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Profit Optimization Through the Application of Theory of Constraints (TOC): A Case Study in Printing Company

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Abstract. Globalization has made industrial competition to become intensified and more stringent. As technology advances, traditional management is deemed insufficient to meet the needs of many companies in order to achieve their goals. The theory of constraints is considered to be a pertinent method to overcome the faced challenges. The theory is aimed to effectively manage constraints that prevent companies from achieving their goals. It is focused on enhancing system capacity constraints and minimizing inventory and operating costs to increase the profit by managing company's resources efficiently. The purpose of this study is to apply the theory on a case study in a printing company to manage obstacles in an effective way by defining constraints that prevent the company from achieving its targets. Thus, it can increase the company's profitability. Results show that there are capacity constraints on glue and laminating machine causing the company to solely produce 72.06% of the total demand. It is suggested that if the company adds one more laminating glue machine, an increasing profit as much as 22.33 % can be attained.

1. Introduction

Limitation of resources to produce products in order to meet market demands is considered to be a constraint that may prevent many companies from achieving their targets. The theory of constraints (TOC) is considered to be a pertinent approach to help companies to improve their performances and efficiency [1].

TOC is very suitable to handle production capacity constraints by identifying bottlenecks and increasing capacity on the identified bottleneck system. Thus, it may benefit companies to increase their profits [2].

According to the theory, company's performance can be measured through three parameters, namely throughput, inventory, and operating costs [3]. Throughput is the rate of product being produced per unit of time. Throughput rate is inversely proportional to the cost associated with raw materials and supplies. When the throughput increases, the cost associated with raw materials and supplies will decrease. This could happen due to the throughput is obtained from the reduction of selling price and materials and supplies cost [2]. Inventory cost is the total of production and labor costs [2]. Whereas operating cost is cost expended to undertake production activities apart from material costs [2].



2. Literature Review

TOC was first introduced by Eliyahu Goldratt [4] and has become one of the most important factors in business management ever since. The TOC philosophy emerged in the 1980s which was an evolution of the previous version in the field of production/operations, called Optimized Production Technology (OPT). The OPT was originally created as a scheduling software program (with a secret algorithm). TOC can be used to improve the performance of complex systems [5]. TOC works to influence the performance from two different perspectives, namely the management system and continuous quality improvement [6].

Performance measurement in TOC is divided into 2 categories, i.e. financial measurement and activity measurement. Financial measurement consists of net income, ROI and cash flow. Activity measurement consists of throughput/purchase, stock/raw material costs, and operating costs.

According to the theory, there is at least one obstacle in each company that prevents them from achieving its objectives. The TOC basically claims that the limitation of company's capacity is considered as a constraint in the production process. Therefore, it is necessary to define and eliminate boundaries to increase the capacity, for example by eliminating congestions during the production activities.

The following is several main assumptions of Theory of Constraints (TOC):

- The main objective of a company is to make profit: If the company is assumed as a chain, the strongest chain is the weakest child chain. From this point of view, the weakest child chain need be found and strengthened.
- Direct labor cost is considered as a part of operating cost: according to the theory, all costs are associated with the operational cost unless the direct materials and inventory costs. Profitability is measured by calculating the selling price, number of sales and direct materials cost and inventory costs. In addition, direct labor costs and manufacturing overhead costs are defined as fixed costs.
- There are external and internal factors that prevent the company from making a profit. It is easy to identify capacity constraints because it generally occurs in the production process.
- Planning the production flow is a difficult task since constraints/bottlenecks must be defined and changes in products, and product mixes must be considered.

The Theory of Constraint (TOC) has 3 focus parameters namely throughput (outcome), stock (raw material costs), and operating costs [3]. The following is an explanation of these parameters.

- Throughput (Outcome) is found from the results of a reduction between the selling price of the product and the cost of raw materials. Contribution margins are found by reducing all variable costs (direct raw materials and inventory costs, direct labor costs, variable parts of overhead costs) from the selling price. Contribution of margin and throughput are different although seems similar. Louderback & Patterson (1996) says that throughput is found by reducing the cost of direct raw materials and inventory costs from the selling price. Because only variable costs contain direct raw material costs and inventory costs in the TOC (Okutmus et al., 2015). Okutmus et al., (2015) said that output or throughput is a measure found by reducing raw material costs and inventory costs from the selling price of the product (Tiryakigil, 2011)
- Stock or Inventory is defined as money invested for producing a product, which is the total of production cost and labor cost [2].
- Operating cost is defined as the cost expended regarding the running of business's core operations. Operation costs includes all production costs except the cost associated with raw materials [2].

The application of TOC consists of 5 steps as know 5FS:

- Identifying the constraints
- Exploiting the constraints effectively
- Subordinating every related decision to the constraints
- Elevating the constraints
- Repeat the process

3. Application of TOC

3.1. Company's Information

This research took place in a local printing company, in Jakarta, Indonesia. The company applies 7 hours of work on Monday to Friday, and 5 hours of work for Saturday. The company recently has a bottleneck problem within its production system. It has 5 work centers, i.e. cutting, printing, ponding, varnishing, and laminating. All work centers have the same time capacity every month. During May 2018 there were 576,000 seconds time capacity. Additionally, the total demands on May 2018 were 136,000 unit, and there were 27 types of product had different demand quantities.

The company produces a product, which consists of two parts, namely the top and bottom. The upper part passes through all work stations except the vertical engine. Varnishing machines are used to varnish the bottom part. After the upper part is finished on the glue and laminating machine, the product will return to the ponding machine for finishing the ponding process. Then it will be cleaned and packed with the bottom. While the bottom does not pass through the process in the printing machine and glue & laminating machine.

3.2. TOC Running

3.2.1. Constraint Identification. The first step of the TOC is to identify constraints. Identification is done by comparing the theoretical capacity and the actual capacity. Theoretical capacity is the available capacity of active working time. While the actual capacity is the capacity of active work time that is actually needed. If actual capacity exceeds the theoretical capacity, then constraints will occur. The following table shows the comparison between theoretical capacity and actual capacity of each machine.

Table 1. Constraints Identification

No	Code	Work Centre (second) (demand x production time)				
		Cutting	Printing	Pond	Vernish	Laminating
1	A1	750	5,000	20,000		
2	A2	750	5,000	20,000		60,000
3	A3	750	5,000	20,000		60,000
4	A4	750	5,000	20,000		60,000
5	B1	1,125	7,500	30,000		90,000
6	B2	450	3,000	12,000		36,000
7	B3	450	3,000	12,000		36,000
8	B4	450	3,000	12,000		36,000
9	B5	750	5,000	20,000		60,000
10	B6	750	5,000	20,000		60,000
11	B7	750	5,000	20,000		60,000
12	B8	750	5,000	20,000		60,000
13	B9	750	5,000	20,000		60,000
14	B10	450	3,000	12,000		36,000
15	B11	450	3,000	12,000		36,000

No	Code	Work Centre (second) (demand x production time)				
		Cutting	Printing	Pond	Vernish	Laminating
16	B12	225	1,500	6,000	9,000	18,000
17	C1	2,400	16,000	64,000		192,000
18	D1	1,500	10,000	40,000	60,000	
19	E1	1,500	10,000	40,000	60,000	
20	F1	450	3,000	12,000	18,000	36,000
21	G1	450	3,000	12,000		36,000
22	H1	1,500	10,000	40,000	60,000	
23	J1	450	3,000	12,000		
24	K1	450	3,000	12,000	18,000	
25	L1	450	3,000	12,000		
26	M1	450	3,000	12,000		
27	N1	450	3,000	12,000	18,000	
Actual Capacity (second)		20,400	136,000	544,000	243,000	1,032,000
Theoretical Capacity (second)		576,000	576,000	576,000	576,000	576,000
Differences		555,600	440,000	32,000	333,000	(456,000)
Capacity Usage Rate		4 %	24 %	94 %	42 %	179 %

As an example the product A2 works in a cutting station with a capacity of 200 sheets/second or 0.15 seconds/sheet. The request of A2 product is 5,000 units. So that at the cutting work station, the actual capacity is $0.15 \times 5,000 = 750$ seconds. At A2 print work station requires actual capacity of $1 \times 5,000 = 5,000$ seconds. The ponding work station requires actual capacity of $4 \times 5,000 = 20,000$ seconds. Whereas glue & laminating work stations require actual capacity of $12 \times 5,000 = 60,000$. The calculation is carried out on all products so that the actual capacity required by each work station will be obtained. After that, a comparison is made between the actual capacity and the theoretical capacity. For example, the actual working capacity of glue and laminating stations is 1,032,000 seconds. This exceeds the existing theoretical capacity of 576,000 seconds. So there is a difference of 456,000 seconds. In other words, the glue & laminating machine is jammed. This is called a constraint (bottleneck). The source of these constraints is called capacity constraints.

3.2.2. Exploiting the Constraints Effectively. At this stage, the throughput rate is calculated by subtracting the raw materials and supplies costs with the selling price of product [2]. Table 2 below shows the throughput rate calculation for each product.

Table 2. Throughput Rate/Product

No	Code	Selling Price (Unit)	Raw Material Cost (Unit)	Throughput Rate (Rp/Unit)
1	A1	1,200	700	500
2	A2	1,450	640	810
3	A3	1,450	550	900
4	A4	1,800	900	900
5	B1	1,450	550	900
6	B2	2,400	800	1,600
7	B3	2,850	1,000	1,850
8	B4	2,850	1,000	1,850

No	Code	Selling Price (Unit)	Raw Material Cost (Unit)	Throughput Rate (Rp/Unit)
9	B5	1,450	640	810
10	B6	1,450	640	810
11	B7	2,400	800	1,600
12	B8	2,400	800	1,600
13	B9	3,000	1,250	1,750
14	B10	2,400	800	1,600
15	B11	2,400	800	1,600
16	B12	8,000	1,900	6,100
17	C1	1,150	600	550
18	D1	1,250	600	650
19	E1	1,250	600	650
20	F1	2,250	1,125	1,125
21	G1	2,850	800	2,050
22	H1	1,800	1,100	700
23	J1	1,350	750	600
24	K1	2,250	1,150	1,100
25	L1	1,700	800	900
26	M1	1,700	800	900
27	N1	2,250	1,000	1,250

Then calculate the constraint rate per product based on the time limit on the work stations which exhibit the bottleneck (glue & laminating). Table 3 shows the constraint rate of the product based on the time constraint.

Table 3. Constraint Rate/Product Based on Time Constraint

No	Code	Constraints Rate (Unit)	Time Constraints (second)	CR/CT (Rp/sec)
2	A2	810	12	68
3	A3	900	12	75
4	A4	900	12	75
5	B1	900	12	75
6	B2	1,600	12	133
7	B3	1,850	12	154
8	B4	1,850	12	154
9	B5	810	12	68
10	B6	810	12	68
11	B7	1,600	12	133
12	B8	1,600	12	133
13	B9	1,750	12	146
14	B10	1,600	12	133
15	B11	1,600	12	133
16	B12	6,100	12	508

No	Code	Constraints Rate (Unit)	Time Constraints (second)	CR/CT (Rp/sec)
17	C1	550	12	46
20	F1	1,125	12	94
21	G1	2,050	12	171

Based on the table above, product B12 have the highest constraint rate. So that the product is prioritized to produce. The next priority sequence is sorted by the value of the constraint rate from the highest to the lowest.

Based on table 3 it can be seen that from 18 types of the bottleneck product, only 12 types can be produced. And A4 products can be produced as many as 500 units of the total 5,000 unit requests. This happens due to the insufficient production time capacity which causes the company fail to meet all customer demands [2].

The next step is calculating the profit based constraints. Table 4 below shows the company's attainable profit. Total selling is obtained by multiplying the selling price with demand. Total raw material cost is obtained by multiplying the raw material cost with demand. Total running expenses are obtained by multiplying running expenses with demand.

Table 4. Calculate profit based constraints

No	Code	Total Selling	Total Raw Material Cost	Running Expenses		Net Profit
				Direct Labor Cost	Operation Cost	
3	A3	7,250,000	2,750,000	725,000	1,725,000	2,050,000
4	A4	900,000	450,000	67,500	152,500	230,000
6	B2	7,200,000	2,400,000	532,500	1,386,000	2,881,500
7	B3	8,550,000	3,000,000	682,500	2,194,500	2,671,500
8	B4	8,550,000	3,000,000	682,500	2,194,500	2,671,500
11	B7	12,000,000	4,000,000	890,000	2,310,000	4,800,000
12	B8	12,000,000	4,000,000	890,000	2,310,000	4,800,000
13	B9	15,000,000	6,250,000	990,000	2,710,000	5,050,000
14	B10	7,200,000	2,400,000	534,000	1,386,000	2,880,000
15	B11	7,200,000	2,400,000	534,000	1,386,000	2,880,000
16	B12	12,000,000	2,850,000	633,750	1,749,500	6,765,750
20	F1	6,750,000	3,375,000	441,000	1,087,500	1,846,500
21	G1	8,550,000	2,400,000	570,000	1,500,000	4,080,000
Total Income		113,150,000	39,275,000	8,172,750	22,091,500	43,610,750

Net income in May 2018 based on constraints is IDR 43,610,750. Net income is obtained by subtracting the Total Sales with the Total Cost of Raw Materials and Operation Costs.

3.2.3. Subordinate Every Related Decision to The Constraints. This research will provide three possible decision alternatives, namely adding one more of both glue & laminating machines, implementing an outsourcing for the remaining products that cannot be done to other companies, and holding overtime hours. In addition, special shifts can also be made. However, it is difficult to do so due to the difficulty of finding labors to work for the additional shift and it would expend very large operational costs.

3.2.4. Elevating The Constraints. The first alternative decision that the company can make is to buy an addition machine for gluing & laminating. A Chinese brand machine costs approximately Rp 150,000,000. So the theoretical capacity will be twice as large as before. But the consequence of buying a machine is the increasing of operation cost. This is due to three things: the addition of operators, the burden of electricity, and the depreciation of the new machines. Depreciation is a reduction in the value of fixed assets within certain period of time based on their economic age. The depreciation cost of the machines based on the straight-line method is IDR 367,000 per month (150 million - 40 million / 25/12). 40 million is the remaining machine value after 25 years later.

The second alternative decision is implementing an outsourcing to other companies. This alternative is feasible to implement since it does not require a high investment, unlike selecting the first alternative which requires a considerably high investment.

The third alternative is to hold overtime. This alternative tends to be the most feasible solution because it has the smallest risk.

3.2.5. Back to Step 1. The first step is to re-identify constraints. Table 5 shows the overview of the constraints reidentification.

Table 5. Constraints Reidentification

No	Code	Work Centre (second)				
		Cutting	Printing	Ponding	Varnishing	Laminating
1	A1	750	5000	20000		
2	A2	750	5000	20000		60000
3	A3	750	5000	20000		60000
4	A4	750	5000	20000		60000
5	B1	1125	7500	30000		90000
6	B2	450	3000	12000		36000
7	B3	450	3000	12000		36000
8	B4	450	3000	12000		36000
9	B5	750	5000	20000		60000
10	B6	750	5000	20000		60000
11	B7	750	5000	20000		60000
12	B8	750	5000	20000		60000
13	B9	750	5000	20000		60000
14	B10	450	3000	12000		36000
15	B11	450	3000	12000		36000
16	B12	225	1500	6000	9000	18000
17	C1	2400	16000	64000		192000
18	D1	1500	10000	40000	60000	
19	E1	1500	10000	40000	60000	
20	F1	450	3000	12000	18000	36000
21	G1	450	3000	12000		36000
22	H1	1500	10000	40000	60000	
23	J1	450	3000	12000		
24	K1	450	3000	12000	18000	

No	Code	Work Centre (second)				
		Cutting	Printing	Ponding	Varnishing	Laminating
25	L1	450	3000	12000		
26	M1	450	3000	12000		
27	N1	450	3000	12000	18000	
Actual Capacity (second)		20,400	136,000	544,000	243,000	1,032,000
Theoretical Capacity (second)		576,000	576,000	576,000	576,000	1,152,000
Difference		555,600	440,000	32,000	333,000	120,000
Usage		4 %	24 %	94 %	42 %	90 %

After reidentifying the repetitive constraints, no bottleneck found within work station. So that the proposed alternative succeeded to overcome the bottleneck problem.

The next stage is to calculate the income that will be obtained by purchasing an additional machine for both gluing & laminating. After purchasing the machines, the net profit that can be achieved is Rp. 56,151,000. With a note of being exposed to the depreciation expenses of Rp. 367,000. (150 million - 40 million / 25/12). This gain increases from the constraint gain. The gained profit may increase by 22.33% from Rp. 43,610,750 to Rp. 56,151,000.

After implementing the outsourcing, the company can make profit as much as Rp. 55,668,000. In other words, outsourcing alternatives can be used to overcome the bottleneck. The obtained benefits are lower than the first alternative. The gained profit may increase by 21.66% from Rp 43,610,750 to Rp 55,668,000.

Implementing the overtime can also reduce the bottlenecks. Profits may also increase as much as 21.45% from Rp 43,610,750 to Rp 55,518,000. This alternative has a lower advantage compared to the two previous alternatives. But this alternative is the most affordable than the two previous alternatives.

4. Discussion

Based on the data processing and analysis, each machine has a capacity of 576,000 seconds. This capacity is insufficient to meet customer demands, which requires 1,032,000 seconds for the total production time. Bottleneck as a capacity constraint is found in the glue & laminating sections which causes the company to solely meet 72.06% of the total demand. In addition, this also makes the company to only produce 12 out of 18 total types of bottleneck products whereas there are requests for 27 types of products, 18 of which are bottlenecks and 9 are non-bottlenecks. Based on the TOC analysis there are 12 bottleneck products which are among the production priorities. The decision is made through a throughput rate calculation to determine production priority.

There are 3 alternatives that companies can do to handle the bottleneck problem: adding one more unit for both glue & laminating machines, implementing outsourcing, and preventing overtime hours. Each alternative has advantages and disadvantages. The first alternative tends to be difficult to realize since it would spend a considerably high investment. However, this alternative would increase the production process and may reduce the bottleneck instantly. The second alternative is considered to be more feasible to implement, even though it is fairly difficult, to find the outsourcing companies. The implementation of outsourcing may benefit the company to save the supply of glue and plastic. The last alternative is to hold overtime which tends to be the easiest scenario to implement. However, this alternative may pay larger costs.

After identifying the constraints, the calculation of obtained net profit associated with the bottleneck is carried out. During the bottleneck condition, the company makes profit of Rp. 43,610,750 from the total sales of 12 types of products and 500 units of A4 products. While the remaining 6 types of product will be done with the 3 alternatives above.

5. Conclusion

Production capacity is one of the identified constraints. Based on the data analysis results, glue & laminating machines are sources of the production process constraints. This causes the company to solely produce 72.06% of the total demands or 98,000 units out of 136,000 units in total.

Efforts to optimize the bottleneck in glue & laminating machines are based on throughput rate per second. It is suggested to arrange some product mixes to enhance the profitability. The best product mixing arrangements are suggested as follow: 1,500 units of Maulins Black Forest, 3,000 units of Han's 26, 3,000 units of Maulins Lapis Eko Surabaya, 3,000 units of Maulins Bolu Eko, 5,000 units of Maulins Sipon, 3,000 units of Maulins Lapis Surabaya Slope, 5,000 units of Maulins Roll Steam, 5,000 units of Maulins Surabaya Steamed Bandung, 3,000 units of Maulins Cake Tape, 3,000 units of Maulins Roll Cake, 3,000 units of Dian Chatering, 5,000 units of Aldi Brownies, and 500 items of Aldi Bolu Hijau.

There are 3 alternatives that can be done to optimize the bottleneck system, i.e. adding one more unit of glue & laminating machines, outsourcing, and holding overtime hours.

Based on the calculation results, an increasing profit could be achieved. Adding one more unit of glue & laminating machines may increase the profit by Rp. 56,151,000 or 22.33%. Without depreciation the company may increase the profit as much as Rp. 56,018,000. While by implementing the outsourcing, Rp. 55,668,000 or 21.66% rising profit is achievable. By holding overtime, the company may achieve an increasing of Rp. 55,518,000 of 21.45% of the profit. From the description above the maximum profit enhancement that can be generated is as much as 22.15% or Rp. 56,018,000.

6. Future Research

For the future work, performing a simulation study, and comparing the simulation result with the TOC results is highly recommended. It is expected to provide a broad insight of method to handle bottleneck problems.

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