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REDESIGNING ASSEMBLY LINE BY APPLYING RANKED POSITIONAL WEIGHT AT HEAVY-INDUSTRIAL FACILITY

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ABSTRACT

To meet customer demand, the company was faced with insufficient capacity problems caused by low efficiency and congestion on the assembly line. Recent data shows that there is an imbalance in the work process time between workstations. This study aims to solve these problems to achieve the desired capacity. The research begins by observing the operating time and collecting other data on the assembly line then analyzed and developed as a solution to these problems. The analysis results show that the assembly line has low line efficiency and the impact on the output target is not as expected. From the time observations made on the assembly line, it can be seen that the current line is inefficient and there is a bottleneck at some workstations. Ranked Positional Weight (RPW) was chosen as a line balancing method to solve the problem. RPW generates new work arrangements for each workstation that has relatively the same uptime. The results of the RPW method showed a significant increase in line efficiency, namely 75.03%, the smoothness index increased by 90.79%, and the balance delay was reduced by 90.52%. After the solution is obtained, a new layout is created to be used as a guide for rearranging the assembly line.

INTRODUCTION

Designing a good production line is one of the important factors to ensure that production runs smoothly and productivity increases. High line production efficiency means all resources are used efficiently and effectively. Thus, the company will be able to produce more output with a shorter lead time.

PT. ABC, which is located in an industrial area in Bekasi Regency, West Java, is a global producer of heavy equipment that is widely used in the construction industry. One of the products is an excavator. Based on the sales forecast for next year, it is estimated that demand for excavators will increase significantly, which is almost double the current market demand.

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Currently, the company has one assembly line that produces a complete excavator. The factory could produce 1,800 excavator units per year. PT. ABC plans to double its production capacity. This can be done by adding new facilities or assembly lines, but in reality, this is difficult. Therefore, it is necessary to analyze the current production line whether its performance can be improved so that its capacity can increase as expected.

From February to August, the resulting production was only 950 units. The production output for eight months based on SAP was 1,100 units. This result occurs due to low line assembly efficiency and a bottleneck workstation. Besides, the imbalance of the work system in the line prevents the company from producing more excavators. Therefore, companies need to increase production capacity by increasing the efficiency of production lines.

There are several methods available to solve this problem. In general, these methods can be classified into heuristics, analytic, or simulation. Much research has been done regarding line balancing. Some of them are using the Rank Positional Weight (RPW) method as performed by (Afifuddin, 2019) which applies it in the soccer shoe industry, in the cigarette industry which production reaches millions per day (Prabowo, 2016) as well as in the pharmaceutical industry (Astuti & Edy purwanto, 2019). Research also performed on comparing several heuristic methods such as carried out by (Srijayasari et al., 2018), (Saiful et al., 2016), and (Prasetyabudi, Adiyanto, & Adityo, 2019) which are applied in military equipment and furniture industry, then (Azwir & Pratomo, 2017) uses several heuristics for balancing welding line, then (Dharmayanti & Marliansyah, 2019) also discuss line balancing in the food industry. Uses of lean manufacturing for line balancing method is also applied for example in the palm oil processing industry (Pujotomo & Rusanti, 2015), improvement of an aromatherapy production system (Purnama & Ikatrinasari, 2013), increasing the production capacity of motorbike mufflers and other automotive industry (Azwir et al., 2020), and also for improving the capacity of the electronic control unit (Sunny et al., 2019). Besides the conventional approach to doing line balancing, another approach is also carried out with a method called OPEX (operational excellence) which can provide solutions to various problems including the line balancing problem (Cahyo, 2019). Use of Harmony Search (Purnomo et al., 2011) as a solution for assembly line balancing. Another solution that can be implemented is through simulation of relayout as implemented in (Kitriastika et al., 2013),. Then the ECRS (Eliminate, Combine, Rearrange, Simplify) method was also developed as an alternative to line balancing (Tiovani, 2019).

Line balancing has a close relationship with a facility layout, which is an arrangement of everything needed for the production or delivery of services. A facility is an entity that facilitates the performance of any job (Wignjosubroto, 2009). If the planning and arrangement are not right, it can result in each work station in the cross-assembly line having different production speeds, resulting in a bottleneck of material between work stations (Baroto, 2002). Therefore it is necessary to make efforts to balance the track (line balancing). Based on research comparing several traditional heuristics methods, it has shown that the difference is not significant however, RPW is the most popular (Manaye, 2019). This research will apply the Ranked Position Weight (Helgesson - Birnie) method because this method is suitable when faced with a not too complex production line such as a single-model flow-line system. It could effectively distribute the workload thus minimize the idle time.

RESEARCH METHOD

Ranked positional weight (RPW) - Helgesson-Birnie is a line balancing method by positioning each operation and gives them a weighing so it can be arranged accordingly.

A. Steps to proceed:

(a) Create a precedence diagram

The precedence diagram is a relationship diagram that shows the order of an operation that has to be done before starting another operation. It determines the sequence of work elements.

(b) Positional weight

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The next step is to calculate the positional weight of each element by summation of the work unit.

(c) Sorting
After all the work elements have been calculated for their positional weight

B. Line Balancing Term and Calculation

To support the RPW implementation several parameters should be computed

1. Operation time, the time that is spent to complete an operation.
2. Cycle time (CT), the total time to make one product at one workstation.
3. Takt time (Tt) is defined as the total time needed to finish one product.

$$Takt\ time = \frac{Net\ Available\ Time}{Demand} \tag{1}$$

4. A workstation is a place of the assembly line where a certain operation work is performed.

$$k = \frac{\sum Ti}{Tt} \tag{2}$$

Where, k: Total workstation number, Ti: Operation time, Tt: Takt time

5. Station time (ST) is the total time of work element that has been done in the same workstation
6. Idle time (IT) is the difference between cycle time and station time.
7. Station Efficiency (SE) is the Efficiency of STi compare to CT.
8. Line efficiency is a ratio of total time at each workstation related to takt time and number of workstations.

$$LE = \frac{\sum_{i=1}^{k} ST_i}{(k \ x\ Tt)} x100\% \tag{3}$$

9. Balance delay or balance loss is a measure of line inefficiency as a result of idle time due to imperfect work arrangements among stations.

$$BD = \frac{(k.\ CT) - \sum_{i=1}^{k} ST_i}{(k.\ CT)} x100\% \tag{4}$$

10. The smoothness index is an index level that shows a relative line smoothness. The smoothness index can be called perfect if the value is equal to zero.

$$SI = \sqrt{\sum_{i=1}^{k} (CT - ST_i)^2} \tag{5}$$

C. Bottleneck Model

A bottleneck is a condition where an operation or facility restricts or inhibits the output in a single sequence for a single production line.

RESULTS AND DISCUSSION

The hydraulic excavator is a crawling driven machine with an upper frame that can rotate 360 degrees against the lower frame which can remove materials.

A. Component of product

Typically, Figure 1. hydraulic excavator has 5 major components which are:

1) Upper Frame, Figure 2, is an upper structure of excavator that consists of the main control mover, hydraulic system, & cabin, which can rotate 360 degrees in either direction against the lower frame.

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2) Lower Frame, Figure 3, is the lower part of the hydraulic excavator on which the machine travels that consisting the drive component.
3) Boom, Figure 4, it’s the first part of the attachment which is mounted to the upper frame.
4) Stick, Figure 5, the second part of attachment which is hinged on one end to the boom and the bucket.
5) The bucket, Figure 6, is part of excavators which digs into earth and gets filled with material

B. Assembly process

Production in the factory is performed on a single-model flow-line system. The whole assembly system consists of 15 workstations, two lines of which are two parallel lines of nine stations. Production is low-volume with about 1800 units per year, no automation process, conveyance between stations is unpowered. All tasks are performed by human operators.

The Assembly process that produces hydraulic excavators consists of various operations. Start from the upper frame station. The number for this station is six stations. At the same time, they're also an operation called lower frame station. After the operation is fulfilled at both lines, then performed operation called docking, this station is to combine the upper frame and lower frame. Then the machine can function forward to another station called attachment. Among these stations, there are two operations of quality inspection, the first one is after finishing the operations at the upper frame station and the second one is after installing attachment.

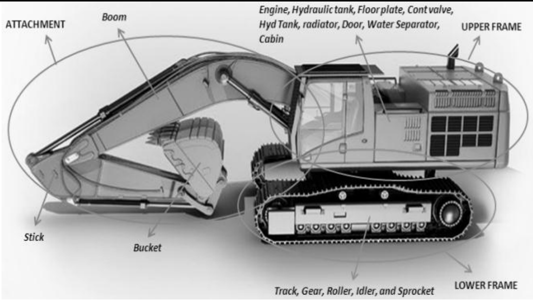

Figure 1. Hydraulic excavator

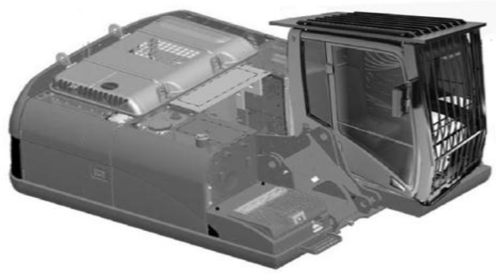
Figure 2. Upper frame

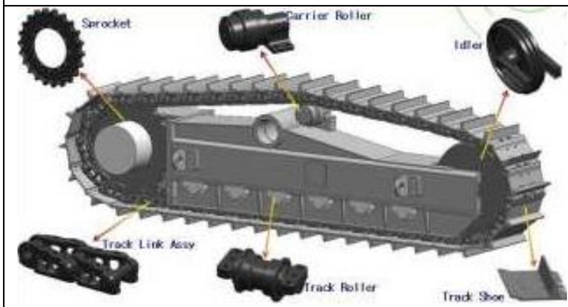

Figure 3. Lower frame


Figure 4. Boom

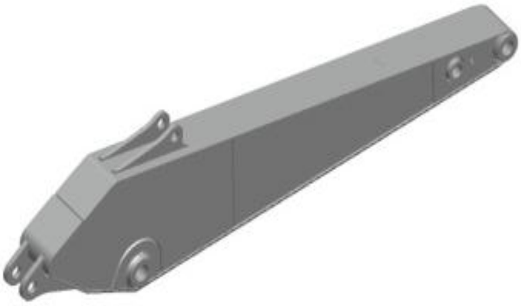
Figure 5. Stick


Figure 6. Bucket

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C. Current assembly layout

The current hydraulic excavator assembly process layout is as the following Figures 7 and Figure 8.

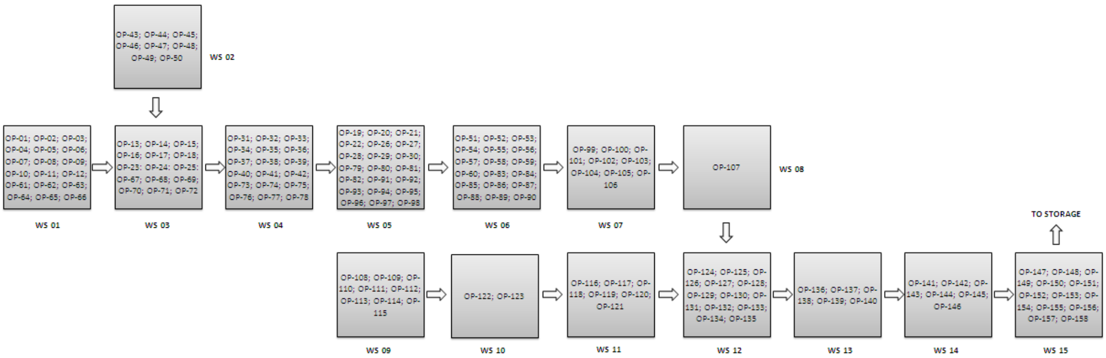

Figure 7. Current assembly process

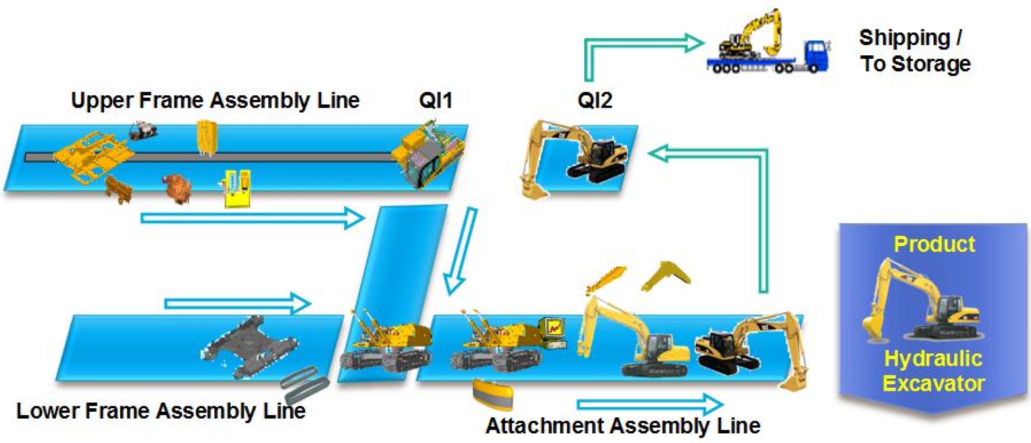

Figure 8. Current assembly layout

D. Standard Time

Table 1. shows some calculated standard time of all operation with total standard time = 2539.06 minutes.

Table 1. The standard time of all operation

No.	Operation	Std time (min)	No.	Operation	Std time (min)
OP-01	PREPARATION	9.44	OP-80	INSTALL VALVE AND FLANGE	34.55
OP-02	INSTALL PLATE PIN	2.62	OP-81	INSTALL HOSE GP	5.62
OP-03	INSTALL GROMMET	10.76	OP-82	INSTALL CONNECTOR	10.98
OP-04	INSTALL HARNESS	47.67	OP-83	INSTALL SUB CABIN	28.78
OP-05	INSTALL HOSE ENGINE	8.35	OP-84	INSTALL BOX GP CABIN	20.56
....	.....	.....	.....	......	....
OP-77	CONNECT CABLE GROUND	5.51	OP-156	INSTALL BUCKET KE STICK	11.78
OP-78	INSTALL PIPE UNDER ENGINE	17.70	OP-157	FILL GREASE	20.28
OP-79	INSTALL RADIATOR	29.60	OP-158	TEST PERFORMANCE	17.79

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E. Cycle time and takt time

After some data collection and processing, it is found that CT is 81.57 min. The production capacity of the factory is planned for 6 vehicles per day. Daily working time is 420 minutes. Takt time is calculated as follows.

$$\text{Takt time} = \frac{Net\ Available\ Time}{Demand} = \frac{7(hr)\ .\ 2(shift)\ .\ 5(days)\ .\ 50(weeks)}{1800} = 116.67 \text{ minutes}$$

$$\text{No. of workstation} = k = \frac{\sum Ti}{Tt} = \frac{2539.06}{116.67} \approx 22$$

To increase capacity while maintaining the existing single line and available work hours, so that it can reach a demand of 3000 units, then

$$\text{Takt time} = \frac{Net\ Available\ Time}{Demand} = \frac{7(hr)\ .2(shift)\ .\ 5(days)\ .\ 50(weeks)}{3000} = 70 \text{ minutes}$$

$$\text{No. of workstation} = k = \frac{\sum Ti}{Tt} = \frac{2539.06}{70} \approx 37$$

F. Current work arrangement and workstation efficiency analysis

Due to that, there is three operator assign at workstation 1, so the station time will be divided by the total number of the operator at that workstation. So the station time will be,

$$ST_1 = \frac{234.97}{3} = 78.32 \text{ minutes}$$

$$IT_1 = CT - ST_1 = 81.57 - 78.32 = 3.25 \text{ minutes}$$

$$SE_1 = \frac{STi}{CT}\ .\ 100\% = \frac{78.32}{81.57}\ .\ 100\% = 96.01\%$$

Table 2. shows the complete computed current work arrangement based on Table 1 and Figures 7 and 8. Figure 9 shows the actual station time (ST) compare to takt time. This shows that if the company wants to increase the capacity to 3000, it means ST has to below 70min. Unfortunately, some work station (1, 3, 4, 5) has ST beyond 70m, while others ST is too low (6, 7, 8, 9, 10). Thus, this situation will open for line balancing opportunities.

Table 2. Current work arrangement

Work Station	Operation	Station time (min)	Takt time (1800cap)	Takt time (3000cap)	# of operator	ST_i (min)
1	OP-01; OP-02; OP-03; OP-04; OP-05; OP-06; OP-07; OP-08; OP-09; OP-10; OP-11; OP-12; OP-61; OP-62; OP-63; OP-64; OP-65; OP-66	234.97	116.67	70.0	3	78.32
2	OP-43; OP-44; OP-45; OP-46; OP-47; OP-48; OP-49; OP-50	208.74	116.67	70.0	3	69.58
3	OP-13; OP-14; OP-15; OP-16; OP-17; OP-18; OP-23: OP-24: OP-25: OP-67; OP-68; OP-69; OP-70; OP-71; OP-72	309.71	116.67	70.0	4	77.43
4	OP-31; OP-32; OP-33; OP-34; OP-35; OP-36; OP-37; OP-38; OP-39; OP-40; OP-41; OP-42; OP-73; OP-74; OP-75; OP-76; OP-77; OP-78	236.93	116.67	70.0	3	78.98
5	OP-19; OP-20; OP-21; OP-22; OP-26; OP-27; OP-28; OP-29; OP-30; OP-79; OP-80; OP-81;	326.30	116.67	70.0	4	81.57

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Work Station	Operation	Station time (min)	Takt time (1800cap)	Takt time (3000cap)	# of operator	ST_i (min)
6	OP-82; OP-91; OP-92; OP-93; OP-94; OP-95; OP-96; OP-97; OP-98 OP-51; OP-52; OP-53; OP-54; OP-55; OP-56; OP-57; OP-58; OP-59; OP-60; OP-83; OP-84; OP-85; OP-86; OP-87; OP-88; OP-89; OP-90	189.77	116.67	70.0	3	63.26
7	OP-99; OP-100; OP-101; OP-102; OP-103; OP-104; OP-105; OP-106	119.08	116.67	70.0	2	59.54
8	OP-107	17.42	116.67	70.0	1	17.42
9	OP-108; OP-109; OP-110; OP-111; OP-112; OP-113; OP-114; OP-115	174.79	116.67	70.0	3	58.26
10	OP-116; OP-117; OP-118; OP-119; OP-120; OP-121	100.47	116.67	70.0	2	50.24
11	OP-122; OP-123	69.15	116.67	70.0	1	69.15
12	OP-124; OP-125; OP-126; OP-127; OP-128; OP-129; OP-130; OP-131; OP-132; OP-133; OP-134; OP-135	206.63	116.67	70.0	3	68.88
13	OP-136; OP-137; OP-138; OP-139; OP-140	68.98	116.67	70.0	1	68.98
14	OP-141; OP-142; OP-143; OP-144; OP-145; OP-146	137.08	116.67	70.0	2	68.54
15	OP-147; OP-148; OP-149; OP-150; OP-151; OP-152; OP-153; OP-154; OP-155; OP-156; OP-157; OP-158	139.05	116.67	70.0	2	69.53
	TOTAL	2539.06			37	979.68

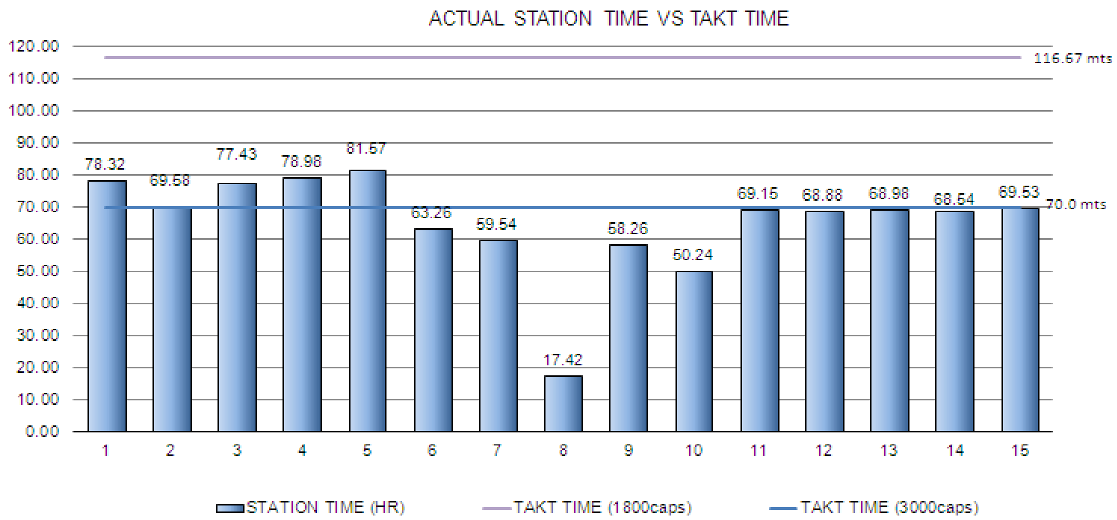

Figure 9. Actual station time vs takt time

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G. Current balance delay, and smoothness index, line efficiency

1) BD $= \frac{(k * CT) - \sum_{i=1}^{k} ST_i}{(k * CT)} . 100\% \quad = \frac{(15 * 81.57) - 979.67}{(15 * 81.57)} . 100\% = 19.93\%$

2) SI $= \sqrt{\sum_{i=1}^{k} (CT - ST_i)^2} = \sqrt{\begin{matrix}(3.25)^2 + (11.99)^2 + (4.14)^2 + (2.59)^2 + (0.0)^2 + (18.31)^2 \\ + (22.03)^2 + (64.15)^2 + (23.31)^2 + (31.33)^2 + (12.42)^2 \\ + (12.69)^2 + (12.59)^2 + (13.03)^2 + (12.04)^2\end{matrix}}$

=86.19

3) LE $= \frac{\sum_{i=1}^{k} ST_i}{(k * Tt)} . 100\% = \frac{\begin{matrix}78.32 + 69.58 + 77.43 + 78.98 + 81.57 + 63.26 + 59.54 + 17.42 \\ + 58.26 + 50.24 + 69.15 + 68.88 + 68.98 + 68.54 + 69.53\end{matrix}}{(15 * 116.67)} . 100\%$

$= \frac{979.67}{(15 * 116.67)} = 55.98\%$

H. Improving by ranked positional weight

Tasks are sorted positions weight ranging from the largest to the smallest. Position weight is obtained by summing the operating time for a task with others that followed.

Below is the example of calculating positional weight for OP-01.

$$\sum \begin{matrix} OP-01, OP-02, OP-03, OP-04, OP-05, OP-06, OP-07, OP-08, OP-09, OP-10, \\ OP-11, OP-12, OP-61, OP-62, OP-63, OP-64, OP-65, OP-66, OP-67, OP-68, \\ OP-69, OP-70, OP-71, OP-72, OP-73, OP-74, OP-75, OP-76, OP-77, OP-78, \\ OP-79, OP-80, OP-81, OP-82, OP-83, OP-84, OP-85, OP-86, OP-87, OP-88, \\ OP-89, OP-90, OP-91, OP-92, OP-93, OP-94, OP-95, OP-96, OP-97, OP-98, \\ OP-99, OP-100, OP-101, OP-102, OP-103, OP-104, OP-105, OP-106, OP-107, \\ OP-122, OP-123, OP-124, OP-125, OP-126, OP-127, OP-128, OP-129, OP-130, \\ OP-131, OP-132, OP-133, OP-134, OP-135, OP-136, OP-137, OP-138, OP-139, \\ OP-140, OP-141, OP-142, OP-143, OP-144, OP-145, OP-146, OP-147, OP-148, \\ OP-149, OP-150, OP-151, OP-152, OP-153, OP-154, OP-155, OP-156, OP-157, \\ OP-158 \end{matrix}$$

= 1503.63

I. Proposed line

The proposed work arrangement generates from RPW, then further layout line assembly proposed.

Table 3. Proposed work arrangements

Work station	Operation	Station time (min)	Takt time (3000caps)	# of operator	STi (min)
1	OP-01; OP-02; OP-03; OP-04; OP-05; OP-06; OP-07; OP-08; OP-09; OP-10; OP-11; OP-12	133.57	70.0	2	66.78
2	OP-13; OP-14; OP-15; OP-16; OP-17; OP-18	209.50	70.0	3	69.83
3	OP-19; OP-20; OP-21; OP-22; OP-23; OP-24; OP-25; OP-26; OP-27; OP-28; OP-29; OP-30	135.81	70.0	2	67.90
4	OP-31; OP-32; OP-33; OP-34; OP-35; OP-36; OP-37; OP-38; OP-39; OP-40; OP-41; OP-42	138.15	70.0	2	69.08
5	OP-43; OP-44; OP-45; OP-46; OP-47; OP-48; OP-49; OP-50	208.74	70.0	3	69.58
6	OP-51; OP-52; OP-53; OP-53; OP-55; OP-56; OP-57; OP-58; OP-59; OP-60	67.97	70.0	1	67.97
7	OP-61; OP-62; OP-63; OP-64	67.69	70.0	1	67.69
8	OP-65; OP-66; OP-67; OP-68	68.90	70.0	1	68.90
9	OP-69; OP-70; OP-71; OP-72; OP-73; OP-74; OP-75; OP-76; OP-77; OP-78	139.83	70.0	2	69.91
10	OP-79; OP-80; OP-81	69.77	70.0	1	69.77

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Work station	Operation	Station time (min)	Takt time (3000caps)	# of operator	STi (min)
11	OP-82; OP-83; OP-84; OP-85; OP-86; OP-87; OP-88; OP-89; OP-90	132.79	70.0	2	66.39
12	OP-91; OP-92; OP-93; OP-94; OP-95; OP-96; OP-97; OP-98	133.70	70.0	2	66.85
13	OP-99; OP-100; OP-101; OP-102; OP-103	68.10	70.0	1	68.10
14	OP-104; OP-105; OP-106, OP-107	68.39	70.0	1	68.39
15	OP-108; OP-109; OP-110	67.75	70.0	1	67.75
16	OP-111; OP-112; OP-113	69.60	70.0	1	69.60
17	OP-114; OP-115; OP-116	68.75	70.0	1	68.75
18	OP-117; OP-118; OP-119; OP-120; OP-121	69.17	70.0	1	69.17
19	OP-122; OP-123	69.15	70.0	1	69.15
20	OP-124; OP-125; OP-126; OP-127; OP-128; OP-129; OP-130; OP-131; OP-132; OP-133; OP-134; OP-135	206.63	70.0	3	68.88
21	OP-136; OP-137; OP-138; OP-139; OP-140	68.98	70.0	1	68.98
22	OP-141; OP-142; OP-143; OP-144; OP-145; OP-146	137.08	70.0	2	68.54
23	OP-147; OP-148; OP-149; OP-150; OP-151; OP-152; OP-153; OP-154; OP-155; OP-156; OP-157; OP-158	139.05	70.0	2	69.53
	Total	2539.06		37	1577.49

The calculation before performing line balancing using the RPW method shows that the line need 15 workstations to balancing line based on 116.67 minutes takt time. RPW generates 23 workstations to balance the line based on 70 minutes takt time, so the next proposed line is using 23 workstations.

After work arrangement has been established based on RPW, the new CT is produced which is 69.91 min. It can be seen in Figure 10 that the station time of each workstation is below takt time for 3000 unit capacity. This means that the new work arrangement can be applied to produce 3000 units of the hydraulic excavator. It is clear from Figure 10 that no station time exceeds takt time.

J. Proposed balance delay, smoothness index, and line efficiency

The proposed balance delay, smoothness index, and line efficiency can be calculated as below:

$$BD = \frac{(k \cdot CT) - \sum_{i=1}^{k} ST_i}{(k \cdot CT)} \,.\, 100\% = \frac{(23 \cdot 69.91) - 1577.5}{(23 \cdot 69.91)} \,.\, 100\% = 1.89\%$$

$$SI = \sqrt{\sum_{i=1}^{k} (CT - ST_i)^2} = \sqrt{\begin{array}{c}(3.13)^2 + (0.08)^2 + (2.01)^2 + (0.84)^2 + (0.33)^2 + (1.94)^2 + (2.22)^2 \\ + (1.02)^2 + (0.0)^2 + (0.14)^2 + (3.52)^2 + (3.06)^2 + (1.81)^2 + (1.52)^2 + \\ (2.17)^2 + (0.32)^2 + (1.16)^2 + (0.75)^2 + (0.76)^2 + (1.04)^2 + (0.93)^2 + \\ (1.38)^2 + (0.39)^2\end{array}}$$

$$= 7.94$$

$$LE = \frac{\sum_{i=1}^{k} ST_i}{(k \cdot Tt)} \,.\, 100\% = \frac{\begin{array}{c}66.78 + 69.83 + 67.90 + 69.08 + 69.58 + 67.97 + 67.69 + 68.90 \\ + 69.91 + 69.77 + 66.39 + 66.85 + 68.10 + 68.39 + 67.75 + \\ 69.60 + 68.75 + 69.17 + 69.15 + 68.88 + 68.98 + 68.54 + 69.53\end{array}}{(23 \cdot 70)} \,.\, 100\% = \frac{1577.50}{(23 \cdot 70)} =$$

$$97.98\%$$

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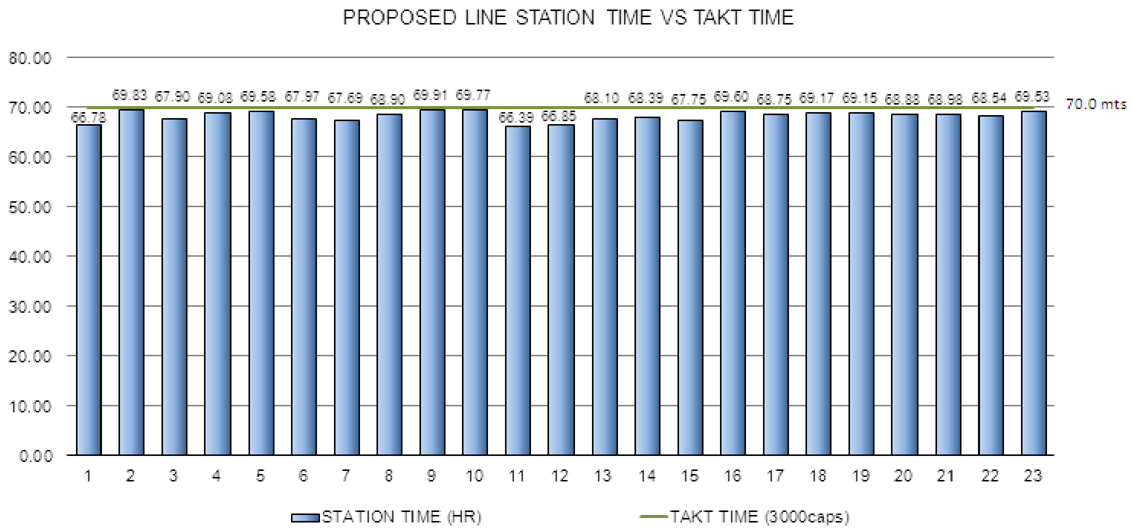

Figure 10. Proposed line station time vs takt time graph

K. Current line and proposed line comparison

The current line production has very low efficiency. This proposed line is expected to improve the current line efficiency so that the production line can meet the target output. Figure 11 shows the comparison.

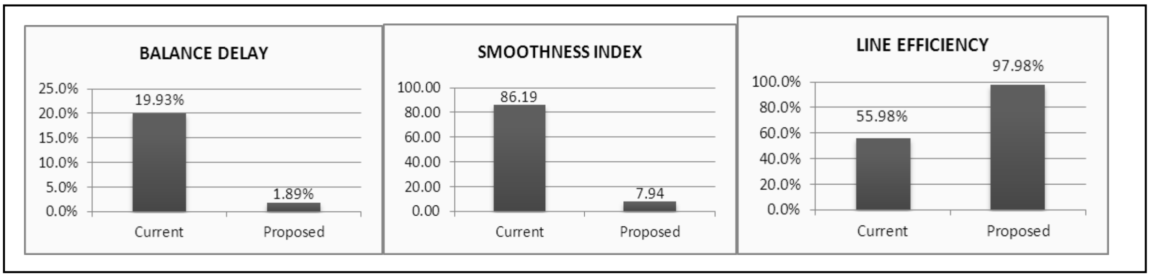

Figure 11. Comparison between current and proposed line

The graphs in Figure 11 show significant improvement in balance delay, smoothness index, and line efficiency. It can be concluded that the new line proposed is better than the current line assembly production.

L. Evaluation

The result from line balancing shows that the proposed line production has more efficient than the current line production. With the addition of a new workstation to become 23 workstations, there will be some change to the current assembly line layout. To make the flow production smooth, then the tree assembly line pattern was chosen for the new assembly line layout as shown in Figures 12 and 13.

The reason why the new layouts shown in Figures 12 and 13 were chosen other than the tree line assembly pattern suits the building area is that it is possible to separate some processes from the main assembly process which is called sub-assembly. These sub-assemblies are independent operations based on priority sequence operations, so they don't violate the main assembly line.

Overall, the improvement by applying line balancing in assembly line production can be summarized in Table 4. From Table 4, it can be seen the differences between current and proposed improvements. Line efficiency improvement is 75.03% which means that the proposed line assembly is more efficient to manage workstation time compared to the current

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line assembly. The smoothness index is also improving 90.79% which means there are no bottleneck stations. Balance delay reduced 90.52% which means that there less idle time.

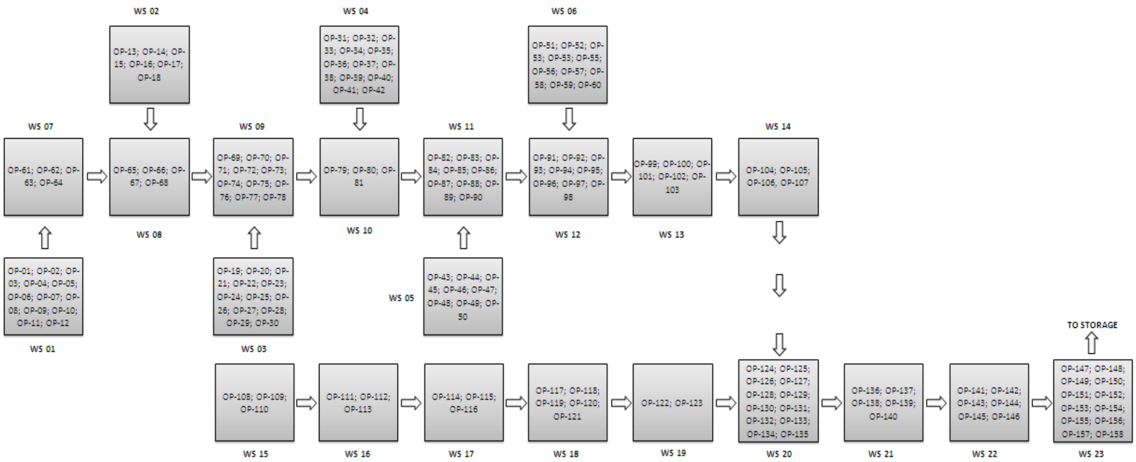

Figure 12. New proposed assembly process

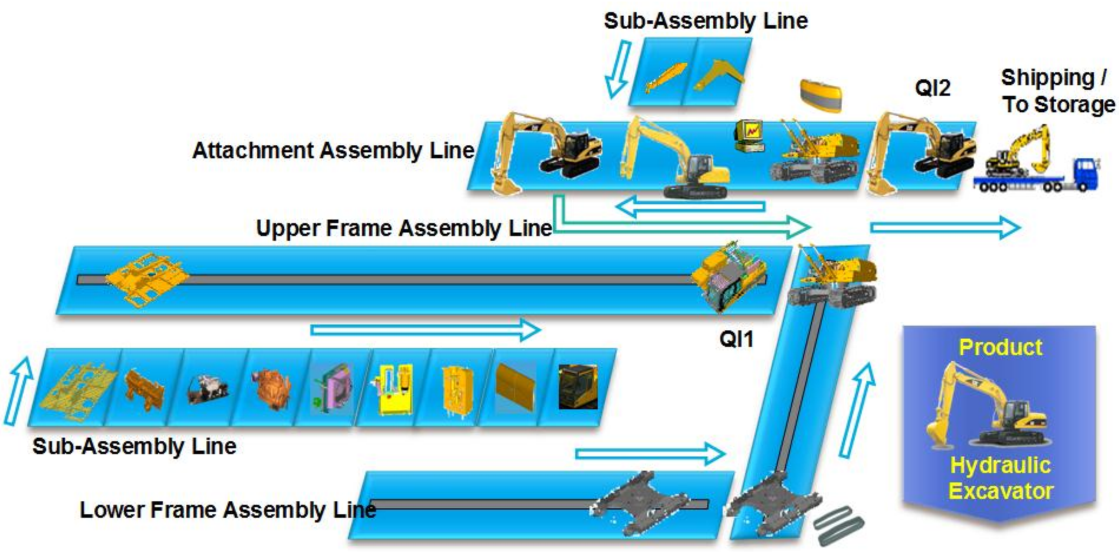

Figure 13. New proposed assembly layout

Table 4. Overall improvements

	Improvement					
	Capacity per year	**LE**	**SI**	**BD**	**No. of WorkStation**	**No. of Operators**
Current	1800	55.98%	86.19	19.93%	15	37
Proposed	3000	97.98%	7.94	1.89%	23	37
Improvement	66.67%	75.03%	90.79%	90.52%	8	0

CONCLUSIONS

Overall, the conclusion can be summarized as follows: (1) Proposed line assembly is more efficient due to workload arrangement. (2) The smaller value of the smoothness index shows that there are no violations of operation between workstations, so the bottleneck workstations are eliminated. (3) Workload arrangements generated from the RPW method are successfully balancing the new line assembly proposed. (4) As the efficiency of line assembly has increased, it is obvious that the line can produce a target output of 3000 capacity per year. The

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management considers that this is a good proposal because of its small investment and soon will be implemented.

REFERENCES

Afifuddin, M. (2019). Penerapan Line Balancing Menggunakan Metode Ranked Position Weight (RPW) untuk Meningkatkan Output Produksi pada Home Industri Pembuatan Sepatu Bola. *Journal of Industrial Engineering Management*, 4(1), 38–46.

Astuti, R. D., & Edy purwanto, H. S. A. (2019). Perbaikan Line Balancing Proses Packing Tablet Xyz Menggunakan Metode Ranked Positional Weight Di Pt. Y. *Performa: Media Ilmiah Teknik Industri*, 18(1).

Azwir, H. H., Aryanto, K. C., & Oemar, H. (2020). Analisis Line Balancing pada Line x cc Machining Department di Perusahaan Otomotif untuk Peningkatan Kapasitas Produksi. *Jurnal IPTEK*, 24(1), 27–36.

Azwir, H. H., & Pratomo, H. W. (2017). Implementasi Line Balancing untuk Peningkatan Efisiensi di Line Welding Studi Kasus: PT X. *Jurnal Rekayasa Sistem Industri*, 6(1), 57.

Baroto, T. (2002). *Perencanaan dan Pengendalian Produksi*. Ghalia Indonesia.

Cahyo, W. N. (2019). A Proposed Framework to Apply Operational Excellence (opex) as a Business Strategy. *Journal of Engineering and Management in Industrial System*, 7(1), 15–24.

Dharmayanti, I., & Marliansyah, H. (2019). Perhitungan Efektifitas Lintasan Produksi Menggunakan Metode Line Balancing. *Jurnal Manajemen Industri dan Logistik*, 3(1), 45–56.

Kitriastika, V., Tanaya, P. I., & Indrayadi, Y. (2013). A Redesign Layout to Increase Productivity of a Company. *Jurnal Ilmiah Teknik Industri*, 12(1), 83–95.

Manaye, M. (2019). Line Balancing Techniques for Productivity Improvement. 7(1), 17.

Prabowo, R. (2016). Penerapan Konsep Line Balancing Untuk Mencapai Efisiensi Kerja Yang Optimal Pada Setiap Stasiun Kerja Pada Pt. Hm. Sampoerna Tbk. *Jurnal IPTEK*, 20(2), 9–19.

Prasetyabudi, W. A., Adiyanto, O., & Adityo, L. B. (2019). Analisa Kapasitas Produksi Di stasiun Perakitan Dengan Metode Penjadwalan Deterministik. *Jurnal Manajemen Industri Dan Logistik*, *03*(01), 1–13.

Pujotomo, D., & Rusanti, D. N. (2015). Usulan Perbaikanuntuk Meningkatkan Produktivitas Fillingplant Dengan Pendekatan Lean Manufacturing Pada Pt Smart Tbk Surabaya. *Jurnal Teknik Industri*, 10(2), 123–132.

Purnama, R. I., & Ikatrinasari, Z. F. (2013). Perbaikan Sistem Produksi Minyak Angin Aromatherapy Melalui Lean Manufacturing Di Pt. Us, Jawa Barat. *Jurnal Teknik Industri*, 8(2), 99–106.

Purnomo, H. D., Wee, H.-M., & Rau, H. (2011). Harmony Search for Balancing Two-sided Assembly Lines. *Jurnal Teknik Industri*, 14(2).

Saiful, S., Mulyadi, M., & Rahman, T. M. (2016). Penyeimbangan Lintasan Produksi Dengan Metode Heuristik (studi Kasus Pt Xyz Makassar). *Jurnal Teknik Industri*, 15(2), 182–189.

Srijayasari, H., Pratikto, P., & Gapsari, F. (2018). Designing Line Balancing for Ammunition Box Production Using Heuristic Method. *Journal of Engineering and Management in Industrial System*, 6(2), 105–113.

Sunny, O., Maukar, A. L., & Sosodoro, I. W. (2019). Perancangan Kapasitas Produksi Produk Electronic Control Unit (Ecu). *JIE Scientific Journal on Research and Application of Industrial System*, 4(1), 53.

Tiovani, O. (2019). Perbaikan Proses Produksi Menggunakan ECRS Based Line Balancing pada Lini Perakitan Stator 4. *Performa: Media Ilmiah Teknik Industri*, 18(1).

Wignjosubroto, S. (2009). *Tata Letak Pabrik dan Pemindahan Bahan*. Guna Widya.