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Enhancing Spare Parts Inventory Control in Automotive SMEs: A Digital Approach with Google Tools Integration

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Abstract

Smooth operation of manufacturing processes is critical for maintaining production efficiency, and machine downtime can significantly disrupt operations, leading to substantial financial losses. One of the primary contributors to extended downtime is the unavailability of replacement parts due to inadequate spare parts management. Traditional manual inventory control often results in unclear spare part statuses, leading to stockouts and further production delays. This study aims to digitalize and optimize spare parts inventory management for small and medium-sized enterprises (SMEs) in the automotive sector by developing an integrated system using Google-based tools. The system leverages Google Sheets as the central database, AppSheet for mobile-based data input and transaction management, and Looker Studio for real-time visualization of inventory status through interactive dashboards. Key features of the system include stock level alerts, barcode scanning for faster data entry, and predictive analytics for demand forecasting. The integration of these tools creates a cohesive system that eliminates manual record-keeping, enhances the accuracy of spare parts tracking, and prevents issues such as stockouts and overstocking. Additionally, the system allows easy access to critical information, including supplier details, pricing, and specifications. Through effective spare parts management, the system not only reduces machine downtime but also optimizes operational costs and improves decision-making processes in inventory management, contributing to more efficient and cost-effective manufacturing operations.

1. Introduction

Efficient spare parts management is essential for manufacturing operations to run smoothly. However, many factories still face challenges with their systems, where machine spare parts are not adequately managed. This often leads to spare parts being unavailable when needed, resulting in prolonged downtime. For machines that are nearly 30 years old, maintenance costs can rise to as much as 2.5% of the machine's original price, highlighting the significant expense of spare parts [1]. Therefore, it is critical for organizations to focus on managing spare parts effectively.

At the same time, there is a growing global focus on sustainability and efficient use of resources. This has created a demand for repairs, placing a requirement on machine manufacturers to produce spare parts and ensure

their availability for as long as the product or machine is in use. This initiative aims to reduce waste, as machines or equipment that cannot be repaired are typically discarded. It also creates business opportunities for repair services, while simultaneously promoting sustainability [2], [3]. However, manufacturers often resist this because of concerns about intellectual property and profits. The movement stresses the need to balance these concerns with environmental responsibility, and researchers and policymakers are looking for an alternative in ensuring balance of spare accessibility with considering the innovation [4].

Research has investigated various inventory networks for spare parts management. Grasping the dynamics of the supply chain is essential for creating effective inventory systems. The type of supply chain model considering both centralized and decentralized which can significantly influence the availability of spare parts. Additionally, analytics by examining the historical usage of spare parts has becomes possible to forecast future demand and recommend optimal inventory policies [5]. Advanced technologies, such as those driven by data analysis and artificial intelligence, can autonomously make decisions without human intervention. Innovations like the Internet of Things (IoT) and blockchain allow devices to operate intelligently in response to their surroundings [6]. A cloud-based inventory management system utilizes cloud storage to maintain inventory data online through an internet connection. This allows users to interact with the data or information from anywhere, at any time. Businesses operating in multiple locations benefit from this capability, as they can access the data remotely [7].

This study was conducted at an SME automotive factory in Malaysia, located in Port Klang, Selangor. The company, SGSB, is a first-tier manufacturer of automotive components in Malaysia's automotive supply chain. With a total operational headcount of 165, the factory operates 24 hours a day on a two-shift schedule to meet the demands of key customers such as Toyota, Perodua, Mazda, and Nissan. The focus of this study is on the Maintenance department, specifically on spare parts management, where the primary goal is to keep machines running efficiently and minimize downtime.

The current method of managing machine spare parts at SGSB is done manually. Spare parts are stored in a designated room, and when a part is taken, the responsible technician records the transaction in a logbook, noting the date, item name, quantity, and the person in charge. However, this manual system often leads to incomplete or delayed entries. Since technicians typically retrieve parts during machine breakdowns, they tend to take the parts directly to the machine and only update the logbook afterward. This delay results in inaccurate and outdated information. On a daily basis, the maintenance supervisor enters the parts transactions into a spreadsheet, including any new parts received. Despite using a spreadsheet to track inventory, it still relies on the data from the logbook. This process is prone to errors, especially when it comes to part discrepancies and quantities, as technicians may input incorrect information. Consequently, real-time stock levels cannot be accurately tracked, and manual stock counts are often required to determine the actual inventory. Fig. 1 illustrate the process of managing spare part manually at SGSB.

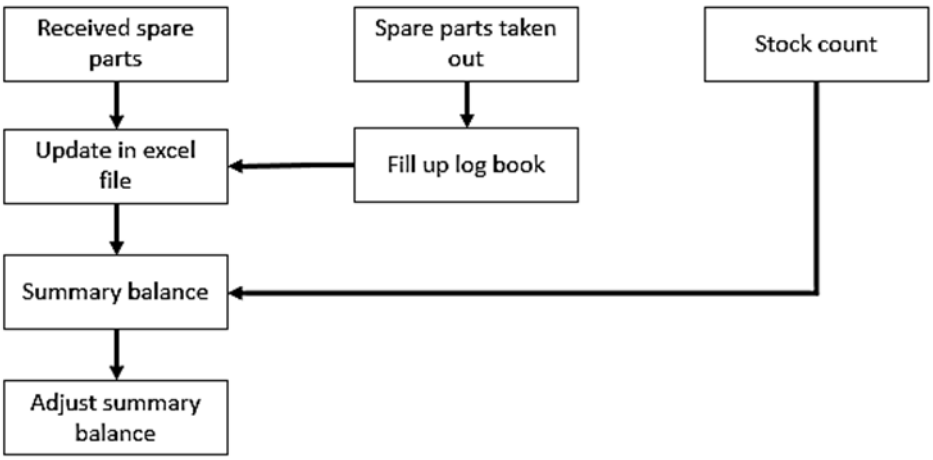

Fig. 1 *The process of managing spare part at SGSB*

As a result, SGSB's current spare parts management system faces several practical challenges that lead to increased downtime and inefficiencies. The manual method limits SGSB maintenance staff's ability to monitor spare parts movement effectively. This causes delays in replenishment and hinders quick analysis of spare parts usage. Consequently, operations are frequently halted due to machine breakdowns caused by spare parts unavailability, leading to longer downtimes and higher operational costs. Without up-to-date spare parts data, SGSB struggles to analyze usage trends, which restricts effective decision-making for optimizing spare part storage. This, in turn, leads to unnecessary purchases of spare parts that don't need to be stocked.

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Solution for the challenges in managing spare parts manually is migrating to digitization using an inventory system. One of existing popular systems for managing inventory widely used in the market today are Enterprise Resource Planning (ERP) systems. These commercial software solutions integrate an organization's processes, such as managing personnel, equipment, materials, methods, finances, and operations, into a single platform, enhancing efficiency, data accuracy, and decision-making across departments [8]. Although ERP systems are customizable to meet specific company needs, they come with disadvantages, including high implementation costs and limited flexibility for extensive customization. Despite these drawbacks, ERP systems offer benefits like increased productivity, reduced operating costs, enhanced data accuracy through automatic updates, and improved task organization, with modules available for warehouse management [9].

The aim of this study is to address the challenges in the current system and propose an IoT solution for a custom spare parts management system. The main objective is to develop a cost-effective IoT-based system to manage machine spare parts at the SGSB factory. This system will provide real-time inventory tracking, data management through a mobile application, and data synchronization with Google Sheets. It will also include customizable reports and analytics powered by Looker Studio. The project aims to enhance spare parts management by minimizing downtime, boosting efficiency, and supporting sustainability goals through the use of web-based software like AppSheet, Google Sheets, and Looker Studio [10], [11].

2. Methodology

2.1 Development of Spare Parts Inventory Control System

Cost Effective IoT Control System (CEICS) was developed using web-based tools from Google, including Google Sheets, Google AppSheet, and Looker Studio. The system is designed and customized to meet the needs of the SGSB maintenance team, following a five-layer architecture model from a previous study. The perception layer collects data via mobile apps and sends it online to the middleware layer for storage, while the application layer displays warehouse information using Business Intelligence tools. The business layer connects the system to the company's management software for overall control [12]. The system consists of three components: a database, mobile application, and dashboard. Google Sheets serves as the platform for storing all operational data, Google AppSheet is used for developing the mobile application, and Looker Studio is utilized for dashboard visualization.

2.1.1 Establishment of System Design

CEICS system database created using Google Sheet works as a platform to store data for SGSB spare part management. A mobile application was initiated using Google AppSheet to feed data into the system, which links to the Google Sheets file. Finally, data will be visualized as the Business Intelligence (BI) tool by using Looker Studio. Fig. 2 illustrates the system infrastructure design for SGSB, showcasing the development process across three main phases. Phase 1 involves establishing a robust database platform, Phase 2 focuses on developing mobile applications, and Phase 3 aims to visualize operational information using BI tools.

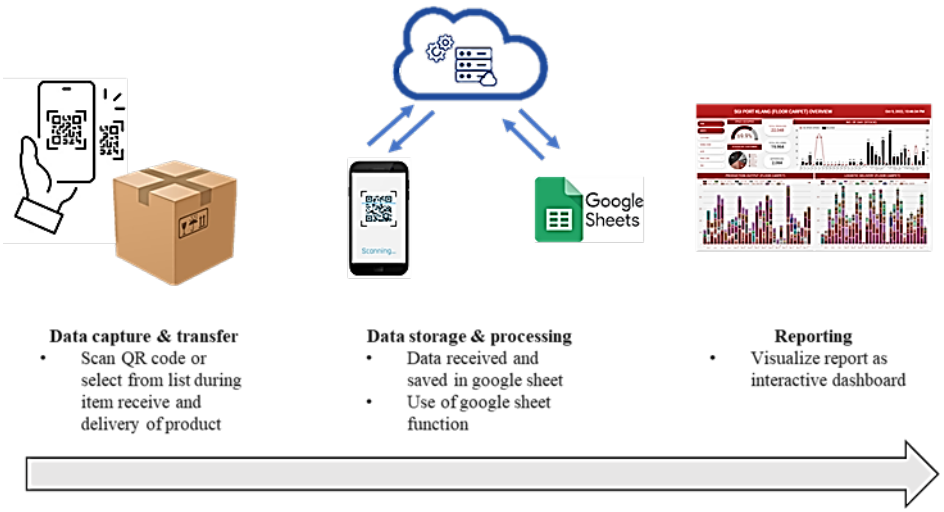

Fig. 2 *System design infrastructure for SGSB spare parts management*

Referring to Fig. 2, the system uses the scanning function of a mobile device to capture information about spare parts received from suppliers and when they are taken for use. This data is then uploaded to Google Sheets, which is stored in the cloud. The data in Google Sheets is linked to Looker Studio, where it is displayed in an

interactive dashboard. This dashboard enables users to generate reports and view information tailored to their specific needs and preferences.

2.1.2 Initiating the System Database

The database for the systems is established using Google Sheets, making full use of its built-in functions. Google Sheets was used as the system's database, leveraging built-in functions to make data readily available for the system. As a cloud-based platform, Google Sheets offers several advantages over Microsoft Excel, particularly in terms of its online document-sharing capabilities. It enables users to work together on the same document from various devices, fostering real-time collaboration. A notable feature is the integrated autosave function, which protects work by automatically saving progress continuously, provided there is an active internet connection [13]. This foundational phase shapes the structure of the system, storing all input-captured data in a Google Sheets file that functions as the system's database stored in Google Drive. Moreover, these features make Google Sheets a highly adaptable and user-friendly tool, facilitating efficient data management and encouraging effective group collaboration [14]. Additionally, the BI tools retrieve and visualize this data on a reporting dashboard. The establishment of the database platform in phase 1 involves six detailed steps as described in Table 1.

Mapping the process involves creating a diagram that illustrates how various elements and tasks in the warehouse are interconnected. This helps identify dependencies, potential issues, and areas needing attention. Creating a master list entail compiling a detailed inventory of all items and information needed, including their names, purposes, and specifications. This ensures that no important elements are overlooked and assists in organizing tasks and resources. Setting up the receiving log involves tracking incoming items by recording details such as the date received, source, item descriptions, and tracking numbers, thus maintaining a clear record of arrivals. Setting up the charge-out log focuses on documenting details of items being distributed or released, including the date, recipient, item descriptions, and any necessary documentation, to track item movement and ensure accurate record-keeping. Creating an integration sheet involves reconciling data from the receiving log and charge-out log to manage inventory balances, tracking quantities received and released to ensure accuracy. Performing a trial run is objectively to test the inventory system with simulated transactions to identify and resolve any issues before full implementation, ensuring smooth and accurate operation.

Table 1 *Development step of database platform*

Step	Item	Purpose
Step 1	Mapping of the interrelationship process.	To get an overview of the overall warehouse operation and its interactions.
Step 2	Identify items and information by creating a master list.	To have a master reference list for the warehouse inventory items.
Step 3	Creating the Receiving Log	Database platform for storing data on items received from suppliers (add inventory).
Step 4	Creating the charge-out log	Database platform for storing data on items delivered to the customer (taken out of inventory).
Step 5	Creating an integration sheet	To link the database of inventory received and taken out and produce an inventory balance
Step 6	Trial run and fix	To simulate IN and OUT inventory, confirm built- in functions in Google Sheet are working properly and manage to get the actual balance inventory.

2.1.3 Development of Mobile Application

The database platform established in Section 2.1.2 serves as the foundation for capturing inventory transactions within this system. However, to ensure that the entire database is not exposed in a Google Sheet for transaction input, a user interface platform for mobile applications was initiated using Google AppSheet. Google AppSheet is a tool that allow user to develop an application without need to have strong programming or coding knowledge. This web-based software runs on internet browser without installation on computer that enables users to develop applications for mobile devices and web interfaces. Google AppSheet offers wide integration with data such as Google Sheet, Office and Dropbox [15]. Several studies have successfully implemented mobile applications in settings such as hospitals, education [16], and health monitoring [17], [18]. Previous study by Casarotto [19] have outlined the process of mobile application development with AppSheet, as illustrated in Fig. 3.

The mobile application development process using Google AppSheet, as shown in Fig. 3, involves several key steps. First, establish a Google account, which is necessary for using AppSheet's development platform. Next,

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create a structured database in Google Sheets, which will serve as the backbone for the mobile application with well-organized tables and data. Then, link these Google Sheets to AppSheet, enabling the platform to access and use the data for building the app. After integration, customize the mobile application in AppSheet by designing the user interface, setting up data views, workflows, and automation, all without extensive coding. Finally, test the application thoroughly to ensure it meets user expectations and make any necessary adjustments before launching it.

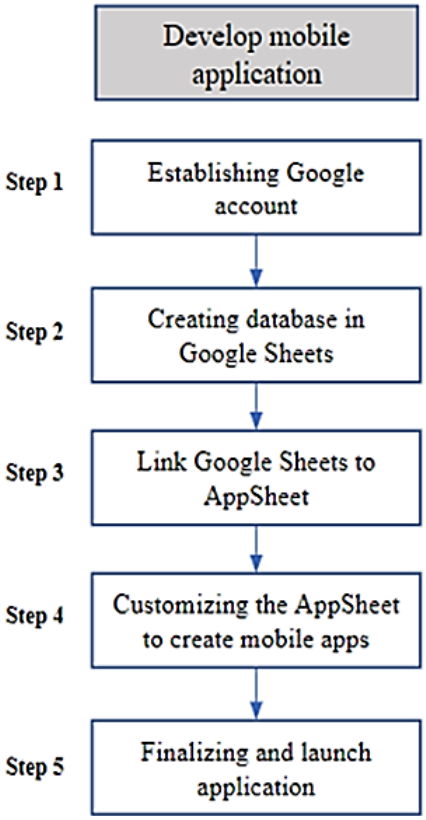

Fig. 3 *Flow of developing a mobile application using AppSheet [19]*

2.1.4 Development of Spare Part Inventory Dashboard

The data visualization was developed using Looker Studio, which serves as a tool for publishing and displaying data from Google Sheets in an interactive format for users. By presenting data visually, Looker Studio compiles metrics and indicators that aid companies in making informed decisions and strategic plans, thereby minimizing the risk of significant errors in pursuing their goals [19]. Data visualization converts large datasets into graphs and charts, facilitating the quick identification of patterns and insights [20]. By visually representing data, it improves understanding and simplifies the decision-making process [21]. Previous studies have demonstrated the successful use of Looker Studio as a tool for developing interactive dashboards across various industries, including sales analysis [22], education [23], and production operations [20].

The process involves three main steps: first, determining and defining which items will be visualized; second, compiling and integrating the relevant data in Google Sheets; and third, using Looker Studio to create the visualizations. Previous study has found outlined this three-step approach for establishing visualizations in Looker Studio, as illustrated in Fig. 4 [24].

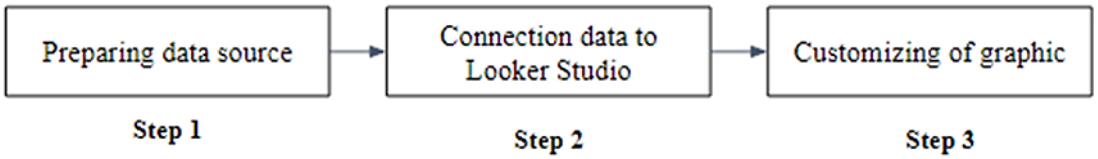

Fig. 4 *Flow chart of establishing visualization using Looker Studio [24]*

3. Results

3.1 System Database

As to provide medium for database which to send and received for mobile application and dashboard, a set of databases was created which are master list sheet, stock-in log sheet and stock-out log sheet. The master list serves as the core of the database, containing detailed information about specific spare parts. This structured approach allows users to quickly find or input necessary data, ensuring efficiency and accuracy. Additionally, by migrating to cloud-based storage, the data is better protected and more accessible, offering a secure and dependable solution for managing the Master list. This shift enhances the efficiency and organization of the system for spare parts management. Fig. 5 shows on Master list file created in spreadsheet that containing information for spare parts item for SGSB.

The transaction of spare parts purchased from suppliers is recorded in the Stock-In log. When a spare part is received, the maintenance coordinator is required to enter detailed information about the item, including the supplier, brand, item category, item name, quantity, and the date of receipt. This log allows for accurate tracking of incoming spare parts, ensuring that users can obtain up-to-date information about the status and details of the incoming items. Additional relevant details, such as the part number and price, can be automatically populated using a 'vlookup' function, improving accuracy and reducing manual data entry. Fig. 6 presents the format of the Stock-In log which gathered the information of received spare part record.

ICS -MASTERLIST

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A1 ITEM ID

	A	B	C	D	E	F	G	H	I
1	ITEM ID	CATEGORY	ITEM NAME	ERP CODE	PART NUMBER	OPENING STOCK	BRAND	ITEM NO	PRICE (EACH)
2	WJA 1	WATER JET A	COIL AXEL 1	S-ME-CN-WJET-CA08	304590	2	KMT	1	RM2,063.00
3	WJA 2	WATER JET A	COIL AXEL 2	S-ME-CN-WJET-CA09	304461	1	KMT	2	RM1,547.00
4	WJA 3	WATER JET A	COIL AXEL 3	S-ME-CN-WJET-CA10	304460	1	KMT	3	RM1,969.00
5	WJA 4	WATER JET A	COIL AXIS 5	S-ME-CN-WJET-CA11	302813	1	KMT	4	RM2,203.00
6	WJA 5	WATER JET A	COIL AXIS 6	S-ME-CN-WJET-CA12	302736	0	KMT	5	RM2,203.00
7	WJA 6	WATER JET A	V BELT		SPA 2500 LW	3	BANDO	6	RM50.00
8	WJA 7	WATER JET A	V BELT		A 55	2	BANDO	7	RM14.00
9	WJA 8	WATER JET A	BEARING		20412815	2	TIMKEN	8	RM500.00
10	WJA 9	WATER JET A	BEARING		SNT 513-611	3	TIMKEN	9	RM500.00
11	WJA 10	WATER JET A	FILTER ELEMENT OIL		05049689	3		10	RM20.00
12	WJA 11	WATER JET A	FILTER INLINE STRAINER		20412815	3	KMT	11	RM122.00
13	WJB 1	WATER JET B	RED DIAMOND ORIFICE 0.007"	S-ME-CN-WJET-OR04	49894249	24	KMT	1	RM24.00
14	WJB 2	WATER JET B	NUT-NOZZLE	S-ME-CN-WJET-NN01	49863665	4	KMT	2	RM26.00
15	WJB 3	WATER JET B	NOZZLE TUBE 3/8" X 8.00	S-ME-CN-WJET-NT01	10138444	2	KMT	3	RM28.00

Fig. 5 *Master list file for SGSB spare parts*

A	B	C	D	E	F	G	H
TRANSACTION ID	DATE	TIME	ITEM ID	CATEGORY	ITEM NAME	QUANTITY	PIC
259e876f	8-Sep23	3:18 PM	WJB 8	WATER JET B	ON OFF VALVE REPAIR KIT	6	ARIF
6e3af013	11-Sep23	2:23 PM	WJB 47	WATER JET B	HP SEAL ASSEMBLY	5	ARIF
5377303c	15-Sep23	10:09 AM	OIL 1	OIL	TELLUS S2 M46 HYDRAULIC OIL	3	ARIF
e36cec21	15-Sep23	8:21 AM	WJB 8	WATER JET B	ON OFF VALVE REPAIR KIT	100	ARIF
3b6a7dd0	23-Sep23	9:38 AM	WJA 5	WATER JET A	COIL AXIS 6	2	ARIF
4c7797a6	23-Sep23	9:37 AM	WJA 4	WATER JET A	COIL AXIS 5	1	ARIF
1a429546	2-Oct23	8:52 AM	WJB 3	WATER JET B	NOZZLE TUBE 3/8" X 8.00	2	ARIF
0b3210e8	2-Oct23	6:53 PM	WJB 3	WATER JET B	NOZZLE TUBE 3/8" X 8.00	4	FAIZAL
c8d6949a	2-Oct23	6:57 PM	WJA 3	WATER JET A	COIL AXEL 3	1	FAIZAL
03b0c9a6	2-Oct23	6:58 PM	WJA 5	WATER JET A	COIL AXIS 6	1	FAIZAL
b5f2c27c	2-Oct23	6:59 PM	WJB 6	WATER JET B	ON OFF VALVE BODY	1	FAIZAL
2adb0a64	2-Oct23	7:00 PM	WJB 33	WATER JET B	SEALING HEAD REPAIR KIT	4	FAIZAL
15f211cc	2-Oct23	7:01 PM	WJB 47	WATER JET B	HP SEAL ASSEMBLY	8	FAIZAL
b85aba2b	27-Oct23	8:07 AM	WJB 1	WATER JET B	RED DIAMOND ORIFICE 0.007"	60	FAIZAL
924bd27e	16-Nov23	9:16 AM	FC 35	FORMING C	SOLENOID VALVE	8	FAIZAL

Fig. 6 *Stock-in log spreadsheet for data of receiving spare parts*

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A similar format is used to create the Stock-Out log, which records spare parts removed from the inventory. Functioning similarly to the Stock-In log, this log captures essential information, such as the date, item, quantity, and the person responsible for taking the part. The synchronized creation and automatic updating of both logs significantly enhance SGSB's inventory management system, providing a comprehensive, real-time record of all spare part transactions. This approach greatly improves organizational oversight and operational efficiency. Fig. 7 displays the data captured from Stock-Out transactions, illustrating the system's effectiveness.

TRANSACTION ID	DATE	TIME	ITEM ID	CATEGORY	ITEM NAME	QUANTITY	PIC
5583cf26	11Sep23	10:24 AM	WJB 34	WATER JET B	O-RING PROXIMITY SWITCH	1	FAIZAL
5fa1a6e7	11Sep23	9:30 AM	WJB 47	WATER JET B	HP SEAL ASSEMBLY	1	FAIZAL
d0c671ca	12Sep23	10:31 AM	WJA 9	WATER JET A	1/4" CLAMP + TOP PLATE	1	FAIZAL
0fcb83e2	12Sep23	3:32 PM	WJA 3	WATER JET A	COIL AXEL 3	1	FAIZAL
0c6faf61	12Sep23	2:19 PM	WJB 27	WATER JET B	INLINE WATER FILTER	1	FAIZAL
118acd68	15Sep23	7:08 PM	WJA 1	WATER JET A	COIL AXEL 1	1	FAIZAL , AIZAT
7bc09779	15Sep23	7:12 PM	WJB 3	WATER JET B	NOZZLE TUBE 3/8" X 8.00	1	ARIF
475a7f78	18Sep23	8:18 AM	WJB 8	WATER JET B	ON OFF VALVE REPAIR KIT	3	LOKMAN
1159353d	18Sep23	8:24 AM	WJB 47	WATER JET B	HP SEAL ASSEMBLY	2	HAIDER
953a3749	18Sep23	8:47 AM	FC 6	FORMING C	PROXIMITY SENSOR PET SUPPLY	2	HAIDER
695902bb	18Sep23	3:27 PM	WJB 33	WATER JET B	SEALING HEAD REPAIR KIT	1	HAIDER
19a5a953	20Sep23	3:47 PM	WJB 1	WATER JET B	RED DIAMOND ORIFICE 0.007"	1	HAIDER
b81b85cb	21Sep23	6:25 PM	WJB 2	WATER JET B	NUT-NOZZLE	1	HAIDER
a5f5e35d	21Sep23	6:25 PM	WJB 3	WATER JET B	NOZZLE TUBE 3/8" X 8.00	1	HAIDER

Fig. 7 *Spreadsheet log for stock-out*

Both transaction of received and taken out for spare part is integrated into one sheet named as Integrated Sheet. Transaction of received item from Receiving Log and taken item from the Stock-Out Log is captured by this sheet so that the quantity balance of each item can be calculated by considering the opening balance. In addition to recording receiving and delivery data, this integrated sheet also includes the opening stock figure. The formulation for determining stock balance takes into account the total opening stock and the received stock, then subtracting the quantity delivered. Fig. 8 depict a format of Integrated sheet established in Google Sheet.

ICS-INTEGRATED SHEET

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E14 fx ='LINK MASTERLIST'!F15

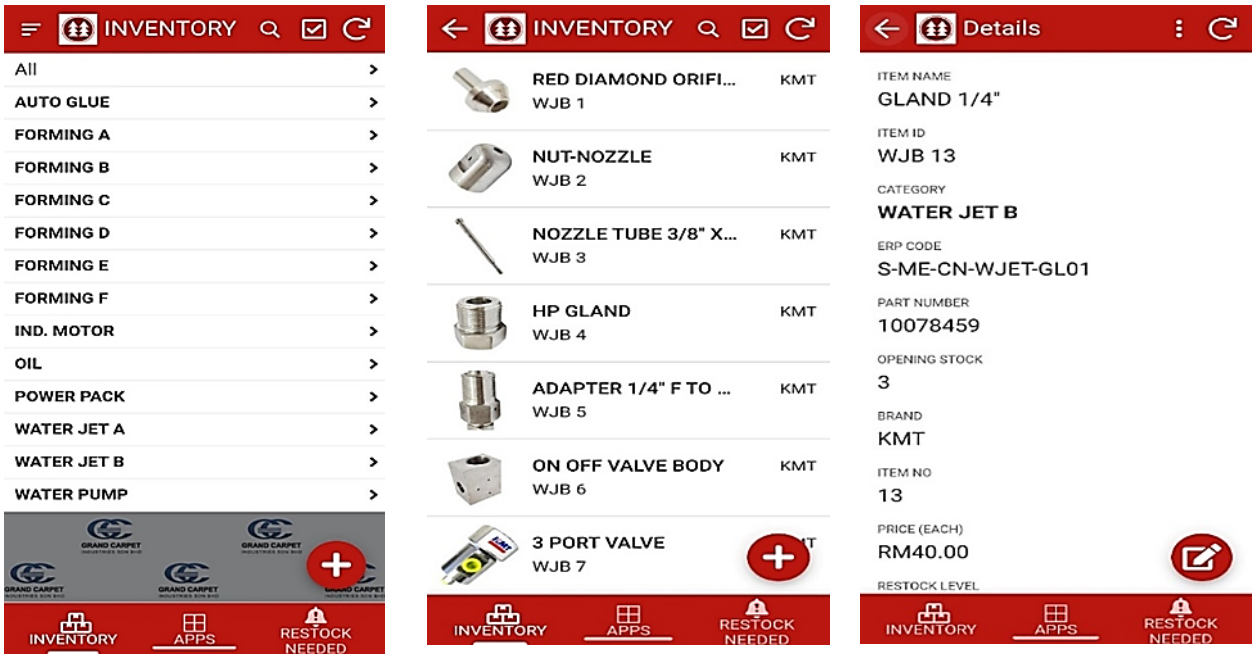
	A	B	C	D	E	F	G	H
1								
2	ITEM ID	CATEGORY	ITEM NAME	PART NUMBER	OPENING STOCK	SUM TOTAL IN	SUM TOTAL OUT	BALANCE
3	WJA 1	WATER JET A	COIL AXEL 1	304590	2	1	1	2
4	WJA 2	WATER JET A	COIL AXEL 2	304461	1	1	1	1
5	WJA 3	WATER JET A	COIL AXEL 3	304460	1	2	2	1
6	WJA 4	WATER JET A	COIL AXIS 5	302813	1	3	2	2
7	WJA 5	WATER JET A	COIL AXIS 6	302736	0	4	3	1
8	WJA 6	WATER JET A	V BELT	SPA 2500 LW	3	4	4	3
9	WJA 7	WATER JET A	V BELT	A 55	2	5	4	3
10	WJA 8	WATER JET A	BEARING	20412815	2	3	3	2
11	WJA 9	WATER JET A	BEARING	SNT 513-611	3	0	1	2
12	WJA 10	WATER JET A	FILTER ELEMENT OIL	05049689	3	0	0	3
13	WJA 11	WATER JET A	FILTER INLINE STRAINER	20412815	3	0	0	3
14	WJB 1	WATER JET B	RED DIAMOND ORIFICE 0.007"	49894249	24	60	66	18
15	WJB 2	WATER JET B	NUT-NOZZLE	49863665	4	0	1	3
16	WJB 3	WATER JET B	NOZZLE TUBE 3/8" X 8.00	10138444	2	12	8	6
17	WJB 4	WATER JET B	HP GLAND	49894249	2	0	0	2
18	WJB 5	WATER JET B	ADAPTER 1/4" F TO 3/8" M	20454363	3	0	0	3

Fig. 8 *Integrated sheet format*

3.2 Mobile Application

A mobile application was developed using AppSheet, consisting of three main segments: the Administration page, Stock-In, and Stock-Out. The Administration page serves as the core of the application and is accessible only to authorized users with specific email credentials. This page is essential for managing inventory information, including tracking stock levels for both stock in and stock out, maintaining detailed records of total inventory costs, receiving notifications for items nearing their restock levels, and providing icon buttons for easy access to the two other applications. By restricting access to certain users, the Administration page ensures a secure and controlled environment for handling critical inventory details, streamlining processes, and facilitating efficient communication with the related applications. Fig. 9 shows the Administration page that purposely developed for system admin managing overall system.

Fig. 9 depicts the administration page of the mobile application, showcasing a clear and intuitive visual interface for users. This application allows administrators to monitor crucial spare part inventory data in real time, accessible on multiple devices, including computers, tablets, and smartphones. Such flexibility ensures that admins can stay updated and manage inventory data remotely at any time. The application's user-friendly design improves the ease and efficiency of real-time monitoring, providing seamless access to vital inventory information across various platforms.



(a) **(b)** **(c)**

Fig. 9 *Administration page (a) Summary; (b) Spare part item; (c) Details on item*

The Stock-In was the dedicated application page for managing the inventory stock-in process, accessible only to users with the spare part inventory system credentials. This application simplified stock-in transactions by giving users the option to manually search for items or expedite the process with a built-in QR code scanner for spare parts. These dual options offered flexibility, allowing users to select the method that best suited their needs. The QR code scanning feature, in particular, significantly sped up the process, resulting in a faster and more efficient stock-in experience. Fig. 10 shows the interface for the Stock-In application. Figs. 10(a) to (c) show the application interfaces for stock receiving activities, where users can track items issued from the system, view current stock balances, and easily input information through a simple form-based page. The intuitive layout allows users to effortlessly navigate and retrieve past transaction records, providing a quick and efficient way to review stock-in activities.

A dedicated application interface has been established to manage items taken out from the inventory system. Similar to the Stock-In process, item registration for stock-out is performed using QR code scanning. This feature helps prevent errors by ensuring that the correct item is registered, especially for spare parts with variations. Additionally, QR code scanning speeds up the registration process, making it more efficient. Fig. 11 illustrate the various interfaces of the stock-out system. Since the application was designed for floor personnel, specifically maintenance technicians who typically withdraw spare parts for machine use, the Stock-Out interface was configured to be straightforward. The interface requires minimal input from the user, ensuring that the process is as simple as possible. This design minimizes the risk of errors when inputting crucial information, such as the item

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and quantity being taken out from the inventory, thereby enhancing the accuracy and efficiency of the stock-out process.

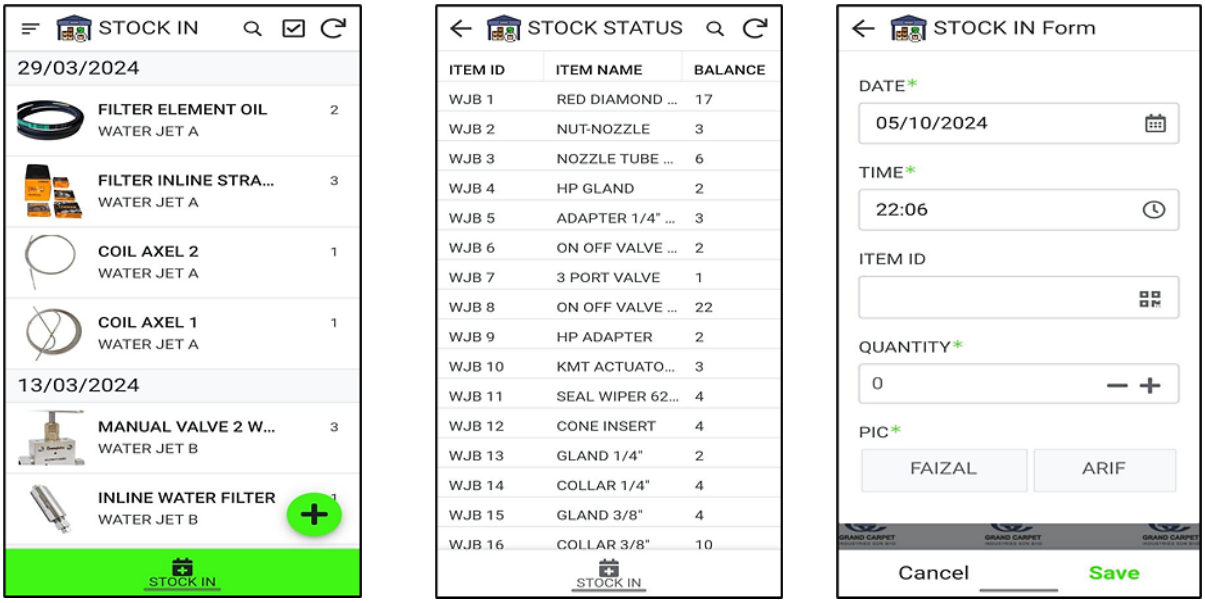

Fig. 10 *Stock-In interface (a) Input and summary; (b) Status of stock; (c) Form for stock register*

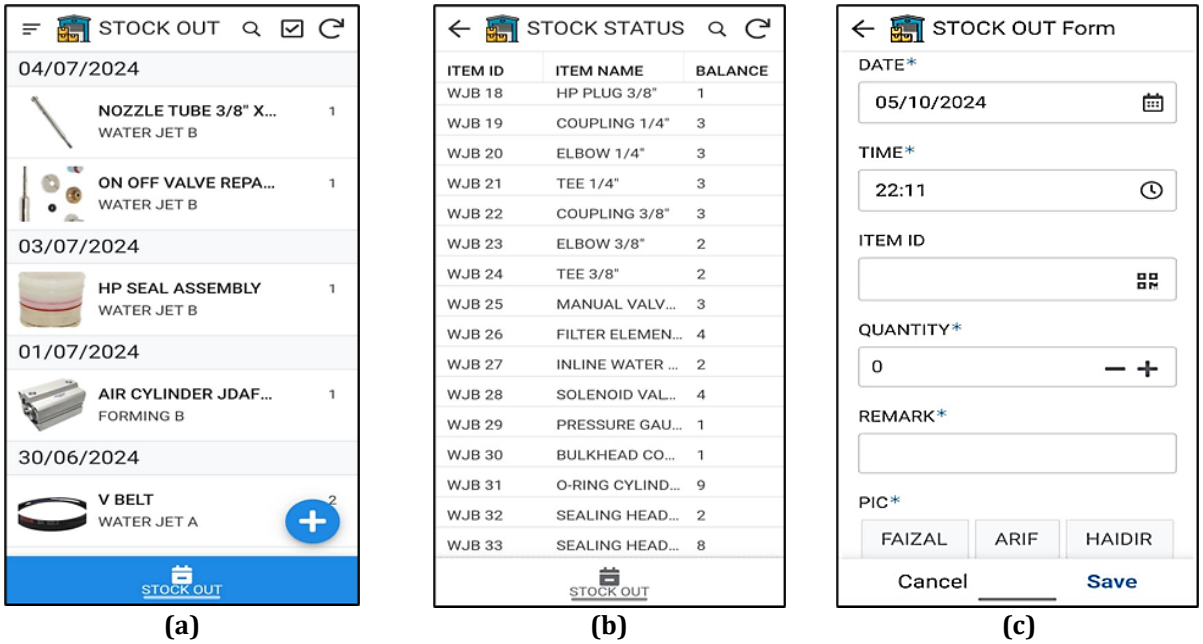

Fig. 11 *Stock-Out interface (a) Input and summary; (b) Status of stock; (c) Form for stock taken out*

3.3 Spare Parts Management Dashboard

The Looker Studio platform was used to create a real-time operational dashboard reporting on the inventory status of machine spare parts for SGSB. The dashboard is organized into three pages: Summary, Stock-In, and Stock-Out. Upon loading, the dashboard initially displays the Summary page, which provides daily transaction data for spare parts added to and removed from stock. Detailed information includes the current spare part balance, the value of spare parts, total stock received, and total stock taken out. Additionally, the dashboard allowed users to filter the data by year, month, and category, providing a customizable analysis. This filtering feature helped users spot transaction trends through informative graphs tailored to the chosen spare part category, improving decision-making based on up-to-date information. Fig. 12 illustrate the summary page of the spare part inventory dashboard.

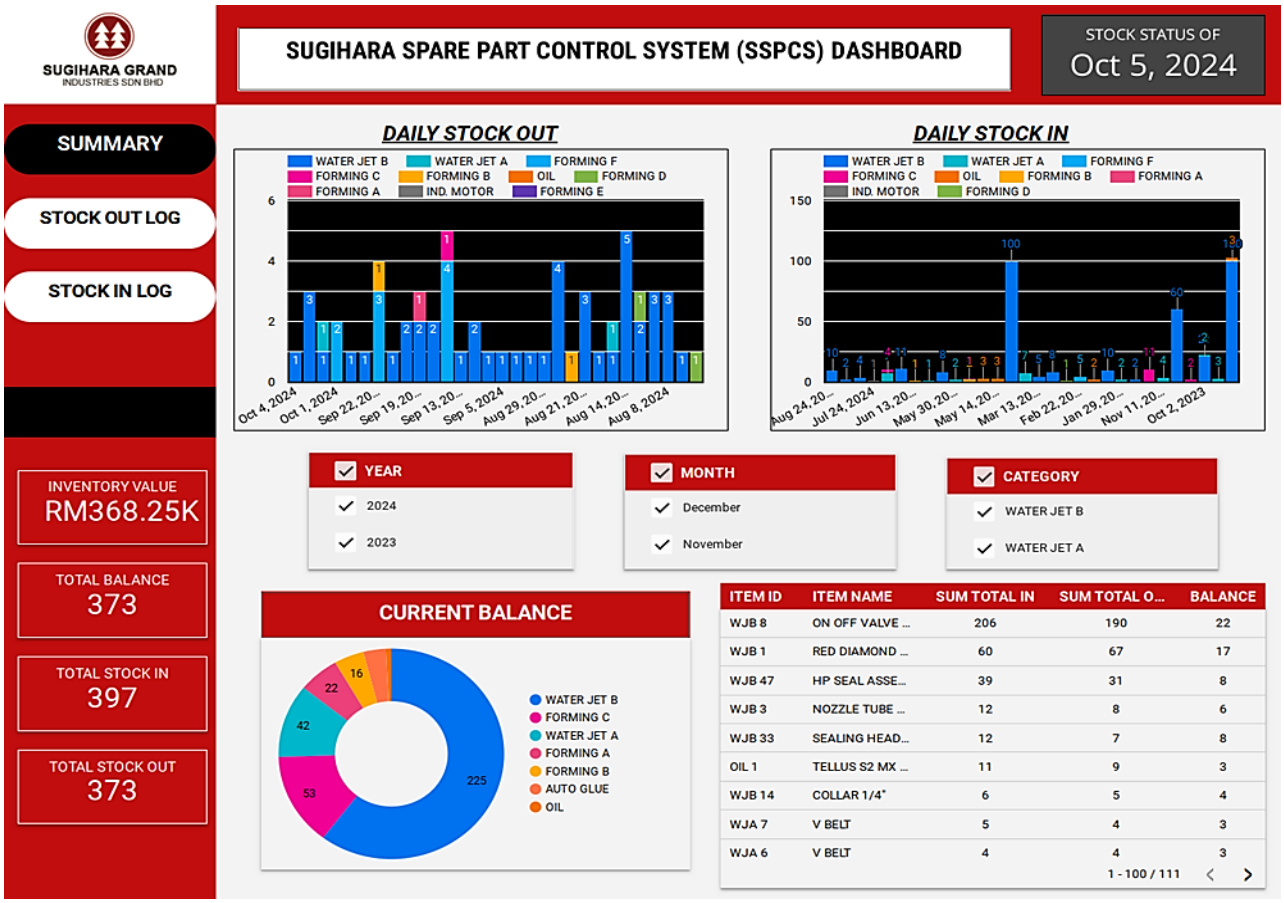

Fig. 12 *Summary page for the spare part inventory dashboard*

The summary page of the dashboard serves as a main resource for SGSB's maintenance team in analyzing spare parts inventory management. Equipped with dynamic trend graphs and adjustable data filters, the dashboard has become an indispensable tool for evaluating transaction processes, identifying patterns, and making informed decisions. By applying custom filters, users can easily display the desired data, allowing them to quickly understand trends, respond immediately to anomalies, and enhance inventory planning to improve the overall spare parts management process.

When the page selection button for the Stock-Out log is clicked, the dashboard displays an extensive table of transactions for spare parts taken out. This table provides key information, including item names, quantities, dates, times, and the individuals responsible for the withdrawals. The page offers a comprehensive overview of the spare parts removed from the system, allowing for quick analysis and documentation. Additionally, with the visual graph presentation feature, trends in stock-outs can be easily understood, enabling fast and accurate decision-making based on reliable information. Fig. 13 shows the interface of the Stock Out page. Referring to the Fig. 13, graphical view makes it easy for users to understand stock-out trends at a glance. It provides clear and specific information that helps guide users toward making efficient and well-informed decisions. By analyzing trends and patterns, users can accurately determine the appropriate minimum and maximum stock levels, which is crucial for avoiding stockouts or overstocking—both of which can lead to inefficiencies and wasted resources. With precise data, the SGSB maintenance team can effectively control spare part inventory, ensure optimal stock levels and improve overall inventory management.

The third page of the operational dashboard, known as the Stock-In page, is specifically designed to provide detailed information on spare part receiving activities. This page allows users to easily view and analyze trends in spare part deliveries by item, as well as monitor the status of orders. Such insights are essential for optimizing the planning of spare part orders and preventing stockouts, ensuring that the right parts are always available when needed. Additionally, the Stock-In page enables users to trace the full order and receiving history, which is crucial for maintaining accurate records and ensuring that inventory levels are well-managed. By having access to this data, users can make informed decisions, improve inventory control, and prevent overstocking or understocking issues. Fig. 14 visualized the page for stock in, summarizing information on items added to the inventory system.

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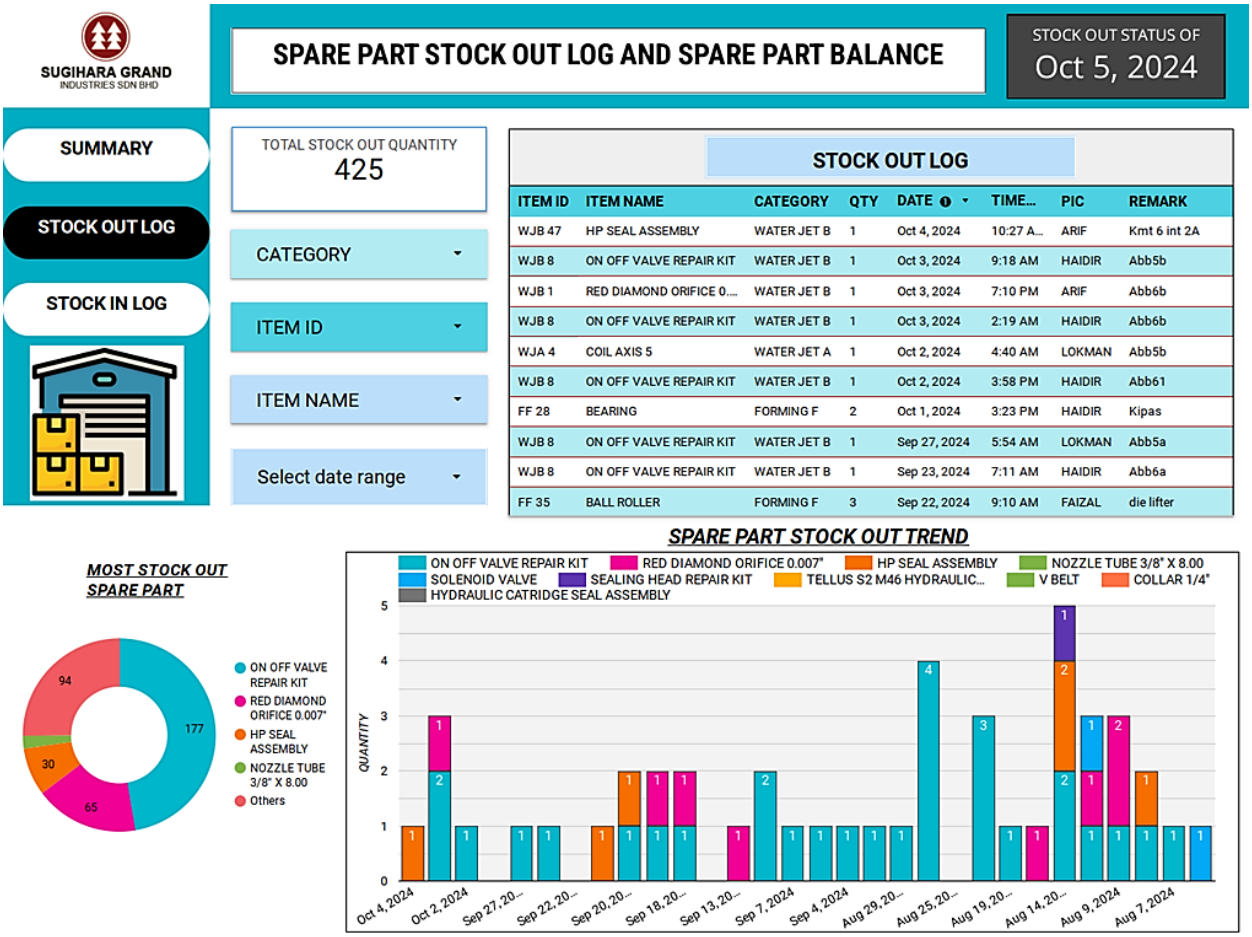

Fig. 13 *Stock Out page for the spare part inventory dashboard*

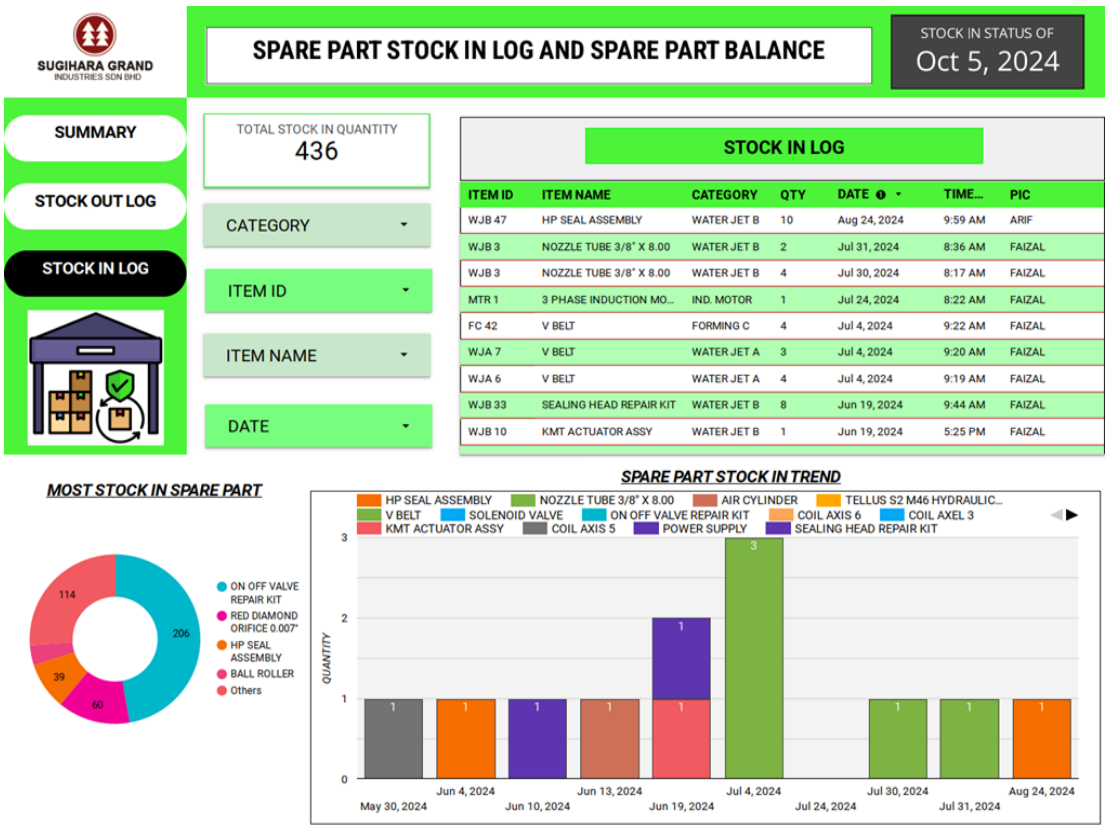

Fig. 14 *Stock in page for the spare part inventory dashboard*

3.4 Summary of Implementation

Introduction of IoT system that integrating web-based software has improved the flow of managing spare parts at SGSB which completely eliminates the manual processes. When parts are taken from storage, technicians can instantly update the inventory using a mobile device with minimal input, instead of manually writing in a logbook. They simply scan the item and select their name, and the system automatically retrieves the part's details, including the name, quantity, and date. The camera-scanning feature ensures that the correct item is reported, preventing errors from selecting the wrong part. Unlike the previous manual method, there's no need to enter data into a spreadsheet, as all information is updated in real time. Fig. 15 shown on process flow of managing spare part after the system implementation.

Since transactions are recorded immediately, the stock balance remains accurate and up to date, eliminating the need for manual stock counting, except for occasional sampling to verify accuracy. This allows the time typically allocated to stock-taking activities to be redirected to more valuable tasks, such as conducting preventive maintenance, while reducing time spent on non-value-added jobs that increasing work efficiency and contribute to cost saving. With accurate real-time stock figures, SGSB can confidently maintain the correct items and quantities, reducing the risk of extended downtime due to unavailable spare parts.

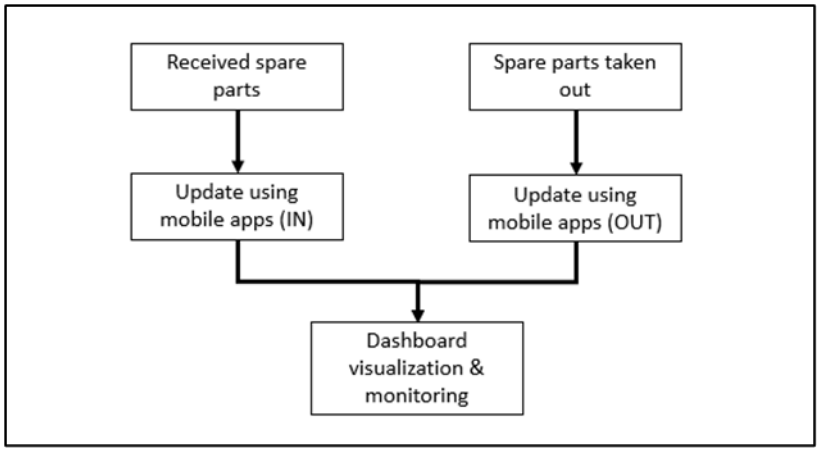

Fig. 15 *Flow of handling spare parts using IoT system*

4. Conclusions

The research study aimed at creating an IoT system for managing spare part inventory was a success. By leveraging web-based tools such as Google Sheets, AppSheet, and Looker Studio, a cost-effective IoT system was established, digitizing the entire process of managing machine spare parts for SGSB. The manual approach, which relied on written logbooks, was completely replaced with a mobile application and interactive dashboard visualizations. Furthermore, the study demonstrated that the system was fully customized to meet user needs and requirements, showcasing a high level of practicality and effectiveness in real-world applications.

The establishment of this system, using freely available web-based software accessible via any web browser, has demonstrated that a practical alternative for spare part inventory management is achievable. Leveraging Google tools proved effective in migrating from a manual approach to a digital system, significantly improving spare part management at SGSB with transparent, real-time information displayed in an interactive dashboard. Compared to commercial inventory systems, this solution has been proven to be cost-effective while addressing nearly all of the user's specific requirements. Unlike commercial systems like ERP, which require substantial investment and offer limited customization, this system offers flexibility at a fraction of the cost.

To ensure long-term maintenance and practicality, the system includes administrative features such as the ability to register new items, which automatically generates a new QR code. Additionally, users can remove obsolete items, keeping the system up to date and relevant. By using this system, the risk of errors in spare part inventory transactions is significantly reduced, and users can easily track spare part consumption trends. This enables SGSB to maintain optimal inventory levels, lowering the risk of stockouts or overstocking and resulting in more cost-efficient spare part management.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mohamad Khairi bin Hassan, Mohd Hazri bin Mohd Rusli;* ***data collection:*** *Muhammad Azim Bin Wan Mokhtar;* ***analysis and interpretation of results:*** *Muhammad Azim Bin Wan Mokhtar, Mohamad Khairi bin Hassan;* ***draft manuscript preparation:*** *Suzilawati binti Kayat, Mohd Hazri bin Mohd Rusli. All authors reviewed the results and approved the final version of the manuscript.*

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