Electronic Journal of Education, Social Economics and Technology
Vol. 7, No. 1, (2026), e671
ISSN 2723-6250 (online)
DOI: https://doi.org/10.33122/ejeset.v7i1.671

Research Article

Workstation Capacity Optimization Using Theory of Contraint and Drum-Buffer-Robe Methods

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ABSTRACT

A company in Pasuruan that produces speaker components is facing a bottleneck problem in cone paper production due to fluctuations in demand resulting in an imbalance in machine capacity and cycle time. This results in the cone paper production process being inefficient in meeting targets, making throughput suboptimal. To overcome these problems, you can apply Theory of Constraints (TOC) through the Drum-Buffer-Rope approach and Linear Programming which is processed using WinQSB software. The research phase includes constraint identification, constraint exploitation, constraint subordination and constraint elevation. Based on the calculation, botlleneck occurs at the cone printing (SK - 1) and coating (SK - 4) work stations. To overcome this, 2 hours of overtime was added at both work stations in August 2024 - January 2025. This step successfully increased throughput, the initial throughput of 24.092.270 increased by 25.406.970 or 6%. Thus, this proposal proved to be effective in optimizing throughput and maximizing production capacity utilization.

Keywords: Bottlenenck; Drum-Buffer-Robe; Linear Programing; Theory of Constraints

1. INTRODUCTION

In industry, production capacity plays an important role to meet market demand. Differences in capacity between In the industrial sector, production capacity plays a crucial role for companies in an effort to meet market needs. Every manufacturing company generally has a number of work stages with varying capacities, depending on the performance of the machines used in each station. One of the main challenges often faced is the imbalance of capacity between work stations, which can trigger bottlenecks in the production flow. In addition, fluctuating market demand can also result in unachieved production targets. Given that the production process aims to produce goods according to customer needs, it is very important to plan various related aspects, such as the selection of the right technology, efficient production machinery, and optimal material handling systems (Rudiawan, 2021). Production is a crucial function in an organization that plays a role in increasing product value through various activities, thereby generating output that adds value to industrial organizations (Henny et al., 2022). The smooth production process can create product yield efficiency and can meet demand targets. So whether or not the production process is smooth is determined by the optimal workstation capacity. Capacity is the maximum amount of output that can be produced by a production facility within a certain period of time. Capacity reflects the highest level of output possible and is often associated with demand fluctuations reflected in the master production schedule (Giu et al., 2022). Efficient optimization of production capacity ensures on-time delivery, minimizes the risk of delays or stock shortages, and supports overall smooth operations (Hidayat, 2021). Companies need to strategically manage production capacity to align with market demand and operational goals (Rudiawan et al., 2021).

Manufacturing is a type of business activity that focuses on processing raw materials into semi-finished or final products that are ready to be used and marketed to certain parties depending on consumer demand for the use of their products (Hermawan, 2023). CV. XYZ is a company that produces speaker frame parts, namely cone paper with various types. The type of production strategy in this company is repetitive, namely continuous production based on demand. In recent years CV XYZ has experienced an increase in production demand with fluctuating demand, this has caused problems in fulfilling demand. The company's performance in meeting production demand and the company's efficiency in running production have decreased due to sub-optimal processes. CV XYZ faces challenges in its production process, namely bottlenecks. This bottleneck occurs at the cone printing and spray coating work stations, which is caused by machine capacity that does not match the target, this is an imbalance in the amount of production which is a constraint in a production system. This results in the existing production results not in accordance with the expected target. Thus, the main objective of production line layout is to ensure optimal task distribution (Ahyan et al., 2021).

To overcome this problem, research is conducted with a systematic approach that focuses on identifying and managing bottlenecks using the Theory of Constraints method with the Drum-Buffer-Rope (DBR) and Linear Programming approaches. The Theory of Constraints method is used for an approach that helps companies recognize and overcome the main obstacles that have a major impact on the production process (Ikhwana et al., 2024). TOC is based on the principle that every system or organization has constraints that limit the achievement of optimal performance. Therefore, it is important to recognize and strategically manage these constraints to improve the company's performance in a sustainable manner (Mariantha, 2018). The term drum-buffer-rope (DBR) in the theory of constraints (TOC) serves to protect against production bottlenecks and promote continuous improvement in the supply chain. The “drum” represents the supplier's production capacity as the rhythm setter of the system. The “buffer” is the inventory that provides backup time to overcome disruptions. Meanwhile, “Rope” describes the linkage between upstream and downstream processes so that demand does not exceed the supplier's production capacity (Kurniasanti et al., 2022). While linear programming acts as a mathematical method that helps find optimal solutions by considering certain constraints (Kusumawati & Wiguna, 2020).

By using Theory of Constraint, profit can be achieved by identifying and finding solutions to various constraints faced by the company. Every company has obstacles that can hinder performance improvement. Therefore, these constraints need to be recognized and managed immediately so that the company can improve its performance.

2. RESEARCH METHOD

This research was conducted at CV XYZ, located in Pasuruan, East Java. The object of research is data obtained from various work stations located in the cone paper production section, which is related to all aspects of the company's production flow. The research was conducted in February 2025 until the data was sufficient, to ensure the accuracy of the desired results.

The production capacity obtained is analyzed and identified using the Theory of Constraint method, the following is a description of the research steps:

2.1 Data Collection

Based on the type,data collection techniques in this study are divided into two categories, namely primarydata and secondary data. Primary data includes cycle time recording ateach work station. Meanwhile, secondary data includes information related to production demand, production realization in the period August 2024 to January 2025, labor resources, as well as efficiency values and utility levels (Undari Sulung, 2024).

2.2 Data Processing

The data processing method in this study includes the calculation of normal time and standard time. Normal time is used to determine the length of the work process based on average capacity in work situations that are considered standard or reasonable. Normal time shows that a well-qualified operator will complete the job (Suradi, St., 2020) and standard time as the time it takes workers with standard abilities to do the job (Putri et al., 2025).

2.3 Identification the Constraint

To identify and evaluate the constraints that limit production capacity, an in-depth analysis is required. This analysis aims to find factors or rules that hinder the smooth running of the production process and reduce overall production efficiency (Adhiputra, 2021).

$$CR = \Sigma a_{ik} b_{kj} \tag{1}$$

$$\text{CA} = \text{Number of working days} \times \text{Working hours} \times \text{Efficiency} \times \text{Utility} \times \text{Number of machines} \tag{2}$$

$$\text{Varians} = \text{CA} - \text{CR} \tag{3}$$

2.4 Exploit the Constraint

The objective of this stage is to determine the optimal number of production units based on available resources, by maximizing the performance of bottleneck workstations through a linear programming approach. Linear programming is a linear mathematical method for determining an optimal solution (Tutuarima et al., 2022). This process is carried out by constructing a mathematical model through a linear programming approach and processed using WinQSB software.(Delinda Brilian Cahayani1, 2025).

2.5 Subordinate the Constraint

This step is taken to harmonize all available resources, apart from those that are the main obstacles. The application of this method is expected to direct improvement efforts in a more focused and efficient manner (Ikhwana et al., 2024).

2.6 Eleve the Constraint

This stage increases the capacity of problematic work stations through process improvements, additional resources, or new technologies to achieve production targets. This process also helps to determine the maximum capacity of each work station to support appropriate investment decisions. (Rohman & Muhammad, 2022).

3. RESULTS AND DISCUSSION

3.1 Data Collection

Measurement of working time was first introduced by F.W. Taylor (Arista, 2020). The purpose of this time measurement is to obtain various work system designs so that the best work design can be obtained (Rahayu & Juhara, 2020). The measurement results are used to determine the standard time for completing the work cycle that applies to all workers on the same task (Damayanthi & Hidayat, 2020). Work time measurement is carried out using the stopwatch time study method, which involves measuring work time using a stopwatch as a measuring tool (Pradana & Pulansari, 2021). The cone paper production process there are 16 work stations, The following cycle time data from 16 work stations are presented in **Table 1**.

Table 1 Observation Time of Cone Paper Production Process

Cycle Time	Workstation (Seconds)															
	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6	WS-7	WS-8	WS-9	WS-10	WS-11	WS-12	WS-13	WS-14	WS - 15	WS - 16
1	206	10	14	66	10	12	12	12	57	12	16	16	49	9	49	10
2	189	9	14	66	11	12	12	12	56	12	16	16	49	9	49	11
3	205	9	14	66	11	12	12	12	57	13	16	20	48	9	48	10
4	189	9	15	63	12	12	12	12	57	12	15	21	49	9	49	11
5	206	9	15	66	13	13	13	13	57	12	15	17	49	9	49	10
6	200	9	16	63	11	13	13	13	56	13	15	16	49	9	49	10
7	206	9	16	63	10	13	13	13	55	13	15	17	49	10	49	10
8	207	10	16	66	10	13	13	13	57	13	15	17	48	10	48	10
9	207	10	16	63	11	12	12	12	57	12	16	25	49	10	49	10
10	205	10	15	66	11	12	12	12	58	13	16	25	49	10	49	10
11	189	9	15	63	12	13	13	13	58	12	15	26	49	9	49	11
12	205	9	16	66	13	12	12	12	60	12	16	25	49	10	49	11
13	208	10	15	63	11	13	13	13	60	12	15	25	48	10	48	11
14	203	9	16	66	11	12	12	12	60	12	16	26	50	10	50	11
15	203	9	15	66	11	12	12	12	56	12	15	20	50	9	50	10
16	208	9	15	67	13	12	12	12	60	12	16	21	50	9	50	10
17	206	9	15	67	11	13	13	13	55	12	16	24	55	9	55	10
18	207	10	16	66	10	13	13	13	56	13	16	25	55	9	55	11
19	207	10	16	67	10	12	12	12	57	13	16	26	49	9	49	10
20	200	10	15	67	10	12	12	12	57	12	15	24	50	10	50	10
21	206	10	15	67	10	12	12	12	57	12	15	25	55	10	55	11
22	208	9	15	63	10	12	12	12	57	12	15	25	55	9	55	11

Cycle Time	Workstation (Seconds)															
	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6	WS-7	WS-8	WS-9	WS-10	WS-11	WS-12	WS-13	WS-14	WS - 15	WS - 16
23	205	9	15	67	10	12	12	12	57	12	15	25	50	10	50	11
24	200	9	15	67	10	12	12	12	60	12	16	25	49	10	49	10
25	207	10	15	67	10	12	12	12	57	12	16	25	48	9	48	10
26	189	10	15	67	10	13	13	13	60	12	16	25	49	9	49	10
27	189	10	16	67	10	13	13	13	57	13	16	25	50	9	50	10
28	200	10	16	67	11	13	13	13	60	13	16	25	55	9	55	10
29	208	10	16	66	11	13	13	13	57	13	16	25	48	9	48	10
30	202	10	16	66	13	13	13	13	57	13	16	26	49	9	49	11
31	206	9	16	67	13	13	13	13	57	13	16	24	50	10	50	11
32	207	9	16	66	13	12	12	12	56	13	16	25	50	10	50	10
33	206	9	15	66	10	13	13	13	60	13	16	25	55	10	55	10
34	208	9	16	66	11	12	12	12	60	13	16	26	50	10	50	10
35	189	9	15	67	13	12	12	12	60	12	16	27	49	10	49	10
36	207	10	15	67	12	12	12	12	60	12	16	16	48	9	48	10
37	206	10	15	67	13	12	12	12	61	13	16	17	49	10	49	10
38	207	9	14	66	10	12	12	12	61	12	16	20	50	10	50	10
39	189	9	14	63	11	12	12	12	61	12	16	26	55	10	55	10
40	208	9	14	63	11	12	12	12	61	12	15	24	50	10	50	10

The following data on cone paper product demand, work resources and efficiency and utility factors are described in **Table 2** and **Table 3**.

Table 2 Product demand data and working days

Month	Product Demand AX – 3072 (Pcs)	Product Demand AX – 3060 (Pcs)	Working days
August 2024	3059	3.290	26
September 2024	2601	2.601	24
October 2024	2910	2.918	27
November 2024	3000	2803	25
December 2024	2701	2.790	25
January 2025	2613	2.690	24

Table 3 Work resource data and efficiency and utility factors

Workstation	Mechine Quality	Efficiency	Utilization
Print Cone	3	96%	94%
Qc Cone	2	96%	94%
Lk Neck Hardener	1	109%	94%
Coat Spray	1	92%	94%
Qc Coating	3	99%	94%
Pot Od	2	93%	94%
Pot Id	1	93%	94%

Workstation	Mechine Quality	Efficiency	Utilization
LK Body	2	93%	94%
Pres Edge	1	99%	94%
Pot H Edge	1	91%	94%
Lk Edge	1	96%	94%
Assembly	2	99%	94%
Assembly Jahit	1	100%	94%
Lh Dpn	1	96%	94%
Lh Blkng	1	96%	94%
Qc Final	1	102%	94%

3.2 Data Processing

Based on the calculation results of the data uniformity and adequacy test, the standard time for each workstation in the cone paper production process is obtained, which can be seen in **Table 4**.

Table 4 Standart Time

Workstation	Standart Time (Minutes)	
	AX - 3072	AX - 3060
1	6,11	6,19
2	0,21	0,21
3	0,41	0,42
4	1,60	1,64
5	0,26	0,26
6	0,33	0,33
7	0,33	0,33
8	0,32	0,32
9	1,53	1,54
10	0,31	0,31
11	0,41	0,41
12	0,63	0,64
13	1,39	1,40
14	0,24	0,24
15	0,24	0,24
16	0,27	0,28

3.2.1 *Identification of Constraint*

By calculating Capacity Requirement and Capacity Available, it can be determined which workstations act as drums and non-drums. Work stations are categorized as drums if the available capacity is smaller than the required capacity, and vice versa (Bidiawati & Setiawati, 2020). he following variance calculations are presented in **Table 5**.

Table 5 Variance Calculation

Work station	Month	Capacity Available	Capacity Requirement	Varians	Desc.
1	Agust- 24	33786	39056	-5270,0	*Bottleneck*
	Sep-24	31187	31992	-805,0	*Bottleneck*
	Oct-24	35085	35843	-758,0	*Bottleneck*

Work station	Month	Capacity Available	Capacity Requirement	Varians	Desc.
	Nov-24	32486	35681	-3195,0	*Bottleneck*
	Dec-24	32486	33773	-1287,0	*Bottleneck*
	Jan-25	31187	32617	-1430,0	*Bottleneck*
2	Agust- 24	22524	1188	21336,00	*Non Bottleneck*
	Sep-24	20791	1613	19178,00	*Non Bottleneck*
	Oct-24	23390	5269	18121,00	*Non Bottleneck*
	Nov-24	21658	1369	20289,00	*Non Bottleneck*
	Dec-24	21658	1477	20181,00	*Non Bottleneck*
	Jan-25	20791	1427	19364,00	*Non Bottleneck*
3	Agust- 24	12787	2352	10435,00	*Non Bottleneck*
	Sep-24	11803	2159	9644,00	*Non Bottleneck*
	Oct-24	13279	2419	10860,00	*Non Bottleneck*
	Nov-24	12295	2407	9888,00	*Non Bottleneck*
	Dec-24	12295	2279	10016,00	*Non Bottleneck*
	Jan-25	11803	2201	9602,00	*Non Bottleneck*
4	Agust- 24	21585	25260	-3675,00	*Bottleneck*
	Sep-24	19925	20262	-337,00	*Bottleneck*
	Oct-24	22416	22718	-302,00	*Bottleneck*
	Nov-24	20755	22151	-1396,00	*Bottleneck*
	Dec-24	20755	21592	-837,00	*Bottleneck*
	Jan-25	19925	20832	-907,00	*Bottleneck*
5	Agust- 24	34842	1471	33371,00	*Non Bottleneck*
	Sep-24	32162	1353	30809,00	*Non Bottleneck*
	Oct-24	36182	1515	34667,00	*Non Bottleneck*
	Nov-24	33502	1509	31993,00	*Non Bottleneck*
	Dec-24	33502	1428	32074,00	*Non Bottleneck*
	Jan-25	32162	1379	30783,00	*Non Bottleneck*
6	Agust- 24	21820	1648	20172,00	*Non Bottleneck*
	Sep-24	20142	1535	18607,00	*Non Bottleneck*
	Oct-24	22659	1719	20940,00	*Non Bottleneck*
	Nov-24	20981	1719	19262,00	*Non Bottleneck*
	Dec-24	20981	1617	19364,00	*Non Bottleneck*
	Jan-25	20142	1562	18580,00	*Non Bottleneck*
7	Agust- 24	10910	1867	9043,00	*Non Bottleneck*
	Sep-24	10071	1717	8354,00	*Non Bottleneck*
	Oct-24	11330	1923	9407,00	*Non Bottleneck*
	Nov-24	10490	1915	8575,00	*Non Bottleneck*
	Dec-24	10490	1812	8678,00	*Non Bottleneck*
	Jan-25	10071	1750	8321,00	*Non Bottleneck*
8	Agust- 24	21820	1811	20009,00	*Non Bottleneck*
	Sep-24	20142	1665	18477,00	*Non Bottleneck*

Work station	Month	Capacity Available	Capacity Requirement	Varians	Desc.
	Oct-24	22659	1865	20794,00	*Non Bottleneck*
	Nov-24	20981	1857	19124,00	*Non Bottleneck*
	Dec-24	20981	1757	19224,00	*Non Bottleneck*
	Jan-25	20142	1697	18445,00	*Non Bottleneck*
9	Agust- 24	23228	8690	14538,00	*Non Bottleneck*
	Sep-24	21441	7985	13456,00	*Non Bottleneck*
	Oct-24	24121	8946	15175,00	*Non Bottleneck*
	Nov-24	22334	8907	13427,00	*Non Bottleneck*
	Dec-24	22334	8429	13905,00	*Non Bottleneck*
	Jan-25	21441	8140	13301,00	*Non Bottleneck*
10	Agust- 24	10675	1754	8921,00	*Non Bottleneck*
	Sep-24	9854	1613	8241,00	*Non Bottleneck*
	Oct-24	11086	1807	9279,00	*Non Bottleneck*
	Nov-24	10265	1799	8466,00	*Non Bottleneck*
	Dec-24	10265	1702	8563,00	*Non Bottleneck*
	Jan-25	9854	1644	8210,00	*Non Bottleneck*
11	Agust- 24	11262	2320	8942,00	*Non Bottleneck*
	Sep-24	10396	2133	8263,00	*Non Bottleneck*
	Oct-24	11695	2389	9306,00	*Non Bottleneck*
	Nov-24	10829	2379	8450,00	*Non Bottleneck*
	Dec-24	10829	2251	8578,00	*Non Bottleneck*
	Jan-25	10396	2174	8222,00	*Non Bottleneck*
12	Agust- 24	23228	3597	19631,00	*Non Bottleneck*
	Sep-24	21441	3303	18138,00	*Non Bottleneck*
	Oct-24	24121	3701	20420,00	*Non Bottleneck*
	Nov-24	22334	3684	18650,00	*Non Bottleneck*
	Dec-24	22334	3487	18847,00	*Non Bottleneck*
	Jan-25	21441	3368	18073,00	*Non Bottleneck*
13	Agust- 24	11731	5516	6215,00	*Non Bottleneck*
	Sep-24	10829	5280	5549,00	*Non Bottleneck*
	Oct-24	12182	5912	6270,00	*Non Bottleneck*
	Nov-24	11280	5964	5316,00	*Non Bottleneck*
	Dec-24	11280	5540	5740,00	*Non Bottleneck*
	Jan-25	10829	5354	5475,00	*Non Bottleneck*
14	Agust- 24	11262	1358	9904,00	*Non Bottleneck*
	Sep-24	10396	1248	9148,00	*Non Bottleneck*
	Oct-24	11695	1399	10296,00	*Non Bottleneck*
	Nov-24	10829	1393	9436,00	*Non Bottleneck*
	Dec-24	10829	1318	9511,00	*Non Bottleneck*
	Jan-25	10396	1273	9123,00	*Non Bottleneck*
15	Agust- 24	11262	1358	9904,00	*Non Bottleneck*

Work station	Month	Capacity Available	Capacity Requirement	Varians	Desc.
	Sep-24	10396	1248	9148,00	*Non Bottleneck*
	Oct-24	11695	1399	10296,00	*Non Bottleneck*
	Nov-24	10829	1393	9436,00	*Non Bottleneck*
	Dec-24	10829	1318	9511,00	*Non Bottleneck*
	Jan-25	10396	1273	9123,00	*Non Bottleneck*
16 Figure 1 Output from WinQSB	Agust- 24	11966	1559	10407,00	*Non Bottleneck*
	Sep-24	11045	1431	9614,00	*Non Bottleneck*
	Oct-24	12426	1603	10823,00	*Non Bottleneck*
	Nov-24	11506	1595	9911,00	*Non Bottleneck*
	Dec-24	11506	1510	9996,00	*Non Bottleneck*
	Jan - 25	11045	1459	9586,00	*Non Bottleneck*

Based on **Table 5**, the cone printing work station (SK - 1) and the coating work station (SK - 4) in August 2024 - January 2025 has unmet production targets. This happens because the available production capacity time is not able to meet production needs. This situation indicates that there are limitations at the relevant stations in supporting the smooth flow of production optimally. Meanwhile, work stations 2, 3, 5 - 16 are table to fulfill the required production capacity time in August 2024 - January 2025.

3.2.2 *Exploiting the Constraint*

The constraint exploitation stage aims to increase the effective capacity of workstations that become the main bottleneck of production, in order to minimize interference and optimize throughput through improving bottleneck performance with linear programming methods (Widiawati, J. A., & Sibarani, 2024). To obtain optimal throughput and production output, constraint exploitation is required by optimizing the performance of bottleneck workstations using linear programming method.

Maximal: $Z = 5000x_1 + 4000x_2$

s.t :$6{,}11x_1 + 6{,}19x_2 \leq 32703$

$1{,}60x_1 + 1{,}64x_2 \leq 20894$

$x_1 \geq 2814$

$x_2 \geq 2849$

$\mathbf{x_1, x_2 \geq 0}$

The above mathematical model is used as input in WinQSB software to obtain the optimal solution. So that the processing results using WinQSB software obtained are presented in **Figure 1.**

	Decision Variable	Solution Value	Unit Cost or Profit c(j)	Total Contribution	Reduced Cost	Basis Status	Allowable Min. c(j)	Allowable Max. c(j)
1	X1	2,814.0000	5,000.0000	14,070,000.0000	0	basic	3,948.3040	M
2	X2	2,505.5670	4,000.0000	10,022,270.0000	0	basic	0	5,065.4660
	Objective	Function	(Max.) =	24,092,270.0000				

	Constraint	Left Hand Side	Direction	Right Hand Side	Slack or Surplus	Shadow Price	Allowable Min. RHS	Allowable Max. RHS
1	C1	32,703.0000	<=	32,703.0000	0	646.2036	17,193.5400	34,828.8500
2	C2	8,611.5290	<=	20,894.0000	12,282.4700	0	8,611.5300	M
3	C3	2,814.0000	<=	2,814.0000	0	1,051.696	2,466.0700	5,352.3730
4	C4	2,505.5670	<=	2,849.0000	343.4330	0	2,505.5670	M

Figure 1 Output from WinQSB

Based on **Figure 1**, it can be concluded that the output results from WinQSB software are known:

$x_1 = 2814$ and $x_2 = 2506$. Maka nilai $Z = 5000(2814) + 4000(2506) = 24.092.270$. This shows that the maximum throughput that will be obtained isr 24.092.270

3.2.3 *Suborninate of Non Constraint*

The next step is to synchronize all resources other than the constraints faced by the company (Kemaluddin & Prasetyaningsih, 2022). The first step in applying this concept is to identify the drum, where at this stage the setup workstation is designated as the drum (Agraprana & Donoriyanto, 2024). Therefore, a Drum-Buffer-Rope map was created to align the bottleneck workstation with other workstations, as shown in **Figure 2.**

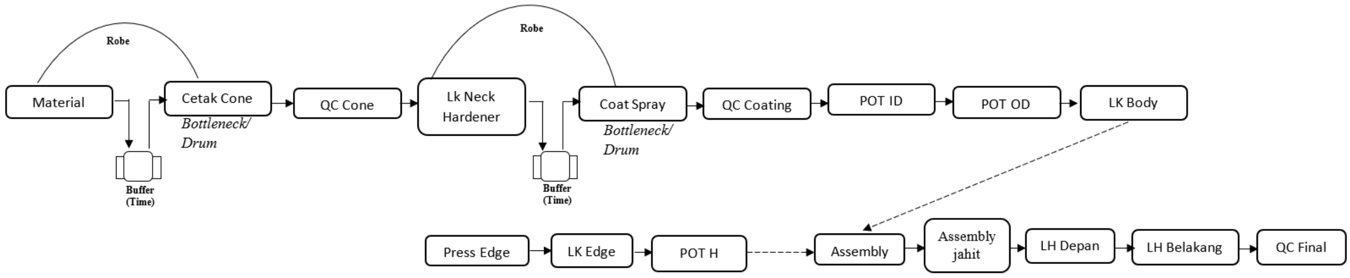

Figure 2 Drum Buffer Rope map

The calculated time buffer is placed at the station before the bottleneck with the aim of maintaining the smooth throughput of the previous process, so as to reduce constraints and prevent product accumulation in the production system.

3.2.4 *Constraint Elevation*

To reduce bottlenecks, constraint elevation is carried out at the cone printing (SK-1) and coating (SK-4) stations by increasing overtime as a capacity optimization solution. The plan to add 2 working hours will be implemented from August 2024 to January 2025. The following are the results of the calculation of production capacity and time variance at both stations during the period.

Table 6 Providing solutions to increase overtime

WS	Month	Capacity Available	Capacity Requirement	Varians	Desc.
1	Agust- 24	42232	39056	3176,0	*Non Bottleneck*
	Sep-24	35085	31992	3093,0	*Non Bottleneck*
	Oct-24	39471	35843	3628,0	*Non Bottleneck*
	Nov-24	36547	35681	866,0	*Non Bottleneck*
	Dec-24	36547	33773	2774,0	*Non Bottleneck*
	Jan-25	35085	32617	2468,0	*Non Bottleneck*
4	Agust- 24	26982	25260	1722,0	*Non Bottleneck*
	Sep-24	22416	20262	2154,0	*Non Bottleneck*
	Oct-24	25218	22718	2500,0	*Non Bottleneck*
	Nov-24	23350	22151	1199,0	*Non Bottleneck*
	Dec-24	23350	21592	1758,0	*Non Bottleneck*
	Jan-25	22416	20832	1584,0	*Non Bottleneck*

Table 6 shows that it is necessary to add overtime at both work stations, so it is necessary to reformulate with linear programming for additional capacity as follows:

Maximal: $Z = 5000x_1 + 4000x_2$

s.t : $6{,}11x_1 + 6{,}19x_2 \leq 37494$

$1{,}60x_1 + 1{,}64x_2 \leq 23955$

$x_1 \geq 2814$

$x_2 \geq 2849$

$\boldsymbol{x_1, x_2 \geq 0}$

The above mathematical model is used as input in WinQSB software to obtain the optimal solution. So that the processing results using WinQSB software obtained are presented in **Figure 3**.

	Decision Variable	Solution Value	Unit Cost or Profit c(j)	Total Contribution	Reduced Cost	Basis Status	Allowable Min. c(j)	Allowabl Max. c(j
1	X1	3,250.1950	5,000.0000	16,250,970.0000	0	basic	3,948.3040	M
2	X2	2,849.0000	4,000.0000	11,396,000.0000	0	basic	-M	5,065.46
	Objective	Function	(Max.) =	27,646,970.0000				
	Constraint	Left Hand Side	Direction	Right Hand Side	Slack or Surplus	Shadow Price	Allowable Min. RHS	Allowabl Max. RH
1	C1	37,494.0000	<=	37,494.0000	0	818.3306	34,828.8500	91,270.89
2	C2	9,872.6720	<=	23,955.0000	14,082.3300	0	9,872.6720	M
3	C3	3,250.1950	>=	2,814.0000	436.1947	0	-M	3,250.19
4	C4	2,849.0000	>=	2,849.0000	0	-1,065.4660	0	3,279.55

Figure 3 Output Software WinQSB

Based on **Figure 3**, it can be concluded that the output results from WinQSB software are known to be $x_1 = 3250$ and $x_2 = 2849$. Then the Value of $Z = 5000(3250\ ) + 4000(2849) = 27.649.970$

	X1	X2	Overtime Pay
Initial State	2814	2505	Rp150.000
Two-Hour Increase In Working Hours	3250	2849	Rp100.000

Result of capacity increase = final throughput - initial throughput

$= Rp25.406.970 - Rp24.092.270$

= Rp1.314.700

Percentage increase in througput = $100\%\left[\left(\frac{25.406.970}{24.092.270}\right) \times 100\%\right]$

$=100\% - 94\%$

$=6\%$

The table above shows that the initial throughput was Rp24,092,270, while the throughput after adding 1 hour of working time was Rp27,646,970. This represents an increase in throughput of Rp1,314,700 or a percentage increase of 6%.

4. CONCLUSION

The calculation results show that throughput increased from Rp24,092,270 with 2,814 units and 2,505 units to Rp25,406,970 with 3,250 units and 2,849 units, or an increase of Rp1,314,700 (approximately 6%) after the implementation of overtime. Additionally, the buffer concept was implemented to ensure that the bottleneck workstations always receive adequate material supply. Meanwhile, the use of ropes is intended to control the flow of work from the previous station to prevent excessive accumulation.

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