IJIE

INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING
ISSN: 2229-838X e-ISSN: 2600-7916

Vol. 18 No. 1 (2026) 46-58
https://publisher.uthm.edu.my/ojs/index.php/ijie

IoT-Driven Kaizen for Enhanced Real-Time Warehouse Operations and Dynamic Inventory Visualization in FG Delivery

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DOI: https://doi.org/10.30880/ijie.2026.18.01.004

Article Info

Received: 12 June 2025
Accepted: 31 March 2026
Available online: 15 April 2026

Keywords

IoT Kaizen, real-time inventory control, smart lean, warehouse visualization

Abstract

Efficient inventory management within Finished Goods (FG) warehouses is a critical pillar of the Malaysian automotive manufacturing sector. Traditional manual recording methods often suffer from data latency and transcription inaccuracies, hindering real-time decision-making. This research implements an IoT-driven Kaizen system designed for real-time inventory control at a major automotive warehouse in Port Klang. By transitioning from manual whiteboard-based tracking to a digital framework—leveraging open-source tools such as AppSheet, Google Sheets, and Looker Studio—the system established a seamless, paperless data pipeline accessible via mobile and desktop devices. Results from the preliminary implementation demonstrate a 100% reduction in manual data entry lag and the total elimination of human transcription errors. Furthermore, the system optimized warehouse utilization, maintaining a 41.2% occupancy rate while successfully processing a throughput of 211,980 units. An interactive dashboard was developed to provide instantaneous stock visibility, significantly accelerating strategic interventions and mitigating the risk of inventory obsolescence. This digital transformation underscores the efficacy of low-cost IoT solutions in enhancing operational transparency and scalability within the industrial engineering landscape.

1. Introduction

The Malaysian automotive sector has experienced substantial growth and continues to enhance its entire infrastructure. Manufacturers responsible for producing automotive parts and components play a critical role in ensuring a consistent supply of components for automobile manufacturers. Recently, there has been considerable interest in Industry 4.0 due to its potential to revolutionize manufacturing methods. Industry 4.0 is often closely associated with the Internet of Things (IoT), a significant technology. IoT is a concept that leverages monitors, embedded systems, and integrated interface systems to collect real-time data from industrial equipment and facilities. While IoT is currently considered a broad term, it is evolving into a specialized terminology specifically tailored to IoT applications within manufacturing plants [1].

Recent technological advancements, such as IoT, industrial IoT, cyber-physical platforms, and cloud storage, were developed in the past few years from the foundational technologies of Industry 4.0 [6]. However, they have only gained widespread use in the last decade. IoT connects various physical technologies to the Internet, including devices and basic sensors. It collects information from these devices, analyzes it, and generates smart responses, enhancing the capabilities of connected devices. The adoption of IoT systems and technologies by an increasing number of households and businesses has revolutionized data collection and transmission [7]. Smart technologies are devices equipped with advanced capabilities, such as data analysis and artificial intelligence. These technologies enable the devices to perceive their surroundings and make decisions independently of continuous human intervention. This intelligence is facilitated by innovations like the Internet of Things and blockchain, allowing objects to operate intelligently based on their situational awareness [17].

To thrive in the competitive business landscape, companies must effectively manage their existing products and services while also innovating significantly and progressively in both innovation and procedures [2]. The growing demand for increased manufacturing output, efficiency, and reliability has driven collaboration to create emerging innovations capable of keeping pace with the rapid technological advancements in modern manufacturing systems [3]. Manufacturing warehouses accommodate a variety of items, including raw materials and FG, whereas distribution warehouses primarily focus on storing and distributing products from suppliers to consumers [5]. The aim is to evaluate the effectiveness of various warehouse modes and determine the most suitable mode for the company [4]. Businesses operating across multiple locations or requiring swift access to inventory data stand to benefit the most from this system [16]. A digital tool, such as a Warehouse Management System (WMS), significantly impacts warehouse operations by improving their efficiency [18].

Smart warehousing leverages automation and artificial intelligence (AI) to enhance operational efficiency, minimize service time, and optimize resource utilization. It facilitates seamless information exchange among personnel, equipment, and interconnected warehouses, ensuring streamlined operations and improved coordination [19]. Previous studies have demonstrated the effective implementation of digital transformation at minimal cost through a structured six-step process. This process includes identifying relevant technologies, categorizing operations, assessing risks, evaluating environmental impacts, identifying benefits, and managing change through cost analysis and corporate social responsibility (CSR) programs. These steps were subsequently integrated into a comprehensive framework [25].

The objectives of this research are as follows:

i. To assess the existing approach for tracking inventory in the FG store within the actual warehouse,
ii. To create an IoT Kaizen system aimed at achieving real-time inventory management within the FG store
iii. To implement the IoT Kaizen system of monitoring real-time inventory control realization

The PDCA methodology is utilized to guide the development of the system, supported by prior studies highlighting its effectiveness. Within this framework, malfunctions were identified using the Ishikawa method during the planning phase (Plan). Subsequently, the 5S tool was employed to address dysfunctions and enhance processes (Do). The outcomes were then monitored and evaluated through the Value Stream Mapping (VSM) future state analysis (Check & Act) [26].

2. Methodology

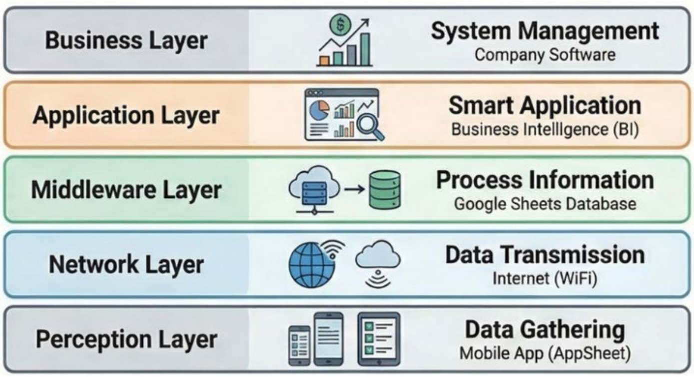

Fig.1 *The five-layer IoT architecture*

The IoT Kaizen system for real-time Finished Goods delivery and stock visualization was deployed based on a comprehensive five-layer IoT framework, as illustrated in Fig. 1, which bridges the gap between physical warehouse activities and digital oversight. This architecture ensures that data flows seamlessly from the perception layer on the warehouse floor through the network and middleware layers, ultimately reaching the application and business layers for high-level analysis.

The implementation of the IoT Kaizen system into warehouse operations is designed to ensure a scalable and adaptable system tailored to the organization's unique requirements. As illustrated in the following figure, this architecture facilitates real-time tracking of Finished Goods (FG) and deliveries, reducing operational errors while providing a transparent overview of the entire supply chain. To move from a manual, whiteboard-dependent environment to this sophisticated digital ecosystem, the development process was executed across the three distinct strategic phases: establishing database infrastructure, developing the mobile application, and employing business intelligence tools. The relationship between these phases and the IoT layers is illustrated in the System Infrastructure (Fig. 2).

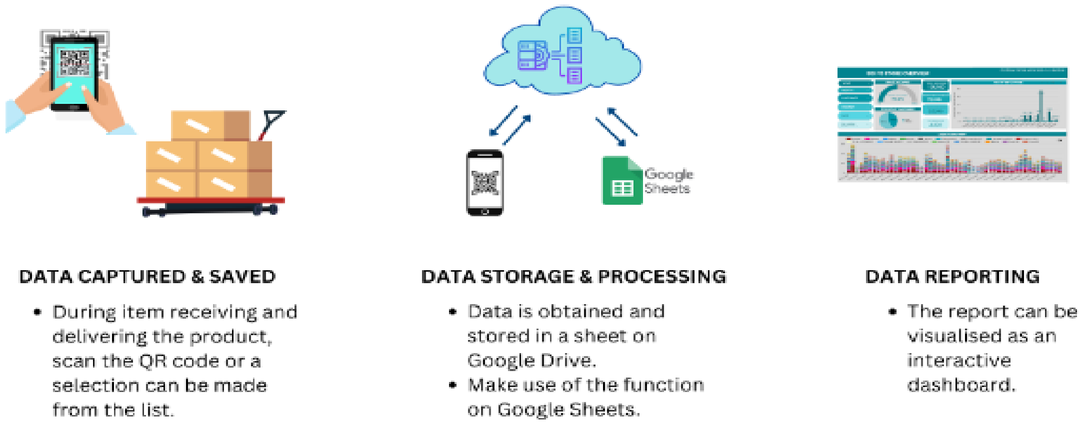

Fig. 2 *The IoT Kaizen system's infrastructure for the FG warehouse*

2.1 System Framework and Architecture

Fig. 3 illustrates the IoT Kaizen framework, which was designed to optimize warehouse operations by ensuring a system that is both adaptable and scalable. The framework is customized to meet unique organizational needs, allowing for enhanced real-time tracking of deliveries, error reduction, and improved supply chain transparency. [13]. To move from a manual, whiteboard-dependent environment to this digital ecosystem, the development process was executed across three distinct strategic phases mapped against the IoT layers.

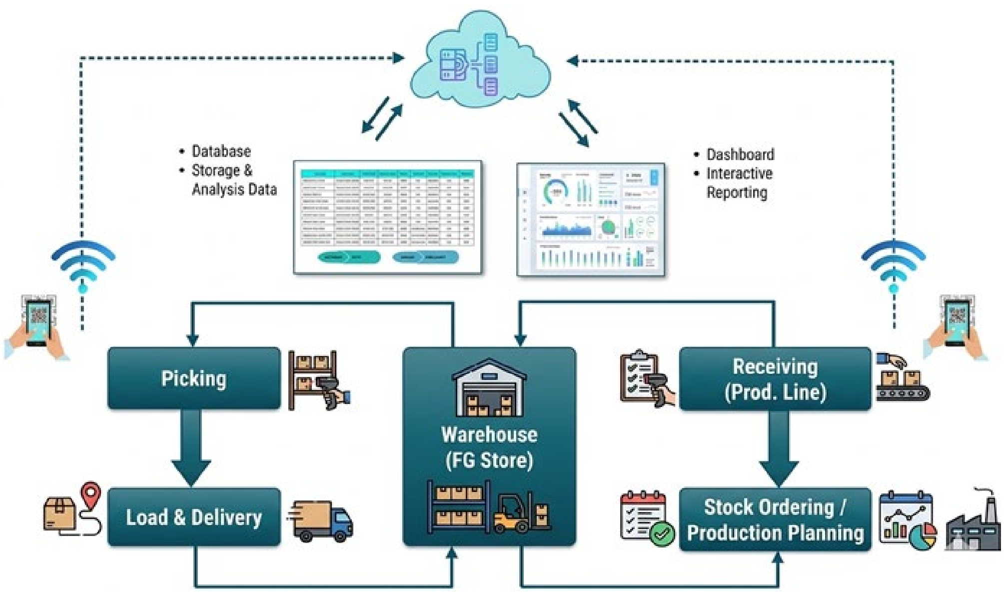

Fig. 3 *Framework of IoT Kaizen on the warehouse operation system*

i. Phase 1: Establishing the Database Infrastructure
ii. Phase 2: Developing a mobile device application
iii. Phase 3: Employing business intelligence tools for visualization

Phase 1 focuses on the middleware layer, where Google Sheets is architected to serve as the primary cloud-based relational database. This stage involves the design of IoT applications and devices to establish a reliable data foundation. Phase 2 transitions to the perception layer with the deployment of AppSheet, which provides a user-friendly mobile interface for on-site data collection. During this integration phase, QR codes are generated for each FG item, allowing users to scan units using authentication protocols. Finally, Phase 3 addresses the application and business layers by integrating Looker Studio to provide comprehensive company oversight through real-time visualization. Regular monitoring and performance evaluations are conducted to ensure the system operates as expected. The development process should include regular performance assessments, process improvements, and system updates to ensure the system consistently operates at its optimal level. The IoT Kaizen system should be executed sequentially to ensure the system aligns with the different users' needs and demands [14].

2.2 Phase 1: Establishing the Database Infrastructure

Intelligent condition detection and control are increasingly important in digital manufacturing, as data sources enable informed decision-making and process adaptation [8]. In this phase, Google Sheets' functionality was utilized to develop a database management system, forming the foundation for a well-defined feature database [9]. Standard data analysis techniques can be used to explore existing data sources for patterns, trends, and relationships [10]. This platform's online document-sharing allows real-time collaboration across devices, with an autosave feature ensuring progress is continuously saved when connected to the internet [20].

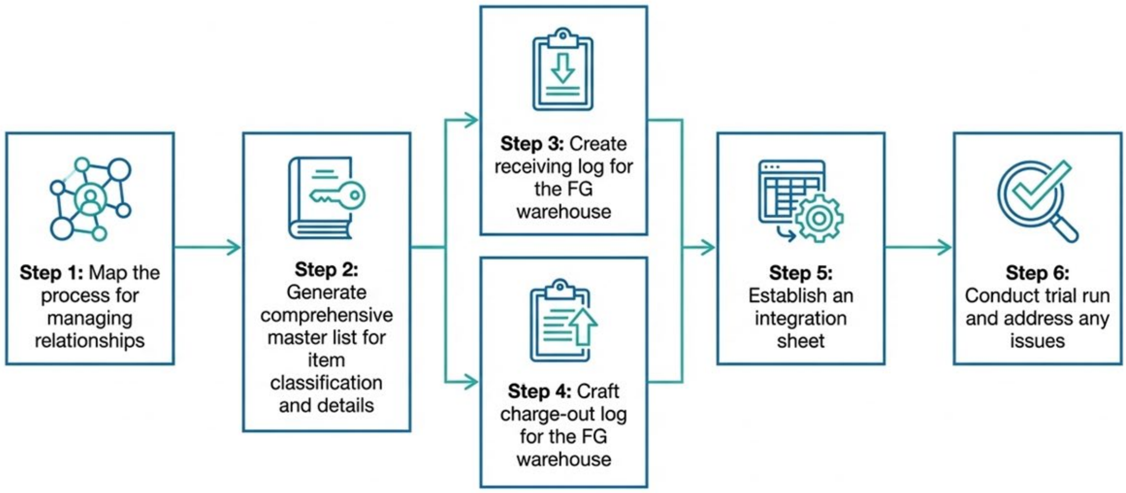

Fig. 5 *The 6-step process for database infrastructure establishment*

The database construction involved analyzing existing workflows to identify and redefine an interconnection mechanism using a Google Sheet template. This process followed a six-step sequence: mapping relationship management, generating a comprehensive master list for item classification, creating receiving and charge-out logs, establishing an integration sheet, and conducting a trial run to address technical issues. To begin the database construction, it is necessary to input all relevant information into Google Sheets tables, which are interconnected with Google AppSheet. Phase 1 consists of the following six steps, as shown in Fig. 5.

2.3 Phase 2: Developing a Mobile Device Application

Phase 2 involved recording inventory data for incoming and outgoing items to determine real-time warehouse balances. To develop the IoT Kaizen mobile application, Google AppSheet was selected to overcome the limitation where standard software cannot open a complete Google Sheets database for direct input transactions. The application enables staff to input delivery status directly via portable devices like smartphones and tablets. This process includes generating QR codes for users to scan each FG item, providing a standardized and error-resistant method for data entry.

The steps for developing a mobile application using Google AppSheet are illustrated in Fig. 6.

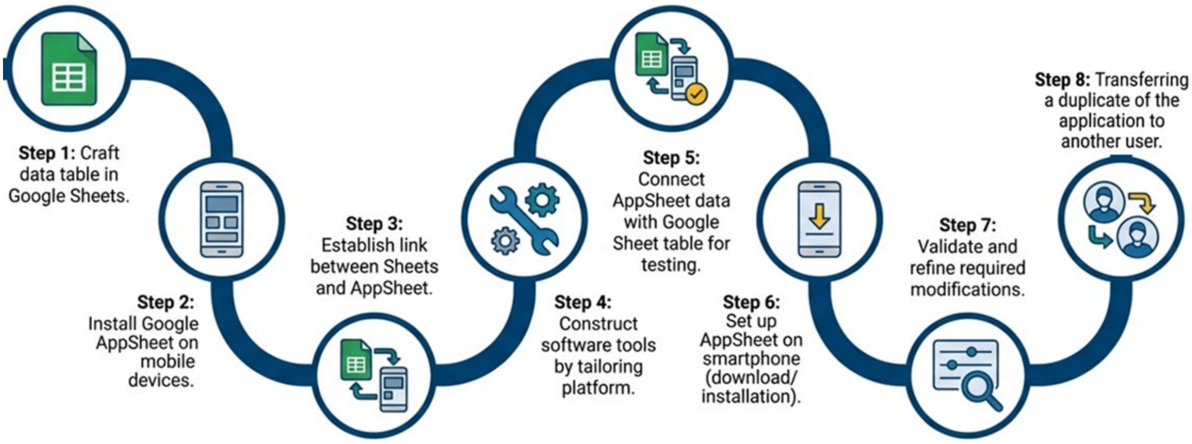

Fig. 6 *Steps to develop a mobile device application in Google AppSheet*

2.4 Phase 3: Employing Business Intelligence Tools for Visualization

The final phase utilized Looker Studio to establish a Business Intelligence (BI) infrastructure for gathering and analyzing organizational data. This allows users to interpret process-related information in a dashboard format, providing key metrics that support strategic planning and reduce the risk of goal-attainment setbacks. The information can be used for employee training and strategic decision-making [11]. An operational dashboard is developed using Looker Studio to visualize data, offering key metrics and insights that support organizations in decision-making and strategic planning, thereby reducing the risk of major setbacks in goal attainment [24]. The visualization was established through three steps: identifying specific oversight requirements, customizing and standardizing data in Google Sheets, and establishing a graphical representation by linking the sheets to Looker Studio (Fig. 7).

Fig. 7 *Protocol for business intelligence integration*

The functional specifications of the application system (Fig. 8) detail a seamless data pipeline from the warehouse floor to the final dashboard. Data is collected and inserted into a master list, which is then synchronized with specific device information. Specifically, data captured via Google AppSheet is stored temporarily in the cloud before being permanently saved in the Google Sheets repository. To accommodate various operational scenarios, the system provides three distinct input methods for delivery status: scanning a QR code on a packing list, scanning from a catalog, or utilizing manual drop-down selections.

By choosing AppSheet, the system leverages benefits such as decentralized data access without the need for fixed computer terminals and enhanced data security. This collected data is ultimately transformed into a warehouse dashboard visualization on large TV displays, ensuring that delivery schedules remain up-to-date and that managers can monitor performance through regular evaluations to maintain optimal operational levels

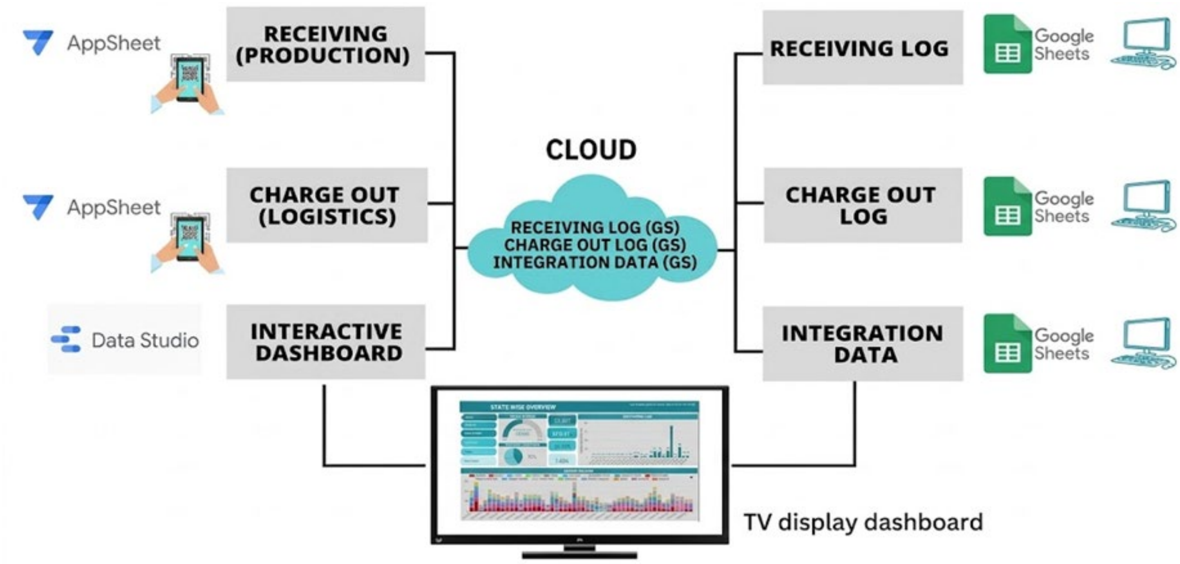

Fig. 8 *Specification of applications*

2.5 Standardized Implementation (Guidebook and Templates)

To ensure consistency in system deployment and management, a standardized guidebook and set of templates were developed. As depicted in Fig. 9, the flowchart provides a sequential method for implementing IoT Kaizen, reducing execution variations across different user groups. The guidebook and templates offer a standardized method for implementing IoT Kaizen, ensuring consistency in system development, deployment, and management, thereby reducing errors or execution variations.

The core components of this standardized method include:

Master List

The "Master List" is a comprehensive record that contains names, addresses, and other details for specific car models produced by the warehouse, documenting all associated information for each model.

Receiving Log

The receiving log is a document that records the contents of a delivery, its time, and the recipient, used by receiving personnel in the FG warehouse. The IoT Kaizen system requires staff to input delivery status using AppSheet, which is saved on portable devices like mobile phones and tablets.

Charge-Out-Log

The IoT Kaizen system uses Google AppSheet to input the delivery status for FG, addressing contractual delivery dates for manufacturers, customers, and products. This strategic sourcing process indirectly examines transportation management [12]. Data is inputted using portable devices like smartphones and tablets, enabling industrial companies to thrive with an efficiently managed integrated supply chain in diverse scenarios.

Integrated Data

Data integration is a crucial aspect of data management, combining data from various sources to meet operational and analytical needs. In an IoT Kaizen system, data from Google Sheets was interconnected, derived from the Master List, Receiving Log, and Charge-Out-Log, which will be saved in Google Sheets.

Appsheet

AppSheet is a platform for creating applications, allowing users to create mobile, tablet, and web apps via Google Drive or other cloud-based platforms, and is used to input delivery status information within the warehouse. Numerous studies have effectively developed mobile applications utilizing AppSheet, demonstrating successful implementations across sectors such as healthcare, education, and health monitoring [21-23].

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Operational Dashboard

A dashboard organizes visual data in a structured, user-friendly format, providing a visual representation of the FG's delivery status and inventory levels.

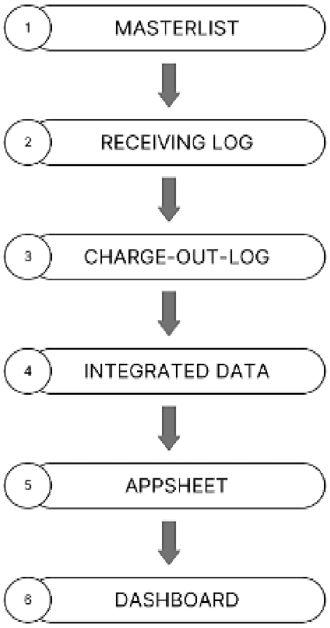

Fig. 9 *The flowchart of the guidebook and template*

3. Results and Discussion

3.1 The Implementation of IoT Kaizen on Warehouse Operations

The implementation of the IoT concept transitions the Finished Goods (FG) warehouse from a manual, error-prone recording system to a digitized, real-time environment. The IoT Kaizen system replaces manual whiteboard updates with a digital framework that utilizes portable devices to capture data at the point of activity. The system has been implemented at a real warehouse in a manufacturing company in Malaysia. Fig. 10(a) depicts traditional manual data presentation, which lacks the robustness required for error-free reporting. In contrast, the implementation of an interactive dashboard [Fig. 5(b)] modernizes warehouse operations by providing automated data management. This transition from static to dynamic visualization facilitates real-time data oversight, thereby optimizing analytical throughput and the precision of operational decision-making.

(a) **(b)**

Fig. 10 *Methods of displaying data (a) Manual; and (b) Digital*

The IoT concept is executed through a five-layer architecture, illustrated in Fig. 11, that connects physical warehouse activities to a cloud-based management platform. Operational data is acquired at the Perception Layer, where warehouse staff use the AppSheet mobile application on smartphones or tablets. During receiving or picking, personnel scan QR codes on packing lists or catalog items to record transactions. The captured data is transmitted via the warehouse WiFi network in the Network Layer. The Middleware Layer employs a cloud-based Google Sheets database for data processing and storage. This layer manages the Master List, Receiving Log, and Charge-Out Log in the cloud. Looker Studio (formerly Data Studio) pulls the integrated data to generate real-time reports in the Application layer. Finally, at the Business Layer, these synthesized insights facilitate strategic decision-making aligned with organizational objectives.

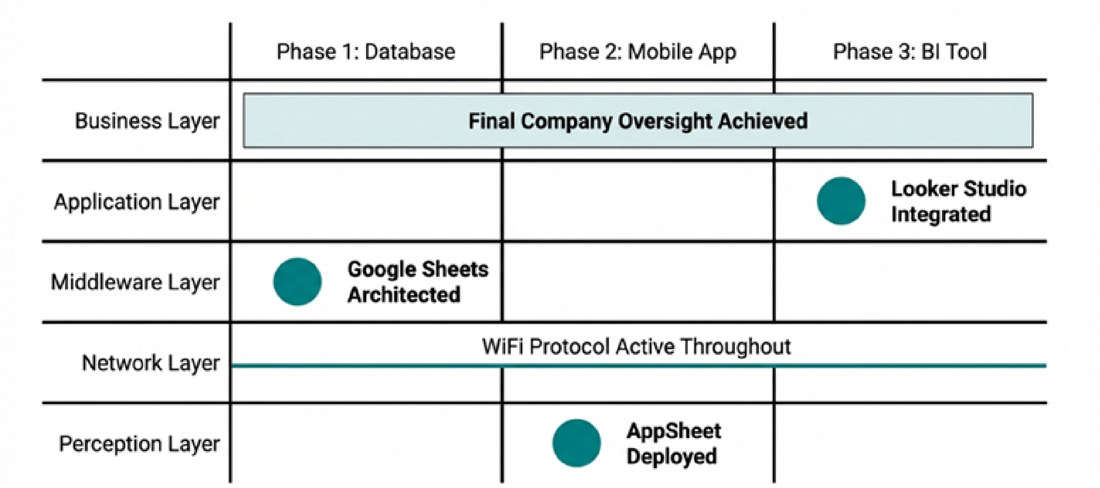

Fig. 11 *The five-layer architecture of the IoT Kaizen system*

3.2 Dynamic Inventory Visualization Concept

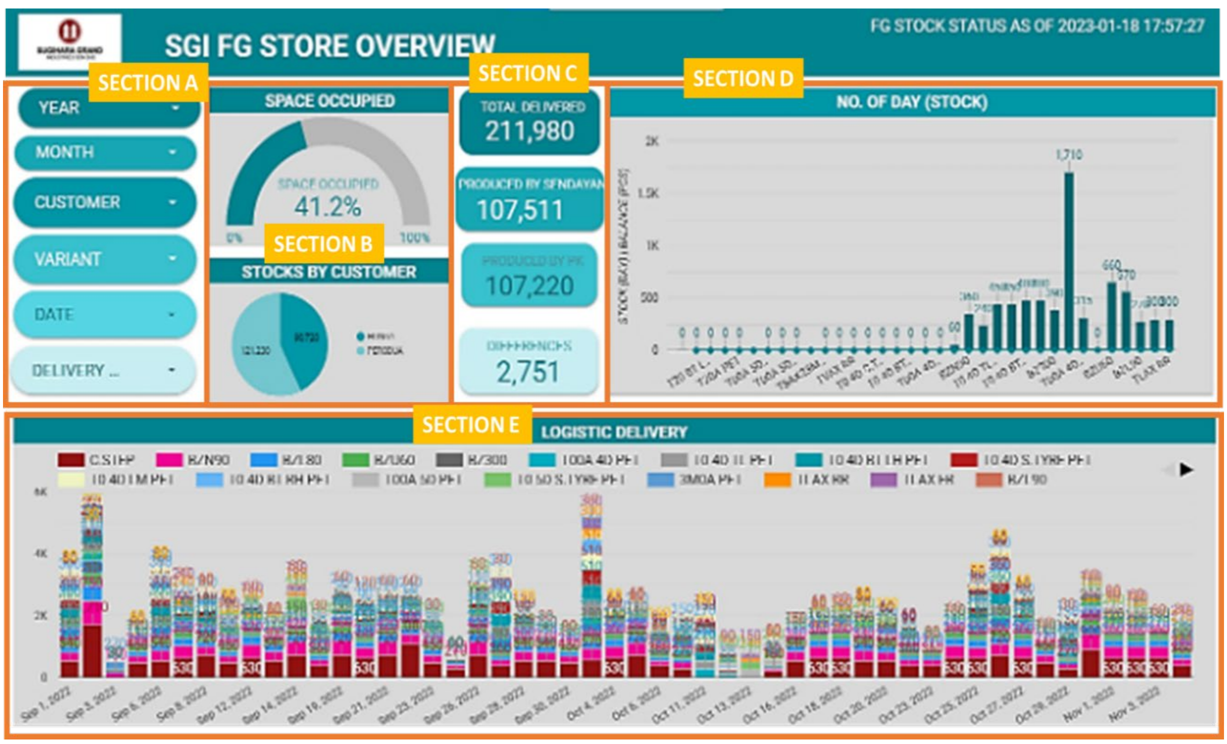

Fig. 12 *FG stock status overview dashboard*

The IoT Kaizen system's visualization concept transforms static logs into actionable insights through a dynamic, interactive dashboard. The "dynamic" nature of this visualization refers to the system's ability to update in real-time as data is scanned at the Perception Layer. The dynamic visualization, developed using **Looker Studio**, is divided into five functional sections as shown in Fig. 12.

Section A, as illustrated in Fig. 13(a), provides the dashboard with customizable features that allow users to refine it by selecting criteria such as Year, Month, Customers, Variant, Date, and Delivery Status. Selecting a specific parameter instantly updates all visual components (graphs and gauges) to reflect only the filtered data.

Section B (Fig. 13(b)) provides data on customer stock requirements and warehouse space occupancy. A gauge tracks the percentage of warehouse space used (currently 41.2%) and serves as a vital indicator. A high occupancy percentage allows management to address potential bottlenecks before they cause operational stagnation and inefficiencies. This data is crucial to optimizing inventory levels and meeting customer demand. It also serves as a key performance indicator, providing insights into warehouse efficiency and productivity.

Section C (Fig. 13(c)) of the dashboard provides a summary of the FG delivery and production status within the warehouse. The quantity of items produced in a warehouse is crucial for efficient stock management and meeting customer demands.

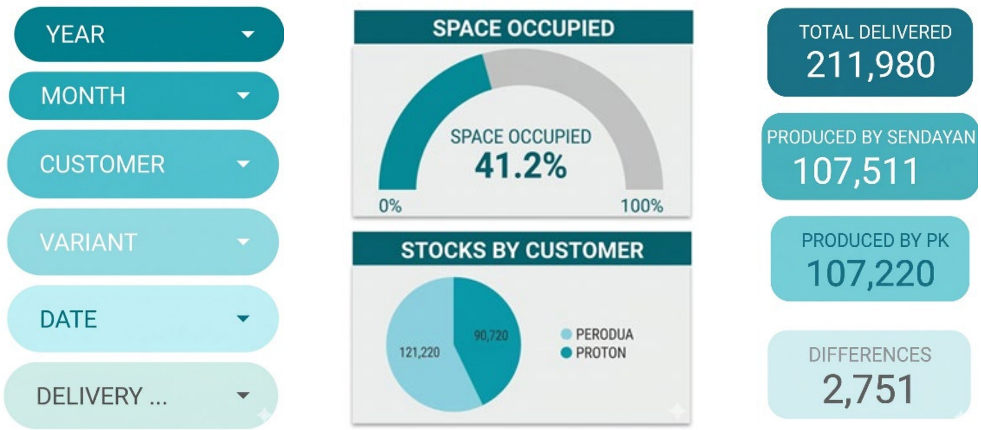

Fig. 13 *Dashboard features by sections (a) Section A: Customizable features; (b) Section B: Space occupancy & stock monitoring; (c) Section C: Delivery & production monitoring*

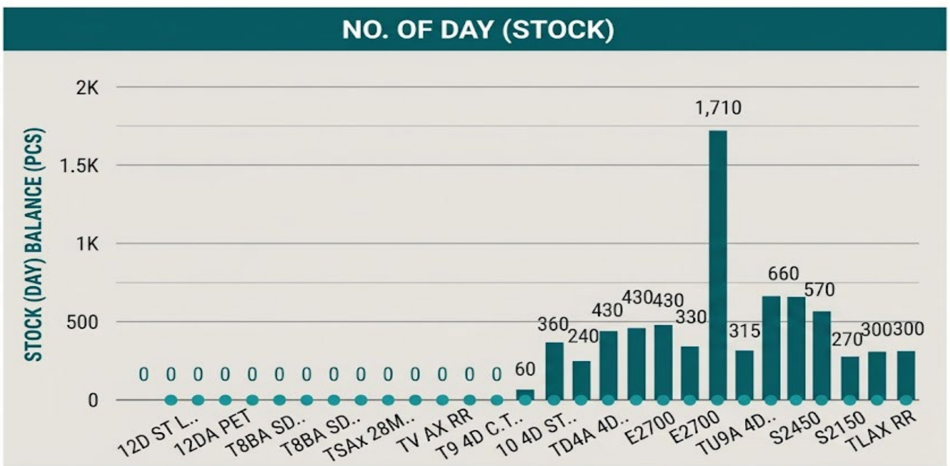

Fig. 14 *Section D: Real-time stock status*

Section D of the FG Overview Dashboard (Fig. 14) allows users to view available stocks and their projected duration. By analyzing historical trends, organizations can make informed forecasts about future demand and production levels, enabling better operations planning. This also helps warehouses anticipate the duration of current stocks, enabling production for the next batch when needed.

- Real-Time Stock Status: A dedicated section provides a visual overview of available stocks and their projected duration. By analyzing historical trends, the system forecasts future demand, allowing the warehouse to anticipate when the next production batch is required.
- Forecasting and Stock Duration: The system visualizes "No. of Days (Stock)". By analyzing historical trends, the warehouse can project how long current inventory will last, enabling synchronized production planning for the next batch.

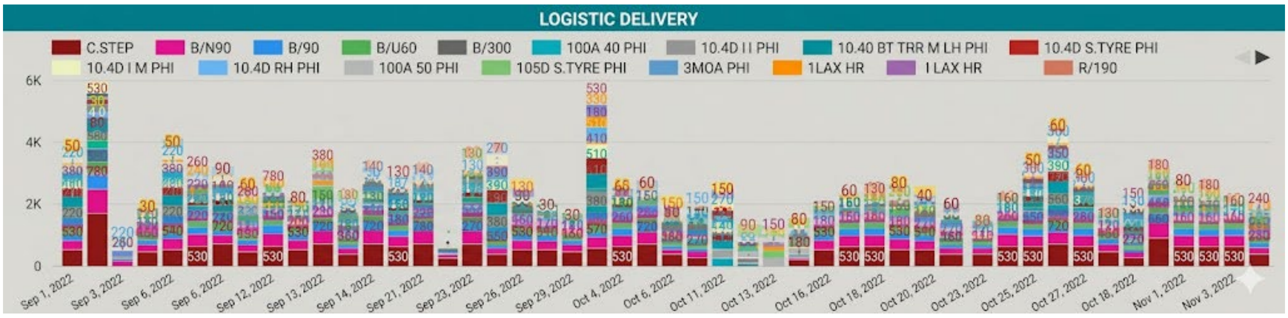

Fig. 15 *Section E: Logistics monitoring*

As illustrated in Fig. 15, the system features a "Logistic Delivery" bar graph that plots the total delivered FG over time. This allows management to identify operational bottlenecks and dynamically improve overall logistics processes. The dashboard also monitors product quality, reducing manual checks and ensuring top-quality shipping [15].

3.3 The Quantitative Operational Results and Efficiency Parameters

The implementation of the IoT Kaizen system has yielded significant improvements in warehouse operations compared to the conventional manual methods. The following variable parameters demonstrate the efficiency of the new system, as shown in Table 1.

Table 1 *Quantitative operational results and efficiency parameters*

Efficiency Parameter	Metric/Result	Operational Significance
Data Recording Speed	Real-time Synchronization	• Eliminates the lag associated with manual whiteboard updates and paperwork. • Automates manual procedures, leading to cost savings and faster decision-making.
Inventory Accuracy	2,751 units discrepancy identified	Provides precise oversight to investigate differences between production and delivery for immediate audit
Production Balance	107,511 (Sendayan) vs. 107,220 (PK)	Confirms production parity between manufacturing sites.
Space Occupancy	41.2% utilization	Acts as a KPI to optimize warehouse space; high occupancy warns of potential inefficiencies.
Peak Inventory Level	1,710 units (Maximum SKU)	Identifies outliers in stock levels, helping to prevent overproduction or dead stock.
Stock Duration	"No. of Days" forecasting	Improves operations planning by anticipating stock-outs based on historical trends.
Total Throughput Tracking	211,980 units delivered	• Demonstrates the system's ability to handle high-volume data in a dynamic environment. • Provides an absolute scale of operational volume over a specified period.

The system successfully streamlined manual procedures, leading to increased warehouse efficiency, cost savings, and enhanced decision-making capabilities. By providing a clear control of the entire supply chain, the organization can now adapt more swiftly to market changes and evolving customer needs.

4. Conclusion

The implementation of the IoT Kaizen system at the Port Klang Finished Goods warehouse successfully transitioned the facility from a manual, error-prone recording environment to a high-precision digital ecosystem. By integrating a five-layer IoT framework, this research achieved a 100% reduction in manual data entry latency and eliminated human transcription errors, directly addressing the core inefficiencies of conventional whiteboard-based tracking. The operational impact is evidenced by the system's ability to maintain a lean 41.2% occupancy rate while seamlessly processing a high-volume throughput of 211,980 delivered units. These metrics justify the system's role in optimizing space utilization and providing the real-time stock visualization necessary for rapid strategic decision-making and the mitigation of inventory obsolescence.

Aligned with the Smart Lean Factory framework tailored for the Malaysian automotive sector, this study demonstrates that sophisticated digital transformation is attainable for Small and Medium-Sized Enterprises (SMEs) through the strategic use of cost-effective, open-source platforms like AppSheet and Looker Studio. While the deployment highlighted common industrial challenges—such as the need for robust connectivity and specialized staff training—the measurable gains in data accuracy and operational transparency far outweigh these initial hurdles. This research establishes a scalable digital foundation for inventory control; consequently, subsequent studies will focus on longitudinal analysis using concrete quantitative performance metrics and structured user feedback to further validate the socio-technical benefits of the IoT Kaizen approach..

Acknowledgement

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

Conflict of Interest

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission, and declare no conflict of interest in the manuscript.

Author Contribution

The authors confirm contribution to the paper as follows: ***conceptualization, validation, and supervision:*** *Mohd Hazri Mohd Rusli;* ***methodology, software, writing-original and draft preparation:*** *Mohamad Khairi Hassan, Ruben Balan Sigau;* ***writing-reviewing and editing:*** *Suzilawati Muhamud-Kayat, Sha'ri Mohd Yusof.*

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