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Impact of Cripple Part Storage Management System Improvement on the Overall Equipment Effectiveness in an Automotive Spare Part Manufacturing Company

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ABSTRACT

Improving productivity and performance is a continuous process in all manufacturing companies. Since a product fabrication process mostly consists of many production and work steps, there is always an opportunity for small improvement. If conducted consistently and continually, a series of small improvements can yield a considerable increase in overall productivity and performance. In this paper, the effort undertaken in an automotive spare part manufacturing company to reduce downtime due to the *dandori* process is presented. Dandori is the installation or setup required between the production of two different spare part types. The setup includes stocking in incomplete lots of products, or the cripple parts, of one type and stocking out the cripple parts of the other. The existing dandori process consisted of 12 steps and required 190.2 seconds. The development of a storage management system was proposed to reduce the downtime required to fill the production check sheets and to find the correct drawer in the storage room. The new dandori process consists of 19 steps and requires 140.4 seconds. The manual check sheet filling was replaced with QR code scanning and data input on a computer, while the manual finding of the correct drawer was assisted by the LED indicators. Production data for the duration 4 months before and 4 months after the improvement was analyzed. In return for the report automation, the availability rate of the process increases from 84.87% to 89.34%, and the overall equipment effectiveness (OEE) increases from 73.11% to 78.37%. The obvious increases encourage further continuous improvement cycle in the company.

Keywords: storage management system, downtime, *dandori*, report automation, overall equipment effectiveness (OEE).

ABSTRAK

Peningkatan produktivitas dan kinerja adalah proses berkelanjutan di semua perusahaan manufaktur. Proses fabrikasi produk yang sebagian besar terdiri dari banyak langkah produksi dan langkah kerja selalu memberikan peluang untuk melakukan perbaikan kecil. Jika dilakukan secara konsisten dan terus-menerus, serangkaian perbaikan kecil dapat menghasilkan peningkatan yang cukup besar dalam produktivitas dan kinerja secara keseluruhan. Dalam tulisan ini dikemukakan upaya yang dilakukan di perusahaan manufaktur suku cadang otomotif untuk mengurangi waktu henti (*downtime*) akibat proses pergantian (*dandori*). Dandori adalah instalasi atau pengaturan yang diperlukan diantara proses produksi dua jenis suku cadang yang berbeda. Pengaturan mencakup menyimpan lot produk yang tidak lengkap (*cripple part*) dari suatu jenis dan mengambil cripple part dari jenis yang lain. Proses dandori yang ada sebelumnya terdiri dari 12 langkah dan membutuhkan waktu 190,2 detik. Pengembangan sistem manajemen penyimpanan diajukan untuk mengurangi waktu henti yang diperlukan untuk mengisi lembar pemeriksaan produksi dan untuk menemukan laci yang benar di ruang penyimpanan. Proses dandori baru terdiri dari 19 langkah dan membutuhkan 140,4 detik. Pengisian lembar pemeriksaan manual diganti dengan pemindaian kode QR dan input data di komputer, sedangkan pencarian manual laci yang benar dibantu oleh indikator LED. Data produksi untuk durasi 4 bulan sebelum dan 4 bulan setelah perbaikan dianalisis. Berkat otomatisasi laporan, tingkat ketersediaan proses (*availability rate*) meningkat dari 84,87% menjadi 89,34%, dan efektivitas peralatan keseluruhan (OEE) meningkat dari 73,11% menjadi 78,37%. Peningkatan nyata yang didapat memberi motiviasi untuk pelaksanaan siklus perbaikan berkelanjutan selanjutnya di perusahaan.

Keywords: sistem manajemen penyimpanan, waktu henti, *dandori*, otomatisasi laporan, efektivitas peralatan keseluruhan (OEE).

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1. Introduction

The production process in an automotive spare part manufacturing company is often faced with unpredictable repeated orders. In practice, the produced quantity of the spare part units will be deliberately manufactured more than the ordered quantity. The excess quantity is categorized as *cripple parts (CPs)*, which must be stored until they can be used to fulfill the customer's eventual next order. CPs are actually fully functioning parts with the lot number to be completed in the upcoming production cycle. Having CPs of various types and numbers will reduce the time required to fulfill the customer's next order while increasing the production line efficiency since the downtime caused by the jig exchange can be reduced. However, CPs require a proper storage management system to quickly determine all CP types' existing quantity and storage location.

Every time a production cycle of a type is completed, a certain process called *dandori* ensues. The literal meaning of dandori is *installation* or *setup*. In this process, the mold unit of a certain part type at the manufacturing machine is replaced by one from another type. The time required in a *dandori* includes filling up the finished production record data, storing the current CPs, dismounting the current mold, mounting the new mold, and filling up the newly started production record data (Widagdo et al., 2005). Dandori time is a time loss that must be minimized by process improvements (Gani and Bendatu, 2015).

Figure 1 shows an example of CPs produced in an automotive spare part manufacturing company in Cikarang, Indonesia. Two CP types are presented; the larger type (1) was produced in 16 units per lot, while the smaller one in 20 units per lot.

Figure 1. Cripple part (CP) example

Figure 2 shows the procedure undertaken after a production cycle for a spare part type is completed. The operator (1) uses a trolley (2) to transport the CPs (3). The operator must first stop at the inspection point (4) to take and fill in the current production check sheet and the new one before he continues to bring the current CPs to the storage room (5). An example of check sheets is presented in Figure 3.

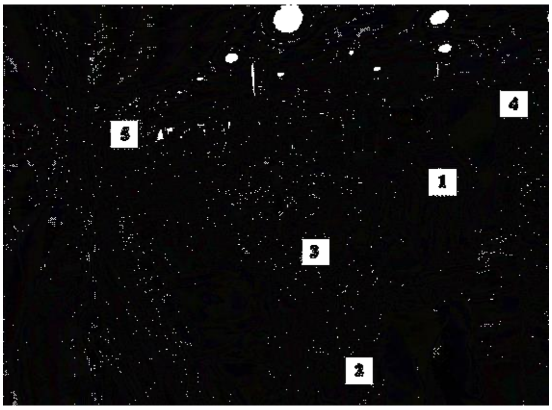
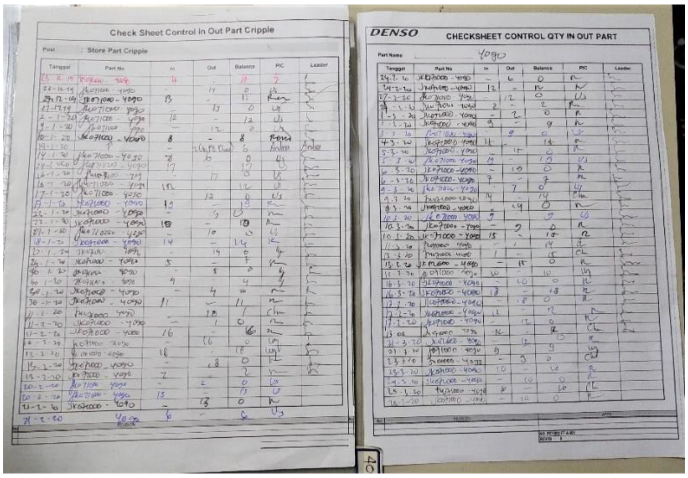


Figure 2. The CP handling after leaving the production machine.



Check Sheet Control In Out Part Cripple

Post : Store Part Cripple

DENSO CHECKSHEET CONTROL QTY IN OUT PART

Part Name Yogo

Tanggal	Part No	In	Out	Balance	PIC	Leader

Figure 3. Paper-based check sheet.

Figure 4 depicts the operator when he was writing the check sheet. The current CPs in a box are to be stored in the storage room. In the same course, the new CPs are taken from the storage room to the production machine (2). Then the production machine may start producing a new part type.

Figure 4. CP handling in the inspection point and the storage room.

For the next production cycle, the working program and the jig of the production machine are to be configured first. The configuration process includes adjusting the new mold and setting the machine parameters, which causes an unavoidable downtime to the production line. The reduction of this downtime will be the objective of this research.

Furthermore, the pre-existing *dandori* process in the company becomes time-consuming due to several factors. The CP storage room is approximately 45 meters from production lines 1 and 3, as shown in the simplified floor plan of the production area in Figure 5. Besides, the storage racks have many drawers due to the various types of spare parts manufactured by the company. The production check sheet was also written in paper-based forms, prone to errors in writing the type numbers, type quantity, and drawer location. Since the drawer may be used interchangeably by different types due to the limited space, in some cases, the drawers must be opened one by one to find the wanted CPs due to inaccurate documentation.

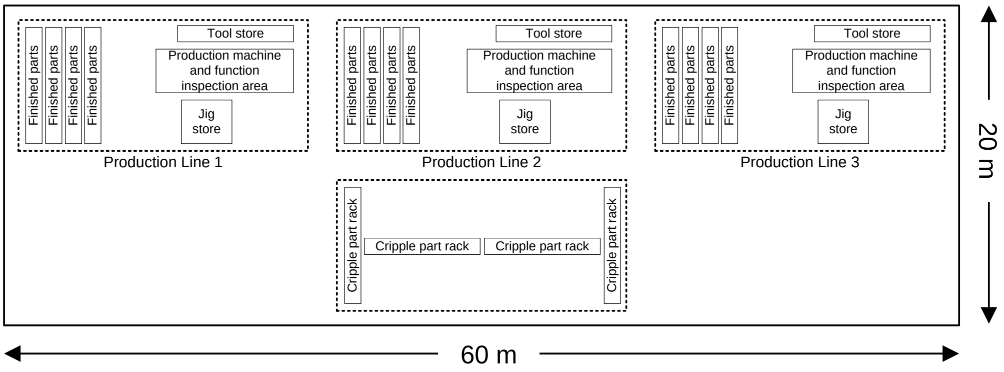


Figure 5. Simplified floor plan of the production area.

The current *dandori* process requires a time of 190.2 seconds. Furthermore, according to the head supervisor of the production line, the dandori time can even be longer for an inexperienced operator. In this paper, the allocated time is sought to be reduced to increase the effectiveness of the production process. This paper proposed a report automation approach to solve CP storage management problems faced in a manufacturing company by providing a structured information system and visual indicator aid. The paper-based check sheet is to be replaced by a digital form. Then, the storage system is modified so that the operator can easily locate the position of a certain CP type by using light-emitting diodes (LEDs) as electronic indicators. The paperless production record data will save the operator's work time and office supplies. Furthermore, the dandori time is desired to be reduced so that the production and work efficiency can be improved for the whole production process.

The improvement result is to be measured and verified by using the Overall Equipment Effectiveness (OEE) method. OEE measures a manufacturing process's performance compared to its full potential based on time, material, and facility constraints (Davis, 1995). OEE has been used to optimize processes such as preventive maintenance (Lestari and Wulandari, 2023). Adaptations to OEE have broadened its implementation in relation to fuzzy inference (Moradizadeh and Mayorga, 2014) or the use of a partial variable (PQ rate) in the improvement of performance and quality of a rubber seal manufacturing process (Sitompul *et al.*, 2022). Arkadiusz and Aleksander (2017) reported that OEE could provide an indication of machines that generate disturbances in operation efficiency.

2. Methods

2.1 Overall Equipment Effectiveness (OEE)

The measurement of Overall Equipment Effectiveness (OEE) is one of the best practices in the manufacturing process.

A perfect OEE is obtained by acquiring perfect connected elements of *availability* (the manufacturing process runs without interruption), *performance* (the process runs at maximum speed or cycle time), and *quality* (the process runs without defects, *i.e.*, the process only produces good parts).

Figure 6 depicts an overview of the three OEE factors.

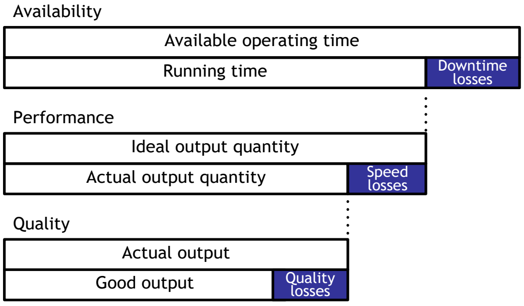


Figure 6. The three factors of Overall Equipment Effectiveness (OEE).

The factors are calculated according to the following formulas (Nakajima, 1988):

$$\text{Availability rate} = AR = \frac{\text{Running time}}{\text{Available operating time}} \times 100\% \tag{1}$$

$$\text{Performance rate} = PR = \frac{\text{Actual output quantity}}{\text{Ideal output quantity}} \times 100\% \tag{2}$$

$$\text{Quality rate} = QR = \frac{\text{Good output quantity}}{\text{Actual output quantity}} \times 100\% \tag{3}$$

The OEE is given as the multiplication of the three factors:

$$OEE = AR \times PR \times QR \times 100\% \tag{4}$$

Thus, it is clear from Equation (4) that the increase of any factors among AR, PR, or QR will increase the OEE.

For a production line with only one product, Equation (2) can be written as:

$$\text{Performance rate} = PR = \frac{\text{Ideal cycle time}}{\text{Actual cycle time}} \times 100\% \tag{5}$$

Equation (5) can be modified for a production line with multiple types of products to give:

$$\text{Performance rate} = PR = \frac{\text{Ideal running time}}{\text{Actual running time}} \times 100\% \tag{6}$$

The ideal running time is the sum of the product of each ideal cycle time and each actual output quantity. Equation (6) can be given as:

$$\text{Performance rate} = PR = \frac{\sum_i (\text{Output quantity})_i (\text{Ideal cycle time})_i}{\text{Actual running time}} \times 100\% \tag{7}$$

The value of OEE is used to determine the value of production performance (Krachangchan and Thawesaengskulthai, 2018). The OEE between 40% to 60% is usually obtained by new companies. This value can be improved by finding the root causes of downtime and then solving them. A value between 60% and 85% represents a value within normal limits for companies with discrete manufacturing, with individual production of different goods or separate units. A discrete manufacturing company must obtain an OEE value of at least 85% to survive world-level business competition (Wibowo, 2019).

2.2 Proposed Improvement

2.2.1 Development of Information System with Microsoft Visual Basic

The first improvement suggested by the authors is the use of a computer and a database program to replace the manual writing of production check sheets. The software to be used in developing the database is Microsoft Visual Basic 6.0. Visual Basic offers a visual integrated development environment (IDE) for making Windows-based applications (Craig and Webb, 1998).

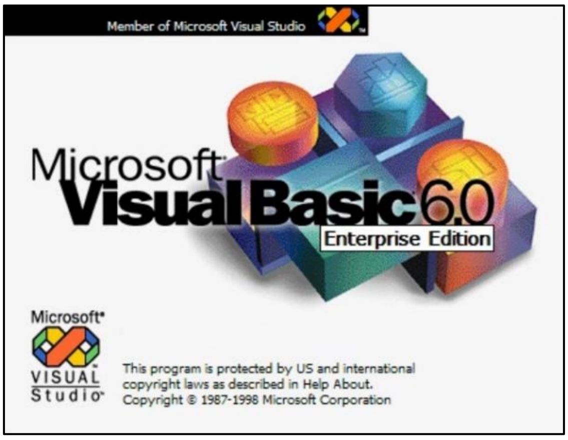


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Figure 7. MS Visual Basic software.

To minimize the human error of inserting data manually, a *kanban* (production command card) system is developed. A *kanban* card containing a quick response (QR) code is assigned to every part type. After a production cycle in a production machine is finished, the operator now fills up the trolley and brings it to the storage room. At this stage, the further steps that the operator must do are shown in Figure 8.

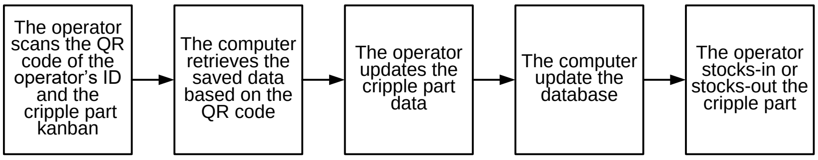


Figure 8. The process flow of updating the database of the information system.

In this process of generating a production report, it is enough for the operator to scan the QR code to open the database program. Furthermore, the accurate data of CP type will be automatically transferred to the computer. The computer will open the corresponding menu where the operator can update or enter the data of the current CP quantity. Then, the operator is required to input the quantity of the current CPs. The computer program will update the database. The operator can now move the CPs to the storage room.

The same procedure is to be done if the operator wants to continue the work with a new type. The *kanban* of the new type is to be scanned, and then the quantity of the existing CPs from the previous production is shown on the computer display.

2.2.2 Installation of LED Indicators

To help the operator find the correct location to store or collect the CPs, the authors proposed the installation of LED indicators above each drawer. This process is explained in Figure 9. The actuator used to connect the computer and the LED actuators is chosen to be a programmable logic controller (PLC) Omron CJ2M, as shown in Figure 10. A PLC is actually a control device with a power supply, mini central processing unit (CPU), memory unit, and a certain number of inputs and outputs (Subagio *et al*, 2016). One unit of such a PLC is expandable to serve 40 input/output units.

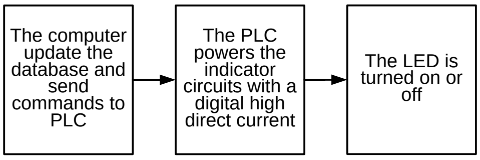


Figure 9. Process flow of LED indicator.

Corresponding data of the drawer assigned to store the CPs is transmitted from the PC to the PLC. Then, the PLC can send the digital signal to the respective LED indicator circuit. Installing the LED indicators is expected to significantly ease the search of the designated CP drawer since the operator can now only focus on finding the flashing LED.

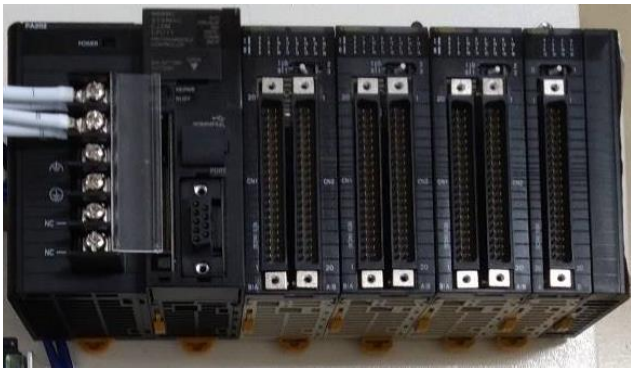


Figure 10. The PLC Omron CJ2M

2.2.3 Complete Block Diagram of The Proposed System

The block diagram of the proposed system is shown in Figure 11. The blue lines indicate the flow of information, while the red lines depict the flow of electric power. The external power supply unit converts the alternating current (AC) to the direct current (DC) according to the requirement of the PLC and the LED indicator circuit. The information system program of Visual Basic communicates directly to the PLC. Then the PLC will turn on or turn off the corresponding LED indicator.

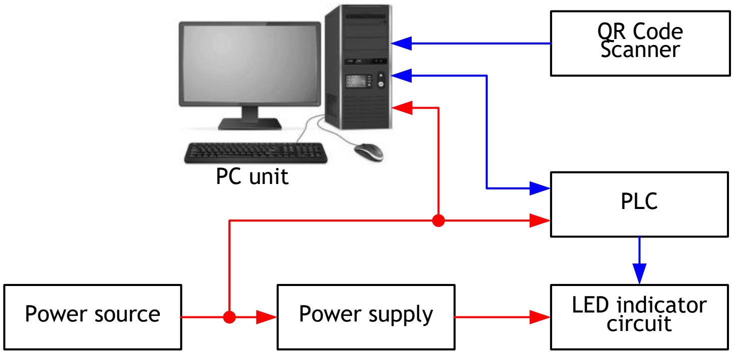


Figure 11. The block diagram of the proposed system.

3. Result and Discussion

3.1 Development and Installation

3.1.1 Development of Information System

A complete database program was developed to accommodate various processes in stocking in and stocking out the CPs. In total, the Visual Basic program consists of 40 pages and 150 data fields. The ready database personal computer is presented in Figure 12.

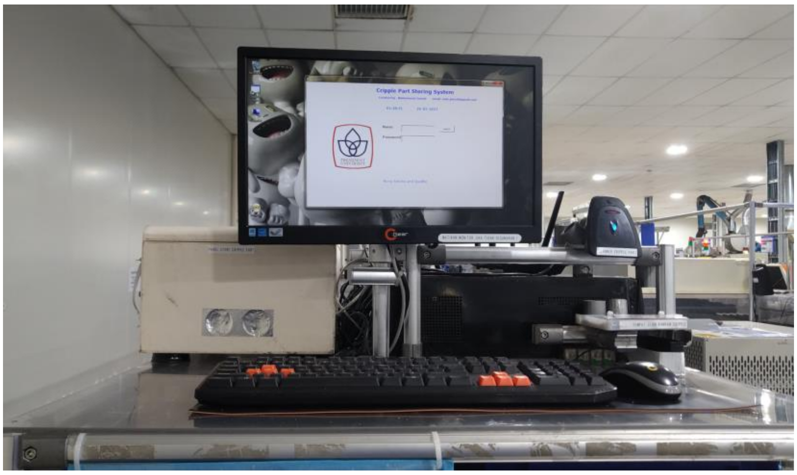
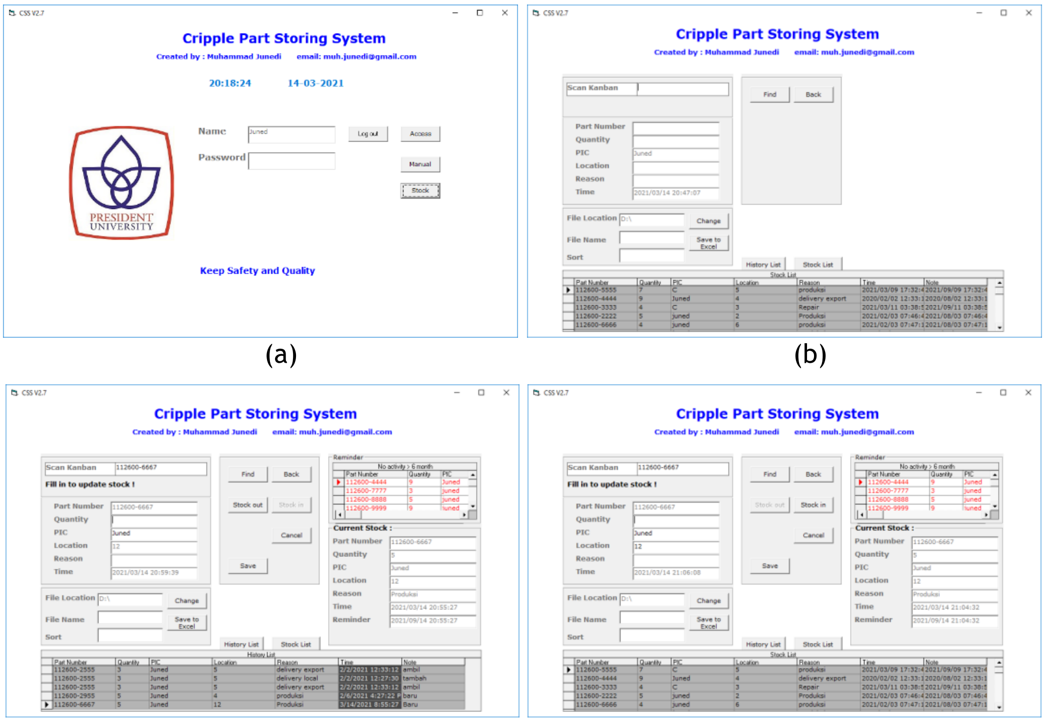


Figure 12. The database computer.

Figure 13(a) shows the program's main screen, where the operator should enter credentials to log in. Figure 13(b) shows the main stock display. The current stored CPs are listed on the lower part of the display. The operator can search the quantity of a particular CP by entering its part number. Figure 13(c) and (d) shows the display of stocking in and stocking out the CPs. In stocking in, the operator enters the part number manually or by scanning the kanban QR code and then inputs the quantity of the CPs. Then, the operator puts the CPs into the indicated drawer. In stocking out, the operator takes the CPs from the indicated drawer after a part number is given.

The current stock can always be monitored from the main stock display. The report automation, in the form of the stock-in and stock-out history and the current overall stock, can be exported into a Microsoft Excel file, as shown in Figure 14, for further analysis.



(a)

Name: Juned
Password:

(b)

Scan Kanban:
Part Number:
Quantity:
PIC: Juned
Location:
Reason:
Time: 2021/03/14 20:47:07
File Location: D:\
File Name:
Sort:

Stock List

Part Number	Quantity	PIC	Location	Reason	Time	Note
112600-5555	7	C	5	produksi	2021/03/09 17:32:4	2021/09/09 17:32:4
112600-4444	9	Juned	4	delivery export	2020/02/02 12:33:1	2020/08/02 12:33:1
112600-3333	4	C	3	Repair	2021/03/11 03:38:5	2021/09/11 03:38:5
112600-2222	5	juned	2	Produksi	2021/02/03 07:46:4	2021/08/03 07:46:4
112600-6666	4	juned	6	produksi	2021/02/03 07:47:1	2021/08/03 07:47:1

(c)

Scan Kanban: 112600-6667
Fill in to update stock !
Part Number: 112600-6667
Quantity:
PIC: Juned
Location: 12
Reason:
Time: 2021/03/14 20:59:39
File Location: D:\
File Name:
Sort:

Reminder

No activity > 6 month

Part Number	Quantity	PIC
112600-4444	9	Juned
112600-7777	3	juned
112600-8888	5	juned
112600-9999	9	juned

Current Stock :
Part Number: 112600-6667
Quantity: 5
PIC: Juned
Location: 12
Reason: Produksi
Time: 2021/03/14 20:55:27
Reminder: 2021/09/14 20:55:27

History List

Part Number	Quantity	PIC	Location	Reason	Time	Note
112600-2555	3	Juned	5	delivery export	2/2/2021 12:33:12	ambil
112600-2555	3	Juned	5	delivery local	2/2/2021 12:27:30	tambah
112600-2555	3	Juned	5	delivery export	2/2/2021 12:33:12	ambil
112600-2955	5	Juned	4	produksi	2/6/2021 4:27:22 P	baru
112600-6667	5	Juned	12	Produksi	3/14/2021 8:55:27	Baru

(c)

Scan Kanban: 112600-6667
Fill in to update stock !
Part Number: 112600-6667
Quantity:
PIC: Juned
Location: 12
Reason:
Time: 2021/03/14 21:06:08
File Location: D:\
File Name:
Sort:

Reminder

No activity > 6 month

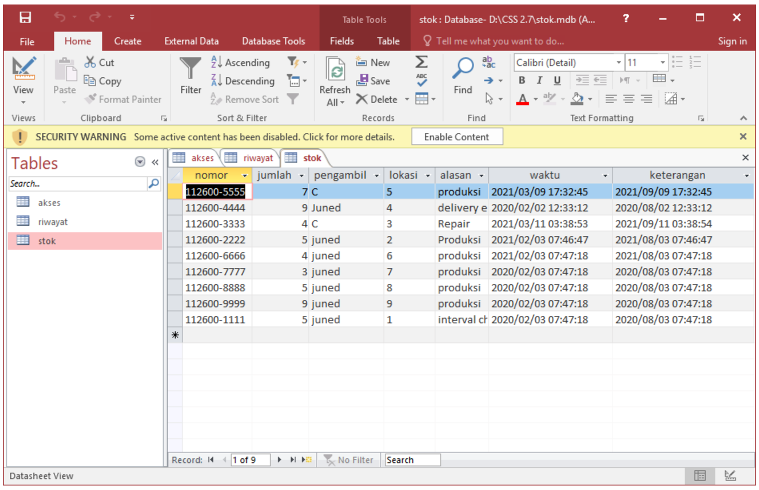
Part Number	Quantity	PIC
112600-4444	9	Juned
112600-7777	3	juned
112600-8888	5	juned
112600-9999	9	juned

Current Stock :
Part Number: 112600-6667
Quantity: 5
PIC: Juned
Location: 12
Reason: Produksi
Time: 2021/03/14 21:04:32
Reminder: 2021/09/14 21:04:32

Stock List

Part Number	Quantity	PIC	Location	Reason	Time	Note
112600-5555	7	C	5	produksi	2021/03/09 17:32:4	2021/09/09 17:32:4
112600-4444	9	Juned	4	delivery export	2020/02/02 12:33:1	2020/08/02 12:33:1
112600-3333	4	C	3	Repair	2021/03/11 03:38:5	2021/09/11 03:38:5
112600-2222	5	juned	2	Produksi	2021/02/03 07:46:4	2021/08/03 07:46:4
112600-6666	4	juned	6	produksi	2021/02/03 07:47:1	2021/08/03 07:47:1

Figure 13. The display of the database program; (a) main display; (b) main stock display; (c) stock-in display; (d) stock-out display



nomor	jumlah	pengambil	lokasi	alasan	waktu	keterangan
112600-5555	7	C	5	produksi	2021/03/09 17:32:45	2021/09/09 17:32:45
112600-4444	9	Juned	4	delivery e	2020/02/02 12:33:12	2020/08/02 12:33:12
112600-3333	4	C	3	Repair	2021/03/11 03:38:53	2021/09/11 03:38:54
112600-2222	5	juned	2	Produksi	2021/02/03 07:46:47	2021/08/03 07:46:47
112600-6666	4	juned	6	produksi	2021/02/03 07:47:18	2021/08/03 07:47:18
112600-7777	3	juned	7	produksi	2020/02/03 07:47:18	2020/08/03 07:47:18
112600-8888	5	juned	8	produksi	2020/02/03 07:47:18	2020/08/03 07:47:18
112600-9999	9	juned	9	produksi	2020/02/03 07:47:18	2020/08/03 07:47:18
112600-1111	5	juned	1	interval ch	2020/02/03 07:47:18	2020/08/03 07:47:18

Figure 14. The overall stock displayed in Microsoft Excel format.

3.1.2 **Installation of LED Indicators**

The exemplary circuit of the LED indicators is shown in Figure 15. The simple circuit consists of an LED and a resistor to adjust the current according to the specifications of the LED. The red LED used is ideally fed with 20 mA with a typical forward voltage between 1.2 to 3.6 V (Schubert, 2006). Here, the voltage from the power supply (24 V) is regulated by a 1090 Ω resistor to get a flowing current of around 20 mA.

Figure 16 shows the installation process of the LED indicators on the storage rack. Holes were drilled on the extruded aluminum bars that constructed the storage rack. Figure 16(a) shows the hole at a connecting bar. The connecting cables were pulled through such holes to the expected location at the midpoint below each drawer. Figure 16(b) shows the hole drilled at such a midpoint. This is the hole where an LED was mounted.

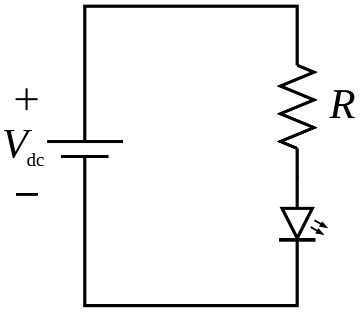


Figure 15. The exemplary LED indicator circuit.

(a) (b)

Figure 16. The installation of LED indicators; (a) drilling a connecting bar; (b) drilling the middle point below a drawer.

Figure 17(a) shows the process of mounting the LEDs to all drawers. Following this, all the cables should be connected accurately to the PLC output terminals, as shown in Figure 17(b).

After the lamp is installed in the store that has been perforated (drilled), the lamp is connected to the PLC through cables, as shown in Figure 17(a). The cables ended in the PLC panel, as shown in Figure 17(b). The final result can be seen in Figure 17(c).


(a) (b) (c)

Figure 17. The installation of LED indicators; (a) mounting the LEDs to all drawers; (b) connecting the cables to the PLC; (c) Fully connected PLC.

Figure 18(a) shows a storage rack before the improvement was conducted. Figure 18(b) shows a storage rack with fully installed LED indicators. The indicator indeed eases the search for the correct drawer significantly. The operator needs only to find the flashing LED. There is no need to read, memorize, and compare the part numbers anymore.


(a) (b)

Figure 18. Installing the LED indicators to the storage rack; (a) Before installation; (b) After installation with LED on.

3.2 Improvement of Dandori Time

Table 1 shows the comparison between the dandori process before and after the improvement. Previously, one dandori process required 190.2 seconds on average. After the improvement, the time required to complete the check sheet, stock in, and stock out is 140.4 seconds. This decrease corresponds to 26.2%.

3.3 Effect of New Dandori Time on Running Time

A typical flow of production data in an 8-hour work shift can be seen in Table 2. This data was taken on Wednesday, 5 August 2020, for the first shift (6:00-14:00) of production line 1. Thirteen different part types were produced. The running time of each part type was measured. The count of a running time starts when the first part of a type is produced. The count is finished when the last part of a type is produced. The total running time was 24,890 seconds or 6.91 hours.

Now, the availability rate of the process can be calculated as:

$$AR = \frac{6.91}{8.00} \times 100\% = 86.38\%. \tag{8}$$

The downtime, 1.09 hours, consists of dandori processes, a planned meeting, maintenance measures, and workplace cleaning. Here, the new dandori time with lower time allocation directly reduces the downtime. Furthermore, the reduced dandori time can potentially be converted mostly to productive running time.

Further using the data that there were 13 dandori processes during the shift, the total duration was 13×190. 2 seconds. This is equal to 2,472.6 seconds or 0.687 hours. Thus, the percentage of dandori time in this shift is:

$$\text{Dandori time} = \frac{0.687}{8.00} \times 100\% = 8.59\%. \tag{9}$$

Table 1. Comparison of the Dandori Process (Before and After Improvement)

Before Improvement		
Sequence	**Work Element**	**Time**
1	Take the cripple part box from the inspection point and put it into the trolley	3.5
2	Push the trolley to the storage room	23.9
3	Find the correct drawer for the cripple parts to stock-in	24.6
4	Push the trolley closer to the correct drawer	8.3
5	Move the cripple parts from the box into the drawer	6.6
6	Take and fill the check sheet for stock-in	28.9
7	Find the correct drawer for the cripple parts to stock-out	24.8
8	Push the trolley closer to the correct drawer	8.1
9	Take the cripple parts from the drawer into the box	3.7
10	Take and fill the check sheet for stock-out	29.4
11	Push the trolley to the inspection point.	24.6
12	Take the cripple part box from the trolley and put it on the inspection point	3.8
Total		190.2

After Improvement		
Sequence	**Work Element**	**Time**
1	Take the cripple part box from the inspection point and put it into the trolley	2.5
2	Push the trolley to the storage room	22.9
3	Scan the stock-in QR-code	5.4
4	Scan the operator's user's ID	4.1
5	Input the stock-in quantity	8.5
6	Find the drawer with a flashing LED indicator and push the trolley closer to it	8.8
7	Move the cripple parts from the box into the drawer	4.4
8	Go to the database computer	6.2
9	Input or confirm the drawer location and finalize stock-in	5.0
10	Scan the stock-out QR code	6.1
11	Find the flashing LED indicator	5.2
12	Push the trolley to the correct drawer.	8.4
13	Take the cripple part from the drawer into the box	2.6
14	Go to the database computer	8.1
15	Scan the operator's user's ID	4.4
16	Finalize stock-out	4.2
17	Confirm that the LED indicator is off	7.6
18	Push the trolley to the inspection point.	23.2
19	Take the cripple part box from the trolley and put it on the inspection point	2.8
Total		140.4

Table 2. A Typical Shift in a Production Line (Production Data)

Type	Produced Item Quantity	Running Time
CB	22	1,760
YS	47	2,820
KL	49	3,773
CK	45	1,980
SK	31	1,302
SB	25	1,025
YK	40	1,360
YK1	45	1,530
YS1	61	3,111
YB	20	960
SK1	20	820
KT	37	2,664
KT1	35	1,785
Total	359	24,890

Summing up, the running time of this typical shift was 86.38%, with 13.62% downtime. As much as 63.07% of the downtimes were caused by the dandori processes. The potential reduction of the dandori time can be investigated by first calculating the new dandori time, 13×140.4 seconds. This is equal to 1825.2 seconds or 0.507 hours. Thus, the percentage of new dandori time in a shift will be:

$$\text{Dandori time} = \frac{0.507}{8.00} \times 100\% = 6.34\%. \tag{10}$$

The difference between 8.59% and 6.34% of dandori time before and after the improvement is 2.25%, or equivalent to 10.8 minutes in the particular shift. This magnitude shows the running time that can be gained to finally improve the OEE value. Figure 19 shows the proportion of the running time, the dandori time, and the remaining downtimes before and after the improvement.

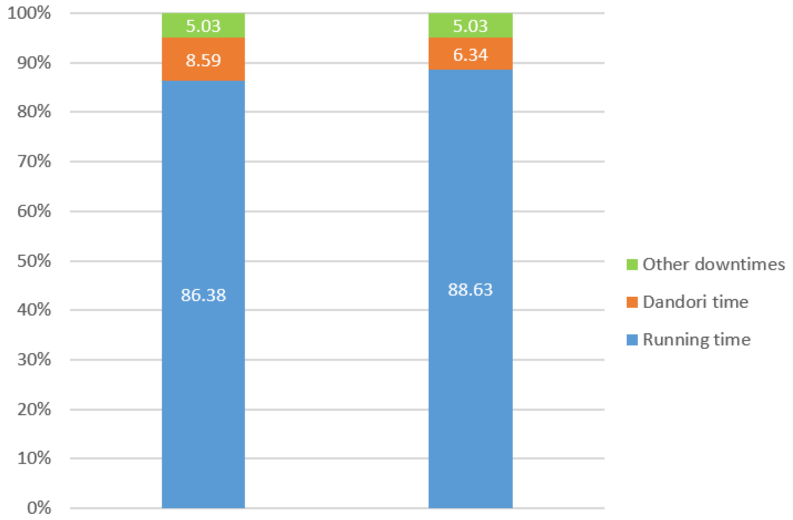


Figure 19. The distribution of the available operating time in shift 1, production line 1, on 5 August 2020; (a) Before improvement; (b) Potential after Improvement.

3.4 OEE Calculation

OEE is the product of AR, PR, and QR, as given by Equation (4). The decrease of the dandori time directly affects AR but not PR and QR. The AR of three production lines was measured and analyzed to prove the betterment due to the new dandori time. The PR and QR were also measured. However, the focus of this paper is the improvement of AR to improve OEE.

The proposed improvement was implemented at the beginning of December 2020. The AR 4 months before the improvement (August 2020 - November 2020) was compared with the AR 4 months after the improvement (December 2020 - March 2021).

Downtimes due to corrective maintenance, preventive maintenance, power shutdowns, etc., were assumed to be randomly and evenly distributed during the whole measurement period.

3.4.1 The Procedure of Data Processing

An example of the data processing from one production shift will now be presented. The production data of line 1 from Monday, 10 August 2020, shift 2 (14:00-22:00) is shown in Table 3.

Table 3. Production Data of Line 1, shift 2 (14:00-22:00), 10 August 2020

Type	Ideal Cycle time (seconds)	Item Quantity per lot	Produced Item Quantity	Quantity of cripple parts	Running Time (seconds)	Good	No Good
CK	40	20	40	0	1,760	37	3
CB	70	20	20	0	1,600	19	1
SK	30	20	30	10	1,260	30	0
SK1	30	20	20	0	820	20	0
SB	33	20	24	4	984	22	2
YK	30	10	50	0	1,700	45	5
YK1	30	20	40	0	1,360	40	0
YS	50	20	44	4	2,640	44	0
YS1	45	20	60	0	3,060	60	0
YB	42	10	13	3	624	12	1
KT	66	16	32	0	2,304	32	0
KT1	47	10	32	2	1,632	29	3
KL	69	10	48	8	3,696	44	4
SL	50	16	34	2	1,802	32	2
Total			487	33	25,242	466	21

The total running time is 25,242 seconds or 7.01 hours. The availability rate of the 8-hour shift can be calculated as:

$$AR = \frac{7.01}{8} \times 100\% = 87.65\%. \tag{11}$$

Furthermore, based on the data on produced item quantity and the ideal cycle time from Table 3, the ideal running time for each type can be calculated and accumulated. Cycle time is running time divided by produced item quantity. Ideal running time is the ideal cycle time multiplied by the produced item quantity. The result is given in Table 4.

Table 4. Calculation of Cycle Time and Ideal Running Time

Type	Cycle Time (seconds)	Ideal Running time (seconds)
CK	44	1,600
CB	80	1,400
SK	42	900
SK1	41	600
SB	41	792
YK	34	1,500
YK1	34	1,200
YS	60	2,200
YS1	51	2,700
YB	48	546
KT	72	2,112
KT1	51	1,504

KL	77	3,312
SL	53	1,700
Total		22,066

The performance rate can readily be calculated as

$$PR = \frac{22{,}066}{25{,}242} \times 100\% = 87.42\% \tag{12}$$

The quality rate of the production can be calculated from the data of good and no-good products, as also given in Table 3. From the accumulated data in the last row for the last two columns, the quality rate can be calculated

$$QR = \frac{466}{487} \times 100\% = 95.69\% \tag{13}$$

The OEE of the particular shift can now be calculated as:

$$\begin{aligned} OEE &= AR \times PR \times QR \\ &= 87.65\% \times 87.42\% \times 95.69\% \\ &= 73.31\% \end{aligned} \tag{14}$$

The same procedure as presented above was repeated to the production data from all shifts during the measurement period.

3.4.2 **The Summary of Data Processing**

The data processing was conducted for all data from the time span between August 2020 and November 2020 (before improvement) and between December 2020 and March 2021 (after improvement). The result is presented in Table 5 and 0.

Table 5. Summary of Data Processing from August 2020 until November 2020 (before improvement)

Subject	August	September	October	November
Available operating time (hours)	368.0	472.0	696.0	792.0
Running time (hours)	281.1	393.8	580.0	674.7
Downtime (hours)	86.9	78.2	116.0	117.3
AR (%)	80.90	85.79	85.71	87.10
Production quantity (items)	27,970	33,515	47,651	54,613
Ideal running time (hours)	242.9	344.4	497.2	586.4
PR (%)	86.41	87.45	85.73	86.92
Production quantity (items)	27,970	33,515	47,651	54,613
Good (items)	27,809	33,317	47,403	54,285
No Good (items)	161	198	248	328
QR (%)	99.42	99.41	99.48	99.40
OEE (%)	69.50	74.58	73.10	75.25

Table 6. Summary of Data Processing from December 2020 until March 2021 (after improvement)

Subject	December	January	February	March
Available operating time (hours)	760.0	712.0	632.0	576.0
Running time (hours)	671.2	599.7	574.0	510.9
Downtime (hours)	88.8	112.3	58	65.1
AR (%)	89.54	86.38	91.59	89.85
Production quantity (items)	53,955	46,104	45,037	37,929
Ideal running time (hours)	588.2	524.1	511.5	451.2
PR (%)	87.63	87.40	89.12	88.32
Production quantity (items)	53,955	46,104	45,037	37,929
Good (items)	53,765	45,825	44,815	37,770
No Good (items)	190	279	222	159
QR (%)	99.65	99.39	99.51	99.58
OEE (%)	78.19	75.04	81.23	79.02

Table 7 shows the average availability rate (AR), performance rate (PR), quality rate (QR), and overall equipment effectiveness (OEE) for the period before and after the improvement. AR increases in percentage by 4.47%, and the OEE increases by 5.26%. The slight increase in PR and QR also contributes to the increase of OEE. However, the decrease in the dandori time only affects AR. The higher value of PR and QR is not the merit of the proposed improvement.

Table 7. Comparison of AR, PR, QR, and OEE

Subject	Before improvement (%)	After improvement (%)	Difference (%)
AR	84.87	89.34	+4.47
PR	86.63	88.12	+1.49
QR	99.43	99.53	+0.10
OEE	73.11	78.37	+5.26

The monthly AR and OEE between August 2020 and March 2021 are presented in Figure 20 and Figure 21. The trend of betterment can be detected visually for AR and OEE.

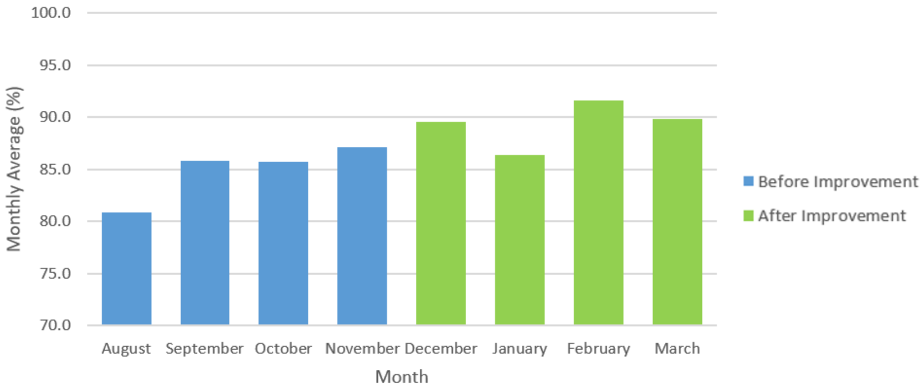


Figure 20. The trend of AR from August 2020 to March 2021.

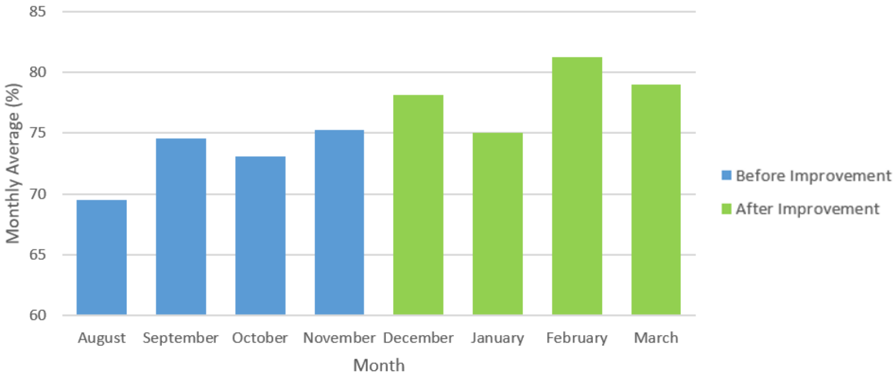


Figure 21. The trend of OEE from August 2020 to March 2021.

3.5 Discussion

The preliminary tests successfully confirmed the reliability of the database information system and the LED indicators to perform the tasks. Afterward, a new workflow was determined, and a new dandori process was created and the dandori time in the production line decreased from 190.2 seconds to 140.4 seconds.

The impact of this improvement can be seen from the increase of AR in the magnitude of 4.47%. From December 2020 – March 2021, the total available operating time was 2,680 hours. Thus, the percentage corresponds to 119.53 hours. Assuming one man-day equals 8 working hours, the time saved is equivalent to 14.94 man-days in 4 months or 3.74 man-days per month.

The proposed improvement enabled time-saving so the operator could perform other productive works. Besides, the digital check sheet significantly reduces the cost of providing and maintaining paper-based check sheets. The summary of the stock history can be printed on request at any time. The use of a QR scanner can also avoid human error in inputting the part type data.

The increase in PR and QR is caused by factors outside the dandori time. This increase may be traced to the varying production machine capability and fluctuating operator performance during the machine operation or product handling.

4. Conclusion

Improvement of a storage management system is proposed in this paper. The system was implemented at an automobile spare part manufacturing company. The system replaces the procedures of manually filling paper-based check sheets and finding the correct drawers in the storage room. The downtime due to the dandori process was reduced by implementing a database information system to support digital check sheets and electronic visual indicators.

A database application was developed using Microsoft Visual Basic. The electronic visual indicators were installed in the existing storage room of the company by mounting LED above each drawer and using a PLC. The dandori time was reduced from 190.2 to 140.4 seconds. The effect of this improvement was assessed by measuring the Availability Rate (AR) of the production process.

Production data was collected for the duration of 4 months before and 4 months after the improvement was implemented. The average AR was improved from 84.87% to 89.34, equivalent to an increase of 4.47%. The AR improvement significantly contributed to the OEE improvement from 73.11% to 78.37%, or equal to an increase of 5.26%. Productivity Rate (PR) and Quality Rate (QR) were also improved by 1.49% and 0.10% as by-products during the data measurement period. The usefulness of OEE in measuring the effectiveness of a production process is validated. The total operator time saved during the 4-month implementation period was 14.94 man-days, which equals 3.74 man-days per month. Furthermore, due to report automation, the use of paper and printers can be highly reduced by using digital check sheets.

Further system improvement includes adding features that can send reminders to the operators if there are idle CPs with more than 6 months without transactions. The integration of IoT will enable the existing system to be accessed easily from anywhere with an internet connection. The improvement results presented in this project are a perfect foundation for further continuous improvement measures in the company.

References

1. Arkadiusz, G., and Aleksander, N. (2017). Application of OEE coefficient for manufacturing lines reliability improvement. Proceedings of the 2017 International Conference on Management Science and Management Innovation (MSMI 2017). doi:10.2991/msmi-17.2017.42

2. Craig, J. C. and Webb, J. (1998). Microsoft Visual Basic 6.0 Developer's Workshop. New York: Microsoft Press, 1998.

3. Davis, R. K., (1995). Productivity Improvements Through TPM. Great Brittain: Prentice Hall.

4. Gani, A. J. and Bendatu, L. Y. (2015). Perbaikan Proses Dandori di PT. Astra Otoparts Tbk. Divisi Adiwira Plastik. Jurnal Tirta, 3(2), 1-8.

5. Krachangchan, K. and Thawesaengskulthai, N. (2018). Loss time reduction to improve overall equipment effectiveness (OEE). 2018 5th International Conference on Industrial Engineering and Applications (ICIEA). https://doi.org/10.1109/iea.2018.8387132

6. Lestari, W. P. and Wulandari, I. A. (2023). Effectiveness Analysis of Milling Machine Using Overall Equipment Effectiveness and Determination of Preventive Maintenance Using Age Replacement. https://doi.org/10.21070/ups.1966

7. Moradizadeh, H. and Mayorga, R. V. (2014). Overall equipment effectiveness and overall line efficiency measurement using fuzzy inference systems. Proceedings of the International Conference on Fuzzy Computation Theory and Applications. https://doi.org/10.5220/0005155101990204

8. Nakajima, S. (1988). Introduction to Total Productive Maintenance, Tokyo: Productivity Press.

9. Schuber, E. F. (2006). Light-Emitting Diodes. New York: Cambridge University Press.

10. Sitompul, E., Wulandari, T., and Galina, M. (2022). A Prototype of an IoT-based Production Performance and Quality Monitoring System Using NodeMCU ESP8266. Jurnal Ilmu Elektroteknika (Techne). 21(1), 45-62.

11. Subagio, D. *et al.* (2016). Rancang Bangun PLC Training Kit Divisi Service Parts and Welding Production Berbasis PLC Omron CJ2M-CPU11," TECHNOLOGIC, 7(2), 1-8.

12. Wibowo A. (2019). OEE (Overall Equipment Effectiveness. KAIZENPRO. https://www.kaizenpro.asia/2019/01/oee-overall-equipment-effectiveness.html.

13. Widagdo *et al.* (2005) Handout Toyota Production System Training for PT. Astra Daihatsu Motor's Vendor. Jakarta: PT. Astra Daihatsu Motor.