. The study also seeks to transform DBL Ceramic LTD's warehousing capabilities, increasing productivity while establishing seamless integration with supply chain partners for enhanced coordination and performance.

2. Literature Review

In warehouse management, optimization is key to maximizing efficiency and reducing costs. Many studies have explored different approaches to optimizing warehouse operations using various technologies and methodologies. Several studies have shown that optimization is essential in improving warehouse management, particularly in reducing operational costs and enhancing efficiency. For instance, the use of genetic algorithms (GAs) has proven effective in optimizing product placement and order picking routes within automated storage and retrieval systems (AS/RS), leading to significant reductions in order picking times and warehouse operation costs [4]. Additionally, dynamic storage assignment strategies, when integrated with advanced algorithms, have enhanced throughput by minimizing congestion in warehouses [5]. The study [6] focused on the use of genetic algorithms (GAs) in automated storage and retrieval systems (AS/RS). These algorithms outperformed heuristic and other optimization methods regarding retrieval time, distance traveled, storage utilization, and throughput. However, dynamic storage assignment posed a challenge that requires further research. Dynamic storage policies and integrated approaches considering storage assignment and order-picking policies outperformed existing methods. A PLC simulation model was developed to evaluate the performance of an automobile panel AS/RS system [7]. The simulation results indicated that increasing storage locations and conveyor speed improved system performance, but the benefits diminished at a certain point due to the robot arm's limited capacity. Proposed solutions included adding more robot arms and optimizing panel storage locations. Petri Nets were utilized in the study to evaluate the flow of goods at a warehouse logistics department [8]. The model identified bottlenecks and proposed solutions such as an automated goods-receiving process and a dynamic scheduling system for dispatching, which significantly improved system performance.

An intelligent warehouse management system based on IoT was proposed in this study [9]. Integrating various technologies, such as RFID and sensors, could significantly improve warehouse efficiency and reduce errors. Another study provided a comprehensive review of models for warehouse management, classifying them based on different factors and analyzing their strengths and weaknesses [10]. Careful planning and consideration of warehouse and product requirements were emphasized for successful implementation. The potential of real-time data collection, analysis, and optimization was highlighted in a paper [11]. Different architectures and technologies were proposed, but the successful implementation required careful consideration of security, privacy, and cost-effectiveness. Logistics automation management using IoT was explored in another study, emphasizing the need to address challenges such as data security and standardization for successful implementation [12]. Implementing an RFID- enabled fully automated warehouse management system was described, emphasizing the benefits of increased efficiency and reduced labor costs [13]. However, careful planning, investment, and evaluation of the system's impact were necessary for success. A smart warehouse management system was discussed using IoT, robotics, and AI technologies [14]. This system enhanced inventory accuracy, reduced labor costs, and improved customer experience. Successful implementation requires careful planning, investment, and employee training.

However, these studies highlight the importance of optimization in warehouse management and showcase different technologies and methodologies to achieve it. Careful planning, consideration of specific warehouse requirements, and investment in resources and training are key to successful implementation and achieving significant benefits in efficiency, cost reduction, and customer satisfaction.

3. Proposed Model

For increasing the capacity of the warehouse and optimize its operations, the integration of Radio-Frequency Identification (RFID) and Internet of Things (IoT) technology can be employed. This study uses the RFID tags to track the movement and location of products within the warehouse. Then the Petri Net simulation of the Automated Storage and Retrieval System (AS/RS) will be integrated with the RFID technology to track the products' movement more accurately. Additionally, an Operation Process Model of AS/RS will be developed to improve the material handling process within the warehouse.

3.1 RFID Process of Product Tracking

The RFID process used in DBL Ceramic involves several steps. First, the server is cleared to prevent unnecessary data storage after each restart. Then, the application is started while the Wi-Fi module is activated, establishing a connection between the module and access point. This allows for the acquisition of all sensor values over the internet.

User commands are sent through the application and uploaded to the DBL Ceramic server. The controller retrieves this information through the Wi-Fi module and takes necessary action based on the user's control signals. An RFID reader with specific parameters for each machine is required to ensure consistent data collection at pre-programmed levels for each equipment.
The sensors are connected based on the necessary parameters for each respective rotor or machine in the factory and warehouse. The RFID tags help in monitoring the equipment's functionality by sending desired sensor data to both the Arduino and RFID reader. The reader then sends data to the higher authority's account on the IoT platform using the Wi- Fi module.
Sensor levels are fixed and written as code in Arduino, which allows for easy identification of the machine's state in the factory and warehouse. Whenever sensors are accessed with an RFID tag, their sensed signal levels go to both the Arduino and RFID reader. The reader collects all the data from the RFID tags and sends it to the IoT platform through the Wi-Fi module. All of this data is recorded and stored within the user's account on the platform with the aid of the DBL Ceramic server.

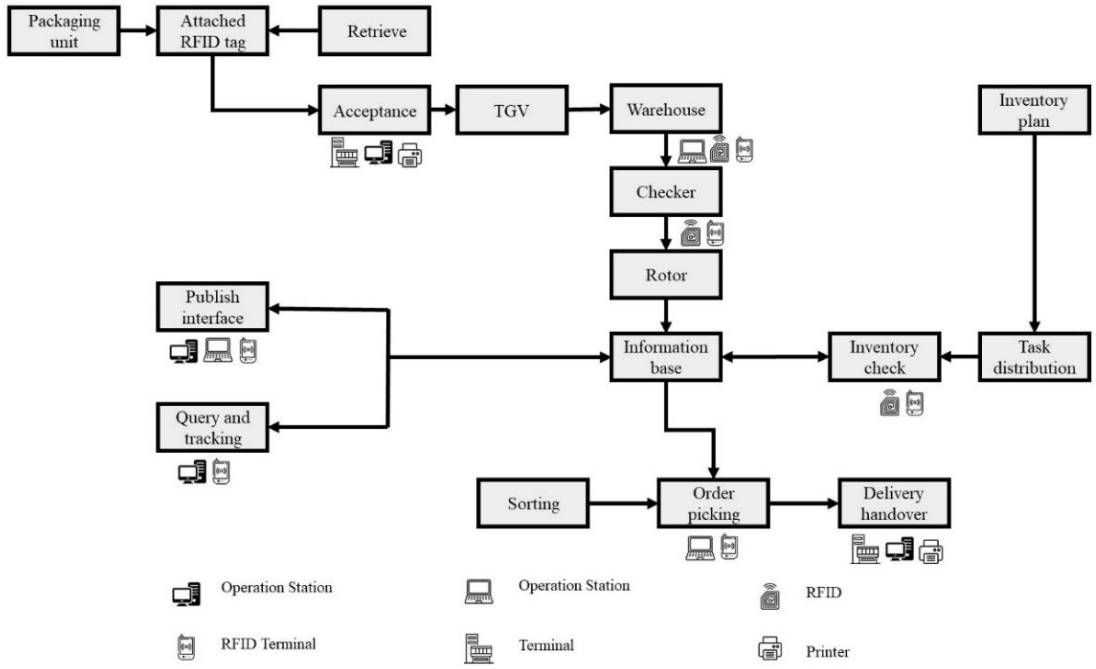


Fig. 1. RFID product tracking flowchart of DBL Ceramics Ltd

3.2 Operation process of AS/RS for material handling

Our proposed Automated Storage and Retrieval System (AS//RS) comprises several key components, including the Roller Conveyor, Rotor, Stacker, and Automatic Sorting Shelves.
Roller Conveyor: Product pallets move one place to another by using conveyor roller technology. The conveyor rollers are 4 feet width and connect packaging unit to distribution unit. Rotor: To ensure accurate routing of the product pallets, we have incorporated two major rotors. The first rotor is located on the warehouse side, while the second is situated on the product delivery side. When a product pallet reaches the rotor, it rotates and points in the correct direction based on the information collected from the Radio- Frequency Identification (RFID) checker. The rollers at every intersection also have rotors.
Stacker: Our AS//RS system also includes a versatile Stacker device that moves vertically. This device collects the product pallets from the Roller Conveyor and transports them to the appropriate level of the shelf.
Automatic Sorting Shelves: The Automatic Sorting Shelves integrate moving rollers on each tier, enabling pallets to shift inward, creating room for additional storage. Illustrated in Figure 3 is the upper segment of our facility, depicting Track Guided Vehicles (TGVs) transporting items from packaging to the buffer zone conveyor. Each item bears a distinct Radio-Frequency Identification (RFID) tag, read by a checker for routing to the suitable rotor. The rotor then guides the item pallet accurately.
Our AS/RS model includes loading and unloading stackers. When an item pallet nears the stacker, the rotor transfers it onto it, transporting it to the relevant shelf level. Units consist of two shelves, a conveyor roller, and two rotors. Upon delivery request, the stacker reaches the designated level, and the roller conveyor shifts the item pallet to the stacker. It subsequently moves the item pallet to the delivery roller, guiding it onto delivery trucks through a conveyor belt.

Our proposed AS/RS model capitalizes on advanced technologies like TGVs, RFID tags, checkers, rotors, stackers, and conveyor rollers. This synergy ensures a highly efficient and automated storage and retrieval system. The setup facilitates seamless item transport from packaging to delivery trucks, minimizing human involvement and maximizing efficiency.

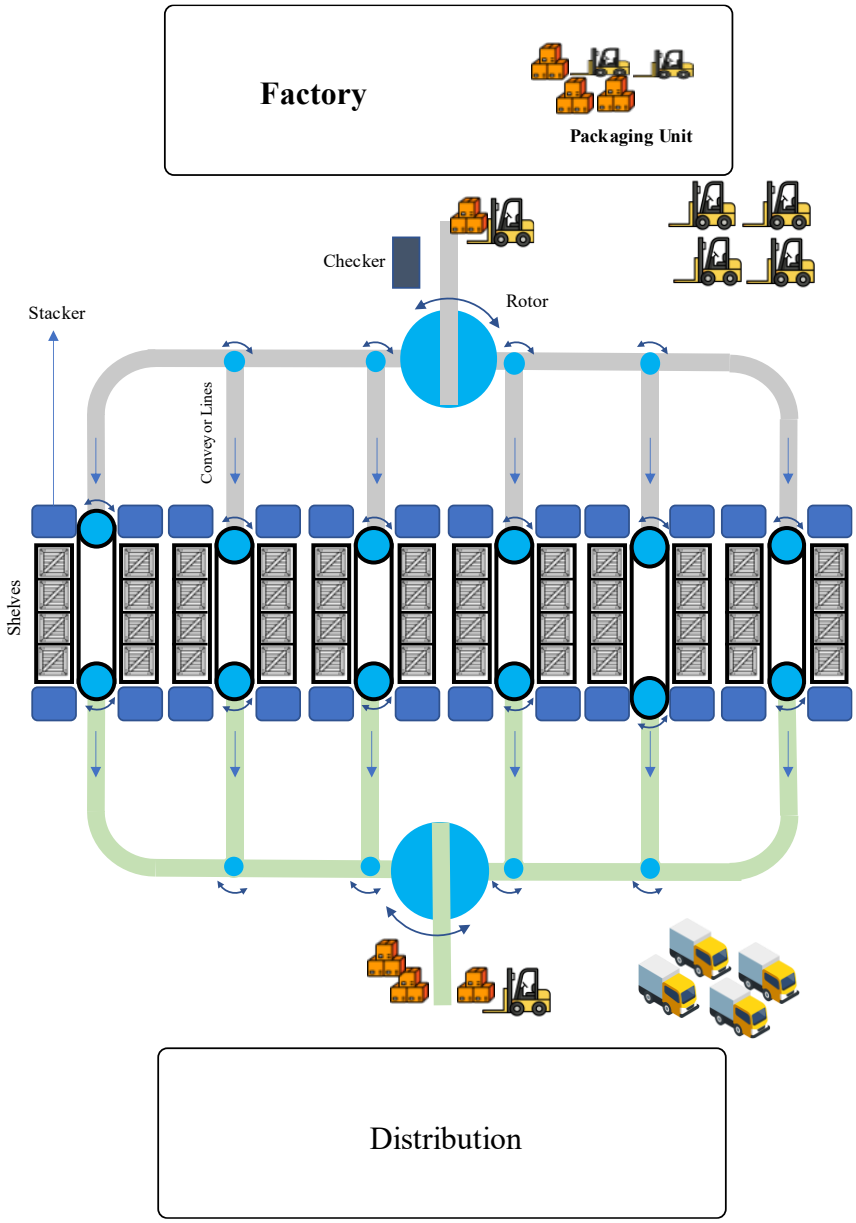


Fig. 2. Proposed AS/RS Model

4. Calculating Warehouse Capacity for DBL Ceramics

There are three warehouses in the factory, each with a length of 300 feet and a width of 100 feet. Each warehouse contains 16 shelves, and each shelf has 10 layers. Each shelf is 250 feet long and the width is 4 feet. Each of layer of the shelves has the capacity of containing 60 pallets of tiles. So, a single layer of the shelf will contain total 45,000 square feet of tiles. Thus, a shelf will contain 450,000 square feet of tiles. Therefore, the total capacity of each warehouse is 16 shelves multiplied by 10 layers per shelf. Each shelf has a capacity of 450,000 square feet, so the total storage capacity of each warehouse is 16 shelves multiplied by 450,000 square feet per shelf, which equals 7,200,000 square feet of tile. FIGURE 3. Proposed AS/RS Model.

Since there are three warehouses, the total storage capacity for all three warehouses combined would be 7,200,000 square feet per warehouse multiplied by 3 warehouses, which gives us a total of 21,600,000 square feet of tile storage capacity for all three warehouses

5. Result

By Implementation of our proposed model has led to a several benefits for DBL Ceramics LTD:
1. Increased Storage Capacity: We were able to make the storage capacity up to 21,600,000 square feet.
2. Improved Inventory Management: The AS/RS system's automated retrieval and real time inventory tracking will reduce inventory management time and labor.
3. Faster Order Processing Speed: The AS/RS system will increase order processing speed, resulting in faster delivery times and higher customer satisfaction.

6. Conclusion

The combination of the Internet of Things (IoT) and Automatic Storage and Retrieval System (AS/RS) offers a game-changing opportunity to enhance ceramic industry logistics. The amalgamation of RFID technology and Petri Net simulation presents a compelling layout for an intelligent warehouse management system, exemplified by the success of DBL Ceramic LTD. Compared to traditional manual methods, the AS/RS solution presents numerous benefits, encompassing real-time tracking, controlled storage conditions, and cost reduction. Integrating Petri nets for simulation aids in pinpointing bottlenecks and refining the warehouse system's functionality.
This proposed approach holds great promise for ceramic businesses aiming to optimize their logistics processes. By adopting advanced technologies like IoT and AS/RS, companies can bolster warehouse efficiency and achieve seamless synchronization between upstream and downstream operations. Future research could extend the proposed model by including the implementation cost of the warehouse. Exploring other factors of the model would also be an interesting area for further research.

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