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Production Planning for Woks to Maximize Capacity using the Theory of Constraints Approach (Case Study in CV SP Alumunium)

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ABSTRACT: CV SP Alumunium is a small and medium-sized aluminum casting industry that produces aluminum-based frying pans using a make-to-order system. Based on data from the period of March–June 2025, the company was unable to fulfill the entire demand of 323,336 units due to a capacity imbalance between work stations. The casting work station, finishing 1-Grinding, and finishing 2-Turning produced capacity requirement values that exceeded the capacity available. This research aims to determine the best improvement alternative to increase production capacity so that the demand for super frying pans and aluminum frying pans can be optimally fulfilled using the Theory of Constraints approach. Bottleneck identification was carried out by comparing the capacity available and capacity requirement at each work station based on standard time obtained through 30 stopwatch observations. Evaluation was conducted on three capacity improvement alternatives, namely the addition of labor and machines, overtime, and subcontracting. The research results show that the finishing 2-Turning work station is the most dominant constraint with the highest bottleneck frequency and the highest CR/CA ratio of 166.02% in April. The best recommended alternative is the combination of overtime and subcontracting with a total margin of Rp3,767,282,311. The combined alternative generated a higher margin compared to the overtime alternative of Rp3,638,566,758 and the subcontracting alternative of Rp3,070,417,980. The combined alternative was able to fulfill the entire demand during the bottleneck period without leaving a capacity deficit that would cause a loss of margin.

KEYWORDS: Theory of Constraints, Bottleneck, Capacity Available, Capacity Requirement, Increase in Production Capacity, Overtime, Subcontract.

I. INTRODUCTION

The small and medium-sized aluminum casting industry is one of the manufacturing sectors that plays an important role in meeting household equipment needs in Indonesia, particularly for products such as pans, pots, and kettles. Production processes in this industry are generally sequential, involving several work stations with different processing times. These differences in processing time between work stations have the potential to cause an imbalance in the production flow, which ultimately gives rise to bottlenecks and reduces the company's overall output capacity. A similar problem was found in the plastic cup production industry, where an imbalance in machine capacity caused a decline in production efficiency and was addressed through a capacity evaluation using the Capacity Requirement Planning (CRP) method [1].

CV SP Alumunium, located in Umbulharjo, Yogyakarta, is a manufacturing company engaged in the production of aluminum-based pans, with its main products being super pans, AL pans, and green pans. The production system applied is make-to-order, with process stages including mold making, aluminum melting, molding, finishing 1, finishing 2 (turning), finishing 2 (polishing), finishing 3, and packing. Super pans and AL pans are the main focus of this study because they have the largest demand volume among all of the company's product lines.

CV SP Aluminum has not yet been able to meet all customer demand in a timely manner based on 2025 production data. In early January, most orders could still be completed according to the due date, but toward the end of the month delays began to appear because production capacity was unable to keep pace with incoming demand volume. This condition even forced the company to temporarily halt the acceptance of new orders for two weeks, from February 1 to 13, in order to clear the accumulated production backlog.

This problem was not solely caused by high demand, but also by a capacity imbalance among work stations. The Finishing 2 (turning) work station was recorded as being able to process only 2,169 units/day, far below the capacity of the Finishing 1 (filing) work station, which reached 4,555 units/day. The results of the Capacity Requirement to Capacity Available (CR/CA) calculation show that the Finishing 2 (turning) work station experienced a bottleneck condition for four consecutive months, from March to June 2025, with the highest CR/CA value reaching 166.02% in

April. The Molding and Finishing 1 (grinding) work stations also experienced bottlenecks during the March to May 2025 period. A similar capacity imbalance condition caused by differences in processing time between work stations was also found in the garment industry, which caused a buildup of work in process at certain work stations and was successfully addressed through the stages of the Theory of Constraints, namely identification, exploitation, and subordination of constraints [2].

This condition shows that CV SP Alumunium requires an appropriate approach to systematically identify and address production constraints. The Theory of Constraints approach has proven effective in addressing bottlenecks caused by differences in standard time between work stations in other manufacturing industries, for example through the application of overtime and the addition of work shifts at the constraint work station [3]. This study aims to identify the work station that is the main constraint at CV SP Alumunium and to formulate improvement alternatives to maximize the production capacity of super pans and AL pans using the Theory of Constraints approach.

II. LITERATUR REVIEW

A. Production System

A production system is a set of interacting subsystems that can be operated to convert production inputs into production outputs [4]. Production output is the main product generated, including byproducts such as waste and information [5]. A production system is also defined as the activity of managing resources to create added value in output effectively and efficiently.

B. Theory of Constraint

Constraints represent limiting factors that hinder a system from maximizing its profitability, ranging from physical bottlenecks like equipment capacity and labor hours to administrative barriers like rigid management procedures [6]. Theory of Constraints (TOC) is an operations management approach that focuses on managing constraints to influence a company's performance and profitability. The Theory of Constraints focuses on finding solutions to overcome constraints so that the production system continues to undergo continuous improvement [7].

C. Production Capacity

Production capacity is the maximum amount of output that a production system can produce in a given period [1]. Production capacity is divided into design capacity, effective capacity, and actual capacity [8]. Capacity planning aims to achieve production efficiency and effectiveness in meeting customer demand.

D. Data Uniformity and Adequacy Test

Work time data need to be tested for uniformity and adequacy before use, using the following upper control limit (UCL) and lower control limit (LCL) [9]:

UCL = $\bar{x} + k\sigma$

LCL = $\bar{x} - k\sigma$

$$\sigma = \frac{\sqrt{\sum(x_i - \bar{x})^2}}{N - 1}$$

The data adequacy test ensures that the number of observations N is sufficient, namely when N′<N [9]:

$$N' = \left[\frac{\frac{k}{s}\sqrt{N\Sigma x^2 - (\Sigma x)^2}}{\Sigma x}\right]^2$$

E. Adjustment Factor, Allowance, and Standard Time

The adjustment factor corrects cycle time into normal time, generally using the Westinghouse method, which assesses skill, effort, working conditions, and consistency [10]. Allowance is additional time given to the operator for personal needs, fatigue, and unavoidable delays [11]. Standard time is calculated through three stages [12]:

CT = $\frac{\sum t_i}{n}$

NT = CT x P

ST = NT x $\frac{100\%}{100\% - A\%}$

F. Bottleneck

A bottleneck describes a work station whose capacity is smaller than the production requirement, so that the target is not achieved [13]. Bottleneck identification is carried out by comparing capacity available (CA) and capacity requirement (CR) [14]:

CA=Working hours × Number of machines × Utilization × Efficiency

CR=Σ(number of product units × standard time per unit)

If the Capacity Requirement (CR) exceeds the Capacity Available (CA), the workstation is categorized as a bottleneck. Capacity that fails to meet production demand results in the company being unable to achieve consumer demand fulfillment [13].

III. METHODOLOGY

A. Data Collection

The data collected included production process flow data, processing time, demand, labor and machines, labor cost, production and selling prices, rating factor, allowance, and subcontracting cost. Processing time data were obtained through 30 repetitions of stopwatch time study for each product type of super pan (type 10-36) and AL pan (type 10-24). Demand data were obtained from customer due date data for January-June 2025, totaling 323,336 units.

Tabel 1. Wok Demand Data

Month	Total (units)
January	41.467

February	41.912
March	57.984
April	67.119
May	68.191
June	46.663
Total	323.336

Labor data show the number of operators per work station with a wage of Rp2,625,000/month for 26 days and 7 working hours per day; the available working hours are 655,200 seconds/month.

Table 2. Labor and Machine/Equipment Data

Work Station	Labor	Machine/Equipment	Qty
Molding	18	Pan mold	18
F1-Grinding	5	Grinder	5
F1-Filing	5	File	5
F2-Turning	9	Lathe machine	9
F2-Polishing	6	Buffing machine	6
Finishing 3	2	Spray gun	2

B. Dara Processing

The data processing stage begins with calculating the process time and cycle time from the observation results, followed by uniformity and sufficiency tests to ensure the data is suitable for use. Once the data is deemed uniform and sufficient, adjustment factors are determined and standard times are calculated, followed by the determination of allowances until standard times are obtained for each work station.

These standard times then serve as the basis for calculating production capacity, including available capacity (CA), capacity requirement (CR), and the CR/CA ratio, which are used to identify bottleneck work stations. The next step is to analyze the constraints and subordinate and synchronize them with the overall production flow, before finally evaluating alternatives for capacity improvement. During the data consistency and adequacy testing phase, the results showed that the data from all monitoring stations were consistent and adequate ($N' < N = 30$), making them suitable for use in the subsequent calculation phase.

Table 3. Cycle Time

Work Station	Tipe	Cycle Time (Seconds)	
		WS	WAL
Molding	10	46,37	39,47
	11	62,60	53,93
	12	73,93	62,40
	13	84,63	72,43
	14	87,97	75,30
	15	95,07	80,67
	16	103,80	87,40
	18	107,93	91,00
	20	119,87	104,40
	22	133,93	113,23
	24	146,03	124,43
	26	199,93	
	28	190,23	
	30	226,17	
	32	268,17	
	34	330,57	
F1-Grinding	10	21,20	20,47
	11	21,63	21,13
	12	23,97	22,67
	13	24,10	23,60
	14	24,87	24,13
	15	25,30	24,37
	16	25,53	25,90
	18	26,53	27,00
	20	29,30	29,37
	22	32,60	32,30
	24	35,93	35,53
	26	43,00	
	28	46,60	
	30	55,93	
	32	66,47	
	34	80,50	
F1-Filing	10	13,33	11,73
	11	13,57	12,00
	12	14,97	13,03
	13	15,00	13,47
	14	15,47	13,77
	15	15,80	13,87
	16	15,93	14,70
	18	16,20	15,43
	20	18,17	16,63
	22	19,97	18,30
	24	22,17	20,23
	26	26,43	
	28	28,73	
	30	34,37	
	32	40,63	
	34	49,17	
Work Station	Tipe	Cycle Time (Seconds)	
		WS	WAL
F2-Turning	10	43,23	39,17
	11	45,47	41,27
	12	47,93	42,53
	13	49,27	44,53
	14	53,47	47,60
	15	57,13	52,60
	16	59,20	56,63
	18	71,13	62,50

	20	74,20	66,43
	22	75,77	68,93
	24	91,53	84,43
	26	124,30	
	28	129,93	
	30	146,90	
	32	166,67	
	34	201,80	
F2-Polishing	10	43,03	42,47
	11	43,90	45,20
	12	48,13	47,73
	13	53,03	54,07
	14	57,40	55,67
	15	61,33	60,47
	16	65,67	66,93
	18	75,70	74,50
	20	78,83	78,03
	22	82,40	81,80
	24	83,47	83,57
Finishing 3	10	3,40	3,99
	11	4,50	3,98
	12	4,30	4,40
	13	4,30	4,80
	14	5,00	5,03
	15	5,33	5,70
	16	6,33	6,77
	18	8,07	7,70
	20	8,17	7,72
	22	8,63	8,17
	24	8,90	9,35
	26	10,07	
	28	10,97	
	30	13,07	
	32	15,10	
	34	18,13	

Table 4. Adjusttment Factor and Allowance

Work Station	Adj. Factor	Allowance (%)
Molding	1,04	42
F1-Grinding	1,03	42
F1-Filing	1,06	35
F2-Turning	1,09	35
F2-Polishing	1,03	39
Finishing 3	1,06	27,5

Table 5. Standard Time

Work Station	Tipe	Cycle Time (Seconds)	
		WS	WAL
Molding	10	83,14	70,75
	11	112,24	96,7

	12	132,56	111,87
	13	151,74	129,87
	14	157,72	135,01

Work Station	Tipe	Cycle Time (Seconds)	
		WS	WAL
	15	170,44	144,63
	16	186,12	156,7
	18	193,53	163,17
	20	214,93	187,18
	22	240,15	203,03
	24	261,84	223,12
	26	358,5	
	28	341,1	
	30	405,53	
	32	480,84	
	34	592,72	
F1-Grinding	10	37,63	36,34
	11	38,41	37,51
	12	42,55	40,24
	13	42,79	41,89
	14	44,15	42,84
	15	44,91	43,25
	16	45,32	45,98
	18	47,1	47,94
	20	52,01	52,13
	22	57,87	57,34
	24	63,81	63,08
	26	76,36	
	28	82,74	
	30	99,32	
	32	118,03	
	34	142,94	
F1-Filing	10	21,73	19,12
	11	22,12	19,56
	12	24,4	21,24
	13	24,46	21,95
	14	25,21	22,44
	15	25,75	22,6
	16	25,96	23,96
	18	26,41	25,15
	20	29,61	27,12
	22	32,55	29,83
	24	36,13	32,98
	26	43,09	
	28	46,84	
	30	56,03	
	32	66,26	
	34	80,16	
F2-Turning	10	72,49	65,67
	11	76,23	69,2
	12	80,36	71,32

	13	82,61	74,67
	14	89,64	79,81
	15	95,8	88,2
	16	99,26	94,96
	18	119,27	104,8
	20	124,41	111,4
	22	127,04	115,58
	24	153,49	141,58
	26	208,43	
	28	217,87	
	30	246,33	
	32	279,47	
	34	338,4	
F2-Polishing	10	72,65	71,7
	11	74,11	76,31
	12	81,26	80,59
	13	89,54	91,27
Work Station	**Tipe**	**Cycle Time (Seconds)**	
		WS	**WAL**
	14	96,91	93,98
	15	103,55	102,09
	16	110,86	113,01
	18	127,81	125,78
	20	133,09	131,75
	22	139,13	138,11
	24	140,93	141,09
Finishing 3	10	4,96	5,51
	11	6,57	5,82
	12	6,27	6,42
	13	6,27	7
	14	7,31	7,35
	15	7,79	8,33
	16	9,25	9,88
	18	11,79	11,25
	20	11,93	11,26
	22	12,62	11,93
	24	13	13,66
	26	14,71	
	28	16,02	
	30	19,1	
	32	22,06	
	34	26,51	

The standard times in Table 5 are then used as the basis for calculating capacity requirements (CR) during the production capacity analysis phase.

IV. RESULTS AND DISCUSSION

A. *Capacity Available*

CA is calculated by multiplying effective working hours, the number of machines, utilization, and efficiency. Utilization is obtained by dividing the working hours used by the working hours available; efficiency is obtained by dividing actual output by standard output [15].

Example for the Molding work station in January:

Working hours = 24 days × 7 hours × 3,600 sec = 604,800 sec/month

CA = Hours × Machines × Utilization × Efficiency

CA = 604,800 × 18 × 88% × 93% = 8,909,430 seconds.

The complete results are presented in Table 6.

Table 6. Capacity Available

Month	Work Station	Working Hours/ Machines	Util./ Efis.	CA (sec)
January	Molding	604.800 sec 18 machines	U:88 % E:93%	8.909.430
January	F1-Grinding	604.800 sec 5 machines	U:92 % E:95%	2.642.976
January	F1-Filing	604.800 sec 5 machines	U:92 % E:95%	2.642.976
January	F2-Turning	604.800 sec 9 machines	U:88 % E:93%	4.454.715
January	F2-Polishing	604.800 sec 6 machines	U:92 % E:95%	3.171.571
January	F3	604.800 sec 2 machines	U:93 % E:96%	1.079.931
February	Molding	604.800 sec 18 machines	U:88 % E:93%	8.909.430
Month	**Work Station**	**Working Hours/ Machines**	**Util./ Efis.**	**CA (sec)**
February	F1-Grinding	604.800 sec 5 machines	U:92 % E:95%	2.642.976
February	F1-Filing	604.800 sec 5 machines	U:92 % E:95%	2.642.976
February	F2-Turning	604.800 sec 9 machines	U:88 % E:93%	4.454.715
February	F2-Polishing	604.800 sec 6 machines	U:92 % E:95%	3.171.571
February	F3	604.800 sec	U:93 %	1.079.931

		2 machines	E:96%	
March	Molding	579.600 sec 18 machines	U:88 % E:93%	8.538.204
March	F1-Grinding	579.600 sec 5 machines	U:92 % E:95%	2.532.852
March	F1-Filing	579.600 sec 5 machines	U:92 % E:95%	2.532.852
March	F2-Turning	579.600 sec 9 machines	U:88 % E:93%	4.269.102
March	F2-Polishing	579.600 sec 6 machines	U:92 % E:95%	3.039.422
March	F3	579.600 sec 2 machines	U:93 % E:96%	1.034.934
April	Molding	504.000 sec 18 machines	U:88 % E:93%	7.424.525
April	F1-Grinding	504.000 sec 5 machines	U:92 % E:95%	2.202.480
April	F1-Filing	504.000 sec 5 machines	U:92 % E:95%	2.202.480
April	F2-Turning	504.000 sec 9 machines	U:88 % E:93%	3.712.262
April	F2-Polishing	504.000 sec 6 machines	U:92 % E:95%	2.642.976
April	F3	504.000 sec 2 machines	U:93 % E:96%	899.942
May	Molding	630.000 sec 18 machines	U:88 % E:93%	9.280.656
May	F1-Grinding	630.000 sec 5 machines	U:92 % E:95%	2.753.100
May	F1-Filing	630.000 sec 5 machines	U:92 % E:95%	2.753.100
May	F2-Turning	630.000 sec 9 machines	U:88 % E:93%	4.640.328
May	F2-Polishing	630.000 sec 6 machines	U:92 % E:95%	3.303.720
May	F3	630.000 sec 2 machines	U:93 % E:96%	1.124.928
June	Molding	579.600 sec 18 machines	U:88 % E:93%	8.538.204
June	F1-Grinding	579.600 sec 5 machines	U:92 % E:95%	2.532.852
June	F1-Filing	579.600 sec 5 machines	U:92 % E:95%	2.532.852
June	F2-Turning	579.600 sec 9 machines	U:88 % E:93%	4.269.102
June	F2-Polishing	579.600 sec 6 machines	U:92 % E:95%	3.039.422
June	F3	579.600 sec 2 machines	U:93 % E:96%	1.034.934

B. Capacity Requirement

CR is calculated by multiplying the demand for each product type by the standard time at the related work station, then summing the results across all types.

Example of CR for the Molding work station in January:

CR = (3,042×83.14) + (2,456×112.24) + ... + (440×223.12) = 6,705,824 seconds

The recapitulation is presented in Table 7.

Table 7. Capacity Requirement

Month	Mld	F1G	F1K	F2B	F2P	F3
Jan	6.705.824	1.947.782	1.077.863	4.090.535	810.236	354.884
Feb	6.788.634	1.973.875	1.082.443	4.137.061	516.506	363.659
Mar	9.178.469	2.682.137	1.483.773	5.590.002	1.009.500	484.956
Apr	10.037.040	3.008.835	1.658.451	6.163.257	2.126.499	538.843
May	11.245.339	3.228.671	1.788.898	6.839.844	1.579.197	593.418
Jun	8.173.888	2.282.005	1.272.603	4.935.956	804.608	420.739

Notes:

Mld = Molding

F1G = Finishing 1 grinding
F1K = Finishing 1 filing
F2B = Finishing 2 turning
F2P = Finishing 2 polishing
F3 = Finishing 3

C. Bottleneck Identification

Bottleneck identification is carried out by comparing CR to CA at each work station for each month; if CR>CA, the station is categorized as a bottleneck.

Example for the Molding work station in January:

Percentage = (CA/CR) × 100%

Percentage = (6,705,824/8,909,430) × 100% = 75.27%

The complete results are presented in Table 8.

Table 8. Bottleneck Identification

Work Station	**Month**	**CA / CR (sec)**	**%CR/CA**	**Remarks**
Molding	Jan	CA:8.909.430 CR:6.705.824	75,27%	Non-BN
Molding	Feb	CA:8.909.430 CR:6.788.634	76,20%	Non-BN
Molding	Mar	CA:8.538.204 CR:9.178.469	107,50%	BN
Molding	Apr	CA:7.424.525 CR:10.037.040	135,19%	BN
Molding	May	CA:9.280.656 CR:11.245.339	121,17%	BN
Molding	Jun	CA:8.538.204 CR:8.173.888	95,73%	Non-BN
F1-Grinding	Jan	CA:2.642.976 CR:1.947.782	73,70%	Non-BN
F1-Grinding	Feb	CA:2.642.976 CR:1.973.875	74,68%	Non-BN
F1-Grinding	Mar	CA:2.532.852 CR:2.682.137	105,89%	BN
F1-Grinding	Apr	CA:2.202.480 CR:3.008.835	136,61%	BN
F1-Grinding	May	CA:2.753.100 CR:3.228.671	117,27%	BN
F1-Grinding	Jun	CA:2.532.852 CR:2.282.005	90,10%	Non-BN
F1-Filing	Jan	CA:2.642.976 CR:1.077.863	40,78%	Non-BN
F1-Filing	Feb	CA:2.642.976 CR:1.082.443	40,96%	Non-BN
F1-Filing	Mar	CA:2.532.852 CR:1.483.773	58,58%	Non-BN
Work Station	**Month**	**CA / CR (sec)**	**%CR/CA**	**Remarks**
F1-Filing	Apr	CA:2.202.480 CR:1.658.451	75,30%	Non-BN
F1-Filing	May	CA:2.753.100 CR:1.788.898	64,98%	Non-BN
F1-Filing	Jun	CA:2.532.852 CR:1.272.603	50,24%	Non-BN
F2-Turning	Jan	CA:4.454.715 CR:4.090.535	91,82%	Non-BN
F2-Turning	Feb	CA:4.454.715 CR:4.137.061	92,87%	Non-BN
F2-Turning	Mar	CA:4.269.102 CR:5.590.002	130,94%	BN

F2-Turning	Apr	CA:3.712.262 CR:6.163.257	166,02%	BN
F2-Turning	May	CA:4.640.328 CR:6.839.844	147,40%	BN
F2-Turning	Jun	CA:4.269.102 CR:4.935.956	115,62%	BN
F2-Polishing	Jan	CA:3.171.571 CR:810.236	25,55%	Non-BN
F2-Polishing	Feb	CA:3.171.571 CR:516.506	16,29%	Non-BN
F2-Polishing	Mar	CA:3.039.422 CR:1.009.500	33,21%	Non-BN
F2-Polishing	Apr	CA:2.642.976 CR:2.126.499	80,46%	Non-BN
F2-Polishing	May	CA:3.303.720 CR:1.579.197	47,80%	Non-BN
F2-Polishing	Jun	CA:3.039.422 CR:804.608	26,47%	Non-BN
Finishing 3	Jan	CA:1.079.931 CR:354.884	32,86%	Non-BN
Finishing 3	Feb	CA:1.079.931 CR:363.659	33,67%	Non-BN
Finishing 3	Mar	CA:1.034.934 CR:484.956	46,86%	Non-BN
Finishing 3	Apr	CA:899.942 CR:538.843	59,88%	Non-BN
Finishing 3	May	CA:1.124.928 CR:593.418	52,75%	Non-BN
Finishing 3	Jun	CA:1.034.934 CR:420.739	40,65%	Non-BN

Capacity calculations show that bottlenecks occurred at the molding workstation, finishing 1-grinding, and finishing 2-turning. The molding workstation experienced bottlenecks during March, April, and May, with CR/CA values of 107.50%, 135.19%, and 121.17%, respectively. The same conditions also occurred at the finishing 1-grinding workstation, which experienced bottlenecks in March, April, and May with CR/CA values of 105.89%, 136.61%, and 117.27%, respectively. The most significant bottleneck occurred at finishing 2-turning, which experienced bottlenecks throughout March, April, May, and June. The bottleneck with the highest CR/CA value reached 166.02% in June.

D. Maximum Production Capacity

Maximum capacity is calculated to determine the maximum number of units that can be produced per day.

Example for the Finishing 2 turning station, super pan type 10:

Maximum capacity = Total available time / standard time per unit

Maximum capacity 420/1.21 = 347 units/machine.

The recapitulation is presented in Table 9.

Table 9. Maximum Production

Work Station	Min (units)	Max (units)	Average	Total/day
Molding	42	355	153	2.754
F1-Grinding	176	688	498	2.490
F1-Filing	313	1.312	911	4.555
F2-Turning	74	385	241	2.169
F2-Polishing	178	350	250	1.500
Finishing 3	954	5.250	2.792	5.584

E. Constraint Exploitation

Constraint exploitation is performed to maximize the capacity of the bottleneck workstations. The workstations experiencing bottlenecks are printing, finishing 1-grinding, and finishing 2-turning. At this stage, the unmet capacity is calculated to determine the production capacity that cannot yet be met by the available capacity.

Example of the calculation of unutilized capacity for Finishing 2-turning in March:

Unaccommodated capacity = CR – CA

= 4,269,102 - 5,590,002

= 1,877,740 seconds

The results are presented in Table 10.

Table 10. Unaccommodated Capacity (Seconds)

Month	Pct	F1G	F1K	F2B	F2P	F3
Jan	0	0	0	0	0	0
Feb	0	0	0	0	0	0

Month	Pct	F1G	F1K	F2B	F2P	F3
Mar	640.265	149.285	0	1.877.740	0	0
Apr	2.612.515	806.355	0	1.522.929	0	0
May	1.964.683	475.571	0	2.570.743	0	0
Jun	0	0	0	1.764.385	0	0
Total	**5.217.463**	**1.431.212**	**0**	**7.735.796**	**0**	**0**

F. Subordination and Synchronization of Constraints

Non-bottleneck capacity is adjusted to follow the capacity of the bottleneck station to prevent a buildup of work-in-process. Finishing 2 turning is the most dominant constraint. Comparison of maximum capacity as shown in Table 11.

Table 11. Comparison of Maximum Capacity

Work Station	Max Cap./day	Difference
Molding	2.754	+585
F1-Grinding	2.490	+321
F1-Filing	4.555	+2.386
F2-Turning	2.169	Constraint
F2-Polishing	1.500	-669
Finishing 3	5.584	+3.415

G. Evaluation of Capacity Improvement Alternatives

The evaluation was conducted for the March - June period using three alternatives: overtime, subcontracting, and a combination of both.

1) Overtime Alternatif

Overtime is limited to a maximum of 3 hours/day in accordance with Law of the Republic of Indonesia No. 13/2003, Article 78 Paragraph 1. The additional capacity per hour is presented in Table 12.

Table 12. Additional Overtime Capacity

Work Station	Operator	CA OT/Worker	Total CA OT
Molding	18	2.946	53.032
F1-Grinding	5	3.010	15.048
F2-Turning	9	2.946	26.516

Overtime requirements are calculated by dividing the unmet capacity by the additional capacity per hour at each work station. The complete results are presented in Table 13.

Table 13. Overtime Requirement for Bottleneck

Month	Work Station	Unaccommodated/ Additional Cap.	OT Hours (month/day)	Deficit/ Remarks
Mar	Molding	640.265 /640.265	12,07 0,46	0 Met
Mar	F1-Grinding	149.285 /149.285	9,49 0,36	0 Met
Mar	F2-Turning	1.320.900 /1.320.900	49,81 1,92	0 Met
Apr	Molding	2.612.515 /2.612.515	49,26 1,89	0 Met
Apr	F1-Grinding	806.355 /806.355	51,26 1,97	0 Met
Apr	F2-Turning	2.450.995 /2.068.260	92,43 3,00	382.734 Not met
May	Molding	1.964.683 /1.964.683	37,05 1,42	0 Met
May	F1-Grinding	475.571 /475.571	30,23 1,16	0 Met
May	F2-Turning	2.199.516 /2.068.260	82,95 3,00	131.256 Not met
Jun	F2 (turning)	666.854 /666.854	25,15 0,97	0 Met

Overtime is not yet able to meet the requirement of Finishing 2 turning in April and May because it exceeds the maximum limit. Overtime cost is calculated from a wage of Rp2,625,000/month divided by 173 hours, with the first hour paid at 1.5× and subsequent hours at 2× the hourly wage

Table 14. Additional Overtime Cost

Month	Work Station	Jam OT (Operator)	Cost/day	Cost/month
Mar	Molding	0,46 hours/day (18 workers)	Rp190.236	Rp4.946.136
Mar	F1-Grinding	0,36 hours/day (5 workers)	Rp41.534	Rp1.079.885
Mar	F2-Turning	1,92 hours/day (9 workers)	Rp455.009	Rp11.830.226

Apr	Molding	1,89 hours/day (18 workers)	Rp898.416	Rp23.358.811

Month	Work Station	Jam OT (Operator)	Cost/day	Cost/month
Apr	F1-Grinding	1,97 hours/day (5 workers)	Rp261.191	Rp6.790.974
Apr	F2-Turning	3,00 hours/day (9 workers)	Rp751.084	Rp19.528.179
May	Molding	1,42 hours/day (18 workers)	Rp641.770	Rp16.686.026
May	F1-Grinding	1,16 hours/day (5 workers)	Rp138.484	Rp3.600.578
May	F2-Turning	3,00 hours/day (9 workers)	Rp751.084	Rp19.528.179
Jun	F2 (turning)	0,97 hours/day (9 workers)	Rp198.136	Rp5.151.539
Total				Rp112.500.533

The margin lost due to the deficit not covered by overtime at Finishing 2 turning (April–May) is calculated proportionally per product type/variant, totaling Rp74,621,039. The initial monthly margin is presented in Table 15.

Table 15. Initial Margin For The Overtime Alternative

Month	Type	Demand	OT Cost	Profit
Mar	Super	35.030	Rp10.787.533	Rp618.876.287
Mar	AL	22.954	Rp7.068.714	Rp270.247.276
Apr	Super	37.715	Rp27.914.665	Rp515.682.220
Apr	AL	29.404	Rp21.763.299	Rp326.382.461
May	Super	43.199	Rp25.222.666	Rp786.031.624
May	AL	24.992	Rp14.592.117	Rp324.619.113
Jun	Super	33.489	Rp3.697.145	Rp686.205.250
Jun	AL	13.174	Rp1.454.394	Rp186.343.566
Total				Rp3.714.387.796

CV SP Alumunium incurs an overtime cost of Rp74,621,039 and an additional electricity cost of Rp1,200,000. The total margin is obtained by subtracting the electricity cost and the margin lost due to the deficit from the alternatives margin.

Table 16. Margin For The Overtime Addition Alternative

Alternative Margin	Deficit	Total Margin
Rp3.714.387.797	Rp74.621.039	Rp3.638.566.758

2) Work Shift Alternative

The shift alternative was not implemented because the company is located in a densely populated residential area with the potential to cause noise disturbance, referring to DIY Governor Regulation No. 40/2017 concerning Noise Level Standards.

3) Subcontracting Alternative

Subcontracting involves a third party working to the company's specifications, with the quantity determined by the bottleneck capacity deficit. The subcontracting requirement for the study period is 46,532 units.

Table 17. Margin For The Subcontracting Alternative

Month	Type	Demand (Int/Sub)	Margin (Int/Sub)	Total
Mar	Super	35.030 (23.263/11.767)	Int.: Rp448,7jt Sub.: Rp118,4jt	Rp567.175.308
Mar	AL	22.954 (15.244/7.710)	Int.: Rp117,3jt Sub.: Rp47,1jt	Rp164.475.756
Apr	Super	37.715 (28.396/9.319)	Int.: Rp474,5jt Sub.: Rp69,4jt	Rp543.889.628
Apr	AL	29.404 (22.138/7.266)	Int.: Rp174,5jt Sub.: Rp42,8jt	Rp217.292.078
May	Super	43.199 (8.803/34.396)	Int.: Rp178,8jt Sub.: Rp366,5jt	Rp545.335.269
May	AL	24.992 (5.093/19.899)	Int.: Rp45,2jt Sub.: Rp140,7jt	Rp185.879.438

Month	**Type**	**Demand (Int/Sub)**	**Margin (Int/Sub)**	**Total**
Jun	Super	33.489 (33.395/94)	Int.: Rp725,2jt Sub.: Rp1,1jt	Rp726.286.601
Jun	AL	13.174 (13.137/37)	Int.: Rp119,8jt Sub.: Rp0,3jt	Rp120.083.901
Total				Rp3.070.417.980

The subcontracting margin is lower than that of internal production because it bears the cost of processing services, round-trip delivery, handling, and quality inspection; consequently, the total subcontracting margin Rp3,070,417,980 is lower than that of the overtime alternative.

4) Combined Overtime + Subcontracting Alternative

Overtime was implemented first at all bottleneck stations. The remaining deficit that was not met in April and May is 513,990 seconds, or approximately 6,940 units was transferred to subcontractors.

Table 18. Margin Combined Overtime + Subcontracting Alternative

Overtime Margin	**Subcontracting Margin**	**Total Margin**
Rp3.714.387.797	Rp54.094.514	Rp3.767.282.311

5) Comparison of Alternatives

Table 19. Comparison Of Total Margin Across Alternatives

Condition	**Total Margin**
Overtime	Rp3.638.566.758
Subkontrak	Rp3.070.417.980
Overtime + Subkontrak	Rp3.767.282.311

The combined alternative produces the highest margin Rp3,767,282,311, followed by overtime Rp3,638,566,758 and subcontracting Rp3,070,417,980. The combined alternative is superior because it utilizes the maximum overtime capacity at all bottleneck stations while covering the remaining deficit through subcontracting, so that all demand during the bottleneck period is met without any loss of margin. Accordingly, the overtime + subcontracting alternative is established as the primary recommendation for improving the production capacity of CV SP Alumunium.

V. CONCLUSIOS

Based on the capacity analysis using the Theory of Constraints approach, the work stations identified as bottlenecks are Molding, Finishing 1-Grinding, and Finishing 2-Turning, which experienced a capacity shortage during the March to June 2025 period. Finishing 2-Turning is the most dominant constraint, with the highest bottleneck frequency and the highest CR/CA ratio of 166.02% in April.

The evaluation results of the three alternatives show that the combined overtime + subcontracting alternative is the best alternative, with a total margin of Rp3,767,282,311, higher than overtime Rp3,638,566,758 and subcontracting Rp3,070,417,980. The combined alternative applies a maximum of 3 hours/day of overtime at all bottleneck stations and shifts the remaining April - May deficit of 513,990 seconds or 6,940 units to subcontracting, so that all demand during the bottleneck period is fulfilled without a capacity deficit that would cause a loss of margin.

The company is advised to implement overtime and subcontracting gradually according to the needs of each bottleneck station, and to establish long-term cooperation with subcontractors to maintain consistent quality and delivery timeliness. This study has not yet considered production scheduling at each work station, so future research is expected to develop a production scheduling analysis so that overtime and subcontracting can be aligned based on delivery due dates.

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