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Comparing Between Production Scheduling Methods to Achieve Efficient Resource Utilization

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***Abstract*—High competition among industries nowadays, requires companies to improve their production services. The speed of production service time, with excellent quality, becomes part of the company's competitive advantage. This study aims to compare several production scheduling methods which are commonly used, so that efficient resource utilization can be obtained. Production Scheduling Methods such as Make to Order, Dannenbring, Branch and Bound, Nawaz Enscore and Ham and Campbell Dudeck Smith were compared using one case of tire retreading production. There were two jobs: tire retreading for truck and bus. Each job, assigned to ten workstations following its production steps. The results were obtained that Dannenbring and Campbell Dudeck Smith gave the same best results with the smallest makespan value, equivalent to 48% efficiency.**

***Keywords*—Branch and Bound, Campbell Dudeck Smith, Dannenbring, Nawaz Enscore and Ham, Production.**

I. INTRODUCTION

ONE of the competitive advantage that must be owned by companies, especially those engaged in services, in addition to quality at this time is the speed of service to meet consumer demand and expectation. The speed of service to meet consumer demand is dependently influenced by the length of production time. Production time is highly dependent on the type of product variation produced, the flow of production process, production machinery and equipment facilities, availability of materials and labor with good skills and the selection of production scheduling methods.

There are many production scheduling methods, such as Make to Order [1], [2], Branch and Bound [3], [4], [5] Campbell Dudeck Smith [6], [7], Dannenbring [8], [9],Nawaz Enscore and Ham (NEH) [10], [6], [11], Integer Programming and Heuristic Algorithm such as Genetic Algorithm [12], [13], Tabu Search [4], and Particle Swarm Optimization [11] or any combination of them [4], [6], [11], [7]. However, there is no study yet, which comparing those methods. Which method is appropriate in what condition. In another side, many small companies still use traditional approach to manage their production scheduling [14]. They commonly prioritize production activities for product type which has higher difficulty level or longer completion time. This is good on one side, the company can concentrate focusing on products which are more difficult or take longer production time, so that the next job will be easy and faster to be accomplished. However, this consideration is not entirely wise since the work of difficult and longer firstly done; there will be an imbalance in the production line; there will be a queue in production; consumer demand will be served longer and this will be a boomerang for the survival of its company in the future. Considering those condition, this study was conducted with theaim of comparing production scheduling makespan result by using five methods (actual make to order, Dannenbring, Branch and Bound, Nawaz Enscore and Ham and Campbell Dudeck Smith) and obtaining the best efficiency result.

II. DESCRIPTION SYSTEM

This research takes a case study on tire retreading production process where they have two types of tires i.e. Truck tires (Job 1) and Bus tires (Job 2). This company through conventional make to order method, did the truck tire retreading first (Job 1) because this product type was known to be more difficult and required relatively longer time to produced so it tooks as precedence to other (Figure 1) Each tire retreading job has 10 stages of production activities. This can be seen in Figure 1. This condition raises the queue of the production process due to increasing makespan. Consumers have to wait longer to have their orders to be completed. Many orders can not be served. Following in Table 1 e number of Consumer order request (demand) and number of production output of Truck and Bus Tires in the last 4 months. Next in Table 2, it can be seen the production time required for each job.

III. METHODOLOGY

In this study, the lowest makespan criteria is used to get the best scheduling method and result in efficiency. The research stages starts from the calculation of the completion time to obtain current makespan. Completion time is obtained from standard time calculations, data uniformity test and data adequacy test. Then the four methods compared (Dannenbring, Branch and Bound, Namaz Enscore and Ham and The Campbell Dudeck and Smith) are used to obtain lowest makespan which also means highest efficiency.

Table 1.
Demand and production

No	Month	Demand (Unit)		Production (Unit)	
		Truck	Bus	Truck	Bus
1	July „19	120	115	110	119
2	August „19	115	110	109	117
3	September „19	110	115	118	110
4	October „19	115	120	110	111

Table 2.
Production duration time per workstation per job

No	Work stations	Duration (time)		
		Truck	Bus	Total Time
1	Arrival and Tire Checking	15	15	30
2	Tire Cleaning	37	33	70
3	Tire Grinding	20	20	40
4	Fur Removal	35	31	66
5	Glueing	24	23	47
6	Rubber Mounting	30	32	62
7	Edge Rubber Mounting	47	38	85
8	Tire Range Mounting	26	24	50
9	Heating Process	180	181	361
10	Final Inspection	10	11	21
	Total	424	408	832

Table 3.
Job scheduling and makespan

Scheduling Methods	Job Order	Makespan (minutes)
Make To Order	1 – 2	832
Dannenbring	2 – 1	432
Branch And Bound	2 – 1	587
Nawaz Enscore And Ham	2 – 1	572
Campbell Dudeck Smith	2 – 1	432

A. Standard Time

1) Cycle Time (WS)

Cycle time is the time taken to complete the production of one unit from beginning to end as given in eq. 1 as follow,

$$WS = \Sigma \frac{X_i}{N}$$

Where Xi= estimated completion time, and *N* = number of observations made.

2) Normal Time (WN)

Normal time is working time that has taken into account the adjustment factor, that is, the average cycle time multiplied by the adjustment factor as seen in eq. 2.

$$P_i = Rating\ Factor$$
$$P = 1 + P_i$$
$$WN = WS \times P$$

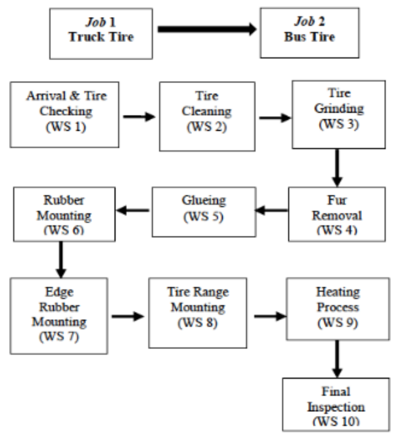

Figure 1. The Process Flow in Job & Work Stations (WS) of Each Job.

Where WS = cycle time; P = adjustment factor ; P= 1 when working time classified in FAIR ; P < 1 when working time classified in too SLOW and P > 1 when working time classified in too FAST.

3) Standard Time (WB)

Standard time is the actual time of the operator uses to produce one unit of product type concerning normal time and allowance, as given in eq. 3 as follow,

$$WB = WN \times \frac{100}{100 - allowance}$$

B. Data Uniformity Test

Control limits are derived from data that is the limit by which to determine the data are uniform or not. The data is uniform when the average is between the controls and if there is data beyond the controls then the data is not uniform. In determining the limits of control may use these following eq. from 4 to 9.

1) The average (x)

$$\bar{\bar{x}} = \frac{\Sigma_{i=1}^{k} \bar{x}_i}{K}$$

2) Deviation Standard (δ)

$$\delta = \frac{\sqrt{n\ \Sigma_{j=1}^{n-1} X^2 j \ - \ (\Sigma_{j=1}^{n-1} X_j)^2}}{n-1}$$

3) Variance (δx)

$$\delta_{\bar{x}} = \frac{\delta}{\sqrt{n}}$$

4) By using 95% confidence level, it is obtained that

$$Z_{x/z} = 1{,}96 \text{ (from table Z)}$$

5) Upper Control Limit (BKA)

$$BKA = \bar{\bar{x}} + 2\,\delta_x$$

6) Lower Control Limit (BKB)

$$BKB = \bar{\bar{x}} - 2\,\delta_x$$

Where Xj = data from jth observation (j=1,2,3, …, n); x i= the average data of ith group observation ; K = number of sub group ; n = number of data in each sub group ; N = number of data.

C. Data Adequacy Test

Data is adequate sufficient when number of observation data (N) is more than number of data in theory (N'). If Xi = the average of observation data in ith sub group ; K = Number of sub group ; n = number of data in each group; N = number of data, then number of data in theory is given in eq. 9 as follow,

$$N' = \left(\frac{\frac{k}{s} \cdot \sqrt{n\, \Sigma_{i=1}^{n} x_i^2 - (\Sigma_{i=1}^{n} x_i)^2}}{\Sigma_{i=1}^{n} x_i} \right)^2$$

D. Dannenbring Methods

Dannenbring method schedules work sequence from the fastest to the slowest.

1) Time of process sequence in first machine (ai) as seen in eq. 10

$$ai = \sum_{j=1}^{m} (m - j + 1).t_{ij}$$

2) Time of process sequence in second machine (bi) as seen in eq. 11

$$bi = \sum_{j=1}^{m} i\,.t_{ij}$$

Where m = number of machines ; i = job ; j = machines used to process job 1 ; tij = processing time for job - i at machine j

E. Branch and Bound Methods

This method can minimize the production processing time and avoid idle machine time. Scheduling each job is done according to calculation at each lower limit makespan is the smallest value of first iteration.

1) Processing time needed for machine 1 (M1) is given in eq. 12 as follow

$$M1 = \sum t_{j1}$$

2) First lower control limit of machine makespan (b1) is given in eq.13 as follow

$$b_1 = q_1 + \sum_{j \in T'} t_{j2} + \min_{j \in T'} \{t_{j2} + t_{j3}\}$$

3) Second lower control limit obtained from machine 2 (b2) is given in eq. 14 as follow

$$b_2 = q_2 + \sum_{j \in T'} t_{j3} + \min_{j \in T'} \{t_{j3}\}$$

4) Processing time on machine 3 (b3) is given in eq. 15 as follow

$$b_3 = q_1 + \sum_{j \in T'} t_{j3}$$

5) Lower control limit obtained from maximum value (B) is given in eq. 16 as follow

$$B = \max\,\{b_1, b_2, b_3\}$$

Where t_i = processing time ; q_1= last completion time on machine 1 among jobs ; q_2= last completion time on machine 2 among jobs ; q_n= last completion time on machine n among jobs.

F. Nawaz Enscore and Ham Methods

The method was developed by Nawaz, Enscore and Ham in 1983. This method is called Incremental Construction Algorithm method. Scheduling using Nawaz, Enscore and Ham method determines working sequence based on SPT approach (Short Processing Time). The order of completion time for each job is sorted from the largest to the smallest using these eq. 17 and 18

$$C_{i,j} = t_{i,j} + \max(C_{i-j}, C_{i,j-1})$$

$$C_{i,0} = 0\,;\; C_{0,j} = 0$$

Where C_{ij} = completion time of job i on machine j ; t_{ij} = processing time of job i on machine j

G. Campbell Dudeck Smith Methods

Campbell Dudeck Smith method is a method that determines the sequence of product processing based on the time of completion of the process from the smallest to the largest by using eq. 20 as follow,

$$t_{B_{i,j}} = \frac{W_{B_{i,j}}\, x\, Q_i}{M_j\, x\, C_{ij}}\,;\, i,j = 1,2,3$$

Where W_{Bij} = processing time for job ; Q_i = number of demand once order on job i ; M_j = number of machines at work station j ; C_{ij} = production capacity per machine j.

IV. RESULT AND DISCUSSION

By comparing those four methods with conventional make to order method which is recently used by the company, we come to the result as seen in Table 3. In Table 3, here is the list of makespan for each method"s job order. Next in Table 2, it can be seen the production time required for each job.

From Table 3, it is clearly seen that both methods of Dannenbring and Campbell Dudeck Smith, delivered same result in makespan 432 minutes. It is 400 minutes faster, compared to actual makespan 832 minutes, so that this result equal to 48.07% efficiency. Both proposed methods delivered same job order start from job 2 (Bus tire retreading), followed by job 1 (truck tire retreading), contrast to actual job order which is job 1 to 2. This result of job sequence is understandable since job 2 has shorter completion time than job 1.

Scheduling job sequence, not only need to consider time period, but also has to control manufacturing cost [15], lean manufacturing to eliminate the waste [16], and maintenance scheduling [17], so that the company may optimize its production capacity [18]. The job sequences need to be evaluated periodically using the concept of continuous improvement, thus it may result in green industrial system [19], [20].

V. CONCLUSIONS

1 After comparing all those methods, we come to conclude that Dannenbring method and Campbell Dudeck Smith (CDS) method delivered the same best result i.e. shortest makespan. Both methods decrease makespan from 832 minutes to 432 minutes, equal to 48% efficiency, with the work sequence: Job 2 then Job 1, bus tire retreading then followed by truck one. For further research, it needs to do more exploration on those methods characteristics, in what condition each method is performing well.

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