

Article

Implementation of Nawaz, Enscore, and Ham (NEH) for Minimize Makespan in Job Shop Scheduling

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Abstract: PT. OPQ is a company that specializes in providing construction materials such as ready-mix concrete, precast concrete, concrete bricks and crushed stone. With 4 different compositions and high demand, it is not uncommon for problems to occur, namely late delivery. This research aims to increase work efficiency by minimizing makespan to reduce idle time which will impact delays in product delivery to customers. The results of production scheduling using the NEH method produce smaller makespan results and faster production process completion times compared to the scheduling method used by the company. The NEH method produces a makespan of 2.29 with the job sequence P3-P4-P2-P1. The method used by the company obtained a makespan of 3.01 with a partial work sequence of P2-P3-P4-P1. This can prove that the calculation results using the NEH method can minimize makespan and this method can be used by companies as a reference for scheduling the production process to overcome the problems being faced by the company.

Keywords: Scheduling; Optimization; Makespan; NEH

1. Introduction

Production scheduling in the manufacturing sector aims to deliver the best results for customers [1]. One of the best ways to provide good service to customers is by delivering products on time and making them available according to their schedule. Optimal and timely products are essential to achieve, and the most important solution is to create an efficient supply chain to achieve the best results in production operations; all production processes must be carried out carefully in advance [2]. Scheduling is the process of formulating a plan that allocates resources to several tasks within a specific timeframe. This is an important step because it helps optimize the company's goals and strategies. [3]. Production scheduling is defined as the process of allocating materials or machines to complete a series of tasks over a specific period of time. Production is very important for businesses that use a make-to-order system, where new products are produced in response to customer demand [4].

Scheduling is the distribution of limited resources to complete a certain number of tasks. Problems will arise if operations are ongoing, each employee requires the same workstation. The failure of the production process is a very important issue in the manufacturing industry. Scheduling the manufacturing process will negatively impact several aspects, including work or process efficiency. The use of scheduling is very important for product planning and development. The purpose of scheduling is to maximize the available resources to plan production and manage resources. With the help of scheduling, tasks can be organized and prioritized while optimizing the amount of time and resources needed for each required process [5]. Optimization is the process of making

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a task as optimal as possible to achieve the desired result. Optimization can only occur when tasks are performed efficiently and effectively [6]. There are various scheduling objectives, which include [7] improving the utilization of equipment or resources by reducing idle time, minimizing the amount of work in the queue that needs to be handled, and eliminating delays.

PT.OPQ is a company that specializes in providing construction materials such as ready-mix concrete, precast concrete, concrete bricks, and crushed stone. With the presence of 4 different compositions and high demand, it is not uncommon for issues to arise, such as delivery delays caused by several factors, including varying customer demands, the lack of effective scheduling implemented in the company, and the alternating use of machines between concrete variations. The decline in customer trust towards the company is often caused by delays in the delivery process. The occurrence of delivery delays at PT. POQ, with a 5-8 hour delay interval during the 1-day loading process, and with such long continuous delays over a period of 6 months, can lead to many disruptions in cooperation with related vendors and a decrease in demand due to the loss of customer trust. This can have a negative impact on the company, such as the termination of partnerships with other companies and a decrease in demand. Therefore, if there are issues in the production and delivery processes, the company needs to improve its management system [8]. The manufacturing system used by this company is designed to meet customer demand based on purchase orders. Business operators generally take advantage of consumers by emphasizing the importance of completion time (makespan). Currently, the company uses the First Come First Serve (FCFS) system. This system has various shortcomings, one of which is that if several orders arrive at the same time, it will be difficult to determine which order is completed first. This issue is likely to affect the completion time (makespan). A long makespan is likely to result in orders being completed after the due date [9]. The measure of scheduling success is the reduction in production completion time (makespan) [10].

Several previous studies include research conducted by Martin [11] that discusses scheduling using the CDS, NEH, and Palmer methods. In that study, the NEH method had a shorter total completion time compared to the CDS and Palmer methods. Additionally, there is research conducted by Nino [1] that discusses the optimization of scheduling systems using the Nawaz Ensore Ham method. In that study, it was found that there was a reduction in Makespan by 3.16 hours. There is also research conducted by Siti [5] that discusses minimizing Makespan using the Nawaz Ensore Ham method, which found a reduction in production process time by 13,519.65 seconds between the Company method and the NEH method. The Nawaz Ensore Ham method has proven to be able to make the production process time faster compared to the Company method. Based on previous research, one of the approaches that can be used to address the issues in my study is by using the Nawaz Ensore Ham method. The Nawaz Ensore Ham method has been used to increase productivity by reducing the amount of time required to complete customer service requests. Nawaz Ensore Ham (NEH) is a heuristic algorithm that determines that tasks requiring more time to complete overall should be given higher priority than tasks requiring less time to complete overall [12]. In 1983, Muhammad Nawaz, E. developed the Nawaz Ensore Ham (NEH) method, which was further refined by Emory Ensore Jr and Inyong Ham. "Dalam sebuah flowshop umum, di mana semua pekerjaan harus melewati semua mesin dalam urutan yang sama, beberapa algoritma heuristik mengusulkan bahwa pekerjaan dengan waktu proses total yang lebih lama harus diberikan prioritas lebih awal daripada pekerjaan dengan waktu proses total yang lebih pendek." This means that the concept of flowshop scheduling is that all jobs must pass through all machines in the same order. This indicates that jobs with longer processing times should have higher priority and vice versa [13]. The principle of the NEH method is to find the optimal solution by swapping job positions, thereby generating many possible job sequences to achieve the best results [14]. The Nawaz

Enscore Ham (NEH) approach is superior to other heuristic methods because it is more accurate in determining the possible job sequences to be scheduled [15]. Production scheduling using the NEH method is carried out to minimize Makespan through several stages.

This research aims to improve work efficiency by minimizing makespan (total production time) to reduce idle time, which will impact the timely delivery of products to customers. The method used in the research can serve as a reference for the Company to improve production process efficiency by minimizing makespan.

2. Materials and Methods

The calculation process using the NEH method is carried out in the following stages [16]:

1. Sum the production process time for each job

2.

$$T = \sum_i^m t_i$$

[5]

Note:

T = total time for each job

t = processing time for each job

i = the job being worked on

3. Sort the total job time from largest to smallest.

4. Arrange iteration $X = 2$ from i with the largest sorting

5. Calculate the makespan value for $X = 2$

6. Create a candidate partial sequence from $X = 2$ and then also calculate its makespan.

7. In the next partial sequence candidate, it is milk and $X = X+1$

8. Selecting the job in the third position from the total production time sorting

9. Calculate the makespan at $X = X+1$

10. Repeat until the job is finished

11. Recap the makespan calculations from all the total jobs that have been calculated.

12. Choose the sequence of jobs with the smallest makespan.

13. Finished

14. Here is the research flowchart that illustrates the stages in conducting scheduling research using the Nawaz Enscore Ham (NEH) method.

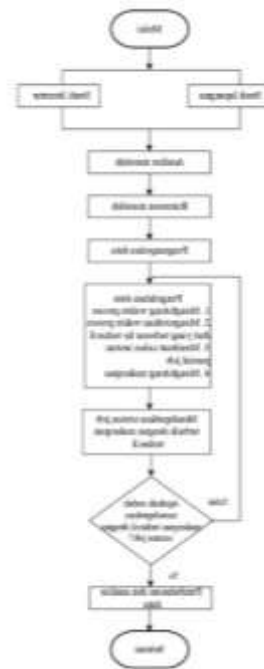


Figure 1. Research Flow Diagram

This research is more focused on the production scheduling of ready-mix concrete. The data collection method used in this research involves direct observation within the company environment and conducting interviews with experts in the relevant field. The data used in this research are production process data, production process time data, and machine data. The production process time data was taken using a stopwatch directly while observing the loading process.

3. Results

A. Nawaz, Ensore, dan Ham (NEH)

The results and discussion using the Nawaz, Ensore, and Ham (NEH) method based on the stages outlined in the method can be seen in the following description:

1. Calculating Total Production Process Time

Here is the data on the processing time of ready mix concrete jobs at PT.OPQ for ready mix concrete, and the total production process time for each job has been calculated to determine which job has the highest total time for ranking in the next stage. The results of the production time calculations can be seen in Table 1 below:

Table 1. Production Process Time

Job Mesin	P1	P2	P3	P4
M1	0,25	0,28	0,28	0,26
M2	0,22	0,20	0,23	0,28
M3	1,00	0,80	0,62	1,00
M4	0,17	0,16	0,11	0,19
M5	0,10	0,19	0,14	0,20
M6	0,20	0,18	0,14	0,15
M7	0,13	0,17	0,19	0,18
M8	0,12	0,14	0,16	0,15
Total	2,19	2,13	1,88	2,41

Explanation:
 M = Machine
 P = Job

2. Total Work Time Sequencing

After calculating the total production time, the next step is to sort the total production time results in descending order because, based on the NEH method's working principle, tasks that take longer to complete overall should be prioritized over tasks that take less time to complete overall. Therefore, the total production time is sorted. The sorting of total job time can be seen in Table 2 below:

Table 2. Sorting total job time

Code	Order	Total Time
P4	1	2,41
P1	2	2,19
P2	3	2,13
P3	4	1,88

In Table 2, the total production time for each job is ordered with P4 in the first position with a total production time of 2.41, followed by P1 in the second position with a total production time of 2.19, P2 in the third position with a total production time of 2.13, and P3 in the fourth position with a total production time of 1.88.

3. Arrange Iteration 1, X=2

The next step is to create iteration X = 2 from i, which means creating 2 i iterations or jobs with the largest total production time sequence. In this study, iteration X = 2 from i is P4 and P1, and create two other partial sequence candidates as alternatives. Calculate the makespan at iteration X = 2 by adding the production time to the setup time, then the makespan calculation at iteration X = 2 can be seen in Table 3 below:

Table 3. Makespan iteration X = 2 alternative 1

Machine	Time	P4	P1
M1	Start	0	0,26
	End		
M2	Start	0,26	0,51
	End		
M3	Start	0,26	0,54
	End		
M4	Start	0,54	0,76
	End		
M5	Start	0,54	1,54
	End		
M6	Start	1,54	2,54
	End		
M7	Start	1,54	1,73
	End		
M8	Start	1,73	1,90
	End		
M9	Start	1,73	1,93
	End		
M10	Start	1,93	2,03
	End		
M11	Start	1,93	2,08
	End		
M12	Start	2,08	2,28
	End		
M13	Start	2,08	2,26
	End		

	Start	2,26	2,40
	End		
	Start	2,26	2,41
M8	End		
	Start	2,41	2,53
	End		

In Table 3, from the makespan calculation results in iteration $X = 2$, the first alternative candidate partial sequence obtained a makespan of 2.53 with the job order P4-P1. In the makespan calculation for iteration $X = 2$, alternative 2 was performed using the same calculation method but with a different job order, P1-P4, resulting in a makespan of 2.34. The makespan calculation results for the job sequence P1-P4 can be seen in table 4 below:

Table 4. Makespan iteration $X = 2$ alternative 2

Machine	Time	P1	P4
	Start	0	0,25
M1	End		
	Start	0,25	0,51
	End		
	Start	0,25	0,47
M2	End		
	Start	0,47	0,75
	End		
	Start	0,47	1,47
M3	End		
	Start	1,47	2,47
	End		
	Start	1,47	1,64
M4	End		
	Start	1,64	1,83
	End		
	Start	1,64	1,74
M5	End		
	Start	1,74	1,93
	End		
	Start	1,74	1,93
M6	End		
	Start	1,93	2,08
	End		
	Start	1,93	2,06
M7	End		
	Start	2,06	2,24
	End		
	Start	2,06	2,19
M8	End		
	Start	2,19	2,34
	End		

4. Arranging Iteration 2, $X=3$

The next step is to increase the number of iterations to $X = X+1$ from i , which means after performing iteration $X = 2$, the next iteration will be $X = X+1=3$. so in the next iteration, there will be 3 job sequences that will form candidate partial sequences with different makespan calculation results for each alternative. In the previous iteration, the candidate partial sequence was taken from the two largest total production times in the first and

second positions. For iteration $X = 3$, the third largest total production time was added, resulting in the first alternative candidate partial sequence being P4-P1-P2. The makespan calculation for iteration $X = 3$ can be seen in Table 5 below:

Table 5. Makespan iteration $X = 3$ alternative 1

Machine	Time	P4	P1	P2
M1	Start	0	0,25	0,49
	End			
M2	Start	0,25	0,49	0,78
	End			
M3	Start	0,25	0,48	0,70
	End			
M4	Start	0,48	0,70	0,91
	End			
M5	Start	0,48	1,48	2,48
	End			
M6	Start	1,48	2,48	3,28
	End			
M7	Start	1,48	1,65	1,82
	End			
M8	Start	1,65	1,82	1,97
	End			
M9	Start	1,65	1,76	1,86
	End			
M10	Start	1,76	1,86	2,05
	End			
M11	Start	1,76	1,93	2,13
	End			
M12	Start	1,93	2,13	2,31
	End			
M13	Start	1,93	2,09	2,22
	End			
M14	Start	2,09	2,22	2,39
	End			
M15	Start	2,09	2,25	2,37
	End			
M16	Start	2,25	2,37	2,52
	End			

In Table 6, from the makespan calculation results in iteration $X = 3$, the first alternative candidate partial sequence obtained a makespan of 2.52 with the job order P4-P1-P2. In the makespan calculation for iteration $X = 3$, alternative 2 was calculated using the same method but with a different job sequence, namely P1-P2-P4, resulting in a makespan of 2.48. The makespan calculation results for the job sequence P1-P2-P4 can be seen in Table 6 below:

Table 6. Makespan iteration $X = 3$ alternative 2

Machine	Time	P1	P2	P4
M1	Start	0	0,24	0,52
	End			
M2	Start	0,24	0,52	0,78
	End			

M2	Start	0,24	0,46	0,66
	End			
M3	Start	0,46	0,66	0,94
	End			
M4	Start	0,46	1,46	2,26
	End			
M5	Start	1,46	2,26	3,26
	End			
M6	Start	1,46	1,62	1,77
	End			
M7	Start	1,62	1,77	1,97
	End			
M8	Start	1,62	1,71	1,90
	End			
M9	Start	1,71	1,90	2,10
	End			
M10	Start	1,71	1,87	2,05
	End			
M11	Start	1,87	2,05	2,20
	End			
M12	Start	1,87	2,03	2,20
	End			
M13	Start	2,03	2,20	2,38
	End			
M14	Start	2,03	2,19	2,33
	End			
M15	Start	2,19	2,33	2,48
	End			

In the next iteration of the partial sequence candidate $X = 3$, the makespan calculation for the partial sequence candidate 3 with the job order P2-P4-P1 resulted in a makespan of 2.40. The makespan calculation results can be seen in Table 7 below:

Table 7. Makespan iteration $X = 3$ alternative 3

Machine	Time	P2	P4	P1
M1	Start	0	0,28	0,54
	End			
M2	Start	0,28	0,54	0,79
	End			
M3	Start	0,28	0,49	0,76
	End			
M4	Start	0,49	0,76	0,98
	End			
M5	Start	0,49	1,29	2,29
	End			
M6	Start	1,29	2,29	3,29
	End			
M7	Start	1,29	1,44	1,64
	End			
M8	Start	1,44	1,64	1,80
	End			
M9	Start	1,44	1,63	1,83
	End			

	Start	1,63	1,83	1,93
	End			
M6	Start	1,63	1,82	1,97
	End			
	Start	1,82	1,97	2,16
	End			
M7	Start	1,82	1,98	2,16
	End			
	Start	1,98	2,16	2,30
	End			
M8	Start	1,98	2,13	2,27
	End			
	Start	2,13	2,27	2,40
	End			

Next, create iterations until the total jobs are all completed and create a candidate partial job sequence in the same way as in the previous stage, repeating until all jobs are finished and the number of jobs is correct.

5. Makespan Recap

The next step is to recapitulate all the makespan calculations for all the total jobs that have been computed. The recap of the makespan calculations for the total jobs available can be seen in Table 8 below:

Table 8. Makespan Calculation Results

Iteration	No. Job Sequence	Makespan
1	P4-P1	2,53
	P1-P4	2,34
	P4-P1-P2	2,52
2	P1-P2-P4	2,48
	P2-P4-P1	2,40
	P2-P3-P1-P4	2,43
3	P1-P2-P3-P4	2,64
	P3-P4-P2-P1	2,29
	P4-P1-P3-P2	2,71

From the calculations above, it can be seen that the smallest makespan calculation is due to the job sequence with the smallest makespan, indicating that this job sequence has minimal idle time, thereby maximizing the production process effectively. Using the NEH method, the smallest makespan result of 2.29 was obtained with the partial job order P3-P4-P2-P1, which means job 3 is done first, followed by job 4, then job 2, and ending with job 1. The output produced, in addition to the calculation table, is a Gantt chart. The Gantt chart of the NEH method optimization sequence can be seen in Figure 2.

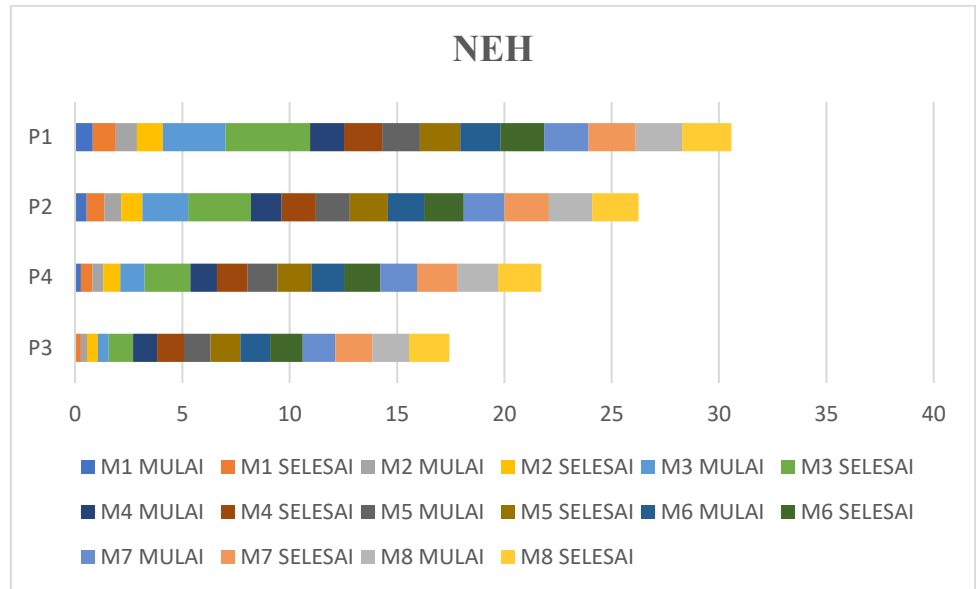


Figure 2. NEH Gantt Chart

B. First Come First Serve (FCFS)

The company schedules using the First Come First Serve (FCFS) method; in this method, orders that arrive first will be prioritized for the production process. In this method, a total makespan of 3.01 hours was obtained with the job processing order P2-P3-P4-P1. The makespan calculation using the First Come First Serve (FCFS) method can be seen in Table 9 below:

Table 9. Makespan FCFS

Machine	Time	P2	P3	P4	P1
M1	Start	0	0,28	0,56	0,82
	End				
M2	Start	0,28	0,56	0,82	1,07
	End				
M3	Start	0,28	0,56	0,82	1,07
	End				
M4	Start	0,51	0,79	1,10	1,29
	End				
M5	Start	0,51	0,79	1,10	1,29
	End				
M6	Start	1,31	1,41	2,10	2,29
	End				
M7	Start	1,31	1,41	2,10	2,29
	End				
M8	Start	1,47	1,52	2,29	2,46
	End				
M9	Start	1,47	1,52	2,29	2,46
	End				
M10	Start	1,66	1,67	2,49	2,56
	End				
M11	Start	1,66	1,67	2,49	2,56
	End				
M12	Start	1,84	1,81	2,64	2,75
	End				
M13	Start	1,84	1,81	2,64	2,75
	End				

M8	Start	2,01	2,00	2,82	2,89
	End				
	Start	2,01	2,00	2,82	2,89
	End				
	Start	2,15	2,16	2,97	3,01
	End				

Based on the method used by the Company and after calculating the makespan, a makespan of 3.01 hours was obtained with the job sequence P2-P3-P4-P1, which means job 2 is done first, followed by job 3, then job 4, and ending with job 1. The output produced, in addition to the calculation table, is a Gantt chart. The Gantt chart of the FCFS method optimization sequence can be seen in Figure 3.

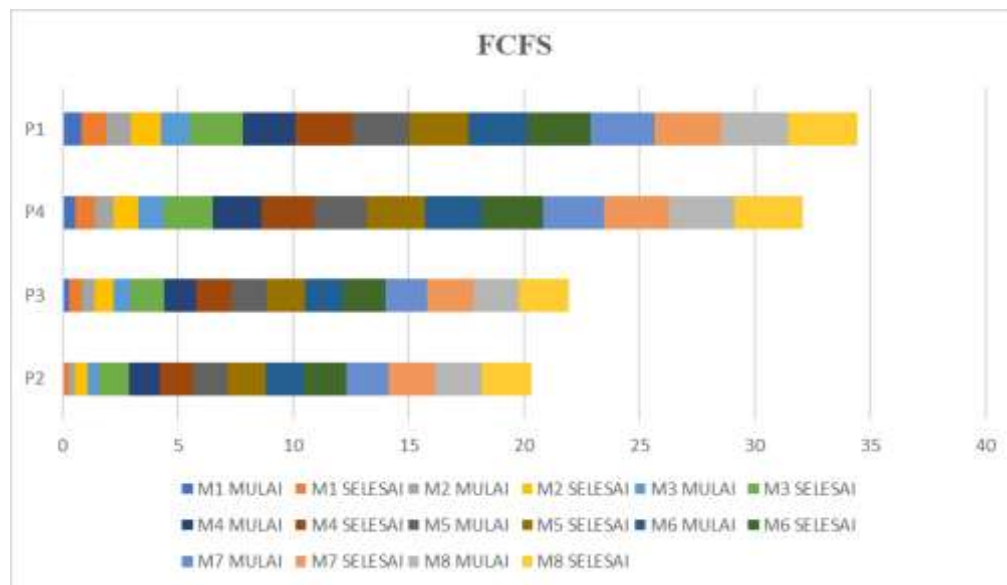


Figure 3. FCFS Gantt Chart

C. Results of NEH and FCFS Method Calculations

After performing the calculations using the NEH method employed in this study and the FCFS method used by the company, the results were obtained as shown in Table 10 below:

Table 10. Makespan Results of NEH and FCFS Methods

No	Method	Makespan
1	Company	3,01
2	NEH	2,29

4. Discussion

From this research, it was concluded that the results of production scheduling using the Nawaz, Enscore, and Ham (NEH) method achieved a smaller makespan and faster production process completion time compared to the scheduling method used by the company. The NEH method achieved a makespan of 2.29 after 3 iterations and has a partial job sequence of 4 sequences: P3-P4-P2-P1. In contrast, the method used by the company resulted in a makespan of 3.01 with a partial job sequence of P2-P3-P4-P1. This can prove that the results of the NEH method calculations can minimize makespan, and this method can be used by the company as a reference for production process scheduling to address the problems currently faced by the company.

5. Conclusion

The study employed the Nawaz-Enscore-Ham (NEH) heuristic to optimize production scheduling in the ready-mix concrete industry, with the primary objective of minimizing makespan. The NEH method, known for its effectiveness in flow shop scheduling, involves calculating the total processing time for each job, sorting jobs in descending order based on these times, and then iteratively building the job sequence to achieve the lowest possible makespan. Data for the study was collected through direct observation and expert interviews, with processing times measured using a stopwatch during the loading process. The results showed that the NEH heuristic significantly outperformed the traditional First Come First Serve (FCFS) method. Specifically, it reduced the makespan from 3.01 hours (FCFS) to 2.29 hours (NEH), achieving an approximate 24% improvement. This demonstrates that the NEH method enhances machine utilization, reduces idle time, and supports more efficient production planning. The findings highlight the value of adopting appropriate scheduling techniques to improve operational efficiency and customer satisfaction in the ready-mix concrete sector.

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