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Design of a Custom Tool Storage Rack Based on 5S Principles

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Abstract

The practice of 5S (Sort, Set in Order, Shine, Standardize, Sustain) improves productivity, but tool storage in machining workshops remains inefficient due to large tool inventories and limited space, leading to misplaced tools, inconsistent storage practices, and retrieval delays, where adding storage alone does not solve monitoring gaps. This project aims to design a 5S-based custom tool storage rack for a machining workshop in Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh branch campus, enhanced with quick response (QR) code tracking for tool identification and Google Teachable Machine (GTM) AI image recognition for placement verification. A three-dimensional (3D) of computer aided design (CAD) model was developed using SolidWorks, focusing on labeled compartments and standardized placement zones. The audits of 5S showed full compliance for Sort, Set in Order, Shine, and Standardize, while Sustain was partial due to user adherence. The QR improved traceability and reduced loss, and GTM achieved high accuracy in detecting tool presence and correct placement under controlled conditions. Findings confirm that the principles of 5S, integrated with QR and AI enhances workshop tool management efficiency.

1. Introduction

Machining workshops in universities are shared technical workspaces that require clear organization and control. A clean and structured workshop improves task efficiency, safety, and tool and machine lifespan. Poor storage leads to delays, misplaced tools, longer handling time, and higher risk of accidents. The 5S method (Sort, Set in Order, Shine, Standardize, Sustain) transforms disorganized storage into a neat, labeled, and visual system, supporting safer workflow and better tool management [1,3]. In addition, the integration of 5S with quick response (QR) code-based tracking system and image-based artificial intelligence (AI) improve tool traceability, placement accuracy, and user compliance with systematic storage procedures [2,4].

Observations at a machining technology workshop in Universiti Tun Hussein Onn Malaysia (UTHM), Pagoh branch campus, revealed that the existing tool storage system is inadequate, leading to frequent misplacement, unclear storage locations, and inconsistent storage practices. To address these issues, this study proposes a custom-designed tool storage rack that integrates 5S principle with a QR code-based tracking system and image-based AI verification using Google Teachable Machine (GTM).

This study is guided by the following question: (1) what are the issues related to tool storage and retrieval in relation to 5S practices in the machining workshop? and (2) how can a conceptual three dimensional (3D) model of the custom tool storage rack, designed using SolidWorks and integrating 5S principles with QR and GTM-based AI, improve tool traceability and placement accuracy?

2. Methodology

This section describes a systematic methodology used in this study, providing a comprehensive explanation of the research methods. The methodology encompasses the research design, which outlines the approach and structure of the study. This is followed by a description of the data collection and analysis methods, including the tools and processes involved in gathering and analysing the data.

2.1 Research Design

This study adopted a semi-quantitative research design to gather primary data. The research design combined observational data and interview findings to address the research objectives. These insights, which included both numerical and descriptive information, guided the engineering design approach for a custom-designed storage rack.

2.2 Data Collection and Analysis Methods

Specifically, Genba observations and semi-structured interviews were employed for data collection. The observations followed a 5S audit checklist adapted from a previous study [2]. Semi-structured interviews were conducted in two phases: (1) a preliminary interview to identify current storage issues and user requirements; and (2) a design validation interview to evaluate the proposed custom tool storage rack. Both interview sessions were guided by interview protocol questions (IPQ) validated by two expert panel members to ensure consistency and reliability.

The data gathered through observations were analysed using descriptive statistics, in terms of numerical counts or frequencies. Meanwhile, data obtained through interview sessions from workshop users, which consists of two students, two instructors, and two assistant engineers, were analysed using descriptive statistics by means of a scoring method, focusing on frequencies and mean scores. Table 1 summarizes the data collection and analysis methods.

Table 1 *Data collection and analysis methods*

Research Study Phases	Research Design Approaches	Data Collection Methods	Data Analysis Methods
Identification of storage issues	Semi-quantitative	▪ Validated interview protocol questions (IPQ) by expert panels ▪ Semi-structured interviews with workshop users ▪ Genba observation using 5S audit checklist	▪ Expert validation using a 3-point scale ▪ Numerical counts or frequencies, and mean score ▪ Descriptive analysis of 5S audit results
Design of tool storage rack	Engineering design	Literature review and user feedback on CAD model	Synthesis of user feedback and literature

3. Results and Discussion

This section presents the findings of the research study and discusses their implications. The discussion focuses on key issues related to tool storage, retrieval, tracking, and AI verification in the existing system, the proposed custom tool storage rack design, and the integration of 5S, QR, and GTM-based AI into the design.

3.1 Tool Storage, Retrieval, Tracking, and AI Verification Issues in the Existing System

There are three categories of tools (hand tools, cutting tools, and measuring tools), comprising seven types of tools, including 30 files, 30 mallets, and 19 calipers, which are placed in the storage rack. Based on Genba observations, several issues were identified in the tool storage rack that affected its effectiveness. Lack of segregation (Sort) led to different tools and accessories being stored together, causing clutter. Undefined locations and missing labels (Set in Order) resulted in inconsistent placement and time-consuming retrieval. Poor housekeeping (Shine), such as dust accumulation, indicated irregular maintenance. Missing visual management elements (Standardize) caused confusion and misuse, while the absence of documented procedures (Sustain) revealed a lack of systematic long-term monitoring.

In addition, tracking system issues were caused by the lack of standardized procedures and visual management, making it difficult to monitor tool usage and location. Poor labeling and the absence of a systematic tracking method led to retrieval delays and inventory uncertainty, indicating the need for a digital or automated system for real-time monitoring and accurate records. Table 2 summarizes the issues of tool storage, retrieval, and digital system identified through observation, reflecting the 5S principles.

Table 2 *Existing issues of tool storage, retrieval, and digital system identified through observation*

Category	Issues Identified	Impact
Sort (Seiri)	Absence of proper segregation; tools and work holding accessories stored together	Increased clutter and operational inefficiency
Set in Order (Seiton)	Lack of defined locations and labeling for tools on the storage rack	Inconsistent placement and time-consuming retrieval
Shine (Seiso)	Poor housekeeping practices, specifically dust accumulation on cabinet racks	Lack of regular maintenance and equipment care
Standardize (Seiketsu)	Missing labels, unclear identification, and lack of visual management	Frequent confusion and misuse of tools
Sustain (Shitsuke)	Absence of documented storage procedures and systematic monitoring	Lack of consistency and failure to drive long-term improvement
QR	No digital tagging or QR code system for tool identification and tracking	Slow manual search/retrieval and lack of real-time inventory data
AI	Lack of intelligent data collection or predictive usage analytics	Inability to optimize stock levels or predict maintenance cycles

Meanwhile, the data collected through preliminary interview were analysed using mean score analysis based on a 5-point Likert scale, where 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree. Based on the interview findings, respondents generally agreed that the existing tool storage was not effectively managed in relation to 5S with the overall mean score of 3.70 obtained. Users reported difficulties in locating and returning items due to the absence of clear labels and fixed locations. These issues indicate weak implementation of the Sort and Set in Order principles, as items were frequently misplaced and mixed.

In terms of QR-based tracking, most respondents with the overall mean score of 4.32, highlighted the lack of a digital system to record borrowing and return activities. The absence of tracking made it difficult to identify missing items, leading to poor accountability. Regarding AI-based verification, respondents indicated that there was no mechanism to automatically verify correct placement of items within the modular storage compartments. The overall mean score recorded was 4.50. Users relied entirely on manual checking, which was often overlooked during busy sessions.

3.2 Proposed Design of Custom Tool Storage Rack

Based on the results of the Genba observations and preliminary interview, a conceptual design of a custom modular tool storage rack was developed to solve the problem of disorganized tools in the machining workshop. The design process followed the 5S principles, focusing on proper arrangement, visual control, and standardization to improve tool visibility, ease of access, and user compliance. The main stages of the design included defining design objectives, generating possible solutions, and selecting the most suitable option. Engineering factors such as size planning, efficient use of space, and ergonomic access were considered to ensure the design is practical and suitable for the workshop environment.

In specific, the design was developed to demonstrate both the physical layout and functional integration of a smart tool management system. The rack features a modular, multi-compartment design, with each tool assigned to a clearly defined storage slot (20 slots and four cabinets). The uniform arrangement of compartments supports systematic organization, ensuring consistent tool placement and enhancing both visibility and accessibility during workshop operations. Integrated internal lighting further improves visibility within each compartment, contributing to safer and more efficient tool handling. The design also integrates a QR code-based tracking system mounted on the side panel of the rack, serving as a log-in and log-out mechanism to record tool usage and user identification in a digital inventory system.

Additionally, a GTM-based AI is incorporated via a mounted display, providing live camera feedback for tool recognition and user verification. This enables real-time updates to the digital inventory database. As illustrated in Fig. 1, the combination of physical storage with digital tracking and AI verification demonstrates the proposed design's capability to enhance tool organization, monitoring, and inventory control within the workshop environment.

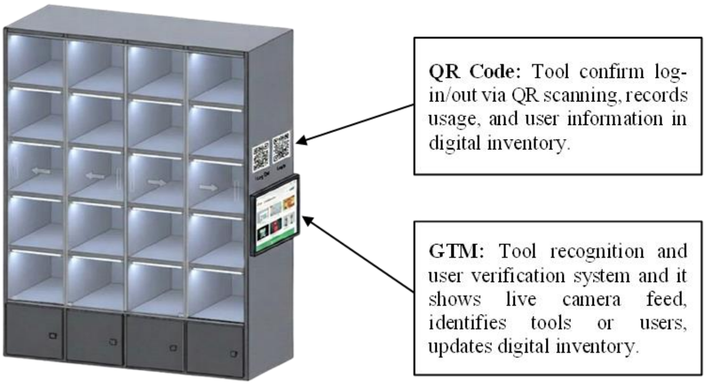

Fig. 1 *Custom-designed tool storage rack*

3.3 Small-Scale Implementation of 5S Practices

The small-scale implementation of 5S practices was evaluated using design-related indicators that represent each 5S principle as item B1 – B5 and were assessed through observation of the existing tool storage rack. The results were quantified using a key performance indicator (KPI)-based approach and are summarized in Table 3, which presents the implementation status and percentage for each 5S principle. The Sort, Set-in-Order, Shine, and Standardize principles were fully implemented at 100% due to effective storage compartments, labeling, organization, and uniform workflow. The Sustain principle reached 80% implementation, as some users did not fully adhere during the short trial period. Overall, the tool storage rack effectively supports the adoption of 5S practices on a small-scale implementation.

Table 3 *Small-scale implementation of 5S practices*

Item No	5S Principle	Implementation Status	Implementation (%)
B1	Sort	Achieved	100%: Unmixing all three categories of tools
B2	Set-in-Order	Achieved	100%: Labeled all seven types of tools
B3	Shine	Achieved	100%: Reduced dust on all 20 slots of storage rack
B4	Standardize	Achieved	100%: Door opening direction for all cabinets
B5	Sustain	Partially Achieved	80%: 15 of 19 calipers returned in assigned location

3.4 Small-Scale Implementation of QR Code Tracking

As described in Table 4, the QR code system (C1 – C4) fully implemented the Sort, Set-in-Order, Shine, and Standardize principles, supporting tool identification, organized placement, individual handling, and consistent tracking. The Sustain principle (C5) reached 80%, with minor bypasses during busy periods. Overall, the system provides a reliable digital platform for managing tools in the workshop.

Table 4 *Small-scale implementation of QR code-based tool tracking*

Item No	5S Principle	Implementation Status	Implementation (%)
C1	Sort	Achieved	100%: All 20 of 20 slots linked to QR
C2	Set-in-Order	Achieved	100%: All 20 of 20 slots linked to QR
C3	Shine	Achieved	100%: All 20 of 20 slots linked to QR
C4	Standardize	Achieved	100%: All 20 of 20 slots linked to QR
C5	Sustain	Partially Achieved	80%: 16 out of 20 scan trials were successful

3.5 Small-Scale Implementation of GTM-based AI Verification

A small-scale GTM-based AI system was implemented to verify caliper placement. As shown in Fig. 2, the model was trained using 20 images per class, captured under varying angles and lighting to improve recognition. GTM automatically extracted visual features and completed training without complex programming, making it practical for small-scale use. The system successfully identified the presence of the calliper with a confidence level of 100%, indicating that the model can clearly distinguish between the presence and absence of the tool.

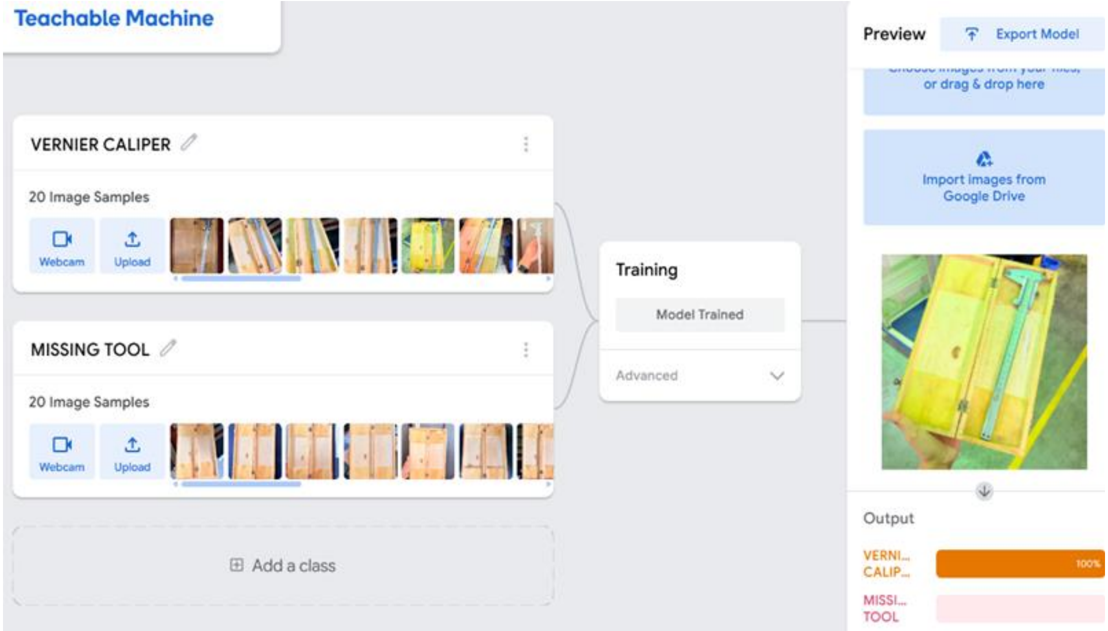

Fig. 2 *Image classification for caliper detection using GTM-based AI*

In addition, the GTM AI-based tool verification system (D1 – D4) achieved 100% effectiveness in verifying the presence, placement, and condition of all 19 calipers during small-scale implementation as summarized in Table 5. This high accuracy was supported by a controlled environment, consistent lighting, fixed camera positioning, and a single well-trained tool category. Nonetheless, the Sustain principle (D5) was partially achieved due to user adherence.

Table 5 *Small-scale implementation of GTM-based AI verification*

Item No	Evaluation Criteria	5S Principle	Total Item	Correctly Verified	Implementation (%)
DI	AI detects whether the caliper is stored or missing	Sort	19	19	100%
D2	AI verifies caliper is placed in assigned compartment	Set in Order	19	19	100%
D3	AI verifies neat and organized placement of caliper	Shine	19	19	100%
D4	AI provides consistent verification of tool storage accuracy	Standardize	19	19	100%
D5	AI supports user discipline by reducing missing tool cases	Sustain	19	15	80%

3.6 Perceived Integration of 5S Principles in the Design

As presented in Table 6, all principles of 5S received high mean scores (4.33 – 4.67) from six respondents of design validation interview, indicating strong agreement that the proposed custom tool storage rack effectively supports 5S implementation. The Sort principle scored highly, suggesting that respondents agreed the compartmentalized storage prevents the mixing of different tools. Similarly, the Set in Order principle had a high mean value, reflecting that the organized arrangement and labeling system facilitate tool identification and retrieval. The Shine principle also scored consistently high, indicating that the design promotes cleanliness and enables visual inspection of the workspace. Furthermore, the principles of Standardize and Sustain were strongly supported, demonstrating that uniform storage methods and workflow are consistently applied across the system. These results collectively highlight the effectiveness of the proposed design in aligning with 5S principles and improving overall workshop organization.

Table 6 *Mean score of perceived 5S integration in the design*

Item No	Questions	Respondent						
		1	2	3	4	5	6	Mean
B1	The design supports Seiri (Sort) principle by preventing mixing of different items	5	5	5	4	4	4	4.50
B2	The design supports Seiton (Set in Order) principle with a clear labeling and proper arrangement	5	5	5	4	4	5	4.67
B3	The design supports Seiso (Shine) principle by making cleaning and inspection easier	5	5	4	4	4	4	4.33
B4	The design supports Seiketsu (Standardize) through consistent storage method and flow	5	5	5	4	4	4	4.50
B5	The design supports Shitsuke (Sustain) through consistent tracking system and continuous improvement	5	5	5	4	4	4	4.50

3.7 Perceived Integration of QR Code in the Design

The mean scores for the QR code-based tool tracking system were generally above 4.30 as depicted in Table 7, indicating that respondents perceived the system as useful and effective. Participants agreed that the QR system supports the Sort principles by helping to prevent misplaced or unrecorded tools and facilitates the Set in Order by enabling proper tool retrieval and return to designated locations. The system also promotes careful handling of tools (Shine) and provides a uniform method for tracking (Standardize and Sustain).

Table 7 *Mean score of perceived QR code integration in the design*

Item No	Questions	Respondent						
		1	2	3	4	5	6	Mean
C1	QR system helps identify and eliminate misplaced or unrecorded tools	5	4	4	4	4	5	4.33
C2	QR labels make it easier to locate, borrow, and return the tools in the correct location	5	4	5	4	4	5	4.50
C3	QR scanning encourages proper handling, reducing dirt and damage	5	4	4	5	4	5	4.33
C4	QR code system creates a uniform method for storing and tracking the tools	5	4	5	5	4	5	4.50
C5	QR tracking system promotes consistent compliance with storage rules	5	4	4	5	4	5	4.50

3.8 Perceived Integration of GTM-Based AI in the Design

The mean analysis of the GTM AI-based tool verification system, presented in Table 8, shows mean scores ranging from 3.83 to 4.33, indicating moderate to high agreement among respondents regarding the system's effectiveness. Respondents acknowledged that the AI system can detect whether tools are stored correctly or missing (Sort), ensure proper placement within assigned compartments (Set in Order), verify neat and accurate tool arrangement (Shine), consistently confirm storage accuracy (Standardize), and supports long-term user discipline (Sustain).

Table 8 *Mean score of perceived GTM-based AI integration in the design*

Item No	Questions	Respondent						
		1	2	3	4	5	6	Mean
C1	AI can detect whether the correct tools are stored or missing	5	4	5	4	3	5	4.33
C2	AI helps ensure the tools are placed in the assigned compartments	5	4	5	4	3	5	4.33
C3	AI encourages clean and organized storage areas by verifying neat placement	5	4	4	4	3	3	4.33
C4	AI provides a consistent method to verify tools storage accuracy	5	4	5	5	4	3	3.83
C5	AI supports long-term user discipline and reduces storage violations	5	4	4	4	5	4	4.33

4. Conclusion

This research study aimed to design an improved tool storage rack based on 5S principles, integrating a QR code tracking system and a GTM-based AI tool for image recognition. Genba observations using a 5S audit checklist, along with user interviews, revealed disorganized tool storage in the machining workshop, highlighting gaps in both QR-based tracking and GTM AI verification. To address these issues, a 3D CAD conceptual tool storage rack was developed in SolidWorks, incorporating 5S practices, digital tracking, and AI verification. The resulting design provides a well-organized, user-friendly system that assigns each tool a designated location for easy access and maintenance, reflecting user feedback and achieving the research objectives. Nonetheless, continuous evaluation, active user involvement, and adherence to systematic organization remain essential to sustain long-term improvements in workshop tool storage and retrieval.

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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:** Nur Hazirah Esmayatim, Rahim Jamian; **data collection:** Nur Hazirah Esmayatim; **analysis and interpretation of results:** Nur Hazirah Esmayatim, Rahim Jamian; **draft manuscript preparation:** Nur Hazirah Esmayatim, Rahim Jamian. All authors reviewed the results and approved the final version of the manuscript.

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