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LOADING AND SEQUENCING JOBS WITH A FASTEST MACHINE AMONG OTHERS

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Abstract:
In this paper, an issue we have addressed is production scheduling which consists of loading and sequencing. The weakness of classic assignment model is that only one job can be assigned to each machine. It can be solved by using Fast Machine Index (FMI). The jobs can be assigned to a machine according to its capability. Then the ordering of jobs at each machine is established in this paper. So, loading and sequencing in a typical case study are done. This has been demonstrated and supported by programs written in Turbo-C language.

By applying FMI method, a good solution for maximizing machine and labor utilization and reducing the idle time on each machine is found. The major findings of this study are generating an optimum sequencing order to complete all the jobs on each machine, The comparison of solutions is done and the significant reduction occurs in the mean flow time and waiting time.

Key Words: Scheduling, Sequencing, Fast Machine Index (FMI), Mean Flow Time, Waiting Cost

1. INTRODUCTION

Scheduling specifies when labour, equipment and facilities are needed to produce a product or a service. It is the last stage of planning before production takes place. The scheduling function differs considerably based on the type of operation, whether they are: process industries, mass production, project, and batch or job shop production. Scheduling decisions can be quite complex in job shop production. Scheduling determines to which machine a part will be routed for processing, which worker will operate a machine that produces a part, and the order in which the parts are to be processed. In a job shop, it is difficult to schedule a variety of jobs with distinctive routing and processing requirement. In addition, although the volume of each customer order may be small, there are probably a great number of different orders in the shop at any one time. This necessitates planning for the production of each job as it arrives, scheduling of limited resources and monitoring of its progress through the system.

In the literature, many researchers tackled different problems of scheduling. [1] considered the flow-shop scheduling problem with sequence-dependent additive setup times as a special case of the general problem, and a polynomially bounded approximate method which was developed to find a minimum makespan permutation schedule. The approximate algorithm was shown to yield optimal results for the two-machine case.

[2] presented a technique for Job-shop sequencing problems via network scheduling technique. In his paper, he examined a new approach to job-shop sequencing problem. This is based on a network scheduling technique on the premises of limited resource availability to achieve minimum total processing time. The method utilized a resource allocation procedure based on random activity (job element) selection and the method of finding the optimal solution of selecting the trial run with the minimum time duration. [3] worked on the

Scheduling to minimize mean tardiness and weighted mean tardiness in flowshop and flow line based manufacturing cell.

Although there are many problems associated with operations scheduling, in this paper, our concern will be job sequencing. Suppose, there is a collection of jobs remaining to be processed on a collection of machines. The problem is how to sequence these jobs to optimize throughput rate of the machines [4, 5]. Good sequence provides less waiting time, decreased and better due date performance.

Recently, [6] proposed meta-heuristic approaches for the two-machine flow-shop problem with weighted late work criterion and common due date. Also, [7] introduced a new approach to two-machine flow shop problem with uncertain processing time. In their paper, flow shop problem with uncertain processing time was represented with fuzzy number. Especially, the scheme used in McCahon and Lee's algorithm for ranking fuzzy processing times was modified to calculate better minimum makespan.

[8] developed an assignment and scheduling model to study the impact of machining flexibility on production issues such as job lateness and machine utilization and suggested an improvement of overall production performance if the equilibrium state can be quantified between scheduling performance and capital investment. Also, [9] solved a resource-constrained operations–machines assignment problem and flexible job-shop scheduling problem iteratively.

[10] focused on a dynamic generalization of the assignment problem where each task consists of a number of units to be performed by an agent or by a limited number of agents at a time.

[11] considered scheduling of five jobs through a flow shop with five machines. They obtained the distribution of makespans and the distribution of the optimal makespans by complete enumeration of all the schedules. [12] considered a permutation flowshop problem with secondary resources with the objective of minimizing the number of tardy jobs. He presented a lower bound for the permutation flowshop problem and evaluated its performance against the optimal solution for small, medium, and large instances.

This paper concentrated on scheduling different jobs when more than one job is assigned to a machine and when one of the existing machines is the fastest for all the jobs. The weakness or strength of the assignment model in literature is that only one job or team can be assigned to each machine or facility at a time. The FMI model suggested overcoming such situations.

After doing this assignment, we established the order of jobs at each machine given a set of jobs assigned on a specific machine. Sequencing reflects job priorities according to the way that jobs are arranged in the queue. There are different orderings of jobs. Proper loading should precede the sequencing of operations.

In this paper, we took a case study of Hadhramout Industrial Company Complex, Mukalla, Yemen as a model to demonstrate how one can allocate more jobs on a set of machines, where one of them is more efficient than others, and how we can assign different jobs when more jobs were allowed to load and allocate considering the capacity of the machine.

2. OPERATIONS SCHEDULING

Crucial to controlling production operations is the detailed scheduling of various aspects of the production function. Although there are many problems associated with scheduling operations, the most critical issue is the loading and sequencing one.

Managers have multiple conflicting scheduling objectives. There are many possible objectives in constructing a schedule including:

- Maximizing machine or labour utilization,
- Meeting customer due dates,
- Minimizing job lateness,
- Minimizing response time,

- Minimizing completion time,
- Minimizing time in the system,
- Minimizing overtime,
- Minimizing idle time.

Job shop scheduling is also known as shop floor. Regardless of the primary scheduling objective, the job shop concerns and concentrates on loading and sequencing. In other words, the main step in production scheduling is both loading and sequencing.

2.1 Loading

Loading is the process of assigning work to limited resources. Many times an operation can be performed by various machines or work centres but with varying efficiencies. So, through loading one can decide which jobs are to be assigned to which team or facilities. Loading is also called shop loading which requires assigning specific jobs or teams to specific facilities. Loading is needed for machine shops, hospitals, and offices. By loading, if there is enough capacity, each worker should be assigned to the task or job that he or she performs best and each job to the machine that can process it most efficiently. The problem of determining the best to allocate jobs to machines or workers can b solved by assignment method of linear programming. With this technique, only one job may be assigned to each machine. The general assignment model with n workers and m jobs mathematically has been stated as:

$$Minimize\ Z = \sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij} X_{ij} \tag{1}$$

$$\text{Subject to } \sum_{i=1}^{n} X_{ij} = 1 \quad \text{for j=1,...,m}$$

$$\sum_{j=1}^{m} X_{ij} = 1 \quad \text{for i=1,...,n}$$

where X_{ij} = 0 or 1 for all i and j.

The element C_{ij} represents the time of assigning job i to machine j.

X_{ij} = 0 if job i is not assigned to machine j

X_{ij} = 1 if job i is assigned to machine j

C_{ij} : Effectiveness associated with assigning job i to machine j

The weakness of the classical assignment model is that no more jobs are allowed to allocate to one machine and also under certain circumstances a weakness of the above assignment model is that splitting the jobs is not allowed. Moreover, the model assumed that the machines in job shop are identical and each one can do each job but with a different time.

2.2 Sequencing

Loading assigns jobs to machine regardless the order in which the jobs will be done. Sequencing establishes the order for performing the jobs at each machine. So, the process of prioritizing job is called sequencing. If no particular order is specified, the operator would probably process the job which arrives first. Sequencing reflects job priorities according to the ways in which jobs are arranged in the queues. There are different costs associated with the various orderings of jobs. Proper loading should precede the sequencing of jobs.

Good sequencing provides less waiting time, decreases delivery delays and ensures better due date performance. There is cost associated with waiting and delays. Total saving from regularly doing it the right way the first time can accumulate to substantial sums. Rescheduling can be significantly more costly when there are many jobs and machines. Sequencing rules have considerable economic importance. Some such rules which are used in literature are:

First Come First Served (FCFS): Jobs are processed in the order in which they arrive at a machine.

Shortest Processing Time (SPT): Jobs are processed according to processing time at a machine, Shortest Job First.

Earliest Due Date (EDD): Jobs are processed according to due date, earliest due date first.

Critical Ratio (CR): Jobs are processed according to smallest ratio of time remaining until due date to processing time remaining.

Slack per Operation (S/O): Jobs are processed according to average slack time.

Rush: Emergency or Preferred customers first.

To determine how good a production sequence is, evaluation measures called makespan and mean flow time are used.

Makespan is the total time needed to complete a group of jobs. It is the length of time between the start of the first job in the group and the completion of the last job in the group. If the processing involves only one machine, makespan will be the same regardless of the priority rule being used.

Mean flow time is the average amount of time required to complete each job in the group. It is average of the wait to start and processing time for every job in the group. So the flow time of job i is the time that elapses from the initiation of the first job on first machine to the completion of job i, it means, it is the amount of time that job spends in the system. The mean flow time, which is a common measure of system performance, is the arithmetic average of the flow time for all n jobs.

The scheduling rule that minimize the mean flow time F is Shortest Processing Time (SPT). If we consider only a single machine, every schedule can be represented by a permutation (that is, ordering) of the integers 1,2,..,n. There is exactly n! different permutation schedules (n!=n(n-1)…(2)(1)). If 1,2,…,n are the permutations of integer n, and then the flow time of job that is scheduled in position k is give by:

$$F_k = \sum_{i=1}^{k} t_i . \qquad (2)$$

It follows that the mean flow time is given by

$$F = \frac{1}{n}\sum_{i=1}^{n} F_k = \frac{1}{n}\sum_{k=1}^{n} \sum_{i=1}^{k} t_i \ . \qquad (3)$$

The double summation term can be written in a different form. Expanding the double summation, we obtain

k=1 : t_1

k=2 : t_1+t_2

: : :

: : :

k=n : $t_1+t_2+\ldots+t_n$.

By summing down the column rather than across the row, we may rewrite F in the form $nt_1+(n-1)t_2+\ldots+t_n$ which is clearly minimized by setting $t_1 \le t_2 \le \ldots \le t_n$.

For the above calculation, the SPT will be used to minimize the mean flow time and waiting time for each machine in this research.

3. PROBLEM FORMULATION

The following notations are used to design the model:

PT_{ij} : Processing time of job i on machine j
N : Number of jobs to be completed
M : Number of machines in the job shop
W : Mean waiting time
W_i : Waiting time for job i
F : Mean flow time
F_i : Flow time for job i
CP_j : Capacity time for machine j

FM : Fastest machine measured in hours

$$\sum PT_{ij} \le CP_j \tag{4}$$

for j=1,2,…,m and i=1,2,…,n.

FMI : Fastest Machine Index.

To create the FMI, it is assumed that one machine is chosen to be the fastest machine among the set of existing machines in job shop. The restrictive assumption is that FMI for each machine applies to all jobs. Thus, a particular machine would be the fastest for all of the jobs in comparison with the other machines.

The equation for FMI is derived in more general terms, as follows:

$$FMI\ of\ M_{ij} = \frac{\Pr oduction\ output\ M_{ij}}{\Pr oduction\ output\ of\ M(FM)} \tag{5}$$

for all jobs.

For each machine, when FMI is computed, the index for FM (Fastest Machine) will be 100% for all jobs.

4. A MODEL

To implement the formula and to achieve the above objective, a real case study has been taken from the industry. The problem was how to allocate 19 tasks on three machines (Sincer Matramatic Markiv); any task can be assigned to any of them. The specification of each task is listed in the form of dimensions of product (mattresses). The tasks are re-labelled in serial numbers as jobs. The processing time to complete each of them is different. However, one of these machines is more efficient than the other two machines. The respective processing time for each job is collected and given in the Table I:

Table I: Data for Jobs and Processing Time.

Task	Job Number	Processing Time (Hr) for M1	Processing Time (Hr) for M2	Processing Time (Hr) for M2
13*180*190	1	5.6	5	5.2
5*75*170	2	3.1	3	3.2
5*65*160	3	5	3.9	4
5*60*160	4	4.8	4.5	4.9
5*55*160	5	4.3	4.2	5
5*60*130	6	4.1	4	4.2
12*150*190	7	4.9	4	4.5
12*140*190	8	4.5	4	4.3
7*120*190	9	4	3.9	4.1
5*40*70	10	2.2	1.9	2.1
5*60*80	11	2.1	1.9	2
5*60*110	12	2.8	2	2.1
5*70*170	13	3,2	3	3.1
5*75*175	14	3.1	3	3.2
11*130*190	15	4.8	3.8	4
5*80*180	16	3.2	3.1	3.3
5*70*180	17	3.3	3	3.5
5*110*190	18	3.7	3.5	3.9
9*190*190	19	3.5	3.1	3.7
Total Time		**72.3**	**64.8**	**70.3**
Capacity of Machine		**25 Hours**	**25 Hours**	**25 Hours**

It is clear from the data that Machine 2 is the Fastest Machine and the maximum capacity for each machine per week is 25 hours. (Five hours per day for five days).

There are two major problems in this job shop scheduling. The first one is assigning the jobs to machines and the other one is to designate the sequencing of job processing at a given machine. The assignment for each machine must not exceed the maximum capacity of each machine. For this reason, we will allow through the assignment model allocation of more jobs to each machine by using the FMI.

5. DATA ANALYSIS

5.1. Calculation of Time for Ordering Obtained By Assignment Method (Proposed Algorithm for FMI)

The following procedure for assignment of jobs to different machines can be used:

Step 1. Since the second machine is the fastest among the others and to process all the jobs on it will take 64.8 hours which is beyond the maximum capacity of this machine. Thus, it is impossible to process all the jobs on that machine. For this reason, the FMI is computed; the index for FM (Machine 2) will be 100% for all the jobs. The result for this step is shown in Table II.

Step 2. Determine the smallest FMI on the other two machines and then eliminate that job from the fastest machine.

Step 3. Subtract the eliminated job time from the fastest machine and in the same time allocate that job to the machine which has the smallest FMI. Note that the first smallest index FMI (102.4%) is for Job (5) on Machine 1. Thus, schedule that job on Machine 1 with process time 4.3 hours and subtract 4.2 hours related to that job from 64.8 hours.

The remaining 18 jobs on fastest machine count 60.6 hours which is still exceeding the capacity of the machine.

Table II: Calculation of Index for Machine M1, M2 and M3.

Job	T(M1)	T(M2)	T(M3)	Index %		
				M1	M2	M3
1	5.8	5	5.2	116	100	104
2	3.1	3	3.2	103.3	100	106.7
3	5	3.9	4	128.2	100	102.6
4	4.8	4.5	4.9	106.7	100	108.9
5	4.3	4.2	5	102.4	100	119
6	4.1	4	4.2	102.5	100	105
7	4.9	4	4.5	122.5	100	112.5
8	4.5	4	4.3	112.5	100	107.5
9	4	3.9	4.1	102.6	100	105.1
10	2.1	1.9	2.1	110.5	100	110.5
11	2.1	1.9	2	110.5	100	105.3
12	2.8	2	2.1	140	100	105
13	3.2	3	3.1	106.7	100	103.3
14	3.1	3	3.2	103.3	100	106.7
15	4.8	3.8	4	126.3	100	105.3
16	3.2	3.1	3.3	103.2	100	106.5
17	3.3	3	3.5	110	100	116.7
18	3.7	3.5	3.9	105.7	100	111.4
19	3.5	3.1	3.7	112.9	100	119.4
	72.3	**64.8**	**70.3**			

Step 4. Repeat Step 2 and Step 3 and each time eliminate the job and its time from the fastest machine and assign them to the other machines until reaching that stage when the remaining jobs on fastest machine has a total time less than or equal to its capacity i.e. 25 hours.

Note that the priority in assigning the jobs is given to the smallest index FMI, not to the shortest time each time.

By using the above procedure, the assignment of jobs on each machine is shown in Table III, Table IV and Table V.

Table III: Calculation of Mean flow and Average Waiting Time for Machine 1.

Job	T(M1)	Machine 1		Waiting Time
		Ti	To	
2	3.1	0	3.1	0
5	4.3	3.1	7.4	3.1
6	4.1	7.4	11.5	7.4
9	4	11.5	15.5	11.5
10	2.1	15.5	17.6	15.5
14	3.1	17.6	20.7	17.6
16	3.2	20.7	23.9	20.7
	23.9		*99.7*	*75.8*
Average Waiting Time (W)			*10.83*	
Mean Flow Time (F)			*14.24*	

Mean flow time (F) = 99.7/7 = 14.24

Average Waiting Time (W) = 75.8/7 = 10.83

Table IV: Calculation of Mean flow and Average Waiting Time for Machine 2.

Job	T(M2)	Machine 2		Waiting Time
		Ti	To	
4	4.5	0	4.5	0
7	4	4.5	8.5	4.5
8	4	8.5	12.5	8.5
17	3	12.5	15.5	12.5
18	3.5	15.5	19	15.5
19	3.1	19	22.1	19
	22.1		*82.1*	*60*
Average Waiting Time (W)			*10*	
Mean Flow Time (F)			*13.68*	

Mean flow time (F) = 82.1/6 = 13.68

Average Waiting Time (W) = 60/6 = 10

Table V: Calculation of Mean flow and Average Waiting Time for Machine 3.

Job	T(M3)	Machine 3		Waiting Time
		Ti	**To**	
1	5.2	0	5.2	0
3	4	5.2	9.2	5.2
11	2	9.2	11.2	9.2
12	2.1	11.2	13.3	11.2
13	3.1	13.3	16.4	13.3
15	4	16.4	20.4	16.4
	20.4		75.7	*55.3*
Average Waiting Time (W)			*9.22*	
Mean Flow Time (F)			*12.62*	

Mean flow time (F) = 75.7/6 = 12.62

Average Waiting Time (W) = 55.3/6 = 9.22

It is clear from the tables that all the jobs are assigned on the three machines and each machine is loaded with the group of job time within the maximum capacity i.e. 25 hours. The total processing time on Machine 1 is 23.9 hours, on Machine 2 is 22.1 hours and Machine 3 is 20.4 hours. The calculation of mean flow time and average waiting time for each machine is also calculated. All the jobs will be finished within 25 hours. The efficiency percentage of each machine will be 95.6%, 88.4% and 81.6% for Machine 1, Machine 2 and Machine 3, respectively.

5.2. Calculation of Time for Sequencing Obtained By Shortest Processing Time (SPT) Rule

So far, assignment of jobs to machines regardless the order in which the jobs are done as shown in Table IV, Table V and Table VI. Although the jobs assigned to each machine has not exceeded the capacity, we must search for good sequencing which will give less waiting time and decreased mean flow time.

The scheduling rule that minimizes the mean flow time (F) and the average waiting time (W) is Shortest Processing Time (SPT). Here, we will consider for each machine with a sequence according to SPT rule. Now, we extend the analysis and carry on to find the optimal sequence to minimize mean flow time (F) and average waiting time (W). So, we consider each group of jobs assigned on any machine, which has been obtained. We calculated the completion time to perform all the jobs and computed the mean flow time as well as the average waiting time. The results are presented in the Table VI, Table VII and Table VIII for Machine 1, Machine 2 and Machine 3, respectively.

Table VI: Calculation of Mean flow and Average Waiting Time for Machine 1.

Job	T(M1)	Machine 1		Waiting Time
		Ti	To	
10	2.1	0	2.1	0
2	3.1	2.1	5.2	2.1
14	3.1	5.2	8.3	5.2
16	3.2	8.3	11.5	8.3
9	4	11.5	15.5	11.5
6	4.1	15.5	19.6	15.5
5	4.3	19.6	23.9	19.6
	23.9		*86.1*	*62.2*
Average Waiting Time (W)			*8.89*	
Mean Flow Time (F)			*12.3*	

Mean flow time (F) = 86.1/7 = 12.3
Average Waiting Time (W) = 62.2/7 = 8.89

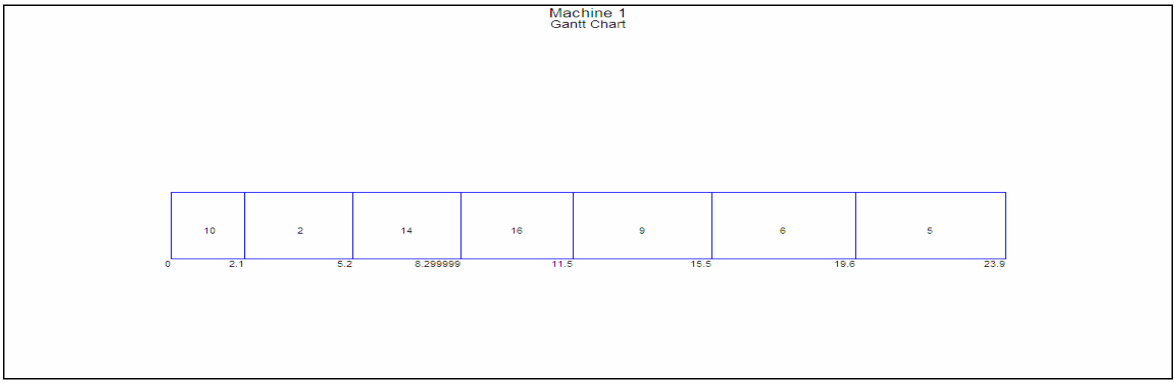

Figure 1: Proposed Sequencing for Machine 1.

Table VII: Calculation of Mean flow and Average Waiting Time for Machine 2.

Job	T(M2)	Machine 2		Waiting Time
		Ti	To	
17	3	0	3	0
19	3.1	3	6.1	3
18	3.5	6.1	9.6	6.1
7	4	9.6	13.6	9.6
8	4	13.6	17.6	13.6
4	4.5	17.6	22.1	17.6
	22.1		*72.0*	*49.9*
Average Waiting Time (W)			*8.32*	
Mean Flow Time (F)			*12.0*	

Mean flow time (F) = 72.0/6 = 12
Average Waiting Time (W) = 49.9/6 = 8.32

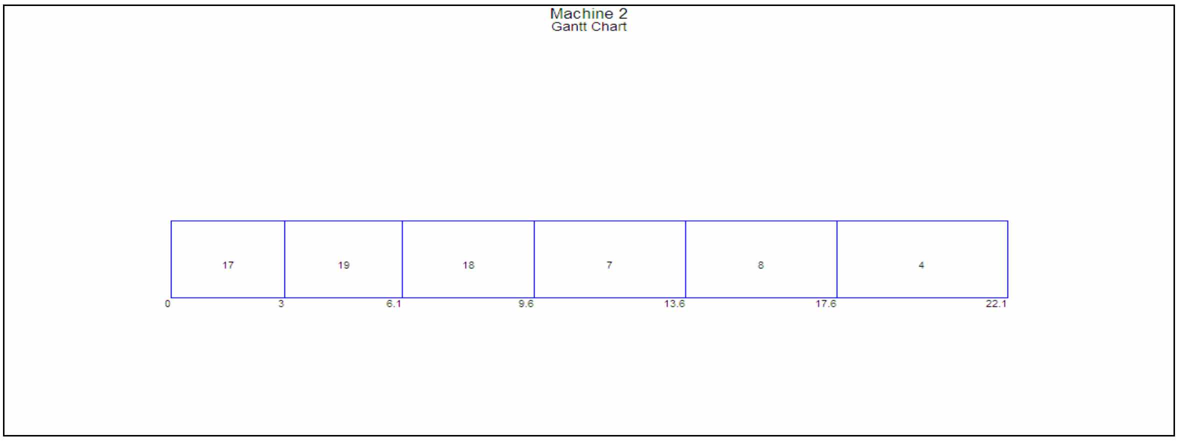

Figure 2: Proposed Sequencing for Machine 2.

Table VIII: Calculation of Mean flow and Average Waiting Time for Machine 3.

Job	T(M3)	Machine 3		Waiting Time
		Ti	To	
11	2	0	2	0
12	2.1	2	4.1	2
13	3.1	4.1	7.2	4.1
3	4	7.2	11.2	7.2
15	4	11.2	15.2	11.2
1	5.2	15.2	20.4	15.2
	20.4		*60.1*	*39.7*
Average Waiting Time (W)			*6.62*	
Mean Flow Time (F)			*10.02*	

Mean flow time (F) = 60.1/6 = 10.02
Average Waiting Time (W) = 39.7/6 = 6.62

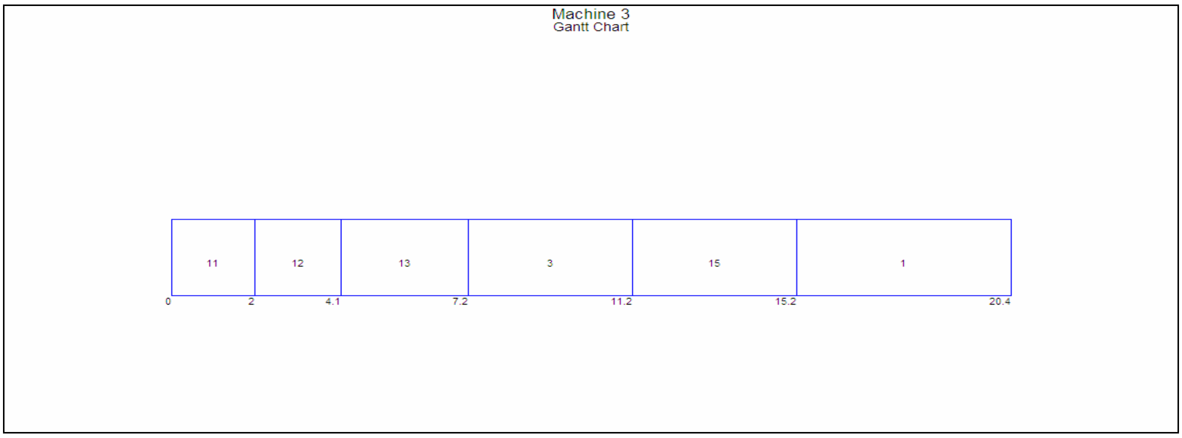

Figure 3: Proposed Sequencing for Machine 3.

It is obvious from each table that the total time to complete all the jobs is 23.9 hours, 22.1 hours and 20.4 hours on Machine 1, Machine 2 and Machine 3, respectively. No machine exceeds the available capacity. The sequence in each machine can be represented in a Gantt chart. The Gantt chart in Figure 1, Figure 2, and Figure 3 are for Machine 1, Machine 2, and Machine 3, respectively. The Gantt chart is prepared by POM software which is very useful to demonstrate how the jobs are carried out after being located on each machine. The time scale on each machine is shown as starting and ending time. Inside the chart, jobs are written in order.

Table IX: Summary of the Result.

	ORDERING OBTAINED BY INDEX ASSIGNMENT METHOD			***SEQUENCING USING SPT RULE***		
Machine	**M1**	**M2**	**M3**	**M1**	**M2**	**M3**
Sequence	2,5,6,9,10,14,16	4,7,8,17,18,19	1,3,11,12,13,15	10,2,14,16,9,6,5	17,19,18,7,8,4	11,12,13,3,15,1
Time Used	23.9	22.1	20.4	23.9	22.1	20.4
Efficiency Percentage	95.6	88.4	81.6	95.6	88.4	81.6
Total Waiting Time	75.8	60.0	55.3	62.2	49.9	39.7
Average Waiting Time (W)	10.83	10.0	9.22	8.89	8.32	6.62
Mean Flow Time (F)	14.24	13.68	12.62	12.3	12	10.02
Saving in Average Waiting Time (W)				1.94	1.68	2.6
Saving in Mean Flow Time (F)				1.94	1.68	2.6
Percentage of Saving in Average Waiting Time (W)				17.9%	16.8%	28.2%
Percentage of Saving in Mean Flow Time (F)				13.6%	12.3%	20.6%

Finally, the summary of the result is given in the Table IX from which we can conclude the following:

1. The total time to perform all the 19 jobs is distributed smoothly among the three machines, almost equally and without violating their capacity constraint.
2. By the FMI index procedure, the average of efficiency percentage is 88.5%.
3. The sequences which have been obtained in the first stage are later on improved by re-sequencing each group of jobs showing a good result. The reduction takes place in mean flow time as well as average waiting time.
4. It is obvious that the total waiting time decreased from 75.8 hours to 62.2 hours for the first machine, from 60 hours to 49.9 hours for the second machine and from 55.3 hours to 39.7 hours for the third machine.
5. The mean flow time is reduced from 10.83 hours to 8.89 hours for Machine 1, from 10.0 hours to 8.32 for Machine 2 and from 9.22 hours to 6.62 hours for Machine 3.
6. In general, we can obtain the same saving in average waiting time (W) and in mean flow time (F) for each machine. The amount of saving was 1.94 hours for Machine 1, 1.68 hours for Machine 2 and 2.6 hours for Machine 3. Percentage of saving in average waiting time (W) and mean flow time (F) can also be seen in the table.

6. CONCLUSION

The problem of production scheduling which consists of loading and sequencing is tackled in this study. The constraint of assigning only one job to each machine has been relaxed. A set of jobs are assigned to a machine without violating the capacity constraint. The programs in Turbo C language are written for FMI method for assigning the different jobs to different machines. A unique assignment solution comes with the amazing result to distribute all the jobs smoothly among the three machines, with an average efficiency of around 88.5 %.

The major findings of this study are generating an optimum sequencing order to complete all the jobs which have been assigned already on each machine. The re-sequencing reduced the mean flow time and waiting time both on the three machines. The percentage of saving of waiting time is 17.9%, 16.8% and 28.2% on Machine 1, Machine 2 and Machine 3, respectively while the percentage of saving in mean flow time is 13.6%, 12.3% and 20.6% on Machine 1, Machine 2 and Machine 3, respectively.

7. RECOMMENDATIONS

Based on the empirical finding of this study, following points are not discussed in this paper and can be tackled later:

1. The preceding analysis of this study assumed that machine setup time is independent of processing order through the three machines, but in many instances, the assumption is not true. Consequently, a manager may want to schedule jobs at three machines in the flow shop taking those dependencies into account. The goal will be how to minimize total setup time.
2. Another extension of this study may be on focusing on bottleneck operations.
3. Finally, the assignment index procedure can be developed to consider lot splitting for large jobs. This probably works best when there are relatively large differences in job time. Consequently, when split assignments are allowed which permits assigning more than one job to a machine or team and also when any job can be divided and split into some parts. Thus, under certain circumstances, the model of this paper can be developed to overcome such conditions.

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