Jurnal Kejuruteraan 36(4) 2024: 1585–1598
https://doi.org/10.17576/jkukm-2024-36(4)-24

Development of IoT Kaizen System for Smart Lean Raw Material Inventory Management: A case study at an SME factory in Malaysia

Mohd Hazri Mohd Rusli[a,b*], Mohamad Khairi Hassan[a,c], Suzilawati Muhamud-Kayat[a] & Elvianney Michael[d]

[a]*School of Mechanical Engineering,*

[b]*Smart Manufacturing Research Institute (SMRI),*

College of Engineering, Universiti Teknologi MARA (UiTM), Shah Alam Selangor Malaysia

[c]*Sugihara Grand Industries Sdn Bhd, Malaysia*

[d]*Dayang Enterprise Sdn. Bhd, Malaysia*

[*]*Corresponding author: hazrirusli@uitm.edu.my*

Received 28 December 2023, Received in revised form 9 May 2024
Accepted 9 June 2024, Available online 30 July 2024

ABSTRACT

Effective Raw Material Inventory Management is crucial for overall company performance, demanding significant improvements. In the current technologically advanced landscape, the imperative adoption of the Internet of Things (IoT) is crucial for propelling inventory management forward and amplifying the visibility of raw materials. This case study is dedicated to developing an IoT Kaizen System, meticulously aligned with the Smart Lean Factory Inventory Control Framework, tailored to enhance Raw Material Inventory Management within an SME factory in Seremban, Negeri Sembilan. With a focal point on Loft Layer materials, the study encompasses Raw Material Ordering, Receiving, and Charging Out Log operations. Leveraging web-based tools such as Google Sheets, AppSheet, and Looker Studio, the system adeptly digitizes manual processes, tracking real-time data and integrating data visualization tools for informed decision-making. Implemented within a genuine industrial context, the project is intricately tailored to meet the unique preferences and requirements of the company, ensuring a customized solution that aligns with industry standards and reflects specific operational nuances. The resulting digital system introduces a structured, simplified, and efficient approach to Raw Material Inventory Management, injecting enhanced operational control and adaptability into the company's workflow. Through the system implementation, warehouse space was reduced by 15%, order processing was done fully digitally that achieve zero case of ordering error and achieved zero case of material stock out. This system can adjust to what's needed in modern manufacturing. It proves that using innovation and technology can make a business better by making things run more smoothly and helping with decision-making.

Keywords: Order processing system; Mobile Apps; Google Sheet; Google Appsheet; Looker Studio; Operational Dashboard; IoT warehouse.

INTRODUCTION

Small and medium-sized enterprises (SMEs) are considered the backbone of the Malaysian economy. According to data released by the Department of Statistics Malaysia (2021) for the year 2020, Small and Medium Enterprises (SMEs) played a substantial role in the country's economic landscape. Contributing 38.2% to the Gross Domestic Product

(GDP) that equivalent to RM 512.8 billion, SMEs has emerged as pivotal contributors. Among these, the manufacturing sector held the position of the fourth largest contributor, trailing behind the agriculture sector (54.0%), construction (48.7%), and services (41.0%) (Statista, 2023).

Effective inventory management practices enable organizations to identify the optimal quantity and timing for ordering stocks. Inventory encompasses components, finished goods, and raw materials utilized in manufacturing or sold. It is regarded as an asset by organizations, with accounting personnel utilizing stock level data for financial reporting purposes (Jenkins 2020). Effective control of inventory will result of increased customer satisfaction, that will return profitability to the organization (Singh et al. 2023). A computerized warehousing system provides advantages such as decreased labor and enhanced efficiency in contrast to manual systems. This not only saves time and energy but also mitigates the likelihood of human errors (Tan & Sidhu 2022).

An Enterprise Resource Planning (ERP) system is a commercial software designed to integrate an organization's operations, encompassing the management of resources such as personnel, machinery, materials, methods, finances, and operations through a unified information-processing system. This integration boosts efficiency, ensures data accuracy, and improves decision-making across different departments (Qureshi 2022). The domain of warehouse operations and management has developed into a specialized subfield within the realm of smart warehousing technology. Three prominent technologies driving this transformation are Radio-Frequency Identification (RFID), Internet of Things (IoT), and Warehouse Management Systems (WMS) (Van Geest et al. 2021). This technology has the potential to accelerate transaction recording and minimize errors, offering advantages to companies handling extensive inventory (Amanda Istiqomah et al. 2020).

Smart technologies, as Chung (2021) describes, are items with advanced features such as data analysis and artificial intelligence. They can understand their environment and make decisions without constant human input. This is achieved through technologies like the Internet of Things and blockchain, allowing objects to act smartly based on their awareness. Cloud-based technology is employed by cloud inventory management systems to store and oversee inventory data, granting enterprises remote accessibility to their inventory information from any location with internet connectivity. Businesses with multiple locations or those necessitating quick access to inventory data are poised to gain the most from this system (Bose et al. 2022).

Smart Warehousing refers to warehouses equipped with automated material handling and Artificial Intelligence (AI), as seen in various studies. The aim is to shorten customer service time, make better use of assets and labor, and improve warehouse efficiency overall. This is done by promoting smooth information sharing among warehouse staff and equipment, and encouraging communication between different warehouses (Min 2023). Smart warehouses provide many benefits, like instant access to information, more automation, better flexibility for operations, automatic decision-making, ability to adjust to changing needs, and less downtime thanks to smart sensors. However, there are drawbacks, such as higher building costs at the start, a long transition period, and needing strong support from top management (Van Geest et al. 2021). A digital solution, like a Warehouse Management System (WMS), will clearly affect warehouse operations by enhancing their effectiveness (Suleiman and Santosh, 2022). Using a smartphone to monitor a business operation allows users to receive real-time results, which can then be used as input for taking action (Widianto et al. 2022).

A case study was conducted at SGSB, an SME warehouse factory located in Seremban, Negeri Sembilan. The daily warehouse operations at SGSB still rely on manual processes, where the ordering, receiving, and distribution of Loft Layer materials are carried out manually. Stock counting is done manually, and based on minimum levels, orders are issued to suppliers. However, there is no proper tracking of the ordering process. Manual recording of receiving records is often not up to date, and the distribution of materials to production is also manually recorded and not updated in real-time. This lack of real-time updates results in inventory stock levels being unknown and leads to inaccuracies in ordering quantities. To prevent stock shortages, high buffer stock is considered, leading to excessive warehouse space consumption. The main objective of this study is to establish an IoT Kaizen System for inventory management that help SGSB manage their material Loft Layer. With the system implementation, SGSB aimed to have a warehouse space reduction, achieve zero case of ordering error and no material stock out to production. This study was initiated to explore web-based software available in the market that can be integrated as a set of system for managing inventory.

METHODOLOGY

Web-based software from Google were explored to integrated as a complete system for Cost-Effective IoT system. Google Sheets used as system database where build-in functions were utilized for making data readily to be used for the system. Google Sheets, a cloud-based platform, provides more than what Microsoft Excel offers, with various additional advantages. Its online document sharing capabilities enable users to collaborate simultaneously on the same document across multiple devices, encouraging real-time collaborative interactions. One notable feature is the built-in autosave function, ensuring work safety by continuously saving progress, dependent on an active internet connection (Simon 2023). This not only prevents data loss but also facilitates continuous updates to databases, improving overall workflow efficiency. Furthermore, Google Sheets is compatible with various integrations, enabling users to seamlessly connect and interact with other tools. Additionally, it is a cost-free part of the Google Workspace suite, making it a budget-friendly choice for businesses. Altogether, these features make Google Sheets a versatile and widely accessible tool, empowering users for effective data management and encouraging collaborative teamwork (Money 2023).

Mobile application is developed using Google AppSheet, which is a no-code development tool that allows users to create application software and mobile apps without coding. It operates on a computer and can be accessed directly from the AppSheet website, eliminating the need for downloading or installation. This empowers users to create mobile apps on devices such as smartphones, tablets, and web interfaces. Users can seamlessly design mobile and web applications by utilizing data sources like Google Drive, DropBox, Office 365, and various cloud-based spreadsheet and database platforms (AppSheet 2023). Several study was found success establish a mobile application that applied at hospital, education and health monitoring (Wijesekara et al. 2020), (M Fariz et al. 2020) and (Jayawardene et al. 2021).

Data visualization is created using Looker Studio that allow user interaction with the data. Looker Studio, is a free tool for making dashboards that look good, can be customized, and work well on different devices. It's a Business Intelligence (BI) tool that turns raw data into useful information for businesses. By showing data visually, Looker Studio collects measurements and signs that help companies make decisions and plans, reducing the chances of taking big risks to reach their goals (Casarotto, 2021). Previous studies have shown successful utilization of Looker Studio as a tool to develop an interactive dashboard for operations in various industrial fields such as in sales analysis (Allaymoun et al.2022), education (Hayati et al. 2021) and production operation (Thongbunchum et al. 2022).

The development of the IoT Kaizen System utilizing the five-layer IoT architecture model by Affia and Aamer, (2021) as shown in Table 1. A mobile application serves as a tool for capturing inventory transactions, sending the data via the mobile network to a middleware layer, which is connected to a database. Business Intelligence tools in the application layer retrieve this data to visualize information. The results generated by the system are then integrated back into the organization's software applications for system management.

TABLE 1. The Five-layer IoT Architecture

Stage	Layer	Application
System Management	Business Layer	Software used in the company
Smart Application	Application Layer	Business Intelligence (BI)
Process Information	Middleware Layer	Database (Google Sheet)
Data Transmission	Network Layer	Internet (Wi-Fi)
Data Gathering	Perception Layer	Mobile Application (AppSheet)

Sumber: Affia & Aamer (2021)

The five-layer architecture model (Affia & Aamer 2021) is use as a basic of system structure establishment at SGSB. Google Sheets serves as the system database, storing all operational data in the Google Cloud. AppSheet is employed to create a mobile application for capturing transaction data for incoming and outgoing raw materials in the warehouse inventory, transmitting this input to the database. Data visualization is accomplished using Looker Studio, which creates interactive dashboards that enable users to access and interact with the operational data. Figure 1 shows the IoT kaizen system structure design for SGSB raw material warehouse.

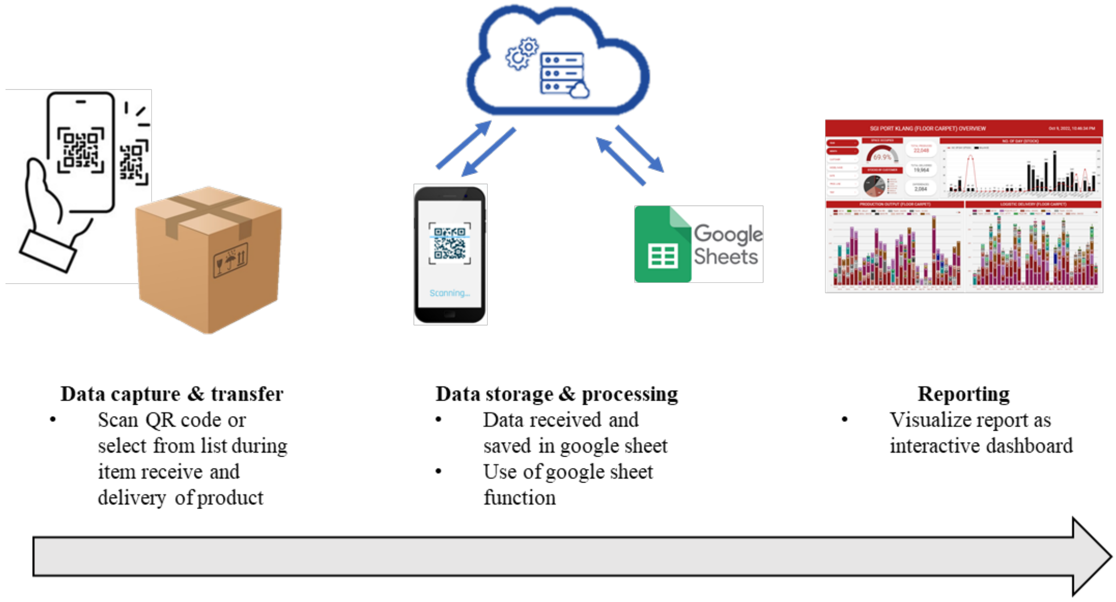

FIGURE 1. IoT kaizen system design raw material store SGSB

The development of the IoT Kaizen system, as depicted in Figure 1, involves three phases. Phase 1 centers on creating the database, which is then utilized for developing a mobile application in Phase 2. Finally, in the third phase of the system, a dashboard visualization is created. Figure 2 illustrates the flow of development for the IoT Kaizen system according to the phase.

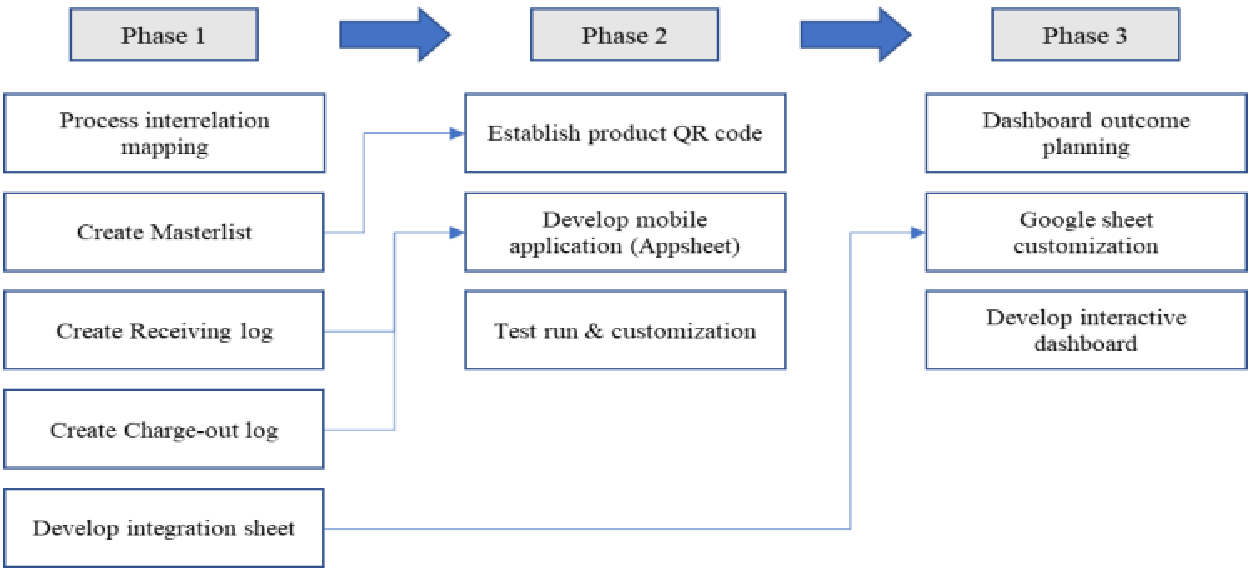

FIGURE 2. IoT kaizen system development flow

PHASE 1: ESTABLISHING DATABASE PLATFORM

The database systems platforms are established using Google Sheets, utilizing its built-in functions to their maximum capacity. This phase is essential in constructing the system's structure and starts with an overview of the process to identify interconnected processes and re-map them. By setting up the Google Sheet format, it transforms into a functional database for operating the system. This initial phase, called Phase 1, comprises five steps, outlined as follows:

Step 1: Mapping of interrelation process.
Step 2: Identify items and create a Master list.
Step 3: Create a Receiving log.
Step 4: Create a Charge-out log.
Step 5: Create an Integration sheet.

Since web-based software is used, user setting information and studies for the interface can be easily obtained on the Internet.

PHASE 2: DEVELOPING MOBILE APPLICATION

The first five steps of Phase 1 establish the foundation for this system, enabling the recording of incoming and outgoing inventory data and providing real-time updates to the inventory balance with each transaction. However, making the entire database accessible in Google Sheets for transaction input is impractical across different Operating Systems. To address this challenge, a mobile application user interface platform was developed using Google AppSheet, with the aim of achieving the following enhancements:

1. Easy entry of data by user.
2. Protect main data in Google Sheets.
3. Fast access without the need to have a fixed station.
4. Avoid delays in updates.

In the initial stage of phase 2, QR codes were generated for each item handled within the warehouse operation. These QR codes serve the purpose of facilitating scanning from the mobile application, eliminating the need to manually enter transaction details for each item. This measure is implemented to prevent incorrect item inputs into the system. Subsequently, a mobile application was developed, following eight steps outlined in Table 2.

TABLE 2. The Step of Mobile Application Development Using Google AppSheet

Step	Application
Step 1	Preparing data tables in Google Sheets
Step 2	Getting Google AppSheet to the computer
Step 3	Connecting data from Google Sheets to Google AppSheet
Step 4	Customizing the Google AppSheet to create mobile apps
Step 5	Test tun input Google AppSheet to Google Sheets table
Step 6	Download and setup Google AppSheet on mobile device
Step 7	Review and edit for customization
Step 8	Sharing the app with another user

Referring to Table 2, the initial step utilized the database created in phase 1. This was followed by the second step, which involved logging into AppSheet on the computer. After connecting the data in Google Sheets with AppSheet, customization of the mobile interface commenced to fulfill step 4. A test run for the application was conducted in Step 5 to ensure that it met the users' needs. Once the application passed the test run, it could be set up on mobile devices, followed by a review to determine the need for any further customization. Finally, the application was shared among the users for implementation.

PHASE 3: VISUALIZE OPERATION INFORMATION USING BI TOOLS

Data visualization transforms extensive data into graphs and charts, aiding in the swift identification of patterns and insights (Thongbunchum et al. 2022). It enhances comprehension by graphically representing data, making it easier for decision-making (Cheng 2023). This process improves agility, reveals data relationships, and expedites trend and outlier identification. Case studies, like one in a healthcare product company, show benefits such as faster reporting, accurate information access, and improved operational efficiency (Nair 2018). The final stage of developing this system involves creating a visualization of the data collected through the mobile application in Phase 2 and stored on Google Sheets developed in Phase 1. This will be achieved by developing a dashboard to display the operational data, which users can interact with using Business Intelligence (BI) tools. Google Data Studio will be utilized for developing the dashboard as follows:

Step 1: Determining parameters to visualize.
Users shall determine what parameters require to be visualized for operational control.
Step 2: Data customization in Google Sheets.
Some customizations may be required to produce outcome results as input for Google Data Sheets visualization.
Step 3: Develop visualization. Customized-ready data in Google Sheets shall be linked with Google Data Studio.

RESULTS AND DISCUSSION

DATABASE ESTABLISHMENT OF LOFT LAYER ITEMS

The loft layer material's master list, receiving log, charge-out log, and integrated sheet were established by utilizing Google Sheet function. Figure 3 shows on the Master List database interface for loft layer materials within PSB warehouse operation. contains essential information, such as supplier details, item name and number, packaging standard, material specifications, color code, item image, and QR code. Any updates or additions to specifications are made in the Master list and subsequently reflected in the Google Sheets linkage file.

ELVIANNEY MICHAEL - GOOGLE SHEET

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	NO.	SUPPLIER	ITEM NAME	ITEM NUMBER	CUSTOMER	ITEM	CAR MODEL	LENGTH (mm)	WIDTH (mm)	THICKNESS (mm)	WEIGHT (kg)	DENSITY (g/M2)
3	1	KAWAFUJI	LOFT LAYER 3M0A	PCF-LOF-3M4A-AA013-A	HONDA	CARPET ASSY FLOOR	HRV	2450	1600	20	3.52	900
4	2	KAWAFUJI	LOFT LAYER 3M0A	PCF-LOF-3M4A-AA013-A	HONDA	CARPET ASSY FLOOR	HRV	2450	1600	20	3.52	900
5	3	KAWAFUJI	LOFT LAYER T20A	PFC-LOF-T20A-AA013-A	HONDA	CARPET ASSY FLOOR	CIVIC	2000	1600	30	3.84	1200
10	8	KAWAFUJI	LOFT LAYER T00A 4D	PCF-LOF-T00A-AA010-A	HONDA	CARPET ASSY FLOOR	CITY	2140	1500	20	2.89	900
16	14	KAWAFUJI	LOFT LAYER T00A 4D	PCF-LOF-T00A-AA010-A	HONDA	CARPET ASSY FLOOR	CITY	2140	1500	20	2.89	900
22	20	KAWAFUJI	LOFT LAYER T00A 5D	PCF-LOF-T00A-AA012-A	HONDA	CARPET ASSY FLOOR	CITY HATCHBACK	2550	1550	20	3.56	900
24	22	KAWAFUJI	LOFT LAYER T00A 5D	PCF-LOF-T00A-AA012-A	HONDA	CARPET ASSY FLOOR	CITY HATCHBACK	2550	1550	20	3.56	900
31	29	KAWAFUJI	LOFT LAYER D88N	PFC-LOF-D88N-AC003-E	PERODUA	CARPET, STEP SIDE, RH	AXIA/BEZZA	2000	1510	15	1.36	450
32	30	KAWAFUJI	LOFT LAYER D88N	PFC-LOF-D88N-AC003-E	PERODUA	CARPET ASSY FLOOR	AXIA/BEZZA	2000	1510	15	1.36	450
33	31	KAWAFUJI	LOFT LAYER D88N	PFC-LOF-D88N-AC003-E	PERODUA	CARPET ASSY FLOOR	AXIA	2000	1510	15	1.36	450
34	32	KAWAFUJI	LOFT LAYER D88N	PFC-LOF-D88N-AC003-E	PERODUA	CARPET ASSY FLOOR	BEZZA	2000	1510	15	1.36	450
35	33	KAWAFUJI	LOFT LAYER D55L	PFC-LOF-D55L-AC011-A	PERODUA	CARPET ASSY FLOOR	ATIVA	2000	1600	22	2.56	800
36	34	-	-	-	PERODUA	BOARD ASSY DECK	ATIVA	-	-	-	-	-
37	35	KAWAFUJI	LOFT LAYER T5SE	PFC-LOF-2WF-AA004-C	NO DATA	NO DATA	NO DATA	2350	1530	18	3.23	900
38	36	KAWAFUJI	LOFT LAYER T7AW	PFC-LOF-AY17-AA005-B	NO DATA	NO DATA	NO DATA	2515	1550	18	3.12	800
39	37	HIROTAKO	LOFT LAYER TEAW	PFC-LOF-TEAZ-AC007-B	NO DATA	NO DATA	NO DATA	1950	1600	15	2.88	900
40	38	HIROTAKO	LOFT LAYER T9AX	PFC-LOF-2CT-AC002-B	NO DATA	NO DATA	NO DATA	2140	1490	18	1.36	900

FIGURE 3. Master list for loft layer material

The ordering and receiving log were established to gather details regarding Loft Layer material ordering and actual reception. This log contains information such as the item name, supplier, ordering date and time, quantity, and the product parameter for the item such as length, width, thickness, weight and density. Figure 4 displays the ordering and receiving logs.

NO	SYSTEM	ITEM NAME	SUPPLIER	STATUS ORDER	MONTH	ORDER/REVISE DATE	TIME ORDERED	PLAN DATE ARRIVE	QUANTITY ORDER (PCS)	ARRIVE STATUS	ARRIVED DATE	ARRIVED TIME	ACTUAL QUANTITY ARRIVED
413	ORDERING	D88N	KAWAFUJI	ORDER	Jul	14/07/23	15:07	15/7/23	700	ARRIVED	15/7/23	14:12:00	700
414	ORDERING	D74A	KAWAFUJI	ORDER	Jul	14/07/23	14:23	17/7/23	480	ARRIVED	17/7/23	14:24:00	480
415	ORDERING	T00A 4D	KAWAFUJI	ORDER	Jul	14/07/23	14:26	17/7/23	470	ARRIVED	17/7/23	14:27:00	470
416	ORDERING	D88N	KAWAFUJI	ORDER	Jul	14/07/23	14:27	17/7/23	700	ARRIVED	17/7/23	16:14:00	700
417	ORDERING	D74A	KAWAFUJI	ORDER	Jul	17/07/23	16:20	18/7/23	480	ARRIVED	18/7/23	12:18:00	480
418	ORDERING	D55L	KAWAFUJI	ORDER	Jul	17/07/23	16:26	18/7/23	470	ARRIVED	18/7/23	12:12:00	470
419	ORDERING	D88N	KAWAFUJI	ORDER	Jul	17/07/23	16:27	18/7/23	700	ARRIVED	18/7/23	13:54:00	700
420	ORDERING	D74A	KAWAFUJI	ORDER	Jul	19/07/23	12:08	20/7/23	480	ARRIVED	20/7/23	11:40:00	480
421	ORDERING	D88N	KAWAFUJI	ORDER	Jul	19/07/23	14:40	20/7/23	700	ARRIVED	20/7/23	14:40:00	700
422	ORDERING	T00A 4D	KAWAFUJI	ORDER	Jul	20/07/23	14:53	21/7/23	470	ARRIVED	21/7/23	14:42:00	470
423	ORDERING	D88N	KAWAFUJI	ORDER	Jul	20/07/23	14:55	22/7/23	700	ARRIVED	22/7/23	14:44:00	700
424	ORDERING	T20A	KAWAFUJI	ORDER	Jul	20/07/23	15:10	24/7/23	300	ARRIVED	24/7/23	14:45:00	300
425	ORDERING	D74A	KAWAFUJI	ORDER	Jul	21/07/23	14:45	24/7/23	480	ARRIVED	24/7/23	14:46:00	480
426	ORDERING	D55L	KAWAFUJI	ORDER	Jul	21/07/23	14:47	24/7/23	470	ARRIVED	24/7/23	14:48:00	470
427	ORDERING	D88N	KAWAFUJI	ORDER	Jul	21/07/23	14:49	25/7/23	700	ARRIVED	25/7/23	14:50:00	700
428	ORDERING	D74A	KAWAFUJI	ORDER	Jul	21/07/23	14:50	25/7/23	480	ARRIVED	25/7/23	14:51:00	480
429	ORDERING	3M0A	KAWAFUJI	ORDER	Jul	21/07/23	14:51	26/7/23	350	ARRIVED	26/7/23	14:52:00	350
430	ORDERING	D55L	KAWAFUJI	ORDER	Jul	21/07/23	15:28	26/7/23	470	ARRIVED	26/7/23	15:28:00	470
431	ORDERING	T20A	KAWAFUJI	ORDER	Jul	24/07/23	14:02	27/7/23	300	ARRIVED	27/7/23	14:02:00	300
432	ORDERING	D74A	KAWAFUJI	ORDER	Jul	24/07/23	14:12	27/7/23	480	ARRIVED	27/7/23	14:12:00	480
433	ORDERING	3M0A	KAWAFUJI	ORDER	Jul	24/07/23	14:14	28/7/23	350	ARRIVED	28/7/23	11:59:00	350
434	ORDERING	D88N	KAWAFUJI	ORDER	Jul	24/07/23	14:17	28/7/23	700	ARRIVED	28/7/23	11:59:00	700

FIGURE 4. Ordering and receiving log

A database was developed to manage loft layer receipts, integrating with the ordering process. When materials need to be ordered, the ordering information is updated to include item details, quantity, and delivery estimates. Upon receiving the item, its status is promptly changed to "received," and additional receiving details such as the date and actual quantity are updated accordingly.

To record the quantity of loft layer materials transferred to production, a charge-out log was created. This log captures transaction details such as the date and time, item name, quantity, production shift, and the person authorizing the release. Figure 5 displays the charge-out log in Google Sheet format.

TO PRODUCTION

NO	MONTH	DATE	TIME	ITEM NAME	QTY	DESCRIPTION (OUT)	SHIFT	PIC
1	Sep	1/9/22	9:02	T00A 4D	300.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. ZUL
2	Sep	2/9/22	9:03	T00A 4D	33.00	TO PRODUCTION	SHIFT D	MR. MUQRI , MR. SAIMON
3	Sep	2/9/22	9:03	D88N	510.00	TO PRODUCTION	SHIFT C	MR. NABIL , MR. ZUL
4	Sep	3/9/22	9:06	D55L	390.00	TO PRODUCTION	SHIFT D	MR. MUQRI
5	Sep	3/9/22	9:08	D88N	120.00	TO PRODUCTION	SHIFT D	MR. MUQRI
6	Sep	3/9/22	9:08	D88N	510.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL , MR. ZUL
7	Sep	3/9/22	9:09	D88N	90.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL , MR. ZUL
8	Sep	4/9/22	10:59	TLAX	120.00	TO PRODUCTION	SHIFT C	MR. DARUS
9	Sep	4/9/22	10:52	T20A	150.00	TO PRODUCTION	SHIFT C	MR. DARUS
10	Sep	4/9/22	9:15	T00A 5D	120.00	TO PRODUCTION	SHIFT D	MR. MUQRI
11	Sep	4/9/22	9:16	T20A	60.00	TO PRODUCTION	SHIFT D	MR. MUQRI
12	Sep	5/9/22	8:44	T00A 4D	180.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL , MR. ZUL
13	Sep	5/9/22	8:46	3M0A	60.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL , MR. ZUL
14	Sep	5/9/22	8:47	TLAX	150.00	TO PRODUCTION	SHIFT D	MR. MUQRI
15	Sep	6/9/22	15:24	T00A 4D	3.00	TO PRODUCTION	SHIFT D	MR. SAFWAN
16	Sep	6/9/22	9:02	D88N	300.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL
17	Sep	6/9/22	9:07	D88N	450.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL
18	Sep	6/9/22	10:55	D88N	300.00	TO PRODUCTION	SHIFT D	MR. MUQRI , MR. SAFWAN
19	Sep	7/9/22	15:08	D88N	280.00	TO PRODUCTION	SHIFT D	MR. MUQRI , MR. SAIMON
20	Sep	7/9/22	18:31	T00A 5D	135.00	TO PRODUCTION	SHIFT D	MR. SAFWAN , MR. SAIMON
21	Sep	7/9/22	20:22	T00A 5D	210.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL , MR. ZUL
22	Sep	7/9/22	20:24	D55L	60.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL , MR. ZUL
23	Sep	7/9/22	20:24	T00A 5D	3.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL , MR. ZUL
25	Sep	8/9/22	17:58	D55L	231.00	TO PRODUCTION	SHIFT D	MR. SAFWAN , MR. SAIMON
26	Sep	8/9/22	18:01	TLAX	150.00	TO PRODUCTION	SHIFT D	/IR. MUQRI , MR. SAFWAN , MR. SAIMON
28	Sep	8/9/22	20:29	D88N	540.00	TO PRODUCTION	SHIFT C	MR. DARUS , MR. NABIL , MR. ZUL

FIGURE 5. Charge-out log for recording inventory out from warehouse

Subsequently, the transactions for loft layer charging in and charging out to production are consolidated into an integrated sheet. This integrated sheet utilizes several Google Sheet functions such as “importrange”, “sum”, “sumif”, “vlooked up”, “filter” and others mathematical equation that generating the inventory balance. Figures 6 illustrate the integrated sheet, that retrieved data of receiving and charge-out to generate balance inventory figure.

STOCK STATUS (LOFT LAYER)

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A	B	C	D	E	F	G
https://dc	MASTERLIST					
https://dc	STOCK IN					
https://dc	STOCK OUT					
			27/06/23			CURRENT
			ADJUSTED			SYSTEM
NO	ITEM NAME	ITEM NUMBER	OPENING STOCK (PCS)	SUM TOTAL IN	SUM TOTAL OUT	BALANCE (PCS)
1	3M0A	PCF-LOF-3M4A-AA013-A	690	16454	11,507	5,637
2	T20A	PFC-LOF-T20A-AA013-A	358	6510	4,332	2,536
3	T00A 4D	PCF-LOF-T00A-AA010-A	432	19860	14,482	5,810
4	T00A 5D	PCF-LOF-T00A-AA012-A	313	11670	7,610	4,373
5	D88N	PFC-LOF-D88N-AC003-E	819	94183	70,726	24,276
6	D55L	PFC-LOF-D55L-AC011-A	494	26833	18,871	8,456
7	T5SE	PFC-LOF-2WF-AA004-C	50	0	0	50
8	T7AW	PFC-LOF-AY17-AA005-B	110	0	0	110
9	TLAX	PK	8447	6	6,325	2,128
10	TEAW	PFC-LOF-TEAZ-AC007-B	147	0	0	147
11	T9AX	PFC-LOF-2CT-AC002-B	0	0	0	0
12	D74A	PFC-LOF-D74A-AA014-A	750	34560	18,477	16,833

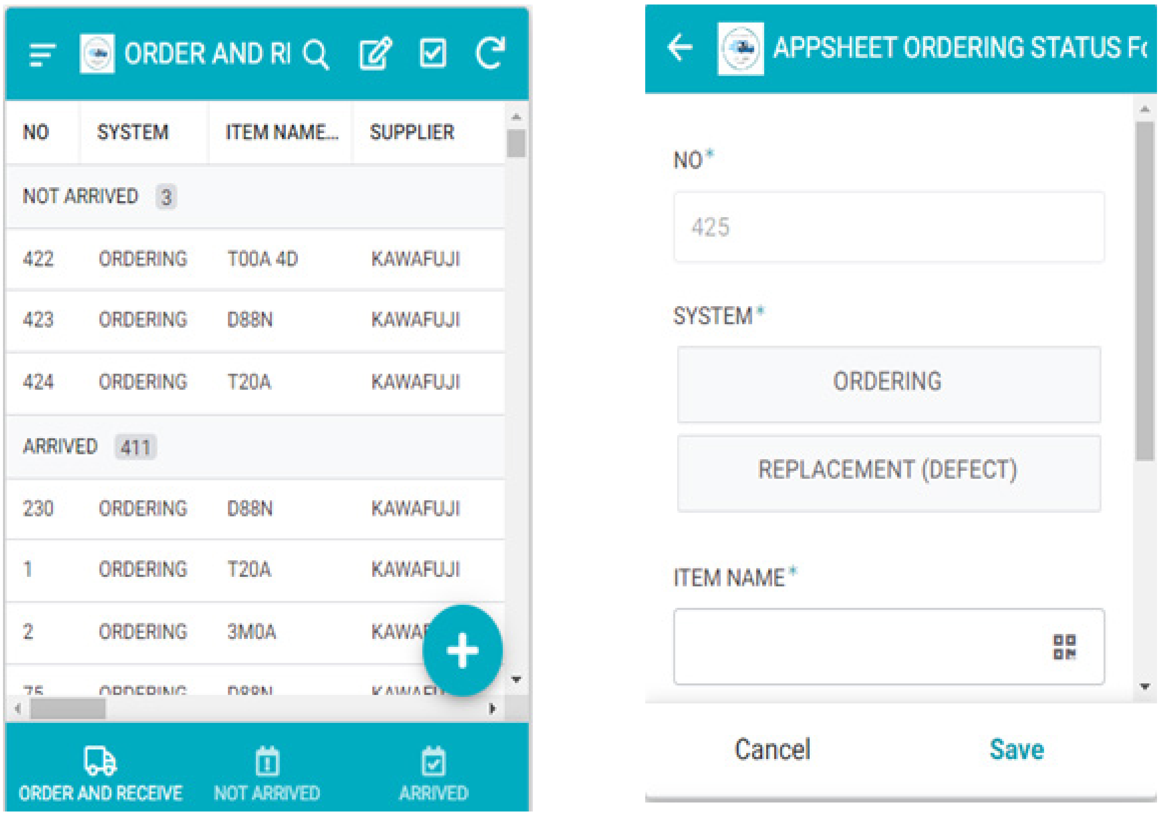
FIGURE 6. Integrated sheet for balance stock

MOBILE APPLICATION FOR LOFT LAYER TRANSACTIONS

Two types of mobile applications were created using AppSheet to simplify data entry for loft layer receipts and the subsequent charging of items to production. The initial application facilitates material ordering and the recording of material upon its receipt. It captures and monitors the order placed with the supplier, tracking the process until the actual item is received. This action triggers an update in the system, indicating the addition of new stock to the inventory. Another set of applications is employed to document data related to loft layer materials transferred to production, resulting in a reduction in inventory levels.

1. Ordering and Receiving Loft Layer Application

This mobile application is integrated with the ordering and receiving database, and its interface is depicted in Figure 7.



(a) (b)

FIGURE 7. Mobile application for ordering and receiving loft layers

Upon launching the application on a mobile device, the interface as shown in Figure 7(a) will be displayed, presenting a summary of loft layers categorized as “not arrived” and “arrived.” This summary provides details on ordered items, indicating whether they have been received or are still pending. When initiating a new order, the interface as shown in Figure 7(b) will appear, offering columns for inputting information about items, with date and time details automatically captured. Upon receiving the ordered item, users can update its status to “arrived” by selecting the specific item on the summary page.

2. Loft layer Charge-Out Application

The mobile application designed to oversee the charging out of loft layer items is created to interface with the charge-out log database. Figure 8 illustrates the mobile application interface specifically developed for capturing details related to loft layer items being transferred to production.

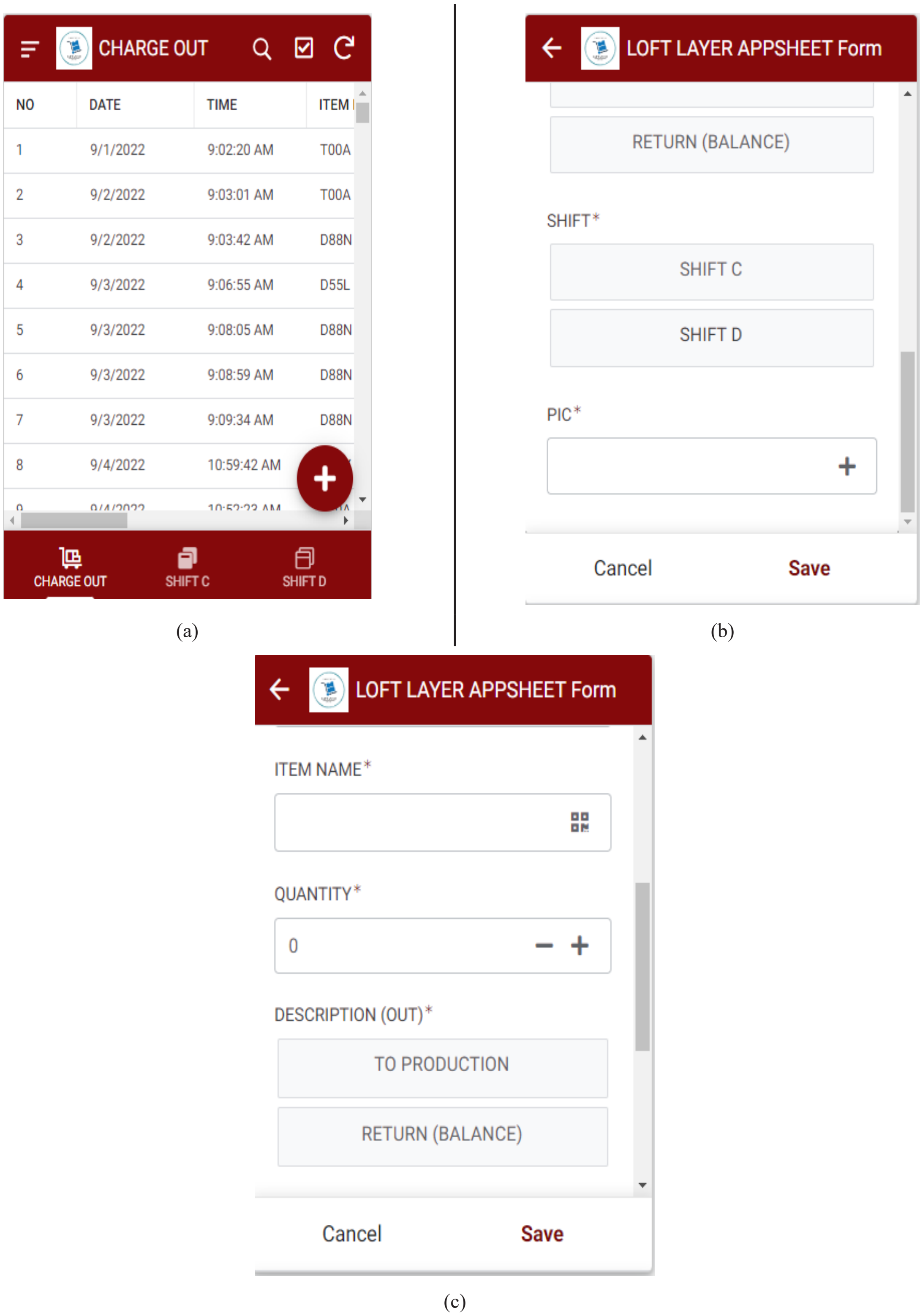


FIGURE 8. Mobile application for charge-out loft layers

The primary interface displayed upon launching the application is represented by Figure 8(a). During each transaction involving the transfer of loft layer items to production, warehouse personnel will input updates for the item, quantity, shift, and the name of the person in charge. This serves as the home interface, providing a summarized view of transactions organized by date and time. Users can access detailed information by selecting a specific transaction. To initiate a new transaction, users can utilize the "+" button, leading them to a form page where transaction details can be input, as illustrated in Figures 8(b) and 8(c). Upon completion of the transaction, pressing the "save" button ensures that all entered data is updated in the charge-out log database.

LOFT LAYER TRANSACTION DASHBOARD

An interactive operational dashboard for Loft Layer material was successfully developed using Looker Studio. The integrated log file functions as a database, establishing a connection to Looker Studio and facilitating the creation of a dashboard for visualizing loft layer transactions and statuses. Responding to user feedback, a dashboard is designed with three primary objectives. Firstly, it aims to provide real-time stock visualization by item, offering valuable insights for both warehouse and production users to plan material and production activities effectively.

Secondly, the dashboard allows users to track the status of ordered loft layer items, enabling monitoring upon arrival and prompt response to any anomalies such as material shortages or sudden production changes. Lastly, the dashboard serves the purpose of analyzing loft layer usage by production shift, offering insights into material yield effectiveness. Figure 9 displays the main page of the dashboard, specifically developed for monitoring loft layer transactions.

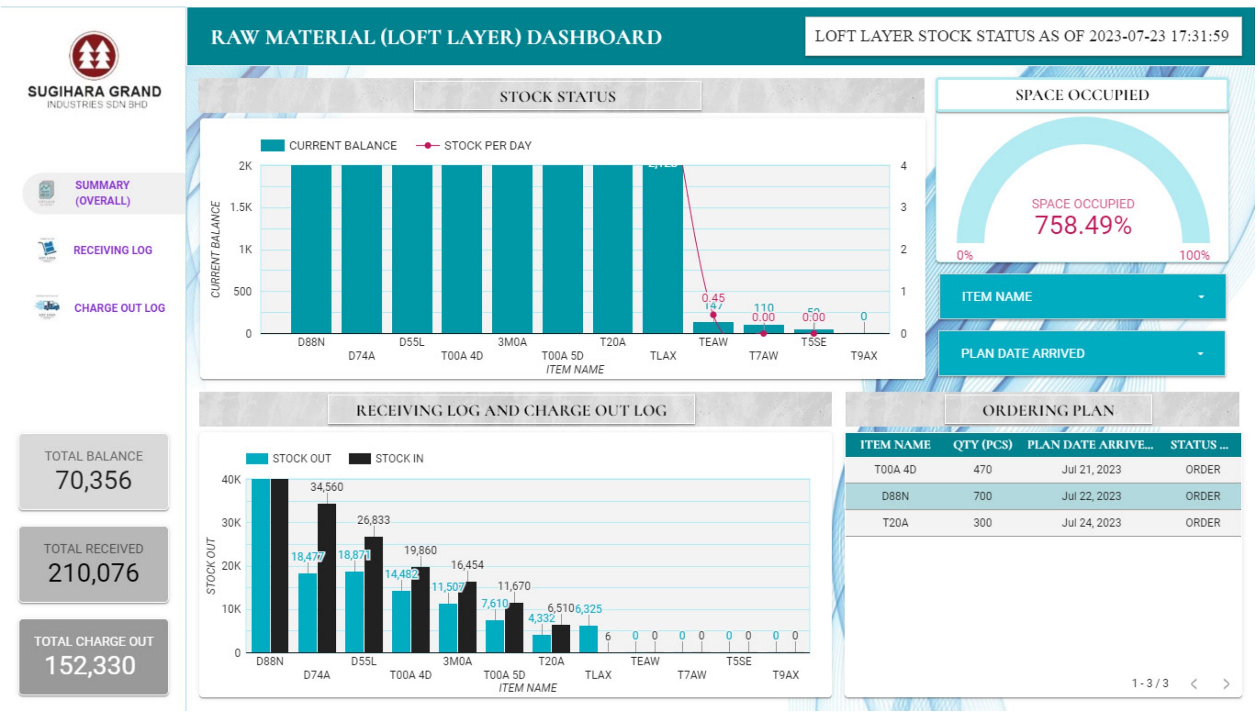


FIGURE 9. Main page for loft layer dashboard

To meet the specified objectives, the dashboard is structured into three visualization pages. The primary page, serving as the dashboard's main interface, presents a comprehensive view, including stock status categorized by model, warehouse space occupancy, a summary of receipts and charge-outs by model, and a list of ordering plans. Utilizing a bar chart for stock and transactions, a gauge to indicate warehouse space utilization, a scorecard for total transactions, and a table for loft layer ordering items, this page offers dynamic insights. The ability to filter data by item name and date via the drop-down list button ensures that the graph, scorecard, gauge, and table only display information for the selected item.

The second page focuses on visualizing ordering and receiving details, presenting a bar chart graph depicting received quantity and balance by model, a table outlining receiving information, a list of discrepancies versus the plan, and a scorecard indicating the total received, as depicted in Figure 10.

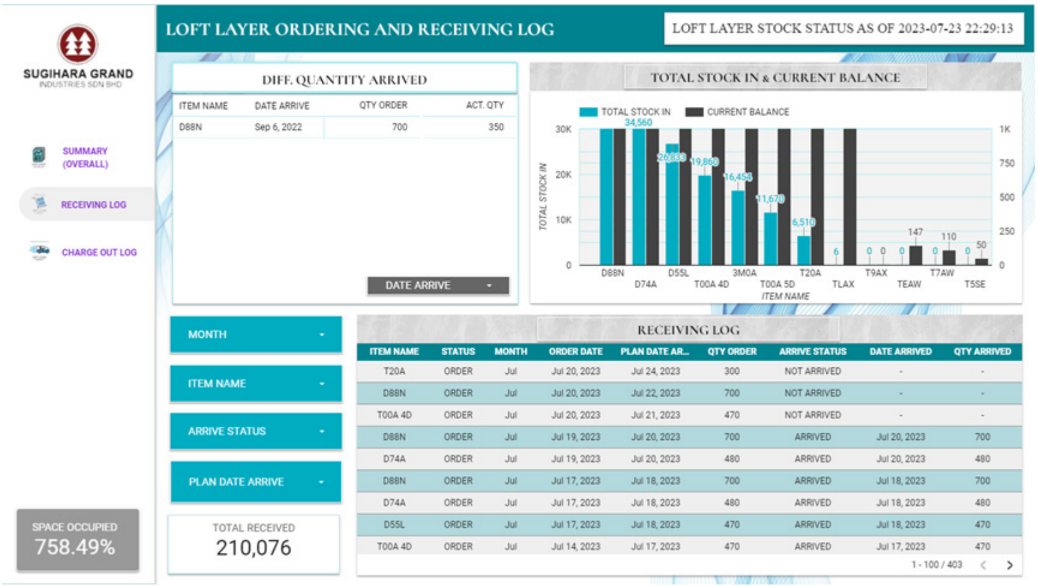


FIGURE 10. Ordering and receiving page

This page provides users with valuable insights into the ordering trends by model, offering detailed information on ordering and receiving that aids in monitoring the timing of orders and receipts. The compilation of loft layer transactions charged out to production is presented on the third page of the dashboard, as illustrated in Figure 11. This page encompasses a list providing transaction details, balance ratios by model visualized in a pie chart, and quantity charge-out by model represented in a bar chart graph.

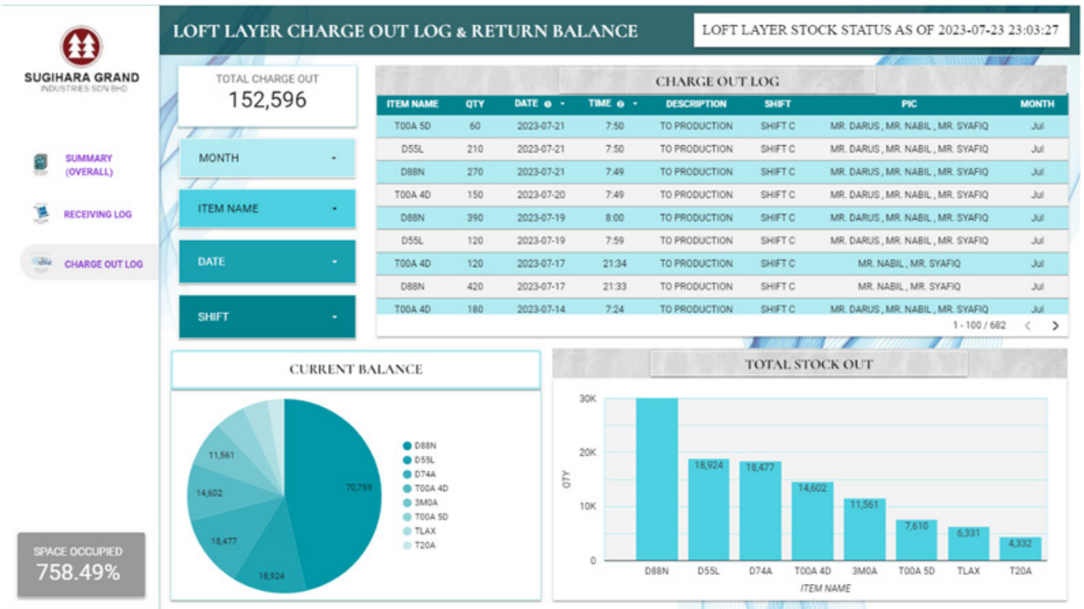


FIGURE 11. Charging out loft layer page

Users have access to detailed information about loft layers transferred to production, including type, quantity, transaction time, and personnel involved. These three pages offer comprehensive data crucial for identifying abnormalities and enabling trend and data analysis. The system provides real-time awareness of loft layer inventory levels, eliminating the need for manual counting to determine stock figures for ordering plans. Material planners can use the visualized production usage plan and receiving frequency to facilitate order placement and efficiently monitor material receipts. Table 3 summarizes the comparison results before and after the IoT system implementation.

TABLE 3. Comparison results before and after IoT system implementation

Item	Before	After
Space Utilization	Status unknown, determined by visual look	Status determined by % ratio space occupancy in the dashboard
Stock Status	The physical stock was manually counted daily, and the balance was not reflected after the transaction	No daily physical count since stock is updated in real-time.
Ordering to supplier	The status of the order was not visualized and needed to refer to the ERP system.	Ordering information is visualized in the dashboard
Material Receiving	Not updated in real-time, have to manually refer to receiving record. Variance in receiving not visualized	Receiving information is updated in real-time once the item is received. Variance ordering visualized in the dashboard
Receiving Trend	The trend of receiving not visualized	The receiving trend is visualized in a graph.
Charge-out Trend	Material issued to production was manually recorded into a check sheet	Transaction out captured by a device in real-time
Parts Verification	Verification was conducted manually by physical checks on items and product tagging.	Verification is done by scanning the QR code to confirm the actual item and tagging.
Rejection Tracking	Rejection from production was manually tracked, difficult to do set tallying.	Rejection quantity is updated in the system in real-time and reflected in the actual stock

Referring to Table 3, SGSB has experienced significant benefits in controlling Loft Layer materials. Real-time stock information from the dashboard has guided the ordering process, enabling better inventory control and resulting in reduced stock levels and warehouse space. Previously, Loft Layer materials occupied 278m² of space due to buffer stock. With real-time information, stock was reduced, occupying only 236m², indicating a 15% reduction in space. Real-time stock updates have also eliminated the need for manual counting, which previously required operations to stop. The tracking and visualization of material orders to suppliers have prevented incorrect orders. Since system implementation, there have been no instances of incorrect orders, compared to 2 to 3 cases per month previously. With smoother stock control, instances of material stockouts in production have also been reduced to 0, compared to an average of 2.5 cases per month previously. The trend of receiving and charging-out to production has helped the coordinator estimate and improve buffer stock to maintain an optimum stock level.

Due to time constraints, the system currently only covers one type of material, which accounts for approximately 25% of the material storage occupancy. Enhancements should be made to extend the coverage to include all items within the raw material warehouse. This would allow SGSB to benefit from improved inventory control and reduced space occupancy. Additionally, the need for stock take events for other items can be completely eliminated, freeing up time for running production.

CONCLUSION

The Cost-Effective IoT System represents an Internet of Things (IoT) solution developed through web-based software, tailored to meet users' specific inventory management needs. This system offers a viable alternative for automotive SMEs in Malaysia seeking a cost-effective and low-risk investment in their inventory control systems.

Being fully customizable to individual user requirements allows the system to be intricately designed for seamless integration with real-site operations. Its effectiveness lies in delivering real-time operational data and interactive visualizations, becoming a primary reference for informed decision-making, ultimately contributing to enhanced operational efficiency. This system has the potential for enhancement through the exploration and utilization of functions available in AppSheet and Looker Studio. For example, features such as printing summary transactions and automatically generating reports could be implemented to meet the needs of operation management at all levels.

ACKNOWLEDGEMENT

This research was funded by the Research Management Centre, Universiti Teknologi MARA Shah Alam Selangor Malaysia (Under STRATEGIC RESEARCH PARTNERSHIP (SRP) Grant: 100-RMC 5/3/SRP (021/2021).

DECLARATION OF COMPETING INTEREST

None

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