International Journal of Engineering & Technology, 7 (2.14) (2018) 297-300

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

Application of Theory of Constraint Principle for Production Scheduling in PT. Nusira Medan

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Abstract

PT. Nusira Medan as a producer of Crumb Rubber, based on orders with First Come First Serve (FCFS) rules. Limited resources lead to delay in order completion time. This causes delays in delivery of orders to consumers. Therefore, this research is to obtain optimal scheduling sequence with the criteria of minimizing waiting time, idle time and makespan The use of the Theory of Constraints principle is to arrange production scheduling as a solution to the problem. Expected results are the most appropriate scheduling to be applied to the company in accordance with the criteria of waiting time, idle time and makespan. The result of the research is the sequence of job scheduling sequence1-2-3-4-5 resulted in makespan of 26.47 days or 211,76 hours, idle time of 37.25 hours and waiting time of 32.85 hours . While the scheduling systems under the First Come First Serve (FCFS) rules of job scheduling sequence to 1-2-3-4-5 with makepan value of 27.46 days, idle time of 48.84 hours and waiting time of 54.24 hours. The reduction of makespan of 0.98 days or 7.84 hours, idle time reduction of 11.59 hours and waiting time of 21.39 hours

Keywords: *Scheduling, Producution, Theory of Constraints*

1. Introduction

PT. Nusira Medan is engaged in Crumb Rubber industry, producing SIR 10 rubber and SIR 20 which is exported to USA, Japan, South Korea and Germany France and Italy. Delivery of order delivery to the consumer should be avoided by making proper production scheduling so that the accumulation of semi-finished goods that give rise to idle time at the next work station can be minimized. Researchers use the Theory of Constraint (TOC) principle to solve the problem. This study aims to maximize the use of resources so as to reduce idle time and increase the productivity of the company that impact on increasing machine utility[1], [2], cost savings and reduce penalties [3][4].

Scheduling is a sorting process[5]–[9] done for the overall product work done on several machines. Scheduling involves elements of all activities or operations that require a certain allocation of resources over a period of time which is often called process time [10][11].

Scheduling according to Kenneth R. Baker is the process of allocating resources to select a set of tasks within a certain timeframe. Scheduling serves as a decision-making tool in setting a schedule. The types of constraints that are often found in scheduling problems are twofold[12]:

a. Capacity limit of available resources
b. Limitations of routing technology.

The scheduling model can be classified according to the environment encountered by the production system grouped under the following conditions:

1) Process with single machine or process with plural machine. A number of machines can be distinguished over single machines and plural machines. Single machine scheduling, is one of the job sorting model where job to be sorted is waiting to be processed on some machine either series, parallel, and also combination.
2) The identical flow pattern pattern or the arbitrary flow pattern of the process. Flow patterns can be differentiated from flow shop and job shop. Each job in the job shop has a different flow, whereas in the flow shop only encountered identical flow patterns from one machine to another machine.
3) Pattern arrival number of jobs (job). The pattern of job/work arrival can be differentiated over static and dynamic arrival patterns. In a static pattern, tasks come simultaneously and are ready to work on machines that do not work. On the other hand the dynamic pattern has the nature of the arrival of the task is not necessarily, so found the time variable.
4) Complete information on work and machinery or any uncertainty in any or both of the above elements [12][13]

Some definitions used in scheduling are as follows:

1. Processing Time (ti); Processing Time is the time it takes to do a job. In this process time includes the time required for preparation and setup (set up) during the process.
2. Due-date (on); Due date is the time limit at which the last operation of a job should be completed.
3. Slack time (SLi); Slack time is the time left to arise as a result of less processing time than its due diligence.

SLi = di – ti

4. Flow time (Fi); Flow time is the timeframe between when work can begin (available) and when the job is done. So flow time is equal to processing time summed up with waiting time before work is processed.
5. Completion time (Ci); Completion time is upon completion of work. Completion time symbolized by C_i.
6. Lateness (Li); Lateness is the difference between completion time (Ci) and its due date.
7. Tardiness (Ti): Tardiness is a positive lateness where work is accomplished later than the due date set. Tardiness symbolized by Ti.
8. Makespan (M): Makespan is the total completion time of work starting from the first sequence done on the first machine or work center to the last work sequences on the last machine or work center [14][15]

Baker divides flow patterns into two flow variations, namely pure flow shop and general flow shop. Although at the flow shop all tasks will flow on the same production line, commonly known as pure flow shop, but sometimes it can be different flow pattern. First, because a shop can handle a variety of tasks. Second, the tasks that come into the flow shop do not have to come in all the machines of a job not through a particular process

Theory of Constraint (TOC)

Theory of Constraint (TOC) is a management system philosophy. The fundamental thesis of the TOC is that constraints result in performance limitations for each system. Most organizations experience only a few basic constraints. The TOC suggests that managers should focus effectively on managing the capacity and capabilities of these constraints if they are to improve the performance of their organizations. The first time TOC is only seen as a production scheduling technique, but then TOC has extensive applications in various organizations.
Theory of Constraints uses five steps to achieve the goal of improving company performance, namely:

Identify company constraints as follows:

a. Interal constraints and external constraints
   Internal constraints are the limiting factors that exist within the company. External constraints are the factors that limit the company from outside the company.
b. Loose constraints and binding constraints.
   Loose constraints are constraints where limited resources are not used entirely by the product mix. The binding constraint is a constraint in which the available resources are fully utilized.

Exploiting the binding constraints.

One way to maximize the use of binding constraints is to assure the optimal product mix produced. First, the inventory buffer is set in front of the major binding constraints. The inventory buffer is also called a time buffer. The time buffer is the inventory needed to keep the constrained resources busy within a certain time interval. The ropes are actions taken to tie the level at which raw materials are sent to the plant at the resource-constrained resource level. The purpose of ropes is to ensure that the inventory of goods in the process does not exceed the required level of time buffer. Thus, the drummer is used to limit the release rate of raw materials and effectively control the production rate of the first operation. The first level of operation then controls the next level of operation. The inventory system of Constraint Theory is often called the Drum-Buffer-Rope System (DBR System)[16][17].

Subordinate anything else to the decision made in the previous step.
The drummer's constraint essentially determines the capacity of the entire plant. All other departments should be subordinated for the needs of drummer constraints. This principle requires many companies to change the way they see things. Lifting a binding constraint[18][19].
The next step is to start a continuous improvement program by reducing the limitations of the binding constraints that affect the company's performance.
Repeating the process. Ultimately the resource constraints will be lifted to the point where the constraints are no longer binding[20].
The rate of arrival of each job at each station is the speed of arrival of orders coming to the work station for a certain period. The arrival rate of each job is obtained by comparing the demand rate with the size of the production lot. Calculation of job per day job rate on work station is as follows:

$$D^h = \frac{1}{(d^h - r_j)m}$$

Information:
D^h = Job demand rate
d^h = Due date
r_j = ready time (Total time job j operation on work station to k)
m = Number of machines

$\lambda_{jk} = \frac{D^h}{Q^h}$Calculation of job arrival rate at each work station is as follows:

Information:
λ_{jk} = Job arrival rate
D_h = Job demand rate
Q_h = Size of production lot (Qh = 1, due to job done per unit order not per lot)

a. Workload calculation
   Workload is the amount of work that a machine must accomplish. The calculation of workload on the work station is as follows

$\rho\_jk = \lambda_{jk}$ x P_{jk}:

Information:
ρ_{jk} = Job j workload at work station k
λ_{jk} = Job j arrival rate at work station k
P_{jk} = time of job j process at work station k

b. Calculation of expected waiting time
   The waiting time of each job is the time it takes the job to wait for the previous job done. The calculation of waiting time at the work station is as follows:

$$E_{wi} = \frac{p_{jk}\ x\ p_{jk}}{2x(1 - p_{jk})}$$

Information:
E_{wi} = Working time j at work station k
ρ_{jk} = Job j workload at work station k
P_{jk} = time of job j process at work station k

c. Lead time calculation
   The calculation of lead time is done to calculate the length of time the workmanship of the product. The calculation of lead time at the work station is as follows (Sutalaksana, 2007) :

$$E[T_{jk}] = E[W_{jk}] + P_{jk}$$

Information:
$[T_{jk}]$ = lead time job j at work station k
$[W_{jk}]$ = Job j waiting time at work station k
P_{jk} = time of job j process at work station k

Level of Accuracy and Level of Trust

The degree of accuracy shows the maximum deviation of measurement results from the actual completion time. While the level of trust indicates the magnitude of the confidence of the measure of the results obtained have met the required precision. So the level of accuracy 5% and 95% confidence level [18].

Testing Data Uniformity

Through this test can be detected any differences in data. The steps of testing data uniformity are as follows:

1. Calculating the average price of observations (N)
2. Calculate the standard deviation (σ)
3. $s = \sqrt{\frac{\sum(xi-x)^2}{N-1}}$ The formula for calculating the standard deviation is as follows:

Information :
s = Standard deviation
x_i = Data obtained from observation
X = Average of observational data
N = Number of observations made

2. Method

SIR is an abbreviation of (Standart Indonesia Rubber) is a rubber lump that has been dried and refined to bandela with a predetermined size. Natural rubber SIR-20 comes from coagulum (latex that has been clumped) or processed products such as lum, wind, residual remnant gums, obtained from the people's plantation with the origin of the same raw material with the coagulum. The difference between SIR 10 and SIR 20 is on the quality standard specification of dirt content, ash content and volatile content according to SIR. In SIR 10 there is a maximum impurity level of 0.10, max ash content of 0.75, and a maximum vapor content of 0.80, whereas in SIR 20 there is a maximum impurity level of 0.20, ash content max 1.00, and substance content vaporize max 0.80.

Demand for the period of 15 September 2017 to 15 October 2017 PT. Nusira Medan can be seen in Table 1.

Table.1: Request Data 15 September 2017 to 15 October 2017

Job	Product Type	Ammount (ton)
1	*SIR 10*	2500
2	*SIR 20*	2000

Data at each work station stack packing production process starting from work station 1 that is Pre-cleaning process to work station 5 that is Packing process can be seen in Table 2.

Table.2: Work Station Data In Production Process

No	Work Station	Process	Labor (Person)
1	WS-1	Pre – Cleaning	6
2	WS-2	Milling	6
3	WS-3	Cooling	4
4	WS-4	Press	5
5	WS-5	Packing	6

WS = Work Station

Standard time is obtained from the normal time that has been added to the allowances that workers need to meet personal needs, eliminate fatigue, or for inevitable obstacles. The standard time recapitulation for all work stations is shown in Table 3.

Table.3: Standard Time of SIR Making Process 20 and SIR 10

Job	Work Station	Normal Time (secods)	Standard Time (seconds)	Total Time (seconds)
I	WS-1	21,24	25,28	1278,51
	WS-2	13,65	16,85	
	WS-3	9,07	9,07	
	WS-4	137,16	145,91	
	WS-5	981,07	1066,38	
II	WS-1	20,12	23,96	1284,69
	WS-2	14,02	17,31	
	WS-3	8,98	8,98	
	WS-4	143,64	152,81	
	WS-5	980,64	1065,91	
III	WS-1	21,09	25,11	1282,68
	WS-2	13,82	17,07	
	WS-3	9,02	9,02	
	WS-4	137,38	146,14	
	WS-5	983,88	1069,43	
IV	WS-1	21,27	25,32	1276,07
	WS-2	13,93	17,20	
	WS-3	8,87	8,87	
	WS-4	136,30	145,00	
	WS-5	978,70	1063,80	
V	WS-1	21,12	25,14	1273,28
	WS-2	13,76	16,99	
	WS-3	9,18	9,18	
	WS-4	129,82	138,10	
	WS-5	982,80	1068,26	

Calculation of the required time is obtained from the sum of processing time plus at the time in each work station. The available time calculation is obtained from the production capacity multiplied by the total processing time. The bottleneck occurs when the required time is greater than the available time, so the work station cannot produce in accordance with predetermined production targets and result in the accumulation of material. Bottleneck workstations can be seen in Table 4.

Table.4: Determination of Bottleneck Work Station

Work Station	Available Time (Hour)	Time Required (Hours)	Description
WS-1	187,2	6,13	Enough
WS-2	187,2	4,56	Enough
WS-3	187,2	28,15	Enough
WS-4	187,2	207,60	Not enough
WS-5	187,2	2,46	Enough

The rate of arrival of each job at each station is the speed of arrival of orders coming to the work station for a certain period. The rate of arrival of each job is obtained by comparing the demand rate with the size of the production lot. Recapitulation of job arrival rate calculation at each work station can be seen in Table 5.

Table.5: Arrival Rate (Minutes)

Job	**WS-1**	**WS-2**	**WS-3**	**WS-4**	**WS-5**
1	48,1	48,1	48,6	49,4	63,5
2	48,6	48,6	48,6	48,2	51,7
3	48,1	48,1	48,6	49,4	63,5
4	48,6	48,6	48,6	48,5	58,5
5	48,1	48,6	48,6	49,1	58,5

Workload is the amount of work that a machine must accomplish. Calculations can be seen in Table 6.

Table.6: Workload (Seconds)

Job	**WS-1**	**WS-2**	**WS-3**	**WS-4**	**WS-5**
1	596,16	432	181,44	794,88	432
2	207,36	172,8	43,2	734,4	172,8
3	596,16	432	181,44	803,52	432
4	345,6	259,2	86,4	682,56	259,2
5	466,56	345,6	138,24	734,4	345,6

Idle time each job is the time required job to wait for the previous job done. Calculations can be seen in Table 7.

Table.7: Idle Time (Seconds)

Job	**WS-1**	**WS-2**	**WS-3**	**WS-4**	**WS-5**
1	0,00	60,48	34,56	86,7	794,88
2	0,00	8,64	8,64	103,68	734,4
3	0,00	60,48	34,56	129,6	803,52
4	0,00	17,28	8,64	112,32	682,56
5	0,00	34,56	17,28	112,32	734,4

The calculation of lead time is done to calculate the length of time the workmanship of the product. The calculation of the lead time of each job on each work station can be seen in Table 8.

Table.8: Lead time (Minute)

Job	**WS-1**	**WS-2**	**WS-3**	**WS-4**	**WS-5**
Job 1	298,5	214,8	90,4	1486,5	214,8
Job 2	104,6	88,2	22,3	384,3	88,2

Job 3	297,4	216,2	90,9	1494,4	216,2
Job 4	171,5	131,1	44,2	732,6	131,1
Job 5	234,9	172,4	68,5	1049,4	172,4

At this stage can be seen improvement in performance on the production floor after using the Theory of Constraint. Based on the release order, the First Come First Serve (FCFS) scheduling has been applied by the company. Gantt charts the process of product work based on the actual conditions (Scheduling based on FCFS) and improvements (Scheduling based on TOC principles) performed can be seen in Table 9.

Table.9: Scheduling First Come First Serve (Hours)

Job	WS-1		WS-2		WS-3		WS-4		WS-5	
	start	Finish	start	fiish	Start	Finish	start	finist	start	finish
1	0	1,6544	1,6544	2,8408	2,8408	3,3488	3,3488	11,4552	11,4552	70,2152
2	1,6544	2,2368	2,8408	3,3312	3,3488	3,3496	11,4552	13,5816	70,2152	85.5360
3	2,2368	3,8816	3,8816	5,08	5,808	5,808	13,5816	21,7048	85.5360	144,9656
4	3,8816	4,8352	5,08	5,808	5,808	6,0544	21,7048	25,7368	144,9656	174,532
5	4,8352	6,1328	6,1328	7,0904	7,0904	7,4728	25,7368	31,4952	174,532	219,0592

3. Analysis and Evaluation

From result of data processing obtained by work station that experience bottleneck that is pressing work station. This is due to the lack of manpower and limited working time available on the production floor resulting in the late production process. To overcome the bottleneck problem is done with TOC approach.

The first step is to identify the company's constraints. The second step is to exploit the binding constraint, by proposing solutions that can solve the problem. The solution is done by adjusting the load of production units, over time and adding the number of labor. The third step is to subordinate solutions to overcome the existing constraints.

Based on the result of the analysis, it is known that TOC method has smaller makespan result than actual method (FCFS). A smaller product completion time will have an effect on reducing the overtime hours the company needs to fill orders.

Gantt chart of the scheduling of the company shows the sequence of workmanship job is 1-2-3-4-5 with makespan generated by 27.46 days or 219.71 hours and the total of all waiting time that occurs is equal to 54.24 hours and idle time of 48.84 hours. While the Gantt chart shows the sequence of workmanship job is 1-2-3-4-5 with makespan generated sebsar 26.47 days or 211.76 hours and Total of all waiting time that occurs is equal to 32.85 hours and idle time of 37.25 hours. Reduction in waiting time and idle time will impact the company on reducing product completion time and increase machine utility.

Based on scheduling results above the job scheduling sequence, idle time based on the Theory of Constraint (TOC) method has the smallest makespan compared to the FCFS method applied by the company. Therefore, the more appropriate scheduling method to apply to a company is scheduling using the Theory of Constraint (TOC) principle, because it will have an impact on reducing product completion time and increasing machine utility.

4. Conclusion

From this research can be concluded as follows:

1. TOC Application finds workstation bottlenecks that have a larger workload than other work stations that become constraints of vulcanization work station or pressing.
2. The scheduling result based on the Theory of Constraint (TOC) principle has the job scheduling sequence ie job 1-2-3-4-5 has makespan of 26.47 days or 211,76 hours with waiting time of 32.85 hours and idle time for 37.25 hours.
3. Scheduling conducted by the company is First Come First Serve which has makespan of 27.4641 days and there is waiting time of 54.24 hours and idle time of 48.84 hours.
4. A more appropriate method to apply to companies is scheduling using the Theory of Constraint (TOC) principle, because the scheduling done has minimized the makepan of 0.98 days or 7.84 hours and reduce the amount of waiting time ie 21.39 hours and idle time of 11.59 hours.

References

[1] C. Rahmawati, Z. Zainuddin, S. Is, and R. Rahim, "Comparison Between PCI and Box Girder in BridgesPrestressed Concrete Design," *J. Phys. Conf. Ser.*, vol. 1007, no. 1, p. 012065, Apr. 2018.

[2] R. Rahim, S. Napid, A. Hasibuan, S. R. Sibuea, and Y. Yusmartato, "Effect of the Machined Surfaces of AISI 4337 Steel to Cutting Conditions on Dry Machining Lathe," *J. Phys. Conf. Ser.*, vol. 1007, p. 012064, Apr. 2018.

[3] N. S. Dina, *Rancangan Sistem Penjadwalan Buku Fiksi dengan Pendekatan Theory of Constraint di PT. Mizan Grafika Sarana*. Bandung: Institut Teknologi Nasional Bandung., 2014.

[4] Z. Fatimah, *Usulan Penjadwalan Produksi dengan Menggunakan Theory of Constraint pada Bagian Welding Rear Body PT Krama Yudha Ratu Motor*. Jakarta: Universitas Indraprasta PGRI, 2015.

[5] R. Rahim, I. Zulkarnain, and H. Jaya, "A review: search visualization with Knuth Morris Pratt algorithm," in *IOP Conference Series: Materials Science and Engineering*, 2017, vol. 237, no. 1, p. 012026.

[6] R. Rahim, I. Zulkarnain, and H. Jaya, "Double hashing technique in closed hashing search process," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 237, no. 1, p. 012027, Sep. 2017.

[7] R. Rahim *et al.*, "Searching Process with Raita Algorithm and its Application," *J. Phys. Conf. Ser.*, vol. 1007, no. 1, p. 012004, Apr. 2018.

[8] R. Rahim, A. S. Ahmar, A. P. Ardyanti, and D. Nofriansyah, "Visual Approach of Searching Process using Boyer-Moore Algorithm," *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 012001, Dec. 2017.

[9] R. Rahim, S. Nurarif, M. Ramadhan, S. Aisyah, and W. Purba, "Comparison Searching Process of Linear, Binary and Interpolation Algorithm," *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 012007, Dec. 2017.

[10] R. Ginting, *Sistem Sistem Produksi*. Yogyakarta: Graha Ilmu, 2007.

[11] A. Hasibuan *et al.*, "Performance analysis of Supply Chain Management with Supply Chain Operation reference model," vol. 1007, pp. 1–8, 2018.

[12] K. Baker, *Elements of sequencing and scheduling*. New York: John Willey, 2001.

[13] E. Singhal, *An Improved NEH Algorithm Applied to Permutation FlowShop Scheduling*. India.: Suresh Gyan Vihar University, 2013.

[14] R. Ginting, *Penjadwalan Mesin*. Yogyakarta: Graha Ilmu, 2009.

[15] S. Sinulingga, *Perencanaan dan pegendalian Produksi*. Yogyakarta: Graha Ilmu, 2013.

[16] A. Hasibuan, *Metodologi Penelitian*. 2013.

[17] S. Wignjosoebroto, *Ergonomi Studi Gerak dan Waktu*. Jakarta: Guna Widya, 2003.

[18] I. Z. Sutalaksana, *Teknik Tata Cara Kerja*. Bandung: ITB, 2005.

[19] W. Sukmoro, *Turning Loss Into Profit Trobosan Untuk Mendongkrak Kinerja*. Jakarta: Penerbit PT. Gramedia Pustaka Utama, 2010.

[20] A. T. Widjaja, *Theory of Constraint (TOC) dan Throughput Accounting*. Jakarta: Harvindo, 2003.