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STOCK MONITORING SYSTEM DESIGN AND IMPLEMENTATION USING LOAD CELL

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ABSTRAK

This study aims to investigate the possibility of implementing the load cell to automatically monitor the inventory stock level. The study involved accuracy, repeatability and linearity testing of the sensor in measuring the weight of the loaded items which then translated into the number. Results shows that the model successfully counts the dynamic stock level loaded onto the shelf and record the timestamps of stock changes during a period of time. On the aspect of weight measurement, there are slight error observed during the experiment, ranging from 1% to 7%. However, the error number is not merely enough for consideration, especially that the nature light weight of the object, that is only 5.5 grams. This study presents a new approach to test the system by presenting the accuracy, repeatability and linearity test. Besides, the system is meant to be attached on the shelf for calculating the actual inventory level, unlike the other study which use the loadcell for frontline stock measurement mechanism. Furthermore, this study successfully provides a real-time inventory system which able to record the timestamp everytime there is a change on the stock level, unlike the other study which only informs during minimum or maximum limit. With those findings, the study enrich the discussion of using this IoT system for stock monitoring.

INTRODUCTION

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Warehouse is an essential component within a supply chain in which the process of receiving, handling, and storing the goods being performed. Considering the ultimate benefits obtained from the efficient warehousing operations, such as cost reduction, inventory optimization, less operation time, and overall performance escalation, numerous studies explore various strategies, technologies, and models for suitable implementation yet improvement (Guliti et al., 2019; Odeyinka & Omoegun, 2024; Savsar et al., 2023). Order picking strategies for improving order completion times and reducing the travel distances (Liu et al., 2022; Rymarczyk et al., 2024), warehouse location strategies to provide better customer service and profitable investments (Pajić & Andrejić, 2024), product location strategies for better warehouse layout (Renaud & Ruiz, 2007; Zhou et al., 2020), are several conducted researches on warehouse strategies. While technological innovations like robotic warehousing (Koster, 2018), automated storage/ retrieval (Tamsir & Hadisantoso, 2020), augmented and virtual reality (Jumahat et al., 2022) and RFID for leveraging the overall performance and real-time visibility (Ang Lou et al., 2024) are profound in the technological-focused studies. Those are common discussions for most large- firms to have, but for the micro, small, and medium-sized enterprises (MSMEs), the topics might be difficult to approach.

MSMEs usually optimized its available resources, although it is limited, while operating the business activities. Having less financial condition, compared to the bigger firms, pushes the MSMEs to outsmart the shortcomings through several means (Kittisak, 2023). During the receiving and storing process, the MSMEs may have poor organization in form of unclear procedure. Received goods are not given detailed information such as the receiving date, lifetime, and others and then being stored without having a label. Since having limited space, the MSMEs rely on manual processes. The received stocks are manually recorded using a simple software or even books, and placed by staff to the location without recording, simply relying on their memory. For the picking process, the staff is inquired to manually check the products availability on the shelf before confirming the order. These manual processes may lead to risk of errors, lost records, and no visibility at all (Khalique et al., 2011; Mishra et al., 2015; Sapry et al., 2019).

Previous studies have presented the possibilities of MSMEs in adopting the technology for warehouse improvement. An intelligent warehousing inventory system which integrates the visual recognition technology, image processing, machine vision and the inventory module successfully elevates the accurate and real-time tracking of stocks movement by scanning the QR code on the shelves and products (Wang et al., 2023). Besides, an inventory management system with Apriori algorithm was created to efficiently manage the stocks, record the transaction, make inventory and point of sales reports, which those are being used for further analysis (Setiawan et al., 2024). Furthermore, an Internet of Things (IOT) concept was demonstrated to the inventory system which subsequently presents the positive correlation between adopting IOT and the reduced inventory costs (Maheshwari et al., 2021). Integrating RFID with ERP system also presented by (Kwon et al., 2008) to escalate the warehousing process duration as the staff are not required to manually check the materials status and agreements which subsequently decrease processing time and workload.

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MSMEs, unfortunately, also face significant challenges in adopting the technology. Lack of digital skills, awareness, and the potential benefit over the costs interfere the intention of technology installation (Akpan et al., 2022; Hendrawan et al., 2024). Furthermore, high-cost assumption to implement new technologies, including the set-up, installation, and maintenance, discourage them of transforming the initial process (Akpan et al., 2021). Also, having limited space make them think that the manual operation is more than enough, especially with the perceived high complexity of new technologies.

Considering the primary obstacles faced by MSMEs, this research aims to create a simple yet useful technology for managing the warehouse, specifically for inventory tracking and its real-time visibility. An integration of load cell and arduino uno is deployed to achieve the goals. A similar studies (Johari & Aziz, 2023) designed an IoT based inventory management system using load cell and NodeMCU to count the stock level. The difference between this paper with the previous one is that this study deploys the accuracy, repeatability, and linearity test to ensure the success of the design, while the previous study only measure the weight of each item. Furthermore, this study also deals with real-time stock calculation in which the system may report the deviation of stocks every desired duration. Another study by (Khamdi et al., 2024) also uses load cell censors as an IoT Based tool to count the number of products. However, the primary difference lies on the function of the tool. The previous paper uses the load cell to count the product's quantity placed on the circular board which then being stored to the system after defining either those are incoming or outcoming stocks. While this research uses the load cell to primarily count the stocks level on the shelf. Incoming and outcouming items will be calculated automatically. Another study by (Mansor et al., 2023) also implements the Loadcell and NodeMCU to calculate inventory levels with further notification through e-mail everytime the stocks are less than the minimum limit or more than the maximum weight. However, the study did not clearly mentioned the real-time stock calculation or deviation as this study tries to achieve. The ultimate contribution of this research are then to present the possibility of real-time inventory level monitoring using a load cell and Arduino Uno, as not clearly described by previous articles, and enrich the discussion of using this IoT system for stock monitoring in the academic field.

METHODS

The model will utilize the load cell to determine the quantity of objects stored on the shelf. Therefore, the staff does not necessarily check the stock personally in the warehouse, as the model may automatically report the level to the system. This model will lead to a better warehouse management system.

This research applies two primary hardware for model creation, including the Arduino Uno and the load cell. Arduino Uno is a popular open-source microcontroller board that, in this case, is used to read the electrical signal sent by the load cell once the product is loaded. The load cell itself is a sensor that measures weight, force, or pressure by converting these into an electrical signal. Inside the load cell, the strain gauges bonded to a metal body undergo electrical resistance changes as a force is applied. These changes will cause a voltage change which is then being transferred to the Arduino Uno for processing. Furthermore, two software programs namely Arduino IDE and Pycharm, which is connected to Google Sheet, are utilized

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in the system. The Arduino IDE is used for programming the Arduino Uno, controlling the tools to read and handle the load cell data. While, Pycharm is applied to write Python code for reading the data. By sensing and calculating the total loaded weight, which is performed by the Arduino ecosystem (Arduino Uno, Load cell, Arduino IDE), the sensor can subsequently identify the quantity of the product stored on the shelf. Furthermore, Google Sheets acts as a tool to present, visualize, or record data. All of the components are installed, as shown in Figure 1.

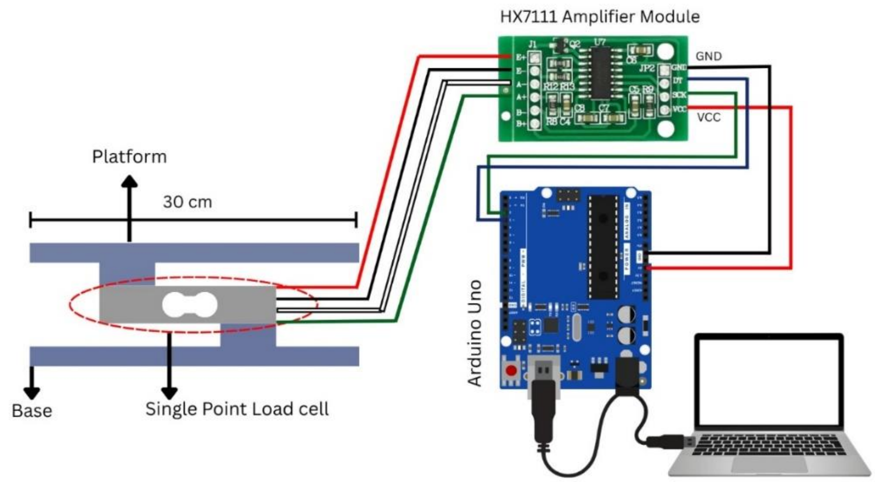

Figure 1. System Architecture (Authors' creation, 2025)

Flow of the system is depicted on Figure 2. The Inventory monitoring process starts with the designing system, presenting the system architecture and how the actual devices are interconnected. Further, installation of the mechanics and electronics devices, including the load cell on the base, the shelf on top of the loadcell, the Arduino Uno. Once properly installed, the sensor should be calibrated by locating a weight on the shelf and repeating the process several times. The results show that the load cell sensor correctly predicts the loaded weight with a variation of 0,24 grams. The calibration is performed to ensure the accuracy of the model before using it to calculate the real products. As the model is ready to use, the main program should be defined first, either the model is used for accuracy and repeatability test, linearity test, or real-time monitoring test. Once programmed for the accuracy and repeatability test, a product can be located on the shelf. The weight of it is calculated and subsequently translated into the total quantity of the product. The information is stored in the spreadsheet, including the quantity and its weight. For the linearity test, the product is located on the shelf and the model will subsequently calculate the quantity. Gradual addition of product is located on the shelf. While for the real-time test, the product is located on the shelf. Every time there is a change in the total weight on the shelf, which is translated into a corresponding quantity, the system will recognize and record it along with its timeline in the spreadsheet. The objects are also placed and removed on the platform with random quantity to assess the system accuracy while calculating the stocks number. This process is applied to provide a complete report of

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the stock level which will assist the staff in monitoring the stock movement automatically. The system uses spreadsheet since it offers convenience and simplicity for SMEs staffs to operate.

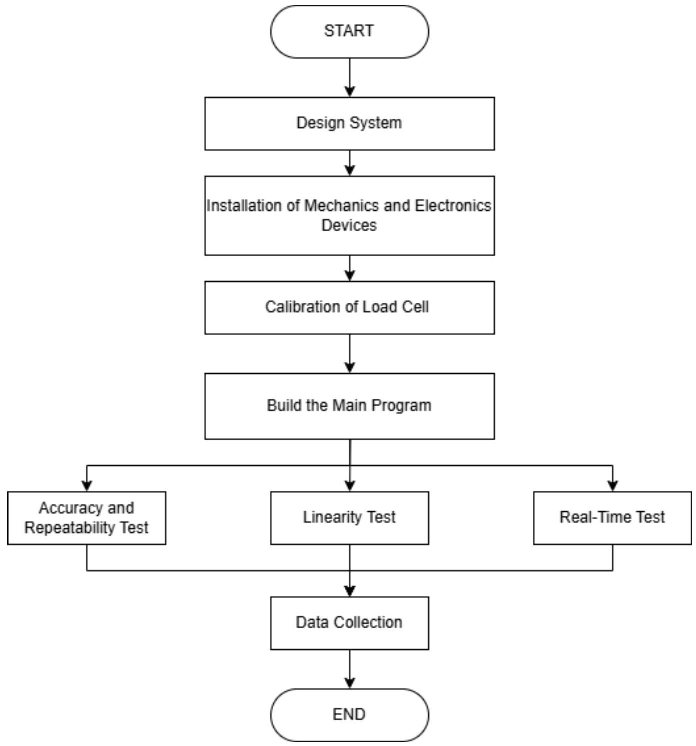

Figure 2. Flowchart of the Model

In order to test the system, an object with defined weight is applied to the inventory system. The object is placed on the shelf individually for several repetitions. The results are subsequently being analyzed to assess the effectiveness and reliability of the model. If the results are consistent, then the system performs well. The object is bolt, a commonly stored items by an MSME with a light weight, which could be more beneficial for system testing.

RESULTS AND DISCUSSION

This study uses two different objects for testing the model, namely the bolt, which has unique weight. Three testing methods are applied to assess the usage of the system, including the accuracy test, repeatability test, and the linearity test. The accuracy test assesses how close the measurement result of the system to the actual weight of the item. The test covers several steps, including the coding and material preparation. First, number of repetitions should be defined into the system to describe how many times the measurement is required to complete the assessment. Number of records describe how many records does each repetition have. In the bolt case with the real weight of 5.5 gram, the study set 10 repetitions (n) with 10 records for each repetition. The actual experiment steps are shown in Figure 3 where the bolt is loaded on the shelf and being recorded by the system. According to 100 data shown in Table 1, the model successfully measures the weight of bolt with an average deviation of 0,24 grams from the 5.5 grams actual weight, representing 4% error. In details, the minimum error is 0,04 grams while the maximum is 0,39 grams, accounted for 1% and 7% respectively. The maximum error percentage may be assumed as quite big. But, since the actual weight of the object is light, 5,5 grams only, 0,39 grams of deviation could lead to a big percentage number. Thus, considering the percentage is not merely enough.

Repeatability test is used to measure the ability of the system to provide the same output for the same input over several repetitions with same conditions. In case of this test, the model shows 5,74 grams of mean calculated weight, which means 0,24 grams heavier than the actual weight with 5,5 grams. While, the standard deviation accounts for 0,06 which then result in the coefficient of variation of 1,11%. The figure shows good precision, slightly higher than 1% which refers to excellent precision, indicating that the model has no major issue about consistency.

The diagram shown in figure 4 is the result of accuracy and repeatability test from 100 repeated measurements. According to the diagram, the value has a random yet stable fluctuation, a commonly expected condition in a load cell system, especially the actual weight is so light with 5.5 grams. Even though fluctuation happens, the variation is small and random, representing a high precision system.

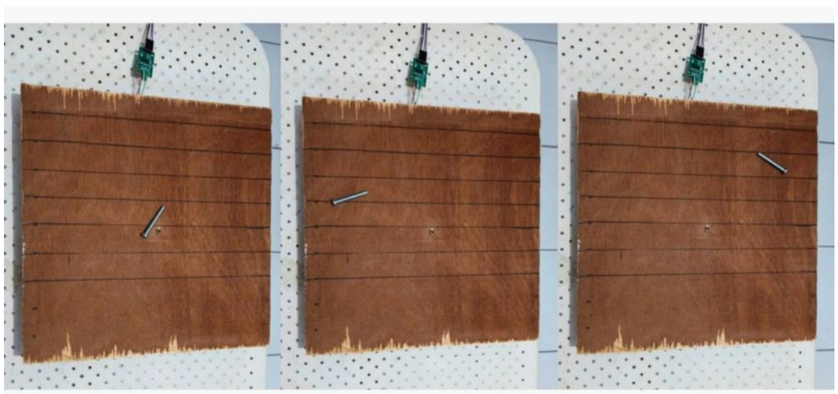

Figure 3. Real Experiment of Accuracy and Repeatability

Table 1. Accuracy and Repeatability Test for Bolt

n	Sensor Value	n	Sensor Value	n	Sensor Value	n	Sensor Value
1	5,69	3	5,68	6	5,79	8	5,68
1	5,71	3	5,73	6	5,76	8	5,84
1	5,7	3	5,71	6	5,69	8	5,78
1	5,61	3	5,68	6	5,73	8	5,72
1	5,8	3	5,77	6	5,77	8	5,76
1	5,75	4	5,68	6	5,77	9	5,85
1	5,67	4	5,72	6	5,76	9	5,75
1	5,54	4	5,68	6	5,8	9	5,82
1	5,62	4	5,74	6	5,77	9	5,74
1	5,64	4	5,75	6	5,74	9	5,78

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2	5,67	4	5,61	7	5,8	9	5,74
2	5,68	4	5,7	7	5,82	9	5,72
2	5,7	4	5,67	7	5,76	9	5,76
2	5,61	4	5,82	7	5,76	9	5,82
2	5,63	4	5,71	7	5,8	9	5,77
2	5,64	5	5,77	7	5,89	10	5,83
2	5,63	5	5,67	7	5,86	10	5,8
2	5,74	5	5,74	7	5,83	10	5,77
2	5,73	5	5,77	7	5,69	10	5,79
2	5,65	5	5,74	7	5,77	10	5,74
3	5,65	5	5,72	8	5,77	10	5,84
3	5,64	5	5,72	8	5,83	10	5,81
3	5,7	5	5,73	8	5,77	10	5,78
3	5,78	5	5,78	8	5,7	10	5,78
3	5,72	5	5,73	8	5,77	10	5,74

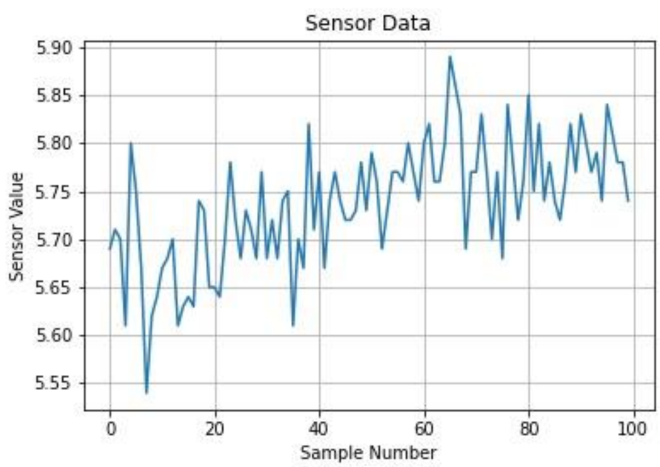

Figure 4. Diagram of Accuracy and Repeatability Test

The next assessment is the linearity test to verify that the model can read proportionally to the actual inclined measurements. First, one bolt is loaded on the shelf and being measured by the system. Once finished, another bolt is loaded and let the system calculated the total weight. The system continuously repeats the measurement, as depicted in Figure 5, until the total bolt is 10 with the results are shown in Table 2. According to table 2, the system has maximum deviation of 1,23 grams with the linearity error of 2,24% of Full-Scale Output (FSO) 55 grams. The Linearity error number is within a reasonable range of measurement. Furthermore, the scatter diagram with trendline of the bolt's linearity test is depicted in Figure 6. The diagram shows that the measurement data almost follows a perfect linear trend compared

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to the actual data. With the R^2 value of 0,99, the system almost predicts the data with high linearity accuracy.

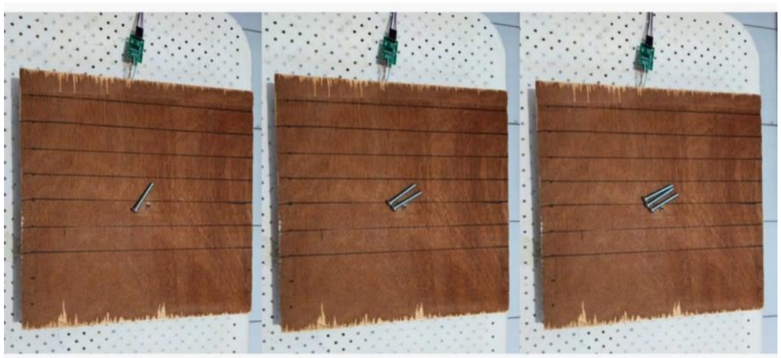

Figure 5. Real Experiment of Linearity Test

Table 2. Linearity Test of Bolt

Timestamp	Number of Item	Sensor Value (g)	Actual Weight (g)	Error
03/06/2025 07:24	1	5,55	5,5	0,05
03/06/2025 07:24	2	11,3	11	0,3
03/06/2025 07:24	3	16,85	16,5	0,35
03/06/2025 07:25	4	22,48	22	0,48
03/06/2025 07:25	5	28,15	27,5	0,65
03/06/2025 07:25	6	33,74	33	0,74
03/06/2025 07:25	7	39,41	38,5	0,91
03/06/2025 07:25	8	44,96	44	0,96
03/06/2025 07:25	9	50,68	49,5	1,18
03/06/2025 07:25	10	56,23	55	1,23
			Linearity error	0,022364

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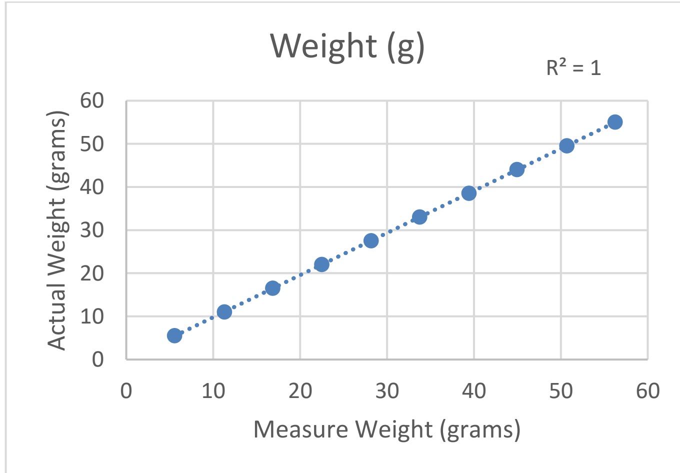

Figure 6. Linearity Diagram of Bolt

Focus of this study is also in the ability of the system to predict how many items are loaded on the shelf and its variation over a time. To assess this function, one or two items are placed and let the system measures its quantity. After a while, put more items on the shelf and let the system, again, calculate the quantity. This process is repeated until the eleven changes are captured. To be more detailed, the model continuously counted the stock level, and it would change the stock information after 5 times reading results. These 5 times reading were chosen to prohibit the system from reading a false signal as perhaps there are noise or instability of the platform. The model may decline the number to increase the real-time aspect, but it would lead to higher data storage, which is quite unnecessary. The experiment also allows to decrease the quantity level on the shelf, not necessarily increase it, as shown in Figure 7. Table 3 shows in detail the result of the system's ability testing conducted over two-minute period. For each row, measured and actual quantities, along with the respected weights were recorded. In term of the quantity, there are no differences between the measured and the actual one across the entire data. However, there are slight variation discovered between actual weight and measured weight, ranging from 0,17 grams with 0 item to 1,95 grams with 15 items on the shelf. Overall, the data suggests that the system is reliable to quantify the loaded item's number.

Figure 7. Real Experiment of Real Time Inventory Checking

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Table 3. Real Time Stock Calculation

Timestamp	Measured qty (item)	Measured weight (g)	Actual Qty (item)	Actual Weight (g)	Qty Error (item)	Weight error (g)
02/06/2025 21:11	2	11,41	2	11	0	0,41
02/06/2025 21:11	6	33,76	6	33	0	0,76
02/06/2025 21:11	2	11,3	2	11	0	0,3
02/06/2025 21:11	9	50,7	9	49,5	0	1,2
02/06/2025 21:12	2	11,23	2	11	0	0,23
02/06/2025 21:12	0	0,17	0	0	0	0,17
02/06/2025 21:12	4	22,57	4	22	0	0,57
02/06/2025 21:12	15	84,45	15	82,5	0	1,95
02/06/2025 21:12	11	61,93	11	60,5	0	1,43
02/06/2025 21:13	6	33,86	6	33	0	0,86
02/06/2025 21:13	10	56,25	10	55	0	1,25

According to the accuracy, repeatability and linearity test during the experiment, the model successfully predicts the stock level with relatively slight errors. These findings strengthen the possibility of load cell usage to be installed as a support for IoT based inventory monitoring system, as previously studied by (Johari & Aziz, 2023; Khamdi et al., 2024; Mansor et al., 2023). Although the experiment have been conducted several times, this research delivers a new approach to test the system by presenting the accuracy, repeatability and linearity test, as shown in Table 1 and 2, Figure 3 and 5. Besides, the system is meant to be attached on the shelf for calculating the actual inventory level, unlike the other study which use the loadcell for frontline stock measurement mechanism. Furthermore, this research successfully provides a real-time inventory system which able to record the timestamp everytime there is a change on the stock level, unlike the other study which only informs during minimum or maximum limit. This information is beneficial to inhibit errors and detect anomalies quicker which leading to better visibility and security.

CONCLUSION

The results of this study illustrate the ability of load cell to correctly predict the quantity of the loaded item on the shelf through weight measurement. Although there are variations on the accuracy and repeatability test of weight measurement, the deviations are not that significant, especially considering the nature weight of the item, only 5,5 grams, which then easily makes the differences elevate the error percentage. Additionally, the primary finding of this research, a dynamic and random quantity calculation test was conducted to assess the ability of the sensor to correctly calculate the stocks level. The system successfully quantifies the dynamic item number changes and recorded the deviation timeline without any miscalculation number between the measured item and the actual item, which this function was not covered in detail by previous studies. To conclude, the load cell system provides an alternative way to automatically control the inventory level using the weight censor which can lead to a better visibility and warehouse management system.

For future research, this model can be escalated by using a more rigid platform to have higher accuracy with considerably less deviations. Furthermore, the model can be improved to

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address unfamiliar objects placed on the shelf and inform the user for this phenomenon, using a more user-friendly interface. An integration with frontline system is a promising study as the actual warehouse system usually set the incoming or outcoming products there, not in the actual shelf. This integration will lead to a better product security and minimize human error.

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