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Line Balancing and Workload Redistribution to Reduce Overtime in a Mixed-Model Production System at CV XYZ

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ABSTRACT

CV XYZ is a spare parts manufacturing company in Surabaya facing production line imbalance in a mixed-model line producing Spur Gear, Shaft Pump, and Housing Bearing. The initial conditions showed Workstation 2 Lathe Machine (1 meter) as the primary bottleneck with a workload of 212.67% and Full Time Equivalent value of 2.31 due to simultaneous processing of two products. This resulted in line efficiency of 66.61 percent, Balance Delay of 33.39 percent, Smoothness Index of 325.68, and 885 man-hours of overtime costing IDR 18,585,000 during October 2025–March 2026. Based on three improvement iterations, the third was selected as the optimal solution with a 6-workstation configuration through optimization of Lathe Machine (1 meter). The proposed improvement increased line efficiency to 85.91 percent, reduced Balance Delay to 14.09 percent, and lowered the Smoothness Index to 87.78. Workforce validation showed 6 operators are sufficient, with Workstations 1 through 4 within the normal category. Second lathe machine optimization reduced overtime to 548 hours, cutting overtime costs IDR 7,077,000. Total operational costs decreased from IDR 112,930,975 to IDR 107,562,767, yielding net saving of IDR 5,368,208 or 4.75 percent without additional labor or investment in new machinery.

INTRODUCTION

Effective and efficient utilization of resources is a key indicator in measuring a manufacturing company's competitiveness. One of the main challenges faced by manufacturing companies is production line imbalance, which causes workload accumulation at certain workstations, increases idle time, and inflates operational costs [1]. Production line imbalance can result in bottleneck conditions where some workstations are overloaded while others remain underutilized [2]. Continuous overtime is a clear indication of suboptimal line productivity, as excessive overtime can reduce worker productivity due to physical and mental fatigue [3]. High overtime occurs due to uneven workload distribution across workstations, where some stations are overloaded while others are underutilized. This imbalance disrupts production flow and ultimately hinders the achievement of production targets [1].

Mixed-model production lines, which process multiple product variants using shared facilities, are more difficult to balance than single-model lines [4]. Each product variant may have different processing sequences, cycle times, and machine dependencies, making workload distribution across workstations more difficult [5]. In such environments, workload imbalance becomes more pronounced because shared equipment is used alternately for different product types. This condition can intensify congestion at certain workstations and reduce efficiency if not properly managed. As a result, the risk of bottleneck formation at shared-resource workstations becomes higher, which can disrupt production flow and reduce overall system performance [1].

CV XYZ is a precision machining and manufacturing company located in Surabaya, Indonesia. The company produces shaft, gear, bushing, and pen components using a make-to-order system, with 6 operators managing a mixed-model production line that simultaneously handles three main products: Spur Gear, Shaft Pump, and Housing Bearing. A critical bottleneck occurs because a single Lathe Machine (1 m) was shared alternately for processing Spur Gear and Housing Bearing, resulting in a workload ratio of 212.67% at Work Station 2. This forces three operators to work beyond regular working hours (7 hours/day) during the October 2025 – March 2026 period, accumulating 885 overtime man-hours at a cost of IDR 18,585,000.

Line balancing is a production strategy aimed at optimizing time and workload across interrelated processes in a production line to avoid bottleneck conditions [5]. The Ranked Positional Weight (RPW) method is a heuristic approach that assigns work elements to workstations based on their positional weights, the sum of the element's processing time and all following elements [6]. In addition, the Full Time Equivalent (FTE) method is used to evaluate workforce requirements based on the ratio of actual workload to available effective working time [7].

Previous studies demonstrate that line balancing methods effectively enhance production efficiency. According to Alfiono and Mundari, the Ranked Positional Weight (RPW) method increased line efficiency to 72.95% and reduced the number of workstations [8]. Similarly, Herdiani found that the RPW method at PT. Mandiri improved average workstation efficiency from 26.52% to 92% while decreasing balance delay to 17.48% [9]. Furthermore, Nathaniel et al. showed that integrating Full Time Equivalent (FTE) and line balancing increased production line efficiency by 13% by identifying overloaded and underloaded workstations [5]. Based on these findings, this research integrates the Ranked Positional Weight (RPW) and Full Time Equivalent (FTE) methods to create a more efficient line balance and reduce overtime in the spur gear production at CV XYZ.

This study aims to: (1) to quantify the initial line imbalance and identify the bottleneck work stations; (2) to propose a rebalanced line configuration using the Ranked Positional Weight (RPW) method and validate workforce adequacy using Full Time Equivalent (FTE) analysis; and (3) to evaluate the financial impact of the proposed improvement in terms of overtime cost reduction and total operational cost savings.

MATERIALS AND METHODS

This research was conducted at CV XYZ Surabaya from January to June 2026 using direct observation and time measurement. The study focused on three products produced on a mixed-model production line. The research stages included data collection, line balancing, and Full Time Equivalent (FTE) analysis to determine operational costs.

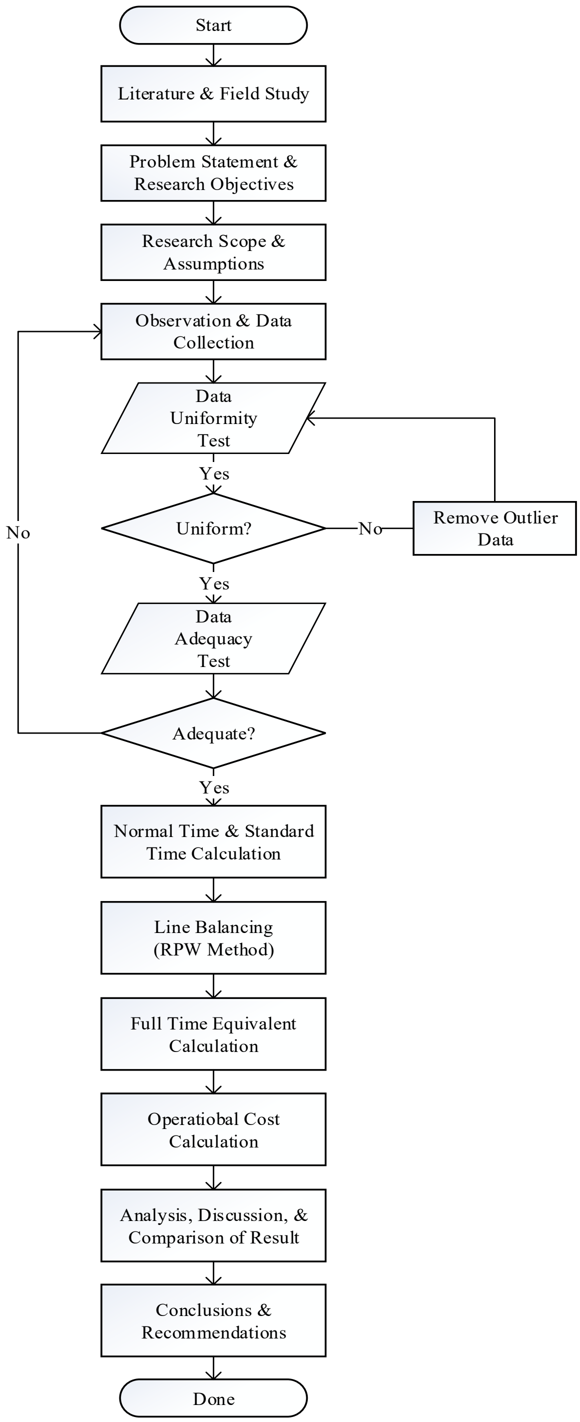

Figure 1. Research Flowchart

Data Collection

Primary data were collected through stopwatch time study observations. For each work element, 60 measurement samples were taken across 10 observation sessions. The stopwatch time study method introduced by Frederick W. Taylor allows measurement of work time for short, repetitive tasks [10]. Secondary data included historical production output from October 2025–March 2026, company profiles, working time regulations, overtime records, wage details, and machine inventories.

Data Uniformity and Adequacy Test

Before time data are used in subsequent calculations, two statistical tests are performed to ensure the data are consistent and representative. The uniformity test checks that all data come from the same system and are not affected by outliers or unusual conditions during observation. [11]. The uniformity test uses Upper Control Limit (UCL) and Lower Control Limit (LCL) with a 95% confidence level and 5% precision. Data points that fall within these limits are considered uniform and acceptable, while those outside the limits may indicate irregularities that need to be further examined or excluded from analysis.

$$\overline{X} = \sum \frac{X_i}{N} \ldots (1)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}} \ldots (2)$$

$$UCL = \bar{X} + k\sigma \ldots (3)$$

$$LCL = \bar{X} - k\sigma \ldots (4)$$

where $\bar{X}$ is the mean observation time, σ is the standard deviation, k is the confidence coefficient (k=2 for 95% confidence level, k=3 for 99% confidence level), N is the number of observations, and Xi is each observed value. The adequacy test verifies that the sample size is sufficient to represent the population:

$$N' = \left[\frac{\frac{k}{s}\sqrt{N \sum xi^2 - \sum(xi^2)}}{\sum xi}\right] \ldots (5)$$

where N' is the required number of observations, N is the actual number of observations taken, Xi is each observed value, s is the desired precision level, and k is the confidence coefficient. If N' ≤ N, the data are declared sufficient and no additional observations are needed.

Standard Time Calculation

Standard time is the time required by a worker with average ability to complete a task under normal working conditions [12]. Its calculation involves three sequential steps: cycle time, normal time, and standard time. Cycle time (CT) is the average time per work element, calculated from the mean of all valid observations after the uniformity test:

$$X = \frac{\sum xi}{N} \ldots (6)$$

Normal time (Wn) is obtained by multiplying the cycle time by the performance rating factor. Performance rating was assessed using the Westinghouse system, which evaluates four aspects of operator performance: skill, effort, working conditions, and consistency [13]. The formula is:

$$Wn = \overline{X} \text{ x } (1 + \text{Performance Rating}) \ldots (7)$$

Standard time (Wb) adds the allowance factor to normal time for personal needs, fatigue, and delays [10]. Standard time (Wb) is then calculated as:

$$Wb = Wn + [Wn \text{ x } allowance\%] \ldots (8)$$

The standard time result is used as the primary basis for all subsequent line balancing and FTE calculations, as it represents the actual time required to complete each work element under normal working conditions with allowances considered.

Weighted Time for Mixed-Model Production

Because the production line handles three products with different volumes, a weighted time approach was applied to ensure proportional calculation. The production proportion (Pi) for each product is:

$$(\mathrm{P_i}) = \frac{\mathrm{n_i}}{\sum \mathrm{n_i}} \ldots(9)$$

Pi represents the production proportion of product *i*, *ni* is the total production volume of product *i*, and Σni is the combined total production of all products. Based on the *Pi* values, the weighted time task time for each work element, as formulates [14]

$$(\mathrm{TT_k}) \ = \sum \mathrm{P_i} \text{ x } \mathrm{T_{ik}} \ldots(10)$$

where $(\mathrm{TT_k})$ is the total weighted average time for task *k*, *Pi* is the production proportion, and $\mathrm{T_{ik}}$ is the standard time of the work element for product model *i.* This weighted time value serves as the primary input for all subsequent line balancing calculations in the mixed-model system.

Line Balancing Using The Ranked Positional Weight (RPW) Method

Line balancing is a method to improve workstation efficiency in a production process by ensuring the workload of each operator does not exceed the established cycle time [15]. The following parameters measure line balancing performance [16]:

Cycle Time (CT) represents the maximum allowable time per unit at each workstation:

$$\mathrm{ti_{max}} \leq \mathrm{CT_{max}} \leq \frac{\mathrm{P}}{\mathrm{Q}} \ldots(11)$$

where timax is the largest operation time, P is effective working hours per period, and Q is production quantity per period.

Minimum Number of Workstations (K):

$$\mathrm{K} = \frac{\Sigma \mathrm{ti}}{\mathrm{CT_{max}}} \ldots(12)$$

Line Efficiency (LE):

$$\mathrm{LE} = \frac{\Sigma \mathrm{ti}}{(\mathrm{K})(\mathrm{CT})} \text{ x } 100\% \ldots(13)$$

Balanced Delay (BD):

$$\mathrm{BD} = \frac{(\mathrm{K} \text{ x } \mathrm{CT_{max}}) - \Sigma \mathrm{ti}}{(\mathrm{K} \text{ x } \mathrm{CT})} \text{ x } 100\% \ldots(14)$$

Smoothness Index (SI):

$$\mathrm{SI} = \sqrt{\Sigma(\mathrm{CT_{max}} - \mathrm{CT_i})^2} \ldots(15)$$

where CTi is the station time of workstation i. A lower SI value indicates more balanced workload distribution [17].

Full Time Equivalent (FTE) Method

According to (Mahawati et al. (2021). FTE is a time-based workload analysis method that converts workload hours into the number of human resources needed. FTE has advantages in optimizing employee performance and helping determine the ideal number of workers [18]. The FTE value is calculated as:

$$\text{FTE} = \frac{\sum \text{Work Time per Period}}{\sum \text{Effective Working Time per Period}} \ldots(16)$$

Effective working days are determined by (Keputusan Menteri PAN No. KEP/75/M.PAN/7/2004):

Effective Working Days = A - (B + C + D)…(17)

where A = total calendar days, B = Saturdays and Sundays, C = national holidays, D = annual leave entitlement. The FTE index classification is: Underload (0–0.99), Normal (1–1.28), and Overload (>1.28) [19].

Operational Cost Analysis

Labor cost is the cost charged for the use of labor [20]. One component of labor cost is overtime wages, which are additional payments given to workers who perform tasks beyond normal working hours [21]. In this study, overtime costs were calculated based on the duration of overtime work required in the production process. Furthermore, machine operating costs were evaluated based on the power consumption specifications of each machine as follows:

-Lathe machine power = 1.8 kW (adjusted to the machine specifications at CV XYZ)
-Electricity tariff = IDR 1,444.70/kWh
-Working days = 142 days (during the research period of October 2025 – March 2026)
-Overtime rate = IDR 21,000/hour

Three main cost components were analyzed to evaluate the financial impact of the proposed production line improvements:

Overtime Cost = Σ Overtime Hours × Overtime Rate…(18)
Base Salary Cost: Number of Operators × Daily Wage × Working Days…(19)
Machine Electricity Cost: Operating Hours × Machine Power × Electricity Tariff …(20)

RESULTS AND DISCUSSIONS

Production Demand and Product Proportion Analysis

This study focuses on three components, namely Spur Gear, Shaft Pump, and Housing Bearing, produced on a mixed model production line with different work elements and processing times. Based on the daily target and available working time of 420 minutes per day and the takt time is determined to be 150.54 minutes per unit.

The product proportion (P_i) was used as the workload weight to calculate the weighted average task time (TT_k) [14]. The results showed that the maximum cycle time exceeded the takt time, indicating bottlenecks and workload imbalance in the production line.

Table 1. Product Proportion and Workload Composition

Product Type	**Total Production (Units)**	**Daily Target (Units)**	***Proportion (Pi)***
Spur Gear	164	1,15	41,2%
Shaft Pump	110	0,77	23,7%
Housing Bearing	122	0,86	35,1%
Total	**396**	**2,79**	**100%**

Measurement of Initial Production Line Efficiency

The initial production line consisted of four workstations (K = 4). The workload distribution analysis indicated an imbalance among workstations, where several stations experienced excessive workloads while others had relatively low workloads.

Table 2. Work Element List

WS	Work Element	Predecessor	Description	ST (Mins)	Pi (Mins)
1	A	-	Measuring	4,33	**4,33**
	B	A	Marking	1,41	**1,41**
	C	B	Cutting	7,10	**7,10**
	D *(S)*	C	Lathe Turning Ø30mm	187,86	**52,18**
	E *(S)*	D *(S)*	Lathe Turning Ø25mm	139,52	**38,75**
	F *(S)*	E *(S)*	Lathe Turning Ø22mm	109,45	**30,40**
	G *(S)*	F *(S)*	Lathe Turning Ø12mm	50,19	**13,94**
	H *(S)*	G *(S)*	Inspection	1,44	**0,40**
	I *(S)*	H *(S)*	Chamfer	23,98	**6,66**
	J *(S)*	I *(S)*	Inspection	1,40	**0,39**
	K *(S)*	J *(S)*	Lathe Undercut Detail A	34,60	**9,61**
	L *(S)*	K *(S)*	Inspection	1,42	**0,39**
2	D *(G)*	C	Outer Diameter Lathe & Facing	66,35	**27,48**
	E *(G)*	D *(G)*	Hub Forming	147,34	**61,02**
	F *(G)*	E *(G)*	Shaft Hole Forming	178,37	**73,87**
	G *(G)*	F *(G)*	Inspection	1,45	**0,60**
	D *(B)*	C	Lathe Turning Ø145mm	207,25	**63,85**
	E *(B)*	D *(B)*	Lathe Turning Ø125mm	149,05	**45,92**
	F (B)	E *(B)*	Lathe Turning Ø112mm	89,50	**27,57**
	G *(B)*	F (B)	Lathe Turning Ø85mm	49,60	**15,28**
	H *(B)*	G *(B)*	Inspection	1,43	**0,44**
	I *(B)*	H *(B)*	Chamfer 1.4x45°	13,86	**4,27**
3	H *(G)*	G *(G)*	Keyway Machining	107,77	**44,63**
	I *(G)*	H *(G)*	Set Screw Hole Drilling	84,45	**34,98**
	J *(G)*	I *(G)*	Thread Making	30,55	**12,65**
	K *(G)*	J *(G)*	Inspection	1,47	**0,61**
	M *(S)*	L *(S)*	Keyway 8x4x40mm	100,96	**28,05**
	N *(S)*	M *(S)*	Inspection	1,44	**0,40**
	O *(S)*	N *(S)*	Keyway 6x3x35mm	89,54	**24,87**
	P *(S)*	O *(S)*	Thread Making	21,34	**5,93**
	J *(B)*	I *(B)*	Bolt Drilling 8xØ13mm	65,15	**20,07**
	K *(B)*	J *(B)*	Inspection	1,42	**0,44**
	L *(B)*	K *(B)*	Shaft Hole Drilling	121,54	**37,44**
4	L *(G)*	K *(G)*	Gear Hobbing	211,73	**87,69**
	M *(G)*	L *(G)*	Inspection	1,45	**0,60**
	N *(G)*	M *(G)*	Heat Treatment	86,85	**35,97**
	O *(G)*	N *(G)*	Gear Grinding	52,83	**21,88**
	Q	O *(G), P* (S), L *(B)*	Final Inspection	11,38	**11,38**

Precedence Diagram

The precedence diagram illustrates the sequence and relationship of each work element based on Table 2. Once the diagram was constructed, the processing time for each element was determined and then used as input in the line balancing analysis. This diagram helps clearly show the dependency between work elements, making it easier to understand the flow of the production process and ensuring that all tasks are arranged in the correct operational sequence.

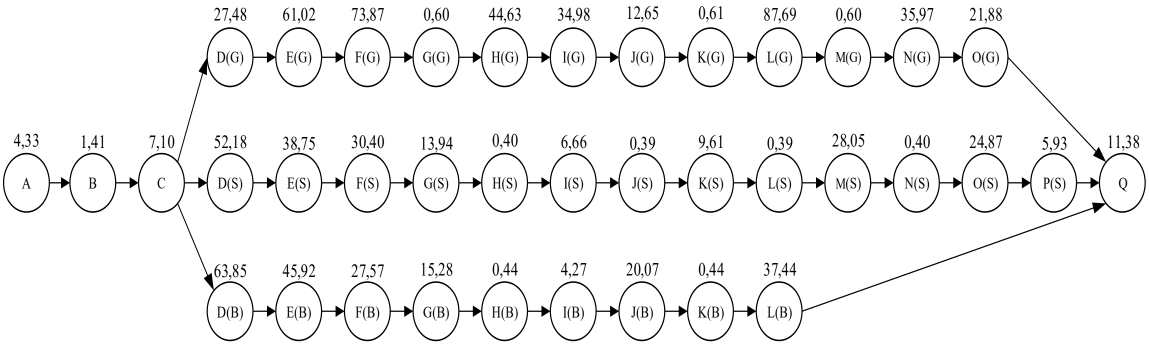

Figure 2. Precedence Diagram For Each Work Element

Initial Production Line Condition

The initial production line consisted of four workstations (K = 4). The workload distribution analysis showed a significant imbalance among the stations, indicating that some workstations carried a much higher load compared to others. Table 3 summarizes the initial workstation configuration, including the distribution of tasks and workload at each station.

Table 3. Workload Distribution in Initial Production Line Condition

WS	Process	Operator	Load Ratio (%)	Note
1	Preparation	1	109,94%	**Overtime**
	Lathe Machine (2 m)			
2	Lathe Machine (1 m) for Spur Gear	1	212,67%	**Overtime**
	Lathe Machine 1 m for Housing Bearing			
3	Milling Machine (Spur Gear & Shaft Pump)	1	101,00%	**Overtime**
	Frais Machine	1	38,48%	**-**
4	Hobbing Machine	1	58,62%	**-**
	Finishing	1	45,96%	**-**

Based on the weighted time calculations for the mixed-model line, the initial production shows a total processing time (ΣTi) = 853.57 minutes across four workstations. Table 3 shows a significant bottleneck at WS 2, which has a workload ratio of 212.67% with Ti max = 320.31 minutes due to the shared use of Lathe Machine (1 m) for both Spur Gear and Housing Bearing production. In addition, WS 1 and 3 (milling) are also overloaded as they exceed 100%, while WS 3 (Frais), WS 4 (Hobbing), and the finishing process are underutilized. The initial line performance indicators line are

Line Efficiency: LE $= \frac{853.46}{4 \text{ x } 320.31} \text{ x } 100\% = 66{,}61\%$

Balanced Delay: BD $= \frac{(4 \text{ x } 320.31 - 853.46)}{(4 \text{ x } 320.31)} \text{ x } 100\% = 33{,}39\%$

Smoothness Index: SI $= \sqrt{(154.74^2 + 0^2 + 168.19^2 + 232.02^2)} = 325.67$

Initial Full Time Equivalent (FTE) Analysis

Based on 142 effective working days at 7 hours/day, with a total allowance of 7.86%, the effective working time was calculated 54,952.72 minutes per six months. This value was used as the basis for calculating the Full Time Equivalent (FTE) of each workstation to evaluate workload distribution under the initial production condition. Table 4 summarizes FTE values for the initial condition.

Table 4. FTE Summary for Initial Condition

SK	Process	Operators	Total Work Time (Min/6Mo)	Eff. Work Time (Min/6Mo)	FTE Value	Category
1	Preparation	1	5.084,64	54.952,72	1,19	***Normal***
	Lathe Machine (2 m)		60.484,82			
2	Lathe Machine (1 m) for Spur Gear	1	64.537,07	54.952,72	2,31	***Overload***
	Lathe Machine (1 m) for Housing Bearing		62.304,34			
3	Milling Machine (Spur Gear & Shaft Pump)	1	60.237,34	54.952,72	1,10	***Normal***
	Frais Machine	1	22.948,38		0,42	***Underload***
4	Hobbing Machine	2	31.323,05	54.952,72	0,57	***Underload***
	Finishing		22.839,91		0,42	

The FTE analysis indicates that WS 2 experiences the highest workload, with an FTE value of 2.31, which falls into the overload category. This condition shows that one operator is insufficient to handle the assigned workload, indicating the need for an additional operator or workload redistribution. In contrast, WS 1 and the milling process at WS 3 are within the normal category, with FTE values of 1.19 and 1.10, respectively. Meanwhile, the remaining processes at WS 3 and WS 4 are underloaded, with FTE values ranging from 0.42 to 0.57. These results indicate that while WS 2 requires workload redistribution, several other workstations still have available capacity that can be utilized to improve line efficiency.

Line Balancing Results Using The Ranked Positional Weight (RPW) Method

The Ranked Positional Weight (RPW) method began with the development of a precedence matrix for 38 work elements from the three products to identify the operational sequence and task relationships in the production line. The minimum number of workstations was estimated at $K = \Sigma Ti / CTmax = 853.57/165{,}58 \approx 6$ workstations.

Table 5. Selected Workstation Configuration

WS	Process	Work Element	Description	ST (Mins	Pi (min)
1	Preparation	A	Measuring	4,33	**165,58**
		B	Marking	1,41	
		C	Cutting	7,10	
	Lathe Machine (2 m)	D *(S)*	LatheTurning Ø30mm	52,18	
		E *(S)*	LatheTurning Ø25mm	38,75	
		F *(S)*	LatheTurning Ø22mm	30,40	
		G *(S)*	LatheTurning Ø12mm	13,94	
		H *(S)*	Inspection	0,40	
		I *(S)*	Chamfer	6,66	
		J *(S)*	Inspection	0,39	
		K *(S)*	LatheUndercut Detail A	9,61	
		L *(S)*	Inspection	0,39	
2	Lathe Machine (1 m) for Spur Gear	D *(G)*	Outer Diameter Lathe & Facing	27,48	**162,97**
		E *(G)*	Hub Forming	61,02	
		F *(G)*	Shaft Hole Forming	73,87	
		G *(G)*	Inspection	0,60	
3	Lathe Machine (1 m) for Housing Bearing	D *(B)*	Lathe Turning Ø145mm	63,85	**157,33**
		E *(B)*	Lathe Turning Ø125mm	45,92	
		F (B)	Lathe Turning Ø112mm	27,57	
		G *(B)*	Lathe Turning Ø85mm	15,28	
		H *(B)*	Inspection	0,44	
		I *(B)*	Chamfer 1.4x45°	4,27	
4	Milling Machine	H *(G)*	Keyway Machining	44,63	**152,11**
		I *(G)*	Set Screw Hole Drilling	34,98	
		J *(G)*	Thread Making	12,65	
		K *(G)*	Inspection	0,61	
		M *(S)*	Keyway 8x4x40mm	28,05	
		N *(S)*	Inspection	0,40	
		O *(S)*	Keyway 6x3x35mm	24,87	
		P *(S)*	Thread Making	5,93	
5	Hobbing Machine	L *(G)*	Gear Hobbing	87,69	**88,29**
		M *(G)*	Inspection	0,60	
6	Frais Machine dan Finishing	J *(B)*	Bolt Drilling 8xØ13mm	20,07	**127,17**
		K *(B)*	Inspection	0,44	
		L *(B)*	Shaft Hole Drilling	37,44	
		N *(G)*	Heat Treatment	35,97	
		O *(G)*	Gear Grinding	21,88	
		Q	Final Inspection	11,38	

Table 5 presents the final proposed workstation configuration based on Iteration 3, which was selected as the best alternative after evaluating all improvement scenarios. The key improvement in the proposed design is separating Lathe Machine (1 m) into two dedicated workstations, WS 2 exclusively for Spur Gear and WS 3 exclusively for Housing Bearing. Table 6 compares the performance indicators of the initial condition and each iteration to evaluate the effectiveness of the proposed improvements.

Table 6. Performance Indicator Comparison

Parameter	Initial Condition	Iteration 1	Iteration 2	Iteration 3 (Selected)
Total Workstations	4	6	6	**6**
Ti max (min)	320.31	175.81	170.17	**165.58**
Line Efficiency (LE)	66.61%	80.91%	83.59%	**85.91%**
Balanced Delay (BD)	33.39%	19.09%	16.41%	**14.09%**
Smoothness Index (SI)	325.67	107.06	96.16	**87.78**

The final six-workstation configuration from Iteration 3 showed the best performance among all alternatives. The maximum workstation time decreased from 320.31 to 165.58 minutes, while Line Efficiency increased from 66.61% to 85.91%. In addition, Balanced Delay decreased from 33.39% to 14.09% and the Smoothness Index decreased from 325.67 to 87.78, indicating a more balanced workload distribution among workstations. Therefore, Iteration 3 was selected as the final proposed solution.

FTE Analysis of Proposed Condition

After line rebalancing, FTE was calculated for each work station using standard time data and daily work frequency based on a combined production target of 2.79 units per day. The effective working time was 54,952.72 minutes over 142 working days. Table 7 summarizes the FTE results for the proposed condition.

Table 7. FTE Summary for Proposed Work Stations

WS	Process	Operators	Total Work Time (Min/6Mo)	Eff. Work Time (Min/6Mo)	FTE Value	Category
1	Preparation + Lathe (2 m)	1	65,562.95	54,952.72	1.19	**Normal**
2	Lathe (1 m) for Spur Gear	1	64,537.07	54,952.72	1.17	**Normal**
3	Lathe (1 m) for Housing Bearing	1	62,304.49	54,952.72	1.13	**Normal**
4	Milling Machine	1	60,237.34	54,952.72	1.10	**Normal**
5	Hobbing Machine	1	34,961.39	54,952.72	0.64	**Underload**
6	Frais + Finishing	1	47,720.73	54,952.72	0.87	**Underload**

The FTE results for the proposed condition indicate a more balanced workload distribution across workstations. WS 1–WS 4 are categorized as normal, with FTE values ranging from 1.10 to 1.19, indicating that the assigned workloads are within the operators effective working capacity. Meanwhile, WS 5 and WS 6 are classified as underload, with FTE values of 0.64 and 0.87, respectively, suggesting that these stations still have available capacity. Overall, the proposed configuration represents a significant improvement over the initial condition, where WS 2 was severely overloaded with an FTE value of 2.31.

Overtime Operational Cost Analysis

Table 8 presents the distribution of overtime across each workstation in the proposed configuration. The table provides a comparison of overtime levels across all workstations to evaluate the effectiveness of the proposed production line configuration.

Table 8. Overtime Distribution by Work Station in The Proposed Condition

WS	Process	Operators	Total Work Time (Min/6Mo)	Eff. Work Time (Min/6Mo)	Overtime (Hours)	Avg/Month (Hours)
1	Preparation + Lathe (2 m)	1	65,567.94	54,952.72	177	**29**
2	Lathe (1 m) for Spur Gear	1	64,537.07	54,952.72	160	**27**
3	Lathe (1 m) for Housing Bearing	1	62,304.49	54,952.72	123	**20**
4	Milling Machine	1	60,237.34	54,952.72	88	**15**
5	Hobbing Machine	1	34,961.39	54,952.72	0	**0**
6	Frais + Finishing	1	47,720.73	54,952.72	0	**0**
		Total			**548**	**91**

Under the proposed configuration, WS 5 and WS 6 generate no overtime, while WS 1–4 each carry moderate overtime loads of 15–29 hours per operator per month, a substantial improvement over the initial condition where WS 2 alone generated the equivalent of full-time double-shift work. Total overtime man-hours drop from 885 to 547 hours, reducing overtime cost from IDR 18,585,000 to IDR 11,487,000.

Table 9. Operational Cost Comparison

Cost Component	Initial Condition (IDR)	Proposed Condition (IDR)	Savings (IDR)	Change (%)
Base Salary (6 Months)	89,460,000	89,460,000	—	—
Overtime Cost	18,585,000	11,508,000	7,077,000	**↓38.1%**
Electricity Cost	4,885,975	6,594,767	1,708,791	**↑25.9%**
Total Operational Cost	112,930,975	107,562,767	5,368,208	**↓4.75%**

The electricity cost for the lathe machine increases from IDR 4,885,975 to IDR 6,594,767 because operating hours rise from 1,879 to 2,536 after adding a second machine. However, this increase of IDR 1,708,791 in electricity cost is offset by a reduction in overtime cost of IDR 7,077,000. As a result, the system generates a net saving of IDR 5,368,208 over six months.

Discussions

The RPW method increased line efficiency from 66.61% to 85.91% and reduced balance delay from 33.39% to 14.09%. The Smoothness Index also decreased from 325.67 to 87.78, indicating a more balanced workload distribution across all workstations. In addition, the maximum workstation time was reduced from 320.31 minutes to 165.58

minutes, showing that the bottleneck at the lathe operation was significantly reduced. These results are consistent with findings by Alfiono & Mundari [8] and Febriani et al. [22], who demonstrated the effectiveness of Ranked Positional Weight (RPW) in reducing waiting time and improving line efficiency.

Although the number of operators working overtime increased from 3 to 4 persons, total overtime man-hours decreased substantially from 885 to 548 hours, representing a reduction of 337 hours or 38.1%. This improvement was achieved through a more balanced workload distribution among workstations. In the initial condition, WS 2 was severely overloaded with an FTE value of 2.31, requiring one operator to handle excessive overtime. In the proposed condition, overtime was distributed across four operators, with each operator working approximately 15–29 hours per month. This result is consistent with Nathaniel et al. [5] who found that line balancing can reduce labor burden by eliminating bottlenecks.

The strategy of optimizing existing underutilized machine assets Lathe Machine (1 m) rather than hiring additional labor is consistent with Hadisaputra & Putri [23], who demonstrated that asset optimization is more cost-effective than workforce expansion in small-to-medium manufacturing enterprises. Futhermore, the FTE analysis, as applied by Sukirman et al. [24] and Kuswardhani et al. [7], proved valuable in providing an objective, data-driven basis for workforce allocation decisions in the proposed line configuration.

Despite the promising results, this study has several limitations, including the exclusion of material handling distances, operator learning effects, and dynamic variations in processing time. Therefore, future studies may focus on redesigning the production layout using Systematic Layout Planning (SLP) to support the new workstation configuration and applying discrete event simulation to evaluate production line performance under more realistic operating conditions.

CONCLUSION

This study shows that the combination of the Ranked Positional Weight (RPW) method and the Full Time Equivalent (FTE) method analysis can effectively overcome imbalance in a mixed model production line. Three principal findings are drawn:

1. The initial production line at CV XYZ showed a significant workload imbalance, with WS 2 becoming the main bottleneck due to the shared use of Lathe Machine (1 m) for Spur Gear and Housing Bearing production. This condition resulted in a line efficiency of 66.61%, a balance delay of 33.39%, a smoothness index of 325.67, and a total of 885 overtime man-hours at a cost of IDR 18,585,000 over six months.
2. The proposed improvement using the Ranked Positional Weight (RPW) method generated the best result in Iteration 3 by reconfiguring the line from four to six workstations and optimizing the utilization of the existing lathe machine. This improvement increased line efficiency from 66.61% to 85.91%, reduced balance delay from 33.39% to 14.09%, lowered the smoothness index from 325.67 to 87.78, and decreased the maximum workstation time from 320.31 minutes to 165.58 minutes. The FTE analysis also confirmed that the existing six operators were sufficient without requiring additional labor.
3. The proposed configuration reduced total overtime from 885 to 548 hours or 38.1% and decreased overtime costs by IDR 7,077,000. Although electricity costs increased due to the operation of the second lathe machine, the company still achieved total operational cost savings of IDR 5,368,208 or 4.75% without additional workers or investment in new machinery.

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