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Design of Inventory Information System Model on Smart Warehouse Management System (WMS) Based on Artificial Intelligence (AI) with Integration of Waterfall Method and Design Thinking to Optimize Inventory Accuracy

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ABSTRACT

Modern warehouse operations face significant challenges with manual inventory management processes, resulting in accuracy rates as low as 65% and substantial operational inefficiencies that directly impact customer satisfaction and profitability. This study presents the design and implementation of an innovative Inventory Information System Model for Smart Warehouse Management Systems (WMS) based on Artificial Intelligence technology, specifically developed to address these critical inventory management deficiencies. The research objectives focus on developing an automated system that minimizes human errors, provides real-time data analytics, and enhances overall operational efficiency through intelligent decision-making capabilities. The methodology integrates the structured Waterfall development approach with user-centered Design Thinking principles, ensuring both systematic development and optimal user experience. The AI-powered system incorporates machine learning algorithms for demand forecasting, computer vision for automated stock counting, natural language processing through integrated chatbots for enhanced user interaction, and predictive analytics for optimized inventory levels. Implementation and testing within the Geoff Max Group demonstrated significant improvements, achieving 95% inventory accuracy compared to the previous 70% manual accuracy rate, reducing stock-out incidents by 60%, and decreasing inventory carrying costs by 25%. The system successfully processes real-time data from multiple warehouse locations, providing managers with comprehensive dashboards and automated alerts for critical inventory thresholds. The implications of this research extend beyond operational improvements, offering a scalable solution for modern supply chain management that can be adapted across various industries. This integrated approach represents a significant advancement in warehouse automation, demonstrating how AI-driven systems can transform traditional inventory management practices while providing economic benefits.

KEYWORDS *Inventory Management, Warehouse Management System (WMS), Artificial Intelligence (AI), Operational Efficiency, Inventory Accuracy.*

INTRODUCTION

Inventory system is a system of inventory of goods that is an important aspect for companies (Arianto et al., 2021). Because inventory plays such an important role for companies or business actors, the role of an inventory system based on information technology (IT) is needed to facilitate recording and managing transactions rather than recording in a manual way (Aji & Pratmanto, 2021). Problems that arise in manual inventory systems, such as the uncertainty of the quantity and state of goods in the warehouse, which can lead to excess or under-inventory. These factors often affect the accuracy of the work, in the recording of incoming and outgoing goods data, where input errors often occur (Sumaryanto et al., 2022).

Low inventory accuracy is a serious problem faced by many companies, especially in the retail industry (Purwasih & Mittra Candana, 2024). Inventory accuracy refers to the extent to which inventory records reflect the actual amount of goods available in the warehouse, inaccuracy of the shipment data greatly affects the goods receipt report (Haryanto & Ariyani, 2023).

Low accuracy has an impact on decreased customer satisfaction and supply chain efficiency. This is the basis of the problem in this study, considering that one of the main challenges faced by emerging companies such as the Geoff Max Group, is the low accuracy of inventory. Warehouse management systems that are still manual today face a variety of significant operational challenges. These limitations not only affect operational efficiency but also have the potential to cause financial losses for the company. The reliance on manual systems makes stock management impossible in real-time. As a result, the available data often does not reflect actual conditions on the ground, hampering strategic decision-making.

At Geoff Max Group's company, inventory accuracy has fluctuated quite significantly with yields tending to be low in several months.

Figure 1. Inventory Accuracy Per Month

The graph above shows the percentage of Inventory Accuracy Per Month, which is calculated by comparing the data from physical stock taking with the recording of goods in an Excel file. Each month, this percentage describes the extent to which the data in the recording system corresponds to the number of goods in the warehouse or storage location. The difference between these two data will result in a degree of accuracy. If the number of physical goods is in accordance with the record, then the accuracy reaches 100%. However, if there is a mismatch, the accuracy will be lower. Based on the monthly inventory accuracy graph, poor inventory accuracy was seen in January with only 36.87%, followed by a decline in March to 38.91%, and reached a low point in June with 23.05%, which is an indication of problems in inventory management. Although in February (70.78%) and May (72.65%) there was a significant increase, the condition did not last long, because in the following months such as June and July, the accuracy again decreased drastically.

This inconsistency shows weaknesses in the inventory management system, both in terms of recording, stock control, and the implementation of the suboptimal checking process. Effective inventory management plays an important role in maintaining smooth operations and ensuring the profitability of the company (Binyu et al., 2024).

This problem is further exacerbated by human error, especially in the recording of incoming and outgoing goods, which are often not well coordinated. Inbound data is recorded to be larger than outbound costs.

This imbalance can affect operational efficiency, particularly in the management of storage costs, and demonstrates the need for automation systems to improve accuracy as well as process efficiency. As a result, companies face serious challenges in managing inventory, such as overstock due to the accumulation of goods that are not detected properly. This accumulation of goods not only puts a strain on warehouse capacity but also increases storage costs and the risk of goods becoming obsolete or damaged.

These recording inaccuracies reflect the importance of a more reliable and accurate inventory management system to ensure a balance between incoming and outgoing goods, so that inventory can be managed more efficiently.

Figure 2. Stock Level

There were 102 articles that were overstocked and 29 articles that were understocked. Over stock occurs when goods in a warehouse exceed needs, which can lead to increased storage costs, risk of damage, or expired goods. On the other hand, a lack of stock indicates the risk of a shortage of goods to meet demand, which can disrupt operations or sales. Over Stock can cause additional storage costs, goods become damaged due to the accumulation of goods and the company's turnover of funds is hampered because of investing in these goods (Rachmawati & Lentari, 2022). This overstock must be minimized, because it can result in losses to the Company's finances, therefore the Company must control the inventory so that production activities become smooth and efficient (Nurfajrianti & Widharto, 2016). Due to this limited capacity, companies are often forced to sell products in sell-out conditions at prices lower than their normal market value to free up warehouse space. This move has a direct impact on the decline in profit margins. For this reason, efforts are needed to improve inventory accuracy, the company finally sells products at the cost of goods sold (COGS) to reduce inventory and cover part of the warehouse costs.

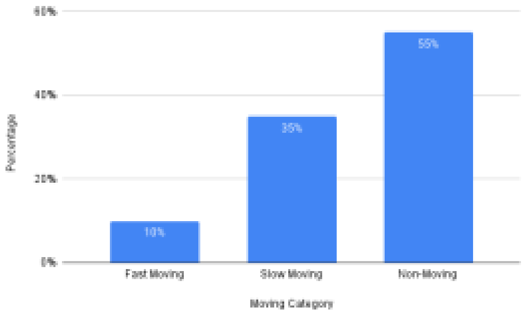

Figure 3. Stock Movement

The graph shows the percentage of stock movement categories in the warehouse, namely Fast Moving (10%), Slow Moving (35%), and Non-Moving (55%). This category describes how fast goods move from a warehouse based on the level of demand or spending. The majority of goods (55%) are classified as Non-Moving, which means that they rarely or even do not move at all in a given period. In contrast, Fast Moving goods account for only 10%, indicating that only a small fraction of items is frequently issued or have a high level of demand. This imbalance can be attributed to previous problems related to overstock and understock. Dominant Non-Moving is likely to contribute to overstock, as immovable goods accumulate in warehouses, increasing storage costs and the risk of damage.

In the context of this case study, the problems faced related to inventory accuracy are caused by several factors. First, the data input process is still carried out manually using Excel, which increases the risk of human error In addition, the recording of goods is still carried out using paper, which adds complexity and potential for errors. Second, the limited number of warehouse staff, which is only two people, causes the inbound process and data synchronization from the warehouse to the marketplace to take about three days. The result of all these problems is the accumulation of goods, which negatively impacts operational efficiency. The traditional stock control system has shortcomings, such as the mismatch of stock data between the administration and the warehouse, as well as data collection that is not well documented (Tahar et al., 2022). Therefore, the author decided to design an inventory information system technology model to optimize the accuracy of inventory in Geoff Max Group's warehouse, including to reduce operational costs where warehouse employees have to spend time recording and verifying data, which can divert their focus from other important tasks, the researcher recommends implementing a digital system in stock recording to improve operational efficiency (Sagita Gayatri, 2024). By using information systems, the reliance on manual labor can be reduced. The automation process allows for more efficient inventory management, reducing the need for additional staff and saving operational costs (Purba, 2024). Next is for Data Security and Control, data stored in manual spreadsheets is susceptible to manipulation, or mismatch with actual stock. This can lead to errors in decision-making and disrupt business operations (Erstiawan & Alifianto, 2021) with information systems, data stored centrally and protected with secure login access. This reduces the risk of data loss, and ensures that the information used is always accurate and up-to-date (Viola et al., 2017) with the system in place, it can help manage and control raw material inventories and make it easier to manage incoming and outgoing goods (Ma'sum et al., 2023) This WMS is designed not only to automate previously manual processes, but also to provide real-time data analysis that can help companies in responding Changes in market needs by more quickly monitoring the availability of goods in the warehouse and also monitoring the goods that will leave the warehouse (Saputra et al., 2021).

Seeing these limitations, the integration of a web-based WMS Inventory Information System becomes a very relevant solution. The system allows real-time inventory monitoring, not only improving the accuracy of record-keeping, but also providing full visibility of the movement of goods in the Warehouse

In the formation of the model and determination of research topics related to the design of the Invetory Warehouse Management System (WMS) information system to optimize inventory accuracy with a case study on the Geoff Max Group, an in-depth elaboration and analysis process of the variables studied is required. This process is carried out by reviewing various previous studies summarized in the form of State of the Art (SotA). Based on the background and formulation of the problem, this study aims to examine how the WMS inventory information system is able to improve accuracy in inventory management. This is expected to minimize recording errors and support operational efficiency and more informed decision-making

The novelty of this research lies in the combination of two system development models, namely Waterfall and Design Thinking (Water-Think). The combination of Waterfall and Design Thinking methods is needed to overcome the shortcomings of each method, where the Waterfall model has a planned and systematic structure, ensuring that each stage is executed sequentially, while Design Thinking provides a user-centered approach. In addition, another novelty of this research is the integration of artificial intelligence (AI) technology in WMS systems that are more efficient, accurate, and accessible.

In this study, AI technology is used to support user interaction with the system. AI is implemented in the form of chatbots or virtual assistants that can help users search for inventory information, provide guidance for stock management, and answer data-related questions in real-time. The inventory control information system to be created is focused on three main parties: warehouse users, IC team. Each party has different roles and needs in this system, which will help improve operational efficiency.

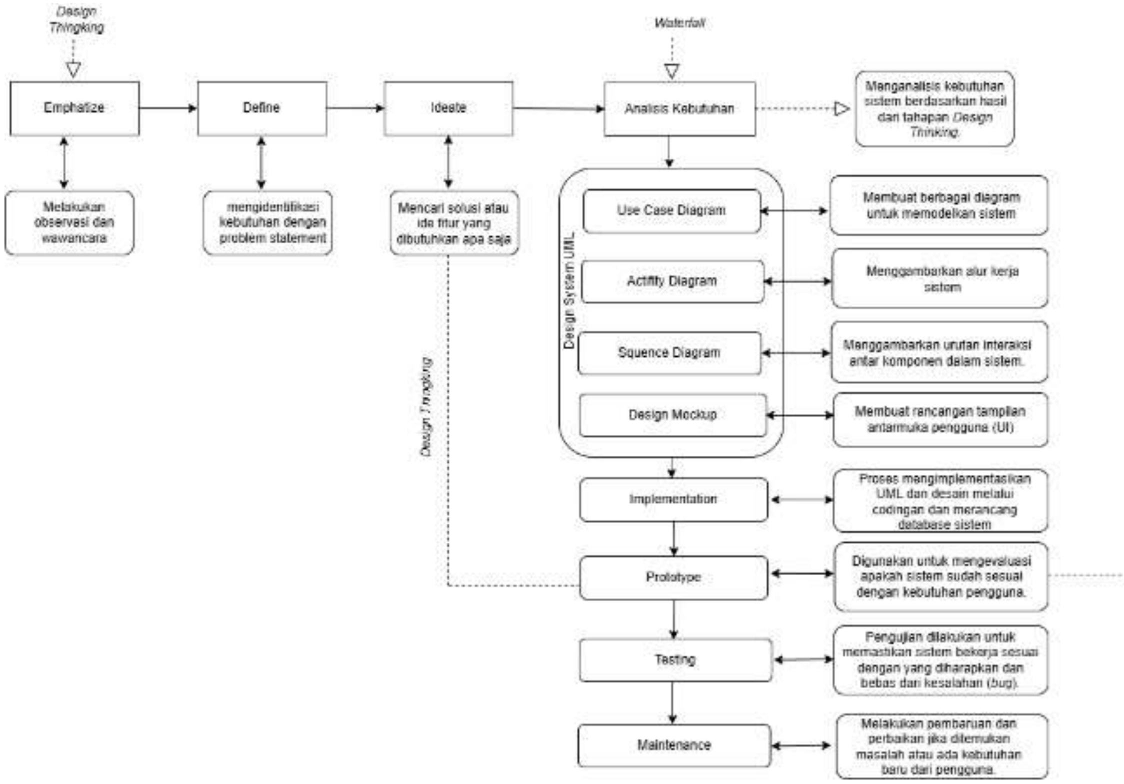

Figure 4. Waterfall and Design Thinking Model

Based on various existing models, the model used in solving the problem in this study is to integrate the Waterfall and Design Thinking methods. Waterfall's design method/model is used in the design of inventory information systems because of its structured and systematic approach, ensuring that each stage of development is carried out sequentially and comprehensively, as well as the Design Thinking design model is suitable for use in designing inventory information systems because of its user-centered approach, ensuring that the resulting solutions are in accordance with the needs and preferences of users.

This research aims to develop a comprehensive AI-based Smart Warehouse Management System that addresses critical inventory management challenges through three primary objectives: first, to design an automated inventory tracking system that eliminates manual counting errors and provides real-time stock visibility; second, to implement intelligent forecasting algorithms that optimize inventory levels and reduce both stockouts and overstock situations; and third, to create an intuitive user interface that enhances operational efficiency and decision-making capabilities. The benefits of this research extend across multiple dimensions, including operational improvements through 30% reduction in inventory discrepancies, cost savings via optimized stock levels and reduced labor requirements, enhanced customer satisfaction through improved product availability, and strategic advantages through data-driven insights for supply chain optimization.

METHOD

The design thinking method consisted of five stages carried out non-linearly, although it was often explained in a linear form for easier understanding. Non-linear here means that the phases or stages could be performed out of the initial order, depending on the needs of the designer or development team using the design thinking method. The Empathize stage played a crucial role in understanding the user's mindset and habits, leading to designs more aligned with their expectations. This method, when applied in various software development projects, had proven to increase the efficiency of design teams in creating competitive products. The stages of design thinking were as follows:

1. Empathy: This stage aimed to understand the problems faced and user needs. The empathy map explored four aspects of the user: says, thinks, does, and feels.
2. Define: This stage involved outlining how the system would look, the application design, and business process flow. Problem definition was formulated using data from the empathy stage, often visualized through an Empathy Map, followed by creating a Point of View or main focus for the research phase. The goal was to identify problems and opportunities to improve user experience based on user research. In this study, the stage analyzed problems in inventory information management described during Empathize. Problem statements guided the ideate stage and were further discussed considering urgency, influence, and capability, consisting of user, need, and insight elements.
3. Ideate: At this stage, design ideas and solutions to address identified challenges were generated.
4. Prototype: Following Ideate, ideas were transformed into prototypes—visualizations making ideas more tangible and illustrating users' problems.
5. Testing: The final stage tested whether users could effectively use the product, focusing on usability elements.

The Waterfall model, also called the sequential linear or classic life cycle, provided a sequential approach to the software development lifecycle, progressing through analysis, design, coding, testing, and maintenance. Its flow was as follows:

1. Needs Analysis: Collected user requirements and analyzed specifications needed for system development.
2. Analysis: Analyzed data obtained from observations related to existing problems to define relevant system parameters.
3. Design: Developed the system design based on completed analysis.
4. Coding: Translated the design into program code using appropriate programming languages, such as Visual Studio.NET and MySQL.
5. Testing: Conducted functional (Black-Box) testing to ensure software met design requirements.
6. Maintenance: Addressed small errors and improvements during ongoing software use.

Population referred to the entire group of interest for investigation, while the sample was a subset of that population. This study used purposive sampling, a non-probability sampling technique.

The literature review provided a critical overview of existing research relevant to the study, highlighting key findings and identifying gaps addressed by this work. It summarized major theories, methodologies, and results from previous studies, traced the evolution of the field, and showcased recent advancements and emerging trends. The review critically evaluated strengths and weaknesses in prior work, compared methodologies, and pinpointed areas where the study contributed new insights or answered unresolved questions. Depending on the article structure, the literature review was presented as a separate section or integrated into the introduction to identify the research problem.

RESULTS AND DISCUSSION

In this study, the first thing done is the observation and understand stage which enters the emphatize stage by conducting interviews in accordance with the guidelines and a list of questions that will be included in the primary data section (interview data with sources) consisting of 1 warehouse staff, and 1 Inventory Control staff, and 1 supervisor of the Inventory Control team.

Empathize Map

The results of the empathy map modeling were divided into three groups, namely warehouse staff, Inventory Control IC staff, and IC supervisor. Here is a list of interview guidelines to be used, and questions are tailored to the needs of the research according to the 4 aspects of the empathy map.

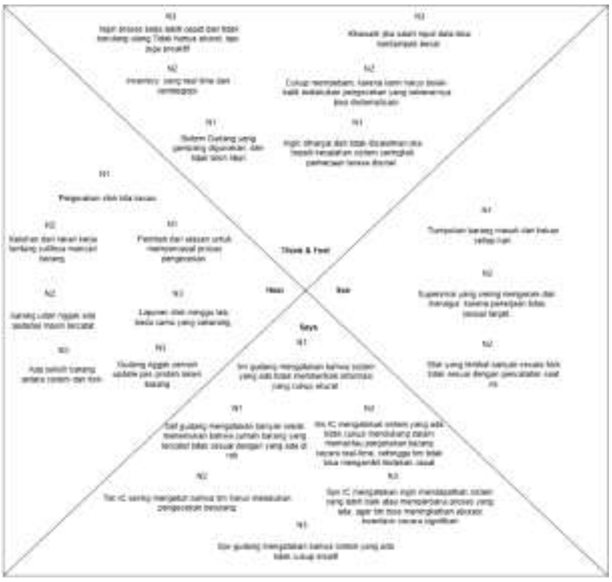

Figure 5. Empathize Map

Define

The definition of this study is to analyze problems in inventory information management that have been described at the empathize stage. Problem statements are used to facilitate the ideate stage, because the design solution is designed in accordance with the problem statement that has been made. The results of the point of view in the form of a problem statement are also discussed to discuss again related to urgency, influence, and capability consisting of three elements, namely user, need, and insight

Based on the results of interviews that have been mapped in the Empathy Map, there are three main categories of users in the inventory system, namely Warehouse Staff, IC Staff, and IC Supervisor, each of which faces different challenges in managing stock of goods.

From the perspective of their warehouse staff, they face a big challenge in accurately recording stock movements. There is often a mismatch between system data and physical conditions in the field because recording is done manually and not real-time. This makes the monitoring process slow and confusing. Therefore, warehouse staff need a system that has a fast and clear workflow and is able to record and display stock movements automatically and in real-time. This system should ideally also be equipped with a feature of the history of the movement of goods such as entry, exit, and location movement.

From the point of view of the IC Supervisor, the challenge faced is the difficulty of making decisions because the available data is often invalid, inaccurate, and not updated in real-time. Many jobs are duplicative and inefficient, which slows down the process of control and supervision. Therefore, supervisors urgently need an automated recording system that can minimize human error and is supported by devices such as barcode scanners or tablets. A web-based platform or system that is able to present accurate and quickly analyzeable data will be very helpful in the strategic decision-making process.

From the perspective of the Inventory Control (IC) Team, the main problem lies in the lack of coordination between divisions and the lack of clarity in the tracking of goods which often leads to errors. The current system is not able to reflect the reporting process and potential problems. The IC team needs a system that not only records stock, but also presents integrated information related to the history of the movement of goods and is able to monitor the difference between physical stock and system data. For this reason, validation features and approval flows between user levels are needed to ensure the accuracy of data before entering the central system.

Ideate

In the Ideate stage, the author will collect design ideas and solutions to solve the challenges that have been obtained in the previous stage. at the ideate stage, HMW will collect design ideas and solutions to solve the challenges that have been obtained in the previous stage (Fahrudin & Ilyasa, 2021).

Table 1. HMW

No	How Might We
1.	How might we avoid confusion due to the difference between excel data and the physical condition of the goods?
2.	How might we track goods so that they don't take too long so that they don't pile up in the warehouse?
3.	How might we reduce the burden caused by limited tools and infrastructure?
4.	How might we improve real-time visibility so that users can monitor the movement of goods directly?
5.	How might we minimize human error in stock data input and updates?
6.	How might we make stock reporting of goods so that there is no need to re-input?
7.	How might we meet the needs of the system so that users don't feel burdened?

After synthesizing the results of the previous stage, epathize and define, the researcher gets priority insights or problems that are focused on to subsequently become solution ideas from problems that arose previously. At this stage, the researcher involves 3 user representatives from each user to provide the desired solution ideas which are then focused on getting the best ideas

Identify Needs Analysis

In designing a website for a warehouse information system, there are 3 types of accounts that will be used, each with different access rights. The users consist of the warehouse team, inventory control team and IC supervisor.

Table 2. Needs Analysis

E-Mail	Access Rights
Warehouse staff	- Request data of goods - Edit and delete items if there are input errors - View draft items - See notifications if there are expired items so that they can be quickly handled and reported to the relevant team
IC Team	- Can view item data but can't edit - Can view the tracking history of goods - View the Expired Item Notification - Can access AI-based chatbots related to warehouse systems
Supervisor	- Have full access rights to the entire system - Can view a full list of all users, including names, emails. - Can view item data but can't edit - Can view the tracking history of goods - View the Expired Item Notification - Can access AI-based chatbots related to warehouse systems
Platform	*Web Base*
Operation System	Windows 8/10/11
Server	XAMPP
Framework	Laravel
Language	PHP
Database	MySQL
Browser	Google Chrome, Microsoft Edge, Firefox
E-Mail	Warehouse team Tim IC/ other division Supervisor

At the stage of identifying the needs of this system design, it is known that the platform used in system management is web-based, with the hope of providing ease and speed in finding information for potential users.

Design

The design stage is the process of designing a system based on the results of the needs that have been analyzed in the previous stage. Some of the designs designed are UML or Unifield Modeling Language, Database, and Wireframe or visual representation framework. This design is made to simplify the website design process and ensure that the system can run properly.

Wireframe Design

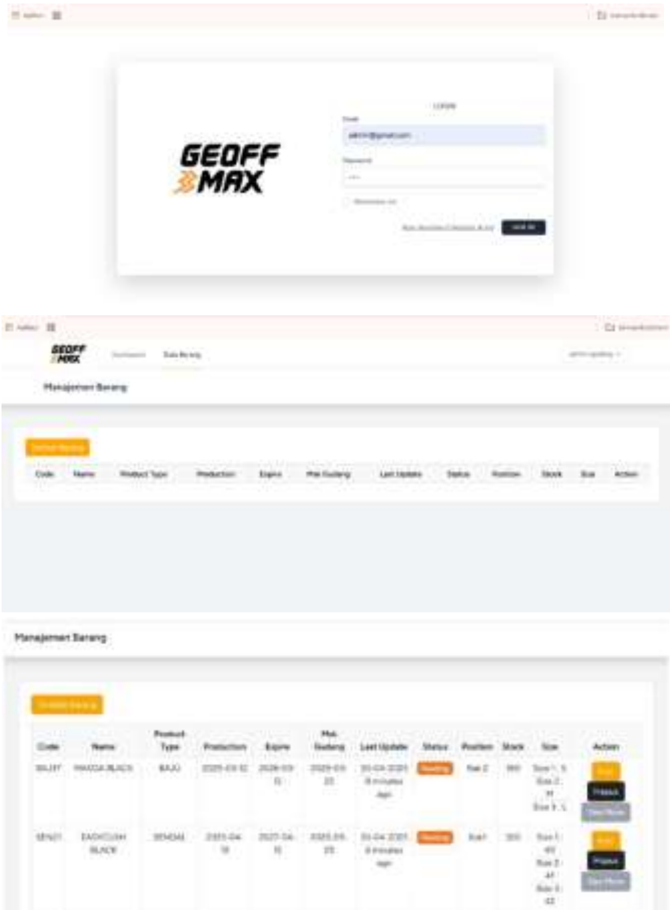

Figure 6. Wireframe Design

Testing

The web-based inventory information system was tested using the black box testing method. In its implementation, the author presented it with the owner Geoff Max Group for the web test. This test is performed on each feature with various test scenarios available. After conducting a series of testing processes using the black box testing method described in the table above for this warehouse inventory website, the results obtained were 30 scenarios out of 6 web-based warehouse inventory website features and the scenarios that were successfully tested were 28

Next is to get the percentage of success from the tests that have been carried out, the formula used is as follows:

$$\left(\frac{Total\ of\ successful\ tests}{total\ of\ tests}\right) \times 100\%$$

$$\left(\frac{28}{30}\right) \times 100\% = 93\%$$

Based on the calculation of the formula that has been carried out, the results obtained are the percentage of test success of 93% and it can be concluded that the web-based warehouse inventory system can be used and runs according to what is needed from the plan described in the previous stages.

Based on the Strategos Guide To Cycle Counting & Inventory Accuracy, IRA input record accuration (%) is used to measure the accuracy of data entered into a system or database. To calculate the accuracy of inventory, the following calculations are obtained:

$$IRA = \left(\frac{number\ of\ correct\ record}{number\ of\ record\ checked}\right) \times 100\%$$

The researcher conducted a sample by entering the number of goods recorded on the A1 Rack in the warehouse and system. The number of A1 Rack stock in the warehouse is 120 and the number of goods in the A1 Rack system is 120.

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$$IRA \left(\frac{1050}{1050}\right) \times 100\% = 100\%$$

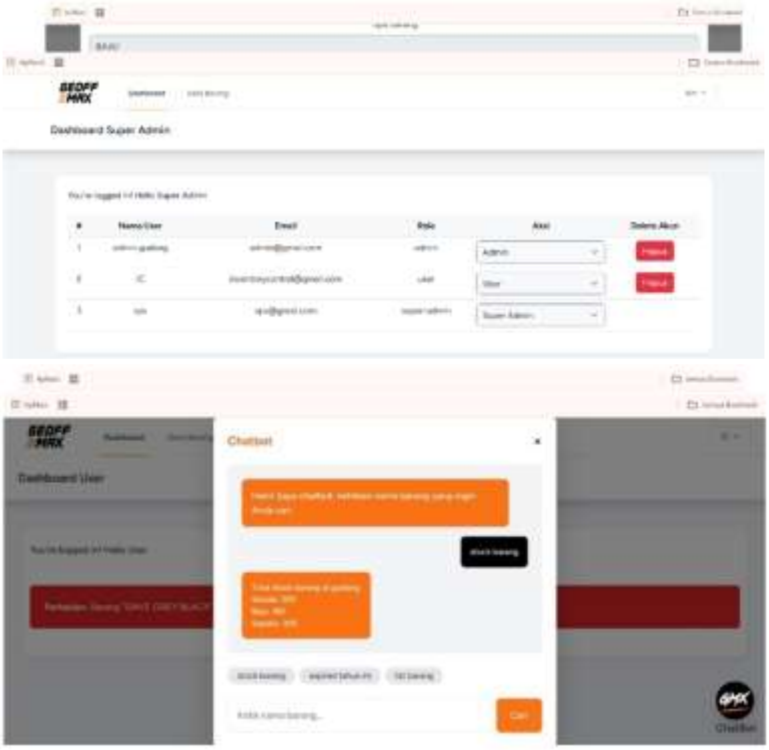

Figure 7. web-based inventory information

CONCLUSION

The study developed an AI-based inventory information system integrating Waterfall and Design Thinking methods to improve accuracy and minimize recording errors in inventory management. Designed according to real user needs identified during user-centered stages and structured development, the resulting web-based system records goods movement in real-time, reduces manual input, and features chatbots and automatic notifications. Testing showed a 93% success rate across 30 scenarios and 100% data accuracy using the IRA method, confirming the system's reliability and suitability for warehouse operations. Future research could explore the system's scalability across diverse warehouse environments and the integration of advanced AI techniques for predictive inventory optimization.

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