

# Analysis of Production Planning and Age Replacement to Minimize Overstock, Stockout, and Downtime

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## ABSTRACT

PT X is a concrete manufacturing industry that produces 2 types of rebar, namely deformed bars and plain bars. In its production activities, the company faces challenges such as the high frequency of roughing mill machine breakdowns, which cause production downtime, and the imbalance between production capacity and demand, resulting in overstock and stockout conditions during certain periods. This research aims to improve the maintenance system of the Roughing Mill machine to reduce downtime so that the production process aligns with the plan, as well as to develop an accurate production plan to ensure production meets demand and minimizes capacity imbalance. The methods used include age replacement, work measurement to determine standard time, and demand forecasting using the linear trend model and moving average, as well as aggregate planning using the demand forecast results and standard time as inputs to develop the production plan, which is then detailed into the master production schedule and evaluated using rough-cut capacity planning. The research results show that the implementation of age replacement was able to reduce downtime from 82.1 hours to 17.09 hours. It increased capacity from 197 to 208 hours per month. The planning capacity is in the range of 190-214 hours per month with an average of 202 hours, which is capable of meeting production needs of 166-174 hours per period. The RCCP results show that the capacity is still sufficient and all demand can be met optimally.

**Key words :** Age replacement, downtime, aggregate planning, production capacity.

## 1. INTRODUCTION

The rebar industry is one of the manufacturing sectors that plays an important role in supporting infrastructure development. With the development of construction, the increasing demand for rebar requires companies to meet production targets in a timely and efficient manner. Good planning can help companies avoid stock shortages or excess

stock situations that can affect the company's performance [1]. Production capacity planning is necessary to maintain the balance between product demand and available production capacity so that the production process can run optimally [2].

PT X is a manufacturing company that produces plain bars and deformed bars located in Sidoarjo Regency, East Java, Indonesia. Although it has been operating for more than five decades, the high downtime of 82.1 hours on the roughing mill machine with a damage frequency of 38 times has caused the production process to not run optimally, potentially resulting in delays in meeting demand. Additionally, the determination of production quantities that have not been based on demand forecasting from previous periods also causes a mismatch between production output and market needs, leading to conditions of excess stock and stock shortages in several production periods. Proper production planning can minimize overstock and optimize production capacity in the future [3].

To address this issue, planned production and maintenance are necessary to minimize machine damage. One of the methods that can be used is age replacement, which is a component replacement scheduling method based on optimal replacement age so that machine failure frequency and downtime can be minimized [4]. Additionally, work measurement and demand forecasting are used as the basis for developing aggregate planning to determine the optimal production quantity for each production period [5]. Aggregate planning aims to determine the optimal production quantity, labor, inventory, and utilization of working time to minimize production costs [6]. The results of aggregate planning are then detailed into the Master Production Schedule (MPS) to determine the production schedule for each product more specifically. The MPS is used as the basis for production control and determining the company's production capacity needs [7]. Rough Cut Capacity Planning (RCCP) analysis is used to determine the alignment between available capacity and the capacity needed at the production workstations. RCCP helps the company identify potential shortages or excesses in production capacity, allowing the production process to run more effectively [8].

Therefore, this research aims to develop a production plan that aligns with the company's capacity and to propose

component replacement intervals on the roughing mill machine to minimize downtime and enhance the effectiveness of the production process.

**2. METHODOLOGY**

The research data was collected during the period from January 2025 to January 2026, including data on machine breakdowns, downtime, production demand, and the company's production data. The research stages are carried out thru several main stages, namely:

1. Machine failure analysis
2. Preventive maintenance using age replacement
3. Work measurement
4. Forecasting
5. Aggregate planning
6. Master production schedule
7. Rough cut capacity planning

The research begins with machine failure analysis to determine the optimal preventive maintenance interval to reduce downtime. Next, work measurement and forecasting are conducted as the basis for production planning and validation of the company's production capacity.

**2.1 Age Replacement**

Age Replacement is used to determine the optimal replacement time interval, thereby minimizing the total downtime that occurs. Time to Failure (TTF) and Time to Repair (TTR) data are analyzed using statistical distributions with the help of Arena Input Analyzer software to obtain the Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR) values. The distributions of TTF and TTR data used in the study are shown in Table 1 and Table 2:

**Table 1 :** Data distribution TTR roll component

Component	Distribution	$\beta$	$\eta$
Roll	Weibull	1.10	1.20

Table 1 presents the Weibull distribution parameters of the roll component with  $\beta = 1.10$  and  $\eta = 1.20$ .

**Table 2:** Data distribution TTF roll component

Component	Distribution	s	$\mu$
Roll	Normal	17.8	37.5

Table 2 presents the Normal distribution parameters of the roll component with  $s = 17.8$  and  $\mu = 37.5$ . Meanwhile, the MTTR and MTTF values based on the selected distributions for the roll component are shown in Table 3:

**Table 3:** MTTR and MTTF values

Component	MTTR (hours)	MTTF (hours)
Roll	1.16	37.5

Based on Table 3, Based on Table 3, the roll component has an MTTR value of 1.16 hours and an MTTF value of 37.5 hours.

The calculation of the Age Replacement method can be determined based on the formula:

$$D_{(tp)} = \frac{(Tp \times R(tp)) + (Tf \times F(tp))}{((tp + Tp) \times R(tp)) + ((M(tp) + Tf) \times F(tp))} \tag{1}$$

Explanation:

$D_{(tp)}$  = Total downtime during the preventive replacement interval

$R_{(tp)}$  = Probability of the preventive cycle

$M_{(tp)}$  = Expected value of the damage cycle length if a repair replacement is performed

$Tf$  = Time to perform damage repair

$Tp$  = Time to perform preventive replacement

$tp$  = Interval time for preventive replacement

$F_{(tp)}$  = Probability density function of damage time

Downtime calculations are performed to determine the total machine downtime before and after the implementation of preventive maintenance using the Age Replacement method [9]. The downtime after preventive maintenance can be calculated using the formula:

$$\text{Downtime} = D_{(tp)} \times \text{Operating Days} \times \text{Operating Hours} \tag{2}$$

Explanation :

$D_{(tp)}$  = Total downtime during the preventive maintenance interval

Next, the effective capacity is calculated by considering machine downtime. The calculation is performed using the following formula:

$$\text{Effective Capacity} = \text{Total Operating Time} - \text{Downtime} \tag{3}$$

**2.2 Forecasting**

Forecasting is used to estimate production demand during the planning period based on historical demand data with the POM-QM software. The selection of the forecasting method is based on the comparison of the smallest error values from MAD (Mean Absolute Deviation), MAPE (Mean Absolute Percentage Error), and MSE (Mean Squared Error) [10]. The selected forecasting method for deformed bars is Exponential Smoothing, while for plain bars, it is the Linear Trend Model. The results of the selected forecasting methods are shown in Table 4:

**Table 4:** Selected forecasting method

Product	Selected Method	MAD	MSE	MAPE
Deformed Bars	Moving Average	19.852	1886.93	7.61%
Plain Bars	Linear Tren Model	0.288	0.113	0.11%

Based on Table 4, the selected forecasting method for Deformed Bars is Moving Average with MAD, MSE, and

MAPE values of 19.852, 1886.93, and 7.61%, respectively. Meanwhile, Plain Bars use the Linear Trend Model with MAD, MSE, and MAPE values of 0.288, 0.113, and 0.11%, respectively.

**2.3 Work Measurement**

Work measurement is conducted to obtain the standard time for each product, which is used as the basis for calculating production capacity in aggregate planning. Work measurement at each work station is shown in Table 5:

**Table 5:** Standard time at each work station

Work Station	Plain Bars (tons/hours)	Deformed Bars (tons/hours)
Reheating	0.143	0.143
Roughing roll	0.327	0.331
Intermediate roll	0.089	0.105
Finishing roll	0.074	0.225
Cooling	0.081	0.089
Bundling	0.066	0.072
Bending	0.067	0.078
QC	0.045	0.046

Table 5 presents the results of standard time measurements at each workstation for Plain Bars and Deformed Bars products. The values vary at each workstation, with Plain Bars and Deformed Bars showing different processing times at each stage.

**2.4 Aggregate Planning**

Aggregate planning is used to balance production demand with available capacity by considering regular time (RT) and overtime (OT). Planning is based on forecasting results and standard time to meet production needs in each period.

**2.5 Master Production Schedule**

Master Production Schedule (MPS) is used to create a production schedule based on the results of aggregate planning, which is then disaggregated into individual products. The MPS results are used as a basis for determining the production quantity for each period.

**2.6 Rought Cut Capacity Planning**

Rough Cut Capacity Planning (RCCP) is a method used to evaluate the alignment between available production capacity and capacity requirements based on the Master Production Schedule. RCCP uses the Bill of Resources (BOR) approach, which is a method for calculating capacity requirements based on the number of products produced and the standard time for each production resource.

**3. RESULT AND DISCUSSION**

Data collection was conducted from January 2025 to January 2026, covering machine damage data, downtime, as well as demand and production output data. The normal working hours are 8 hours per day, while the overtime hours are 3 hours per day. The research data is shown in Table 6 and Table 7:

**Table 6:** Roll component failure and downtime data of roughing mill machine

Mount	Working Days (days)	Failure Frequency (times)	Total Dontime (hours)
August 2025	26	5	7.9
September 2025	26	12	23.8
October 2025	27	17	15.9
November 2025	25	6	14.1
December 2025	27	4	8.1
Januari 2026	27	4	12.3
Total	158	38	82.1

Table 6 shows the production data related to roll component failures in the roughing mill machine, including working days, failure frequency, and total downtime. The total working days are 158 days, with 38 roll component failure occurrences and a total downtime of 82.1 hours.

**Table 7:** Demand and production data of deformed bars and plain bars

Mount	Deformed Bars		Plain Bars	
	Demand (tons)	Production (tons)	Demand (tons)	Production (tons)
January 2025	190	198	222	230
February 2025	195	202	227	235
March 2025	188	194	233	241
April 2025	192	198	238	246
May 2025	197	204	244	252
June 2025	185	191	249	256
July 2025	198	205	255	263
August 2025	193	198	260	266
September 2025	331	265	266	190
October 2025	187	194	271	278
November 2025	194	201	277	285
December 2025	189	196	282	290
January 2026	191	198	288	296

Table 7 shows that most months experienced overstock conditions, while stockout occurred in September, indicating that production was not fully aligned with demand.

### 3.1 Age Replacement Analysis

Based on the distribution parameters in Tables 1–3, an Age Replacement calculation was performed to determine the optimal replacement interval shown in Table 8:

**Table 8:** Age replacement results

tp (hours)	$R_{(tp)}$	$F_{(tp)}$	$M_{(tp)}$	$D_{(tp)}$
15	0.8205	0.1795	208.968	0.01355
16	0.8076	0.1924	194.951	0.01353
17	0.7945	0.2055	182.448	0.01352
18	0.7811	0.2189	171.287	0.01353
19	0.7675	0.2325	161.318	0.01354

Table 8 shows that the optimal replacement interval is obtained at  $tp = 17$  hours because it results in a minimum value of 0.01352. Based on the Age Replacement calculation results in Table 8, the following is a comparison of downtime reduction before and after the implementation of preventive maintenance in Table 9:

**Table 9:** Downtime reduction results

Condition	Downtime (hours)
Before Maintenance	82.1
After Maintenance	17.09

The results of the downtime reduction calculations in Table 9, indicate a reduction in downtime from 82.1 hours to 17.09 hours. followed by the comparison of capacity before and after the implementation of age replacement in Table 10:

**Table 10:** Effective capacity results

Condition	Effective Capacity (hours/month)
Before Maintenance	197
After Maintenance	208

Table 10 presents the comparison of effective capacity before and after the implementation of the age replacement method. The effective capacity increased from 193 hours/month to 203 hours/month following the reduction in machine downtime. Available capacity increased after the reduction of machine downtime.

### 3.2 Demand Forecasting

Based on the selected forecasting method in table 4, the production forecasting results are shown in table 11:

**Table 11:** Demand forecasting results

Mount	Demand Product	
	Deformed Bars (tons)	Plain Bars (tons)
February 2026	209	294
March	212	299

2026		
April 2026	214	305
May 2026	216	311
June 2026	202	316
July 2026	204	321

Table 1 presents the demand forecasting results for Deformed Bars and Plain Bars, which are used to estimate future product demand based on historical data.

### 3.3 Bottleneck and Standard Time Analysis

Based on the standard work measurement time in Table 5, the work station for the roughing roll process has the largest standard time for both products, thus it is used as the basis for capacity calculation in aggregate planning. In Table 12:

**Table 12:** Standard time for roughing roll process

Product	Bottleneck Process	Standard Time (tons/hours)
Deformed Bars	Roughing roll	0.331
Plain Bars	Roughing roll	0.327

Table 12 presents the selected standard time for the roughing roll process. Based on the work measurement results in Table 5, the roughing roll station is identified as the bottleneck for both products, with standard times of 0.331 hours/tons for Deformed Bars and 0.327 hours/tons for Plain Bars, and is therefore used as the basis for capacity calculation in aggregate planning.

### 3.4 Aggregate Planning Analysis

Based on the demand forecasting results in table 11 and the standard time results for both steel products in table 12, here is the aggregate demand requirement found in table 13:

**Table 13:** Aggregate demand

Mount	Demand Product (tons)		Standard Time Product (tons/hours)		Aggregate Demand (hours)
	Deformed Bars	Plain Bars	Deformed Bars	Plain Bars	
February 2026	209	294	0.331	0.327	166
March 2026	212	299	0.331	0.327	168
April 2026	214	305	0.331	0.327	171
May 2026	216	311	0.331	0.327	174
June 2026	202	316	0.331	0.327	171
July 2026	204	321	0.331	0.327	173

Table 13 shows the aggregate demand calculation results for each month based on work measurement data, combining product demand, standard time, and aggregate demand. The results indicate the total workload required for each production period from February to July 2026.

Based on the downtime reduction results in Table 9, the effective available capacity is determined by the number of working days each month with a regular time capacity of 8 working hours per day and an overtime capacity of 3 overtime working hours per day. The effective available capacity results are shown in Table 14:

**Table 14:** Effective available capacity

Mount	Working days (days)	Reguler time (hours)	Overtime (hours)
February 2025	24	190	72
March 2025	25	198	75
April 2025	25	198	75
May 2025	26	206	78
June 2025	26	206	78
February 2025	27	214	81

Table 14 presents the effective available capacity, including working days, regular time, and overtime hours used in the capacity calculation process. Based on the results of the aggregate demand and effective available capacity in Table 13 and Table 14, the aggregate planning has been prepared as shown in Table 15:

**Table 15:** Aggregate planning

Mount	Demand (hours)	Reguler time (hours)	Overtime (hours)
February 2025	166	190	-
March 2025	168	198	-
April 2025	171	198	-
May 2025	174	206	-
June 2025	171	206	-
February 2025	173	214	-

The results of the aggregate planning show that the effective regular time capacity can meet all demand needs from February to July 2026. Therefore, no additional capacity thru overtime work is needed because all demand can be met by the available regular time capacity.

### 3.5 Master Production Schedule Analysis

Based on the aggregate planning results in Table 15 and the standard time in Table 12, the disaggregated Master Production Schedule results for each product are shown in Table 16:

**Table 16:** Master production Schedule

Mount	Aggregate Planning (hours)	Time Disaggregation (hours)		Standard Time Product (tons/hours)		Master Production Schedule (tons)	
		Deformed Bars	Plain Bars	Deformed Bars	Plain Bars	Deformed Bars	Plain Bars
February 2026	166	69.179	96.138	0.331	0.327	209	294
March 2026	168	70.172	97.773	0.331	0.327	212	299
April 2026	171	70.834	99.735	0.331	0.327	214	305
May 2026	174	71.496	101.697	0.331	0.327	216	311
June 2026	171	66.862	103.332	0.331	0.327	202	316
July 2026	173	67.524	104.967	0.331	0.327	204	321

Table 16 shows the disaggregated Master Production Schedule results for each product, which are generated by converting the aggregate planning results in Table 15 using the standard time parameters in Table 12 to obtain a detailed production schedule.

### 3.6 RCCP and Capacity Analysis

Based on the results of the Master Production Schedule in Table 16, RCCP uses the Bill of Resources to convert the production plan into capacity requirements to validate the alignment between demand and available capacity. The RCCP results for each product are presented in Table 17 and Table 18:

**Table 17:** RCCP machine capacity requirements for plain bars production

Description	Mount					
	February 2026 (hours)	March 2026 (hours)	April 2026 (hours)	May 2026 (hours)	June 2026 (hours)	July 2026 (hours)
(1) Standard Machine Hours	96.14	97.77	99.74	101.70	103.33	104.97
(2) Efficiency Level (Actual Condition)	0.95	0.95	0.95	0.95	0.95	0.95
(3) Actual Requirement (1)/(2)	101.20	102.92	104.98	107.05	108.77	110.49
(4) Available Effective Capacity	111.15	115.83	115.83	120.51	120.51	125.19
(5) Capacity Balance (4)-(3)	10.0	12.9	10.8	13.5	11.7	14.7

**Table 18:** RCCP machine capacity requirements for deformed bars production

Description	Mount					
	February 2026 (hours)	March 2026 (hours)	April 2026 (hours)	May 2026 (hours)	June 2026 (hours)	July 2026 (hours)
(1) Standard Machine Hours	69.18	70.17	70.83	71.50	66.86	67.52
(2) Efficiency Level (Actual Condition)	0.95	0.95	0.95	0.95	0.95	0.95
(3) Actual Requirement (1)/(2)	72.82	73.87	74.56	75.26	70.38	71.08
(4) Available Effective Capacity	78.85	82.17	82.17	85.49	85.49	88.81
(5) Capacity Balance (4)-(3)	6.0	8.3	7.6	10.2	15.1	17.7

Tables 17 and 18 present the Rough-Cut Capacity Planning (RCCP) results for each product. The RCCP is developed based on the Master Production Schedule in Table 16 and the

Bill of Resources, considering an actual efficiency level of 0.95 to convert the production plan into capacity requirements and evaluate the alignment between demand and available capacity. Based on the RCCP results, the following is a comparison between actual needs and effective capacity for Plain Bars and Deformed Bars products as shown in the following figures 1 and 2:

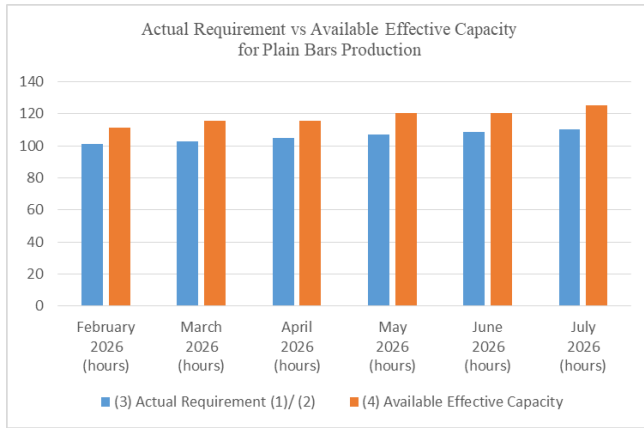


Figure 1: Actual requirement vs effective capacity of plain bars

The graph in Figure 1 shows the comparison between capacity requirements and available capacity for the production of plain bars during the period from February to July 2026. The actual capacity requirement, after considering an efficiency of 0.95, falls within the range of 70.4-75.3 hours, while the effective capacity ranges from 78.9-88.8 hours. The analysis results show that the available capacity is always higher than the requirement, allowing all demand to be met without capacity constraints, even with a relatively higher production load compared to deformed bars products.

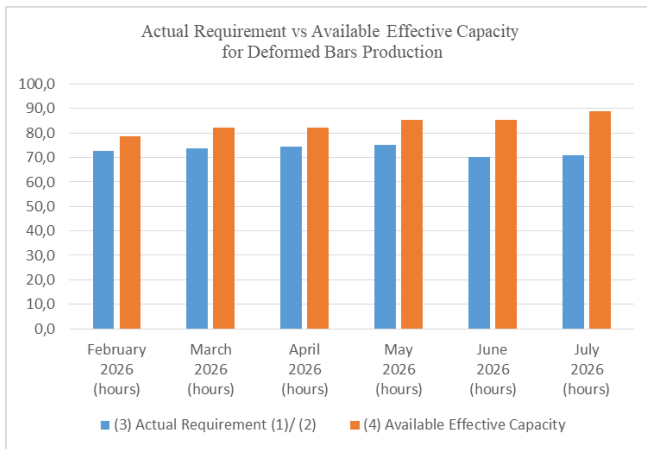


Figure 2 : Actual requirement vs effective capacity of deformed bars

The graph in Figure 2 shows the comparison between capacity needs and available capacity for the production of deformed bars during the period of February-July 2026. The actual capacity requirement, after considering an efficiency of 0.95, is in the range of 101-110 hours, while the available

capacity is higher, at 111.15-125.19 hours. The analysis results show that the available capacity is always higher than the requirement, so all demand can be met without capacity constraints.

#### 4. CONCLUSION

The implementation of preventive maintenance using the age replacement method on the Roughing Mill machine has improved the machine's reliability and the company's production capacity. The research results show that downtime was successfully reduced from 82.1 hours to 17.09 hours, thereby increasing the effective production capacity from 197 hours to 208 hours per month. Additionally, the production planning results indicate that the capacity is within the range of 190-214 hours per month with an average of 202 hours, which is capable of meeting the production needs of 166-174 hours per period. The RCCP results also show that the production capacity for plain bars and deformed bars is sufficient, allowing all demand to be met optimally. Therefore, the company is advised to implement preventive maintenance using age replacement and integrated production planning to ensure that the production process remains effective, stable, and in line with the available capacity.

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