

Shadow Core Development to Reduce Hidden Waste in Operator Tool Management in the Manufacturing Industry

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Abstract

In the Industry 4.0 era, reducing hidden waste is a major challenge to improve operational efficiency in the manufacturing industry. This research is an innovation of "Shadow Core" that integrates the concept of shadow board and toolbox with a cluster-based grouping system. Shadow Core is designed to overcome the weaknesses of conventional methods in operator tool management which often cause wasted tool search time and machine downtime. Through a Research and Development (R&D) approach with a 3D model (Define, Design, Development), the Shadow Core prototype was tested in an industrial environment for one month. The results showed a significant increase in efficiency with a decrease in tool search time per case by up to 90% and total search time per day by 75%. The application of Shadow Core has proven to be an effective solution to eliminate hidden waste, increase operational productivity, and contribute to the development of a more efficient tool management system in the manufacturing sector.

Keywords: Development, Shadow Core, Hidden Waste.

1. PENDAHULUAN

In the Industry 4.0 era, technological and information developments have opened up opportunities for various new innovations that are driving increasingly fierce competition between industries [1]. Every industry is competing to increase its competitiveness by optimizing work efficiency, one of which is by minimizing hidden waste[2]. Hidden waste in the context of the manufacturing industry includes not only wasted space and raw materials, but also wasted work time, such as time wasted when workers have to search for necessary tools, which cumulatively reduces production process efficiency and increases machine downtime [3]. This condition, especially in operator tool management, often becomes a weak point that is not directly visible but has a significant impact on overall productivity [4].

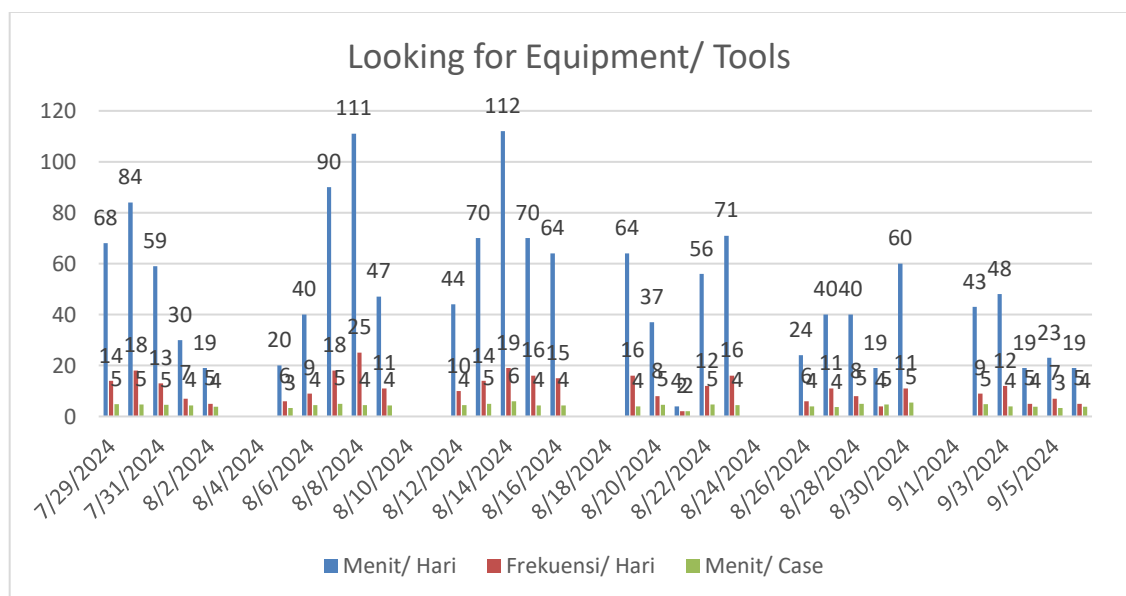


Figure 1. Graph Before Shadow Core Implementation

Observations revealed that the tool management system still relies on a single central toolbox for a single machine consisting of 25 units. Under these conditions, the tools stored in the toolbox are collected without systematic grouping, requiring operators to spend additional time finding the necessary tools [5]. Long search times, tool queues, and delays in machine repairs are the main causes of hidden waste [6]. This concept aligns with lean manufacturing principles, which emphasize the importance of identifying and eliminating all activities that do not add value to the final product [7]. Furthermore, it emphasizes that hidden activities in the production process require a systematic approach to optimize the process and increase overall added value [8]. Real-world conditions in the industry demonstrate the long time spent searching for equipment/tools, as shown in Figure 1.

Efforts to address this issue have sparked innovation in the development of a new tool, the shadow core. This innovation is the result of integrating a shadow board, known for its effectiveness in mapping required tools and facilitating operator retrieval, with a toolbox that offers superior mobility. The shadow core is expected to address the weaknesses of each tool, thereby reducing search time and increasing the speed of machine repairs [9]. Therefore, implementing the shadow core innovation is an appropriate strategy for reducing hidden waste and improving overall operational efficiency [10].

The desired output of this research is to eliminate hidden waste so that the work and operational processes can run smoothly without disrupting the performance of the machine or operator. By integrating shadow core innovation into the operator tool management system, it is expected that the time wasted in searching for tools can be minimized, so that the repair and production process can take place continuously [11]. The contribution of this research is an effort to fill the existing gap in operator tool management in the manufacturing industry, which has resulted in operational inefficiencies and financial losses [12].

2. METODE PENELITIAN

This study uses a Research and Development (R&D) approach with a 3D model, which consists of the Define, Design, and Development stages [13].

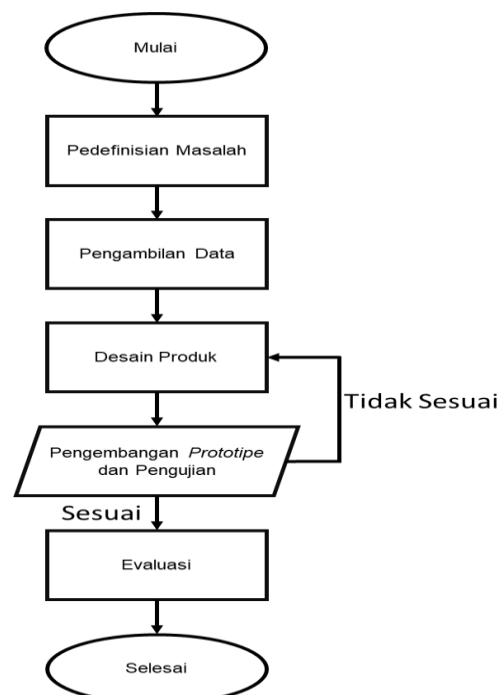


Figure 2. Research Flowchart

2.1 Define Phase

In the Define phase, researchers defined existing problems by identifying operational needs and constraints at the Converting 1B industrial site. Observations were conducted directly for 30 days using direct field observations covering four main aspects, namely tool retrieval time, tool arrangement, toolbox location, and tool storage [14]. The observation results showed that operators often experienced difficulties in finding and retrieving tools due to unsystematic arrangement and less strategic toolbox locations, which resulted in long search times and decreased work efficiency. The research object included two main components, namely the shadow board and

the toolbox [15]. The shadow board, although effective in mapping the required tools and facilitating retrieval, has limited mobility and requires a considerable amount of space [16]. On the other hand, the toolbox has the advantage of mobility but tends to mix up tools, thus hindering the process of finding the right tool [17].

Design Phase

In the Design phase, researchers developed a product design template in the form of a technical specification document that included dimensions, working mechanisms, grouping systems, and how the Shadow Core innovation works. This document served as a guideline for creating a prototype designed to integrate the advantages of the Shadow Board and Toolbox through the application of a grouping system (Schuhmacher en Hummel 2019)

Machine units in a cluster. Figure 3 shows the cluster division at PT. XYZ

Cluster 1							
Nama Unit	1	2	3	4	5	6	7
	Unwind	Paper Guide	Printing	Perforasi	Slitter	Folding	Cross Cutter
Tooling Setiap Cluster	Kunci L: 3-4-6-8-10-14						
	KUNCI PAS: 10-13-14-17-18-19-24, KUNCI PAS RING: 19-24						
	Tang Kombinasi, Obeng, Palu Karet, Snapping, Drip, Kunci Cross Cutter						

Cluster 2			
Nama Unit	8	9	10
	Over-Lapping	Collecting	Cross Angle
Tooling Setiap Cluster	KUNCI L: 3-4-5-6-8		
	KUNCI PAS: 10-13-19, KUNCI PAS RING: 32		
	Palu Karet		

Cluster 3						
Nama Unit	11	12	13	14	15	16
	Feeder 1	Feeder 2	Rotary	Separator Cover	Lem Punggung	Heater
Tooling Setiap Cluster	KUNSI L: 3-4-5-6-8					
	KUNCI PAS: 10-13-17, KUNCI PAS RING: 19					
	Tang Kombinasi, Obeng					

Cluster 4			
Nama Unit	17	18	19
	Long Belt	Back Tape	Code Stamp
Tooling Setiap Cluster	KUNCI L: 3-6-8-10		
	KUNCI PAS: 10-17		
	Obeng		

Cluster 5						
Nama Unit	20	21	22	23	24	25
	Trans-norm	Drying Belt	Aligner	Tail Cutting	Trimmer	Delivery
Tooling Setiap Cluster	KUNCI L: 3-6-8-10					
	KUNCI PAS: 10-13-17-19					
	Palu Karet					

Figure 3. Cluster Division in Shadow Core

The implementation of this system aims to identify the effectiveness of Shadow Core in reducing hidden waste. Figure 4 shows the design of the shadow core.

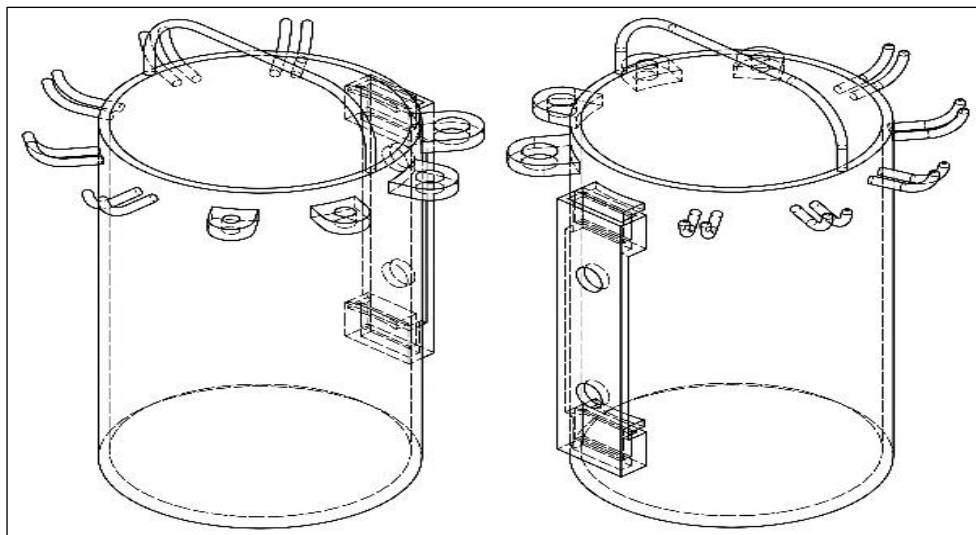


Figure 4. Shadow Core Design

2.3 Development Phase

Next, in the Development phase, a shadow core prototype was developed and tested using a trial instrument. The testing was conducted using quantitative measurements, such as comparing machine repair times before and after product implementation, as well as a questionnaire response to gather feedback from operators regarding the

ease of use and effectiveness of the tool grouping system. Data obtained from the trial was then analyzed in depth to evaluate the extent to which the product was able to reduce hidden waste and improve operational performance [18]. This research was conducted over six months, from June to December, with the aim of producing an innovative solution that not only optimizes operator tool management but also significantly contributes to increasing operational efficiency in the manufacturing industry [19].

3. RESULT AND DISCUSSION

Initial Observation Results

A 30-day observation period revealed issues in operator tool management, particularly regarding the efficient use of the central toolbox and shadow board. Based on observations, the average time required to search for a tool reached 5 minutes per search. The relatively high frequency of tool searches, at 11 times, further emphasizes that the central toolbox is unable to efficiently support operational needs. The graph in Figure 5 shows the equipment or tool search process before the implementation of the Shadow Core innovation [20].

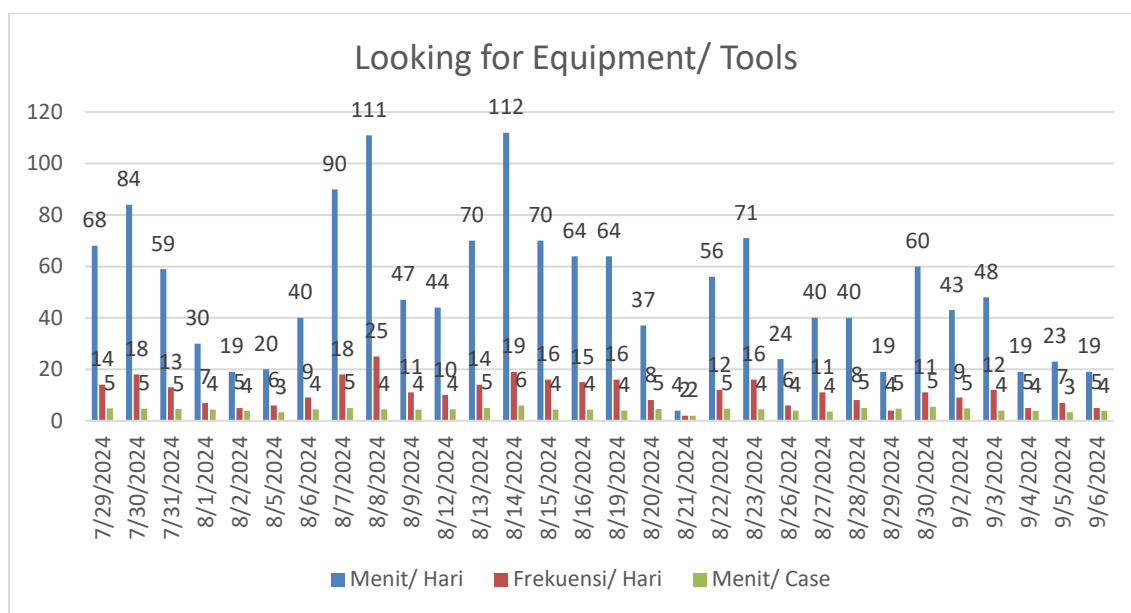


Figure 5. Graph before Shadow Core Implementation

Hidden sources of waste in the operator equipment management system were also identified. This hidden waste is caused by several factors, including [21].

1. Intensive use of tools but not supported by a neat storage system by the operator.
2. The limited number of tools, with only one tool available for each specific size for use by 25 machines, causes delays in repairs when the same tool is needed by multiple machines simultaneously. For example, when an L8 wrench is used by unit 1, unit 7 must wait until repairs in unit 1 are completed before it can use the tool. This situation often causes machines to run at slower speeds or even stop, thus disrupting operational productivity.
3. Operators lack awareness of how to organize and return tools to their proper storage locations. This is exacerbated by the location of the toolbox and central shadow board, which are too far from easy access. As a result, tools are often left around the machine unit, potentially causing them to be lost and requiring additional operator time to search for them elsewhere.

Further analysis revealed that the operator tool management system, which uses a central toolbox and shadow board, has numerous shortcomings. This system is not only difficult to access quickly but also does not provide sufficient tools to support operational needs. Furthermore, operators' lack of discipline in tidying up tools after use exacerbates the situation, leading to a decrease in overall work efficiency.

3.2 Shadow Core Prototype Design and Construction

The Shadow Core design and prototyping process began with determining technical specifications based on the needs of the manufacturing industry. Shadow Core was designed to address challenges encountered in conventional tool management systems, particularly inefficient central toolboxes and shadow boards. Shadow

Core's primary components consist of two parts: the tool tray and the tool tray holder, both of which are constructed from steel to ensure strength and durability in demanding work environments.

The Shadow Core container measures 150 mm high, 90 mm in diameter, and 3 mm thick, constructed from steel pipe. Hooks are located around the container, allowing for proper tool placement, depending on the machine's location. These hooks are customized to meet the needs of each cluster, simplifying tool management and accessibility. The top of the container features an ergonomic handle measuring 3 mm in diameter, 90 mm in length, 31.5 mm in height, and a 21.5 mm curved radius to facilitate operator movement of the Shadow Core [22].

The rear of the container is equipped with two additional hooks that allow the container to be attached to the tool holder. The tool holder has dimensions of 112 mm in length, 25 mm in width, and 10 mm in height. At each end of the tool holder there is a block with a central hole designed to ensure stability when mounted on the machine using a 10 mm diameter bolt [23]. The position of this hole is located in the middle of the tool holder with a distance between the holes of 52 mm. Figure 6 shows the design blueprint of the shadow core.

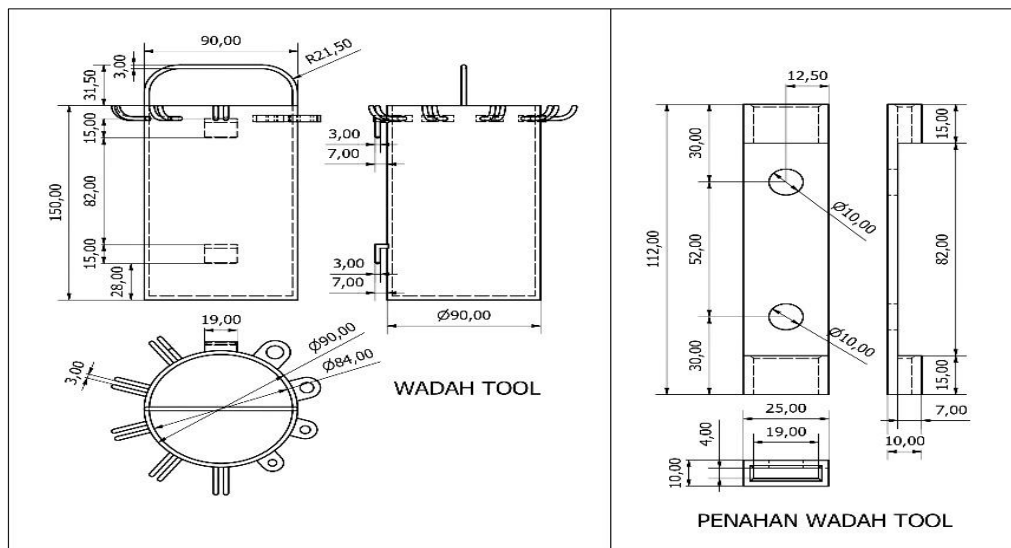


Figure 6. Shadow Core Design

The tool grouping mechanism in Shadow Core is designed based on the operational needs of each cluster. Each cluster is grouped based on its function, the type of tool required, and the level of difficulty of each machine unit. This grouping allows operators to more easily access the required tools, reducing search time and increasing work efficiency. Figure 7 shows the actual use of Shadow Core [24].

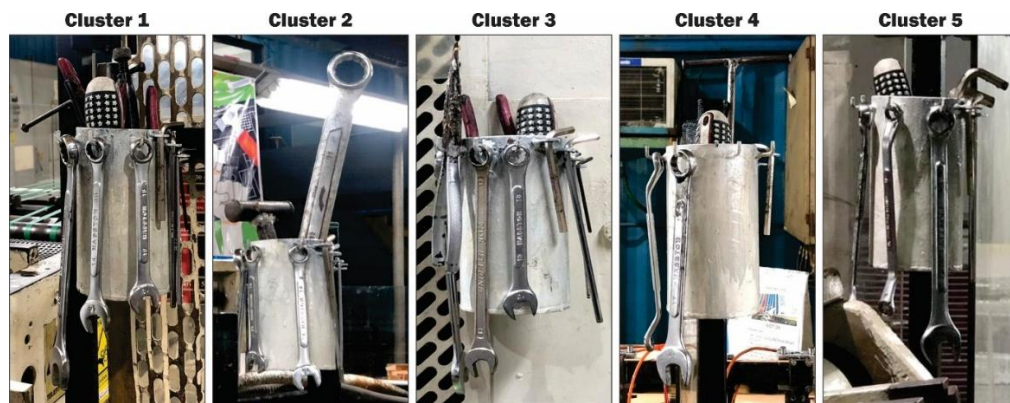


Figure 7. Shadow Core Cluster Grouping

The integration of the shadow board and toolbox is one of Shadow Core's key innovations. Shadow Core combines the tool mapping functionality of the shadow board with the high mobility offered by the toolbox. This innovation ensures that tools are not only neatly organized but also easily moved to the machine unit location where they are needed [25].

Shadow Core operates with a grouping system based on predetermined clusters. In a single machine consisting of 25 units, tools are grouped into five clusters, each consisting of three to six units. Each Shadow Core

has been designed to meet the tool needs of a specific cluster and is managed by a single operator in each cluster [26]. Operators can easily retrieve tools, either by lifting the Shadow Core or directly retrieving the required tool without having to manually search in the central toolbox. This system allows for faster, more efficient, and more organized tool management compared to conventional methods. Figure 8 shows the layout of the Shadow Core placement.

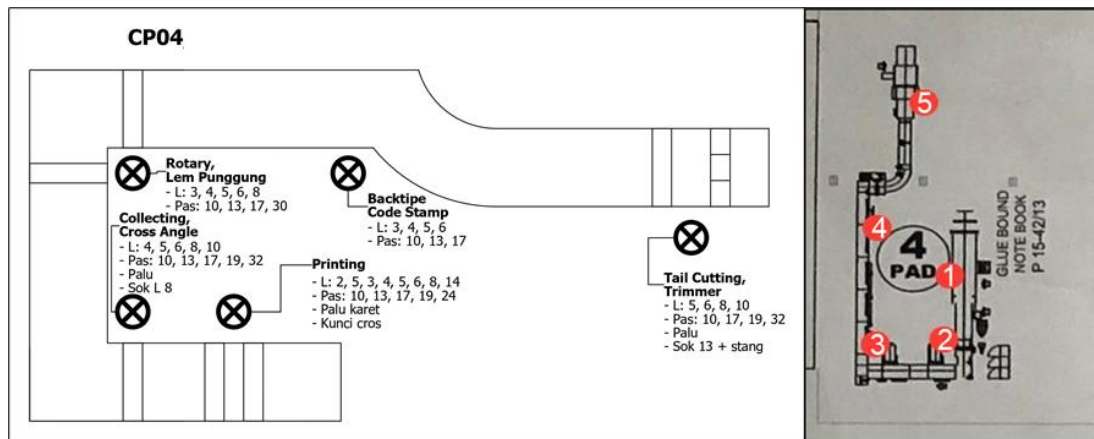


Figure 8. Shadow Core Layout

In conventional systems that use a central toolbox and shadow board, operators often face delays due to having to search for tools in locations far from the machine units. Furthermore, the limited number of tools exacerbates the situation, especially when the same tool is needed by multiple machine units within a short time. With the implementation of Shadow Core, all of these shortcomings can be overcome. Grouping tools based on clusters and increasing tool accessibility allows operators to work more efficiently without experiencing obstacles due to a suboptimal tool management system [22].

Trial Results

After the use of shadow cores, the reduction in searching for equipment/tools decreased by up to 90%. This reduction can occur due to the new system for tool placement, which makes tools easy to reach and eliminates waiting time because each operator has their own shadow core divided into their respective clusters, as illustrated in the graph below.

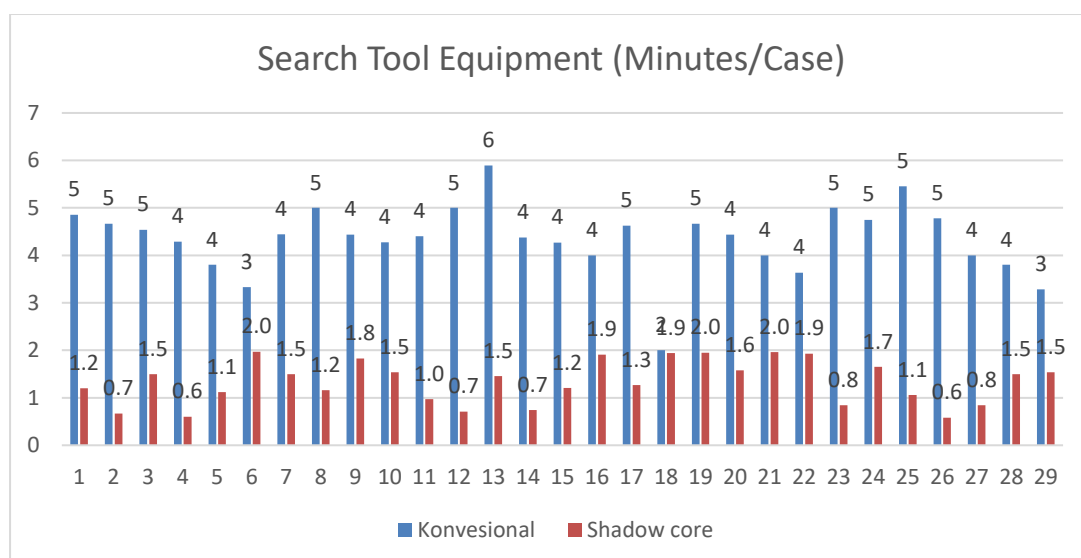


Figure 9. Comparison Chart of Time to Search for Equipment/Tools

The results of the comparison of implementation using conventional tools and Shadow core can be seen in the image below.

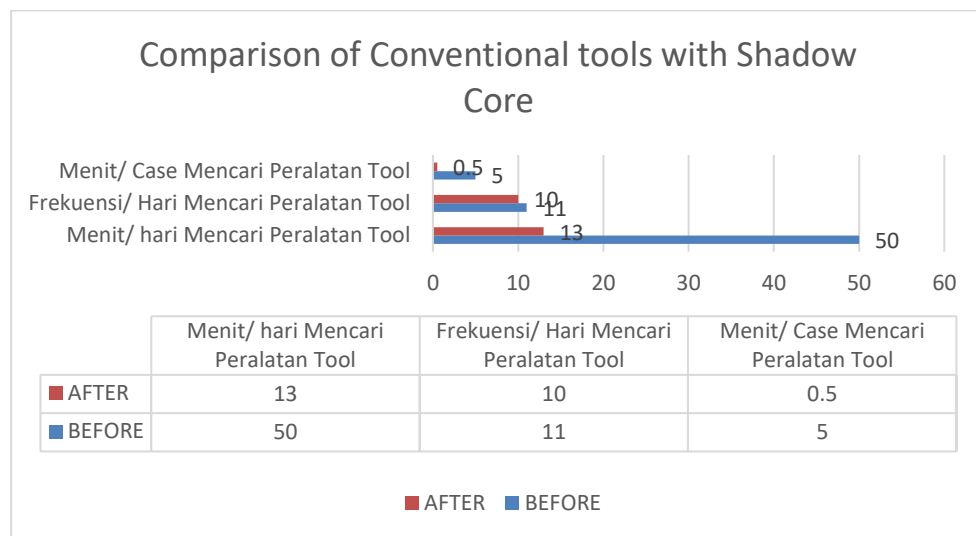


Figure 10. Comparison of Conventional Tool Implementation with Shadow Core

The implementation of Shadow Core demonstrated significant efficiency improvements in the equipment search process. Quantitatively, the equipment search time per case dropped dramatically from 5 minutes to just 0.5 minutes, representing a 90% increase in efficiency. Furthermore, while the daily search frequency was relatively small, from 11 to 10 times, the total daily search time was also quite significant, from 50 minutes to 13 minutes, representing a 75% increase in efficiency. This conclusion indicates that the cluster-based grouping system and Shadow Core distribution within each operator directly reduces hidden waste by accelerating equipment access, thus supporting improved operational performance in the manufacturing industry [25].

4. CONCLUSION

This study shows that the implementation of Shadow Core innovation in operator tool management in the manufacturing industry provides significant improvements in operational efficiency. Based on the trial results, the use of Shadow Core successfully reduced search time per case from 5 minutes to 0.5 minutes (a 90% increase in efficiency), and reduced the total search time per day from 50 minutes to 13 minutes (a 75% increase in efficiency), despite a relatively small decrease in the frequency of searches per day (from 11 to 10 times). The advantages of the cluster-based grouping system implemented through Shadow Core allow each operator to gain direct access to the required tools without having to travel long distances as in conventional central toolbox and shadow board systems. This not only reduces hidden waste that has hampered productivity but also supports the smooth process of continuous improvement and production (Afaz *et al.* 2024).

Thus, the Shadow Core innovation has proven to be an effective solution for optimizing operator tool management, which in turn can improve operational efficiency and productivity in industrial manufacturing environments. The results of this research are expected to serve as a reference for the development of more efficient and applicable tool management systems in other industrial sectors.

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