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Application of Theory of Constraint to Achieve Optimal Working Station Efficiency and Forecasting with Quadratic Method in PT. XYZ

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Application of Theory of Constraint to Achieve Optimal Working Station Efficiency and Forecasting with Quadratic Method in PT XYZ

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Abstract. A manufacturing system is a collection of equipment and human resources integrated to carry out the operation process into a quality finished product. With various activities in it making the production process one of the spearheads of creating a product in accordance with market needs, it is necessary to have a systematic, effective and efficient workflow to optimize the workstation at production time. PT XYZ manufactures carton boxes of various sizes. Cardboard paper as raw material is obtained from several other paper mill companies. PT XYZ has an imbalance of production efficiency which is a bottleneck (stacking) at the manual stitching workstation that is the carton box's union with the stapler. Based on the existing problems, this study aims to determine the process of producing carton boxes and identify workstations that experience bottlenecks. The estimate production demand and be careful to minimize congestion to optimize work efficiency at workstations in the production process and compare repair costs conducted. The data obtained will be predicted using quadratic forecasting to determine the shadow of future requests. The method used to minimize congestion and handle work efficiency at each workstation is Theory of Constraint (TOC). With the Theory of constraint method, the percentage of loads experiencing congestion is 105.89%. After the best choice is made by adding 1 operator to the connection process, the percentage of loads experiencing congestion is 70.59%. So, the bottleneck condition is solved, and production runs smoothly.

Keywords: Quadratic Forecasting, Bottleneck, Theory of Constraint

INTRODUCTION

PT XYZ manufactures carton boxes of various sizes. Cardboard paper as raw material is obtained from several other paper mill companies. From observations that have been made, the problem that occurred at PT. This XYZ has an imbalance of production efficiency, which is the bottleneck (stacking) in a manual sewing workstation, namely the cardboard boxes' union with staplers. Cardboard production is the densest, namely cardboard used to package heavy items such as refrigerators, televisions, etc. The method used to handle work efficiency at each workstation is the Theory of Constraint (TOC). TOC can minimize bottleneck condition, optimize work efficiency at the workstation, and minimize all the relevant costs. The bottleneck picture (stacking) on the Stitch Manual machine that occurs can be seen in Figure 1.

Besides, forecasting is an activity to determine what will happen in the future, using and considering data from the past. Forecasting has several properties that need to be considered, namely forecasting that contains errors, forecasting must provide information about the magnitude of errors that might occur, and short-term forecasting has better

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accuracy. Request a carton box at PT. XYZ each month has an uncertain number of requests, therefore with the occurrence of bottlenecks (build-up) at the work station, it is necessary to estimate the production demand to know the shadow of the number of requests in the future to determine the adequacy of demand. The number of operators and processing time that will be required. Forecasting will be used using the quadratic method.

FIGURE 1. The bottleneck on The Stitch Manual Department

RESEARCH METHOD

The research methodology is a detailed procedure for conducting research. The type of research method used is a descriptive method to systematically describe the facts or characteristics of specific fields precisely and carefully use primary and secondary data.

Measurement Of Work

According to Ralph M. Barnes (1980) [1], work measurements were carried out to get the standard time for work completion. Measure working time related to standard time management through time studies. Learning time is a standard time management technique for a job by giving breaks.

Stopwatch Time Study

Measurement of working time using stop time was introduced by Frederick W. Taylor (1957) [2] in the 19th century. This method is useful for short and repetitive jobs. We will get a standard time to complete the work cycle used as a standard time to complete the work for all workers who will do the same work from the measurement results. In general, steps to measure time with a stopwatch time study are as follows:

a.. Recording Information

Information such as type of operation, number of machines and workers, workpieces, materials, customers, and order quantity is required before making an observation sheet. The goal is that research results can be used as a source of information in the future. Determination of objectives and selection of operators according to requirements is also essential for measurement accuracy.

b. Data Collection and Recording

In collecting data, the observer is at the worksite directly and brings some equipment such as a stopwatch, observation sheet, observation board, and stationery. There are several methods to measure time with a stopwatch that is continuous, repetitive, and accumulative.

Forecasting

According to Fadly and Kartini (1982) [5], forecasting methods used are quadratic; sales forecasting methods used in a company are very much like the salesperson composition method, executive opinion method, statistical method forecasting sales.

Bottleneck

The bottleneck is a source that has the same or smaller capacity than needed. The bottleneck is a process that limits throughput. In the TOC method, bottlenecks can be minimized from the system where the Constraint is located. The bottleneck is closely related to a capacity-constraint resource (CCR), which is the capacity of production processes close to the standard, Goldratt. Bottleneck and CCR identification tables can be seen in Table 1 on the next page.

TABLE 1. Identification CCR-Bottleneck (Goldratt, Eliyahu M.and Jeff Cox. "The Goal: a process of on-going improvement." (1984) [6]

Category	Bottleneck	Non-Bottleneck
CCR	Inhibits the actual flow, both in amount and time. Must be considered in product flow planning	Inhibits the actual flow of time, but not quantity. Must be considered in product flow planning.
Non-CCR	May inhibit actual flow, both in quantity and time. Does not require consideration in product flow planning.	Does not inhibit actual flow in terms of quantity and time. Does not require consideration in product flow planning.

Theory of Constraint

Theory of Constraints (TOC) is a management philosophy developed initially by Eliyahu M. Goldratt (1990) [7]. It can be interpreted that TOC is an approach to improve processes that focus on limited elements to increase output. Businesses that focus on problems can increase or maximize existing initiatives so that the system can make significant progress; obstacles need to be improved. Identified and the whole system needs to be managed. [8][9]

Simulation

Tersine (1994) [10], simulation is research by including manipulating system models to evaluate alternative designs or decision rules. With simulations, a system experiment can reduce the risk of existing structural confusion with changes that do not produce profits.

Modelling with Promodel

Promodel is a simulation software that can simulate and analyse production systems of various types and various sizes. Promodel is discrete simulation software, although it can be modelled by changing the system continuously for some industrial processes. In simulations using promodels, animations representing the system being modelled can be displayed. Promodel sees production systems as setting process locations such as machines or workstations where entities are processed according to the logic of the process in accordance with the logic of the process that has been created.

RESULT AND DISCUSSION

The first step taken is collecting cycle time data to get the standard time, and the cycle time that has been processed will be added to the adjustment factor and added to the leeway factor. Besides, forecasting carton box products as a shadow are needed for the following year.

Forecasting

Forecasting is done by comparing several methods, namely Simple Moving Average, Double Moving Average, Weighted Moving Average, Single Exponential Smoothing, Double Exponential Smoothing, Cyclic, Linear, and Quadratic. The best forecasting results based on the lowest error value is the quadratic method.

TABLE 2. Layer Type of Carton Box Forecasting Results

Months	Period	Observation Value	Forecasting
Jan-19	1	37.522	49.606
Feb-19	2	53.497	44.607
Mar-19	3	56.244	40.886
Apr-19	4	38.585	38.442
May-19	5	29.361	37.276
Jun-19	6	27.109	37.387
Jul-19	7	36.965	38.776
Aug-19	8	49.140	41.442
Sep-19	9		45.386

TABLE 3. Box A1 Type Carton Box Forecasting Results

Months	Period	Observation Value	Forecasting
Jan-19	1	59.697	63.090
Feb-19	2	57.420	56.965
Mar-19	3	67.771	52.765
Apr-19	4	35.887	50.491
Mei-19	5	49.366	50.141
Jun-19	6	56.031	51.717
Jul-19	7	53.321	55.218
Aug-19	8	61.538	60.644
Sep-19	9		67.995

TABLE 4. Die Cut Type Carton Box Forecasting Results

Months	Period	Observation Value	Forecasting
Jan-19	1	46.752	56.834
Feb-19	2	68.501	60.071
Mar-19	3	75.646	63.431
Apr-19	4	64.103	66.913
Mei-19	5	65.489	70.518
Jun-19	6	69.327	74.245
Jul-19	7	73.181	78.095
Aug-19	8	89.176	82.068
Sep-19	9		86.163

Standard Time

Implementation of the theory of constraints in minimizing obstacles in the production process requires data processing time for each production stage element, which can also be called a cycle time. Below is the cycle time that has been processed so that the standard time is obtained. Calculation of standard time can be seen in Table 5.

TABLE 5. Calculation of the Standard Time of Carton Box Production Process

Operator	Waktu Siklus per Proses (s)							Cycle Time	Amount of Prod.	Amount of Prod.	Demand
Assembling & Packaging	Single wall	Double wall	Printing	Cutting	Folding	Assembling	Packaging	(s)	(Day)	(Month)	
1 & 1	2,6	2,6	2,5	2,4	1,6	8,1	3,4	8,1	3.556	71.111	165.204
2 & 1	2,6	2,6	2,5	2,4	1,6	4,1	3,4	4,1	7.111	142.222	165.204
3 & 1	2,6	2,6	2,5	2,4	1,6	2,7	1,7	2,7	10.667	213.333	165.204
3 & 2	2,6	2,6	2,5	2,4	1,6	2,7	1,7	1,7	16.941	338.824	165.204

Theory of Constraint

Constraint theory is used to look for problems that occur at workstations, namely bottlenecks. Begin by identifying the bottleneck to determine which workstations are experiencing bottlenecks and then minimize the specified method's bottlenecks.

Identification of Bottleneck

The available capacity is 8 working hours, which is equivalent to 28800 seconds for 1 shift. Calculation of total time needed can be seen in Table 6 and Table 7 Calculation of Load Percentage.

TABLE 6. Calculation of Total Time Required

Process	Standard Time (s)	Ruquired Capacity (s)			Total Time (s
		Layer 2.053	Box A1 2.756	Die Cut 3.451	
Single Wall	2,6	5.413	7.269	9.101	21.784
Double Wall	2,6	5.413	5.413	9.101	19.928
Printing	2,5	5.135	5.135	8.634	18.905
Cutting	2,4	4.879	4.879	8.203	17.962
Folding	1,6	3.216	3.216	5.408	11.840
Assembling	4,0	8.284	8.284	13.928	30.497
Packaging	1,7	3.538	3.538	5.949	13.026
	Total				**133.941**

TABLE 7. Load Percentage Calculation

Process	Total Time (s)	Required Capacity (s)	Load Percentage (%)
Single Wall	21.784	57600	37,82
Double Wall	19.928	57600	34,60
Printing	18.905	57600	32,82
Cutting	17.962	57600	31,18
Folding	11.840	57600	20,56
Assembling	**30.497**	**28800**	**105,89**
Packaging	13.026	28800	45,23

Based on the Calculation of the percentage of the load in table 7, some sub-processes experience bottlenecks because they have a load percentage of more than 100% in connecting carton boxes. Each sub-process is then categorized into 2 classifications, namely capacity-constrained resources and bottlenecks can be seen in Table 8. Process elements, including bottlenecks, will be minimized by selecting the best alternative.

TABLE 8. Bottleneck-CCR classification

	Bottleneck	**Non-Bottleneck**
Capacity Constraint Resource (CCR)	Assembly of Carton Box	Making a Single Wall, Making a Double Wall, Cutting Shapes
Non-Capacity Constraint Resource (CCR)		Printing Folding Packaging

Bottlenec Minimization

TABLE 9. Calculation of the Total Time Required After Bottleneck Minimization

Process	Standard Time (s)	Required Capacity (s)			Total Time (s)
		Layer 2.053	Box A1 2.756	Die Cut 3.451	
Single Wall	2,6	5.413	7.269	9.101	21.784
Double Wall	2,6	5.413	5.413	9.101	19.928
Printing	2,5	5.135	5.135	8.634	18.905
Cutting	2,4	4.879	4.879	8.203	17.962
Folding	1,6	3.216	3.216	5.408	11.840
Assembling	2,7	5.523	5.523	9.285	20.331
Packaging	3,4	7.077	7.077	11.898	26.052
	Total				**136.802**

TABLE 10. Load Percentage Calculation After Bottleneck Minimization

Process	Total Time (s)	Required Capacity (s)	Load Percentage (%)
Single Wall	21.784	57600	37,82
Double Wall	19.928	57600	34,60
Printing	18.905	57600	32.82
Cutting	17.962	57600	31,18
Folding	11.840	57600	20,56
Assembling	**20.331**	**28800**	**70,59**
Packaging	26.052	28800	90.46

Can be seen as the results of the identification of bottlenecks. Bottlenecks are known to be in the process of connecting carton boxes. Constraint theory will minimize congestion by maximizing resource constraints and adjusting other resources to these constraints.

The Calculation will then be done by increasing the number of operators experiencing congestion, which is the process of connecting carton boxes that will be adjusted to the production capacity needed from the number of carton box requests. The total time calculation after bottleneck minimization can be seen in Table 9. The Calculation of Load Percentage after bottleneck minimization can be seen in table 10.

Calculation of Costs

From this bottleneck minimization, the cost calculation shows the profit results per day in producing carton boxes, which can be seen in Table 11.

TABLE 11. Calculation of Costs

Expenditures Type	Total (Day)	
Electricity	Rp	1.176.100
Water (4E)	Rp	2.667
Raw Material	Rp	4.130.091
Worker Salary	Rp	1.480.000
Total Expenditures (Day)	Rp	6.788.857
Total Revenue (Day)	Rp	19.297.034
Profit (Day)	**Rp**	**12.508.177**
Profit (Month)	**Rp**	**250.163.542**

Output Simulation

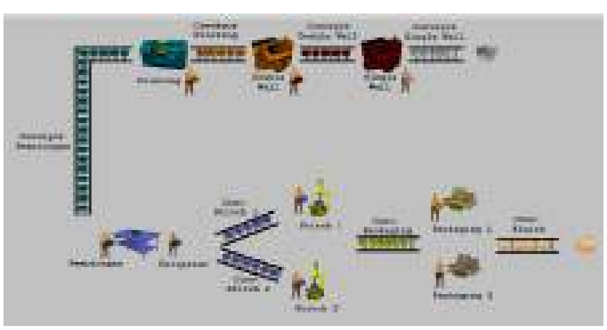

FIGURE 3. The layout of the Initial Production Process

FIGURE 4. Graph of Initial Production Simulation Results

After doing the implementation, the production process will be simulated before the research results are applied and after the research results are applied to show a picture of the process flow that occurs in producing carton boxes. The simulation is carried out with the help of the Promodel 9.3 application. Figure layout of the initial production process can be seen in Figure 3. Here is a graph of the simulation results in the initial production process shown in Figure 4.

From the results of the simulation of the initial production process, it can be seen that the stitching process is a bottleneck with a percentage of part occupied stitch 1 of 99.30% and stitch 2 of 82.14%. Therefore, improvements were made to the production process flow with the Theory of Constraint method. Overview of the Production Process Layout after improvement can be seen in Table 5. A graph of the simulation results in the initial production process shown in Figure 6

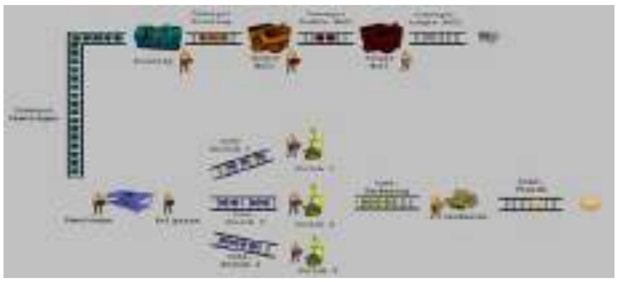

FIGURE 5. Graph of Results of Simulation of Repair Production

FIGURE 6. Graphic Production Simulation Results Improvements

DISCUSSION AND CONCLUSION

Discussion

In previous research [8], the safety stock method was used beside the theory of constraint method. In another research [9] was calculated the number of laborers. This research used a number of labour calculations too, but this research did the simulation for validation. That is made this paper better than previous researches.

Conclusion

Based on research that has been done, it can be concluded as follows:

1. The carton box production process begins with sheet making, printing, shape cutting, folding, splicing, and packaging. In the carton box production process, bottlenecks occur, namely queues, to enter the next process due to excessive processing time due to lack of operators in the connection process.
2. Based on the forecasting demand results, the demand forecasting results for the following month, September 2019, are still included in production capacity; the average production capacity for all carton box production processes is 352,152 units. While the forecasting result of layer type carton box is 45,386 units, box type A1 box is 67,995 units, and die-cut type carton box is 86,163 units with a total demand of 199,544 units.
3. Based on the bottleneck analysis results using Constraint's Theory, the bottleneck process occurs when joining carton boxes. This process is a bottleneck because the workload is 105.89%, which exceeds the available production capacity, thereby hampering production flow. With the Theory of Constraint method, the results of repairs are carried out by adding one operator to the connection process and resulting in a load percentage of 70.59% so that bottlenecks in the connection process and production process can no longer run smoothly.
4. Based on the cost calculation results, the profit gained in producing carton boxes is Rp. 12,508,177 per Day, and with a monthly profit (20 Days) of Rp. 250,163,542.

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