Production Scheduling Using The Theory Of Constraint Approach And The Nawaz Enscore Ham Method

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Abstract- *Production process scheduling is an activity to plan and allocate available resources with a predetermined period to complete a production process activity. CV. KotamaShoes is a company that produces various types of leather shoes. The company uses a scheduling system for the first come first serve method, which means that the order that comes first will be done first. However, the company has a problem with constraints during production so that it has an impact on the longer total time to complete the product. Therefore, it will describe the solution of existing problems with the proposed Theory of Constraint (TOC) approach to finding work stations that experience problems and the Nawaz Enscore Ham (NEH) Alghoritm method to minimize the time of product completion or makespan.*

Keywords- Production Scheduling, TOC, NEH

I. INTRODUCTION

In today's business world, competition is increasingly competitive so that companies not only have to pay attention to product quality but also pay attention to product completion time and the timeliness of products to consumers. This is intended to meet consumer satisfaction so that product demand will continue to increase. There are several factors that affect the timeliness of the product to the consumer, including the availability of raw materials, distribution activities, the length of time to complete the product, and others. Completion of a product on time can be achieved by planning and scheduling good production.

CV. Kotama Shoes is a company that produces various types of leather shoes. The company produces leather shoes based on order (make-to-order). Existing orders vary widely, starting from the type, size, and quantity. Until now, the scheduling system implemented by the company is First Come First Serve (FCFS), which means the company will produce the first orders that come. Thus, subsequent orders have to wait until the previous order has been produced. In the production process, there are obstacles to the accumulation of semi-finished goods in the workplace. This has an impact on product completion time that is not on time or on time.

One of the concepts that can be used to eliminate the constraints of the accumulation of semi-finished goods is to use the Theory of Constraint (TOC) approach and the Nawaz Enscore Ham (NEH) method. TOC is a "systems management philosophy" which states that constraints result in performance limitations for each system [1]. In addition, to minimize product completion time, it can be done using the Nawaz Enscore Ham (NEH) method, which is a flow shop scheduling method to minimize the total production completion time [2].
The purpose of this research is to determine the work station which is a constraint station, to know the results of scheduling using the Theory of Constraint (TOC) approach and the Nawaz method, Enscore Ham (NEH), to compare the performance of the company's previous scheduling method with the proposed scheduling method.

This research is related to how to apply the Theory of Constraint (TOC) approach and the Nawaz Enscore Ham (NEH) method which is carried out in a private shoe manufacturing company located in Medan City. The data required is data related to the time of all workstations. The data is based on data that occurs in the company.

The Nawaz, Enscore, Ham (NEH) method was developed by Muhammad Nawaz, E.EmoryEnscore Jr., and Inyong Ham in 1983. "In a general flow shop, where all the jobs must pass through all the machines in the same order, certain heuristic algorithms propose that the jobs with higher total process time should be given higher priority than the jobs with less total process time" which means in the scheduling of flows in general, where all jobs must pass through all machines in the same order. This metaheuristic algorithm proposes that tasks with a greater total processing time should be given greater priority than tasks with a smaller total processing time [3].

Flow shop scheduling has its own library of precise and heuristic methods namely the Johnson algorithm [4], the

branch and bound method [5], the Campbell-Dudek-Smith algorithm [6], the Nawaz-Enscore-Ham algorithm [7], the Quick Access algorithm [8] etc., to troubleshoot m-machine n-jobs.

Theory of Constraints is one of management philosophy based on achievement principles which concern on continuous improvement through concerning on the constraints system. In production scheduling, TOC has the role of synchronization of all sub-systems. Synchronization means flow rate production setting from each of subsystem with the purpose to avoid the excessive burden on work station which had the lowest capacity as the constraint station.

II. METHODOLOGY

The settlement is carried out in two stages, namely using the Nawaz Enscore Ham (NEH) method in the first stage and then using the Theory of Constraint (TOC) approach in the second stage.

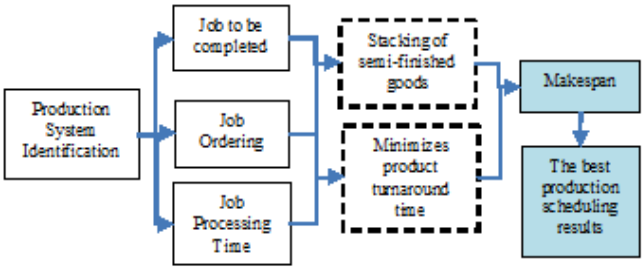

Figure 1. Research Framework

A. The Nawaz, Enscore, and Ham (NEH) method

The Nawaz, Enscore, and Ham (NEH) method was developed and used in the processing time for each job and to reduce the time from production. The steps for using NEH come from heuristics, namely [9]:

1) Sorting jobs based on Short Processing Time (SPT) rules.
2) Start by trying the sequences (j1, j2) and (j2, j1). Next, calculate the makespan of the two sequences and choose the smallest one (j2, j1).
3) Continue the sequence based on the next job (j3). Then calculate the makespan of the three sequences, namely (j3, j2, j1), (j2, j3, j1), (j2, j1, j3), and choose the smallest order.
4) Continue the calculation to get the smallest order.

B. Theory of Constraint (TOC) Approach

Theory of Constraint (TOC) was created by Eliyahu Moshe Goldratt in the early 1970s. Goldratt was an Israeli physicist who was later involved in designing the production system, In 1988 Goldratt wrote a book entitled "The Goal: A Process of Ongoing Improvement", Theory Of Constraint is often called the Drum-Buffer-Rope System (DBR System).
Eliyahu M. Goldratt stated that the TOC uses five steps to achieve the goal of improving company performance, as follows:

B.1. Identification of System Constraints

The first step is to identify the constraints in the system that limit the throughput or process to achieve the goal. Don R Hansen and Marryanne M. Mowen distinguish the following types of constraints:

1) Internal constraints and external constraints

Internal constraints are a limiting factor in the company. External limitations are the factors that limit companies that come from outside the company.

2) Constraints are not binding and constraints are binding

Unbound constraints are constraints where limited resources are not fully used by the product mix. Binding constraints are constraints where the available resources are fully utilized.

B.2. Exploit the existing constraints

One of the ways to maximize the use of binding constraints is to ensure the optimal product mix produced. However, this effort is more than just guaranteeing the optimal mix production. In many companies, the main one is called the drummer (the major binding constraint). For example, assume that only there is one binding internal constraint, which can automatically become the drummer. The production rate constraint of the drummer determines the overall production rate of the factory. The downstream process, which starts with the drummer's constraint, is required to follow the production level. Downstream process scheduling can be done easily after the components are completed in the drummer process, the next process will start operating immediately.

B.3. Subordination of other resources

Drummer constraints essentially determine the capacity of the entire factory. All other departments must be subordinated to the needs of the drummer's constraints. This principle requires many companies to change the way they

perceive things. For example, the use of efficiency measures at the departmental level may not be appropriate.

B.4. Evaluation of System Constraints

The next step is to initiate a program of continuous improvement by reducing the limitations of binding constraints affecting company performance. Adding decisions that can increase the overall output of the constrained activity or task.

B.5. Repeating the process

Eventually, the resource boundary will be lifted to the point where it is no longer binding.

C. Location, Type and Source of Data

The location of the research was carried out at CV. Kotama Shoes, a company located in Medan, North Sumatra, Indonesia. The company produces various types of leather shoes based on order (make-to-order). This research is focused on production scheduling, problem formulation of how to solve the accumulation of semi-finished goods at work stations and minimize product turnaround time. The data taken are work station data in the product manufacturing process, cycle time data, demand data, set-up time data, and an overview of the company. In addition, observations were made related to several other data such as the number of machines, processing time, and types of products.

D. Population andSample

The population is a generalization area consisting of objects/subjects that have certain magnitudes and characteristics that are determined by researchers to be studied and then draw conclusions [10]. The population in this study are companies that have carried out powder coating activities since 1989 until now.

The sample is a subgroup or part of the population and can represent the population. The research sample used was the activity of scheduling the shoe-making production process which was carried out from September 2017 to August 2018. The sampling technique used was to take time data on the area of each station.

E. Data Collection

The data taken are work station data in the product manufacturing process, cycle time data, demand data, set-up time data, and an overview of the company. Data is taken by observing several data such as the number of machines, processing time, and type of product.

Table 1. Data of Demand (unit)

Period	Types of Products				Total
	Loafers	Boots	Semi Boots	Casual	
September	352	430	320	315	1.417
October	320	350	372	335	1.377
November	423	315	428	310	1.476
December	504	328	423	310	1.565
January	520	325	321	315	1.481
February	412	324	410	325	1.471
March	530	325	332	315	1.502
April	521	335	423	322	1.601
May	415	303	370	305	1.393
June	356	420	235	300	1.331
July	321	424	435	306	1.486
August	432	385	256	315	1.388
Total	**5.106**	**4.264**	**4.325**	**3.773**	**17.468**

Table 2. Workstation Data

Work Station	Process	Worker
1	Pattern making	1
2	Cutting	1
3	Put together	1
4	Sewing	1
5	Assembling	2
6	Pressing	1
7	Sterilization	1
8	Finishing	2

Table 3. Work Time Measurement Data for Each Job

Ob.	Job	Work Station Time (Minutes)							
		WS 1	WS-2	WS-3	WS-4	WS-5	WS-6	WS-7	WS-8
I	1	03,28	02,52	06,23	4.43	80,24	02,32	03,22	28,25
	2	03,15	02,42	06,33	4,37	80,17	02,28	03,32	29,05
	3	03,22	02,48	05,56	4,20	80,10	02,26	03,37	28,42
	4	03,19	02,58	06,20	4,18	80,05	02,18	03,29	28,32
II	1	02,48	03,22	06,23	4,33	80,34	02,30	03,12	27,45
	2	02,50	03,32	06,33	4,37	80,27	02,36	03,23	28,15
	3	02,52	03,48	05,56	4,30	80,20	02,42	03,35	28,42
	4	02,57	03,28	06,20	4,28	80,05	02,28	03,26	28,32
III	1	03,36	03,23	06,13	4,30	80,44	02,33	03,15	27,35
	2	03,38	03,18	06,37	4,33	80,37	02,28	03,13	28,24
	3	03,30	03,45	06,23	4,28	80,20	02,26	03,25	28,22
	4	03,34	03,28	06,28	4,35	80,25	02,22	03,12	28,33
IV	1	03,25	02,42	06,26	4,33	80,21	02,20	03,32	28,45
	2	03,20	02,52	06,32	4,37	80,18	02,15	03,22	29,05
	3	03,27	02,38	06,16	4,22	80,14	02,18	03,27	28,42
	4	03,19	02,48	06,20	4,24	80,12	02,23	03,29	28,47

III. RESULTS ANDDISCUSSION

A. Identification of System Constraints

The identification that is observed is at work stations that are in the process of making leather shoes, the following

is the flow of the work station making process from start to finished product.

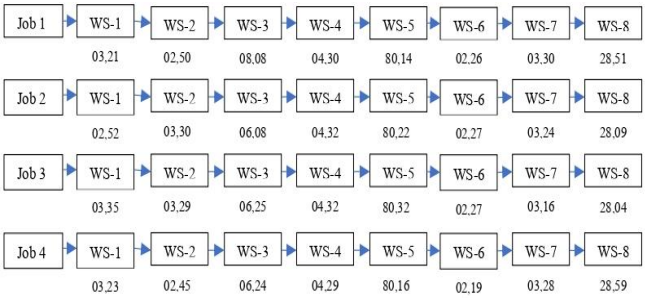

Figure 2. Flow of The Shoe-making

B. Exploit the existing constraints

The next stage is to exploit the existing constraints, namely the completion stages as follows:

1) Data uniformity test

In conducting data processing, it is necessary to test the uniformity of the data first so that the data obtained can determine the standard time. This is done to find out whether the data is within the upper control limit (UCL) or the lower control limit (LCL) and to find out whether the data is under control or out of control.

2) Data adequacy test

After the data uniformity test stage has been carried out, the data adequacy test stage is then carried out. The data sufficiency test was carried out to determine whether the data from the cycle time obtained were sufficient to state that the data had a predetermined level of accuracy. In this study, the level of confidence = 95%, and an accuracy level of 5% were used.

3) Standard time calculation

Standard time is obtained from the normal time that has been added with (allowance) or the allowance needed by workers to carry out activities outside of their work, and also to eliminate feelings of fatigue (fatigue) or an inevitable obstacle that occurs.

4) Production forecasting

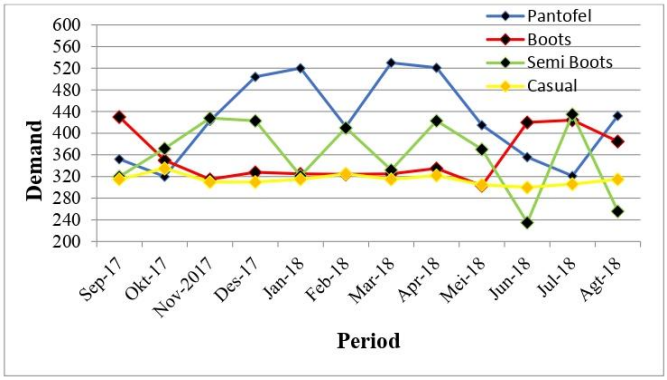

Figure 3. Demand Production

Table 4. Arrival Rate (hours)

Job	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6	WS-7	WS-8
Job 1	0,0555	0,0333	0,0595	0,1042	0,0303	0,0314	0,0166	1,0309
Job 2	0,0521	0,0427	0,0595	0,1190	0,0282	0,0326	0,0172	0,0303
Job 3	0,1666	0,0416	0,4166	0,1190	0,0416	0,0326	0,1666	0,0273
Job 4	0,0617	0,0287	0,3333	0,0980	0,0252	0,0248	0,0183	0,0193

Table 5. Processing Time (hours)

Job	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6	WS-7	WS-8
Job 1	31,1640	23,2044	57,8318	38,7270	772,47	29,6537	33,1562	258,94
Job 2	24,7657	31,0285	58,7036	39,4320	783,87	15,1528	33,8579	258,93
Job 3	25,2151	23,6707	51,6280	30,1909	600,51	23,1160	25,2171	197,74
Job 4	24,3498	17,6140	46,1053	30,0364	599,18	22,3125	26,2060	201,60

Table 6. Average Workload Time (hours)

Job	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6	WS-7	WS-8
Job 1	1,7296	0,7727	3,4409	4,0354	23,4058	0,9311	0,5504	6,1652
Job 2	1,2902	1.3249	3,4929	4,6924	22,1052	0,4939	0,5824	7,8455
Job 3	4,2008	0,9847	2,1508	3,5927	24,9813	0,7536	4,2012	5,3983
Job 4	1,5023	0,5052	15,3668	2,9436	15,0994	0,5534	0,4796	3,8909

Table 7. Waiting Time (hours)

Job	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6	WS-7	WS-8
Job 1	0,0680	0,0225	0,2522	0,1983	24,130	0,0348	0,0229	1,7144
Job 2	0,0397	0,0508	0,2559	0,2317	22,686	0,0093	0,0244	2,5639
Job 3	0,1740	0,0378	0,0181	0,1780	26,409	0,0283	0,1738	1,7580
Job 4	0,0595	0,0144	1,2063	0,1444	15,392	0,0200	0,0204	1,2855
Total	0,3412	0,1255	1,7325	0,7524	88,6178	0,0924	0,2415	7,3218

So it can be seen that there are constraints at work station 5 or assembling, where the work station experiences a very long processing time. Early time complete (ETC) and last time complete (LTC) calculations based on constraint workstations.

Table 8. ETC and LTC Calculations for Each Job

Job	ETC	LTC
Job 1	1522348,46	2471452
Job 2	1523132,35	2486347
Job 3	930767,57	1507719
Job 4	922131,21	1491594

C. Subordination of other resources

In the subordination step, then anything different from the previous decision was carried out. After knowing the smallest ETC value, then another alternative is carried out, namely scheduling using winQSB software, namely job scheduling.

Table 9. Makespan of Partial Order Candidates in Iteration 3 (hours)

Partial Order	Total Makespan
3-2-1-4	1046,150
3-2-4-1	1299,837
4-3-2-1	1310,667
3-4-2-1	1311,563

Based on iteration 3, the makespan value for each partial sequence is obtained, and the smallest makespan value is in the partial sequence 3-2-1-4 with a makespan value of 1046,150 hours. Thus, the makespan value selected using the Nawaz, Enscore, and Ham (NEH) algorithm is a partial sequence, namely job3-2-1-4 with a makespan value of 1046,150 hours.

D. Evaluation of System Constraints

At this stage, it is seen whether there is an increase in performance that occurs on the production floor after scheduling using the theory of constraint approach. This can be seen based on the scheduling carried out by the previous company, namely by using the company's scheduling system where the first order comes to be done so that the company does not take other factors into account. The company method has a makespan value of 3086.21 with a 1-2-3-4 job order while using the TOC approach, the makespan value is 607 hours with a 4-3-1-2 job order.

E. Repeating the Process

An approach using the theory of constraints, what needs to be done is to fix the constraints between differences in a capacity that cause large waiting times and find better scheduling. Based on the improvements that have been made, the fifth step of the theory of constraints does not need to be done again.

IV. CONCLUSION

The use of the theory of constraint approach in this study has found that work station 5 or assembly work station is a work station that causes problems in production scheduling. In addition to knowing the station causing the problem, existing obstacles can also be identified. Furthermore, the Nawaz Enscore Ham (NEH) method solves the identified constraints which result in makespan 607 hours with the job sequence: 4-3-1-2.

V. ACKNOWLEDGMENT

Acknowledgments for CV. Kotama shoes that have participated during this research process to completion.

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