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WEIGHTED MEAN FLOW TIME IN NO-WAIT UNCERTAIN SCHEDULING UNDER VARIOUS PARAMETERS

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Abstract- This paper considers a nxm no-wait flowshop scheduling problem in which each job has an uncertain processing time on the machines. The objective of this paper pertains to determine an optimal or near optimal sequence for n-job problem which associates 'weight' with each job in the sense of relative importance in the process and includes job block and transportation time of jobs from one machine to other to minimize the total weighted mean flow time.

Keywords- <AHR>, no-wait scheduling, Job block, weightage of job, transportation time, uncertain environment

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Introduction

Flow shop scheduling deals with determination of optimal sequence of jobs which is to be processed on some machines in a fixed order so that it satisfies certain scheduling conditions. Job scheduling is an important tool in production management. It is useful in increasing the production of the product, meet the demands of the market in time and to minimize the flow time or cost of the product etc. Various researchers Johnson, Maggu & Dass, Miyazaki & Nishiyama [4,5,7] studied various scheduling models under different permutations, combinations and arguments such as transportation time of the job after dropping the job on machine 2, priority of a job and job block criteria in scheduling. Nonetheless, scheduling is more significant both in fuzzy and deterministic environment. In deterministic situation, jobs have to be performed correctly and in a timely fashion as well. On the contrary, the execution request of jobs in fuzzy environment is unpredictable. Zadeh L.A. [9] in 1975 studied fuzzy logic and approximate reasoning.

In a flow shop, the scheduling problem can be classified into two categories namely with and without an operation interval waiting time. In a flow shop system with waiting times, the jobs are processed from one machine to the next one allowing waiting time in between, whereas, in a no-wait flow shop scheduling, the jobs will not wait for the processing from one machine to the next machine without waiting time. Therefore, in the classical flow shop sequencing problem with waiting time jobs may be queued in front of each machine. In such a case, an unlimited buffer is considered at the front of each machine [2]. In contrast, in a no-wait flowshop, jobs are processed from one machine to the next without waiting for the machine. For no-wait scheduling, it may be due to either initiated from the nature of production or the lack of intermediate buffers. In some industries, due to the temperature or other attributes of the materials it is required that each operation follow the previous one immediately. This means, when necessary, the start of a job on a given machine can be delayed in order that the operation's completion coincides with the start of the next operation on the subsequent machine. Applications of a no-wait flow shop can be found in many industries such as plastic production processes that require a series of processes to immediately follow one after another in order to prevent material degradation during production. Similar situations also arise in the chemical and pharmaceutical industries. Aldowaisan and Allahverdi [1]; Hall and Sriskandarajah [3]; Raaymakers and Hoogeveen [6] have studied the no-wait problem extensively in the scheduling literature. Sunita Gupta [8] studied two machine no wait flow shop scheduling in uncertain environment.

Problem discussed here is wider and practically more applicable and has significant use of theoretical results in process industries or in situations where weightage in jobs become significant due to quality maintains. The concept of job block has many applications in production situation where the priority of one job over the other is taken in to account as it may raise an additional cost for providing this facility. This paper gives a general case considering for n stage flow shop no-wait uncertain scheduling. Various constraints along with weightage of jobs have been considered under uncertain environment making the problem wider and general. Problem description, assumptions and objective functions are defined in section 2. In section 3, the algorithm has been mentioned for m stage scheduling and in section 4, a numerical illustration has been demonstrated.

Problem Description and the Assumptions

No-Wait Flow Shop Scheduling Problem

In this paper, scheduling problem is described as follows: Consider an *n* job m machine no-wait flow shop scheduling problem where the machines are ceaselessly ready and the job can be processed on one machine at a time and every machine can process one job at a time. Preemption of the job is not allowed i.e., once an operation is started, it must be completed. The objective is to seek a schedule that minimizes the weighted mean completion time The problem is considered under the following assumptions: (1) All jobs are available at zero time; (2) machines are always available; (3) processing time of each job on each machine is known and constant; (4) setup times and removal times are included in processing times; (5) preemption is not allowed; (6) passing is not allowed; (7) Transportation times are considered; (8) each machine can process only one job at the same time; (9) a job cannot processed on more than one machine at the same time; and (11) jobs cannot wait between two successive machines and intermediate storage does not exist.

Objectives Functions

<AHR> of the processing time of jobs in uncertain scheduling

Sometime the processing time is not deterministic may be due to uncertain environment or other factor, So the processing time of jobs is considered here in three environment say (i) in very favorable conditions where all the factors are in our support (ii) In normal situation (iii) in worst conditions like in rich areas where the labour is not available, work place may be hilly and the transportation is very difficult and also the environment is not in favor.

For finding the jobs' processing time <AHR> i.e. Average high ranking of the jobs is calculated as

<AHR> = $\frac{3b+(c-a)}{3}$ where (a,b,c) is the processing time of the job in three environments.

Optimal Sequence in no-wait scheduling

For the optimal sequence in no-wait scheduling, an algorithm in next section is developed.

Minimizing the Weighted Mean Flow Time

A no-wait flow shop scheduling problem by minimizing the weighted mean completion time (i.e. $C=\frac{1}{W}\sum_i w_i C_i$), where C_i is the completion time for job and is w_i a possible weight related to job *i* and $W=\sum w_i$ is considered here.

Algorithm

Step 1: Find <AHR> of the fuzzy processing time of each job.

Step 2: Modify the problem in two fictitious machines S''_i and H"i as

$S''_i = A_i + t_i + B_i + g_i + C_i + h_i$

$H''_i = t_i + B_i + g_i + C_i + h_i + D_i$

Step 3: Find min (S''_i, H"i)

If min (S''_i, H"i) = S''_i then define $S_i' = S''_i - w_i$ and $H_i' =$ H"I

If min (S''_i, H"i) = H"i then define $S_i' = S''_i$ and $H_i' = H''_i + w_i$

Step 4: Define a new reduced problem as $S_i = \frac{S_i'}{w_i}$ and $Hi = \frac{H_i'}{w_i}$

Take a job block β(l,m) on S_i & Hi using equivalent job block theorem given by Maggu and Dass (1977) as $S_\beta = S_{il} + G_{im} - \min(H_{il}, S_{im})$. $H_\beta = H_{il} + H_{im} - \min(H_{il}, S_{im})$

Step 5: To determine the optimal sequence T= {$\pi_1, \pi_2, ... \pi_n$}, select a job having maximum processing time on machine S_i and put it at the first position of the sequence T. Let it be π_1, then select the 2nd job π_2 of the optimal sequence T, consider all the jobs whose processing time on S_i is greater than the processing time of π_1 on H_i and among them the one whose processing time is maximum on H_i is considered as 2nd job of the optimal sequence. It is denoted by π_2. For the next selection of jobs in the sequence, again consider the jobs whose processing time on S_i is greater than the processing time of π_2 on H_i and among them the one whose processing time is maximum on H_i is considered as 3rd job as π_3. Continue this process till the jobs are available. If no such job is available whose processing time on S_i is greater than the processing time of its previous job on H_i then again start the process till all the jobs are there. If there are more than one jobs having same maximum processing time on machine during the selection of jobs for the optimal sequence, than consider the one whose processing time on machine H_i is maximum.

Step 6: Find the idle time of the machines for the jobs and process the jobs on machines.

Step 7: Calculate the weighted mean flow time and the make span of the jobs.

Computational Experiments

Consider 5 jobs and 4 machines flow shop scheduling problem whose processing time is given in uncertain environment. β = (2,4) is job block, t_i g_i and h_i represent the transportation time and w_i represent the weightage of the jobs as in [Table-1]. Our aim is to optimize the make span and to find the mean flow time of the machines.

Table 1- Weightage of the Jobs

J	M_1	t_i	M_2	g_i	M_3	h_i	M_4	w_i
1	(10,12,16)	1	(5,8,10)	4	(6,7,8)	4	(3,5,7)	2
2	(12,14,16)	2	(6,9,12)	2	(6,8,10)	5	(2,4,6)	3
3	(6,9,12)	3	(10,12,13)	3	(8,9,10)	2	(10,12,13)	5
4	(5,7,8)	4	(8,10,12)	6	(7,9,10)	4	(6,7,8)	4
5	(8,10,12)	4	(2,4,8)	5	(8,10,12)	3	(11,12,14)	1

Solution

As per step1of algorithm finding <A H R> of processing time of all the jobs are tabulated in [Table-2]. As per step 2, 3 & 4 and using step 5 we have 5,1, β ,3 i.e. 5, 1, 2, 4, 3 is an optimal sequence and taking this optimal sequence the flow time of jobs on machines is as [Table-3].

Here idle time for job 1 on machine 5 is $\frac{6}{3}$ so the starting time of processing of 1st job on machine 1 is $\frac{34}{3}+\frac{6}{3}=\frac{40}{3}$. Similarly idle time for job 4 on machine 2 is $\frac{3}{3}$ so the starting time of job 4 on machine 1 is $\frac{122}{3}+\frac{6}{3}+\frac{3}{3}=\frac{131}{3}$ and idle time of machine 3is $\frac{7}{5}$ and so the starting time of job 5 on machine 1 is $\frac{146}{3}+\frac{6}{3}+\frac{3}{3}+\frac{7}{3}=\frac{162}{3}$. Hence for the no-wait scheduling, the processing of the jobs with the same optimal Sequence is given in [Table-4].

Table 2- Processing time of all the Jobs

Job	A_i	t_i	B_i	g_i	C_i	h_i	D_i	w_i
1	$\frac{42}{3}$	1	$\frac{29}{3}$	4	$\frac{23}{3}$	4	$\frac{19}{3}$	2
2	$\frac{46}{3}$	2	$\frac{33}{3}$	2	$\frac{28}{3}$	5	$\frac{16}{3}$	3
3	$\frac{33}{3}$	3	$\frac{39}{3}$	3	$\frac{29}{3}$	2	$\frac{39}{3}$	5
4	$\frac{24}{3}$	4	$\frac{34}{3}$	6	$\frac{30}{3}$	4	$\frac{23}{3}$	4
5	$\frac{34}{3}$	4	$\frac{18}{3}$	5	$\frac{34}{3}$	3	$\frac{39}{3}$	1

Table 3- Flow time of jobs on Machines

J	A	B	C	D	w_i
5	$0-\frac{34}{3}$	$\frac{46}{3}-\frac{64}{3}$	$\frac{79}{3}-\frac{113}{3}$	$\frac{122}{3}-\frac{161}{3}$	1
1	$\frac{34}{3}-\frac{76}{3}$	$\frac{79}{3}-\frac{108}{3}$	$\frac{120}{3}-\frac{143}{3}$	$\frac{161}{3}-\frac{180}{3}$	2
2	$\frac{76}{3}-\frac{122}{3}$	$\frac{128}{3}-\frac{161}{3}$	$\frac{167}{3}-\frac{195}{3}$	$\frac{210}{3}-\frac{226}{3}$	3
4	$\frac{122}{3}-\frac{146}{3}$	$\frac{161}{3}-\frac{195}{3}$	$\frac{213}{3}-\frac{243}{3}$	$\frac{255}{3}-\frac{278}{3}$	4
3	$\frac{146}{3}-\frac{179}{3}$	$\frac{195}{3}-\frac{234}{3}$	$\frac{243}{3}-\frac{272}{3}$	$\frac{278}{3}-\frac{317}{3}$	5

Table 4- Processing of the Jobs with the Optimal Sequence

J	A	B	C	D	w_i
5	$0-\frac{34}{3}$	$\frac{46}{3}-\frac{64}{3}$	$\frac{79}{3}-\frac{113}{3}$	$\frac{122}{3}-\frac{161}{3}$	1
1	$\frac{40}{3}-\frac{82}{3}$	$\frac{85}{3}-\frac{114}{3}$	$\frac{126}{3}-\frac{149}{3}$	$\frac{161}{3}-\frac{180}{3}$	2
2	$\frac{82}{3}-\frac{128}{3}$	$\frac{134}{3}-\frac{167}{3}$	$\frac{173}{3}-\frac{201}{3}$	$\frac{216}{3}-\frac{232}{3}$	3
4	$\frac{131}{3}-\frac{155}{3}$	$\frac{167}{3}-\frac{201}{3}$	$\frac{219}{3}-\frac{249}{3}$	$\frac{261}{3}-\frac{284}{3}$	4
3	$\frac{162}{3}-\frac{195}{3}$	$\frac{204}{3}-\frac{243}{3}$	$\frac{252}{3}-\frac{281}{3}$	$\frac{287}{3}-\frac{326}{3}$	5

Weighted Mean Flow Time

$$\frac{1}{15}\left(\frac{161}{3}\times 1+\frac{140}{3}\times 2+\frac{150}{3}\times 3+\frac{153}{3}\times 4+\frac{164}{3}\times 5\right) = 51.62$$

Total elapsed time = 108.67

Conclusion and Further Research

This paper employs fuzzy numbers to describe uncertain processing times in n- machines flow shop problems. It is assumed that in the cases where there exist various sources and different types of uncertainty in a flow shop, which cause imprecise job processing times fuzzy mathematics is an appropriate tool to find an optimal job sequence. A new algorithm is developed to solve the no-wait n-stage uncertain scheduling problem. In general the results revealed that the proposed outperforms give an optimal sequence which minimize the flow time and the machines' idle time of the problem. So in case of finding hiring time of the machines or the machine utility cost, this algorithm is very useful. Therefore the proposed algorithm can be considered as an efficient algorithm for a no-wait uncertain flow shop with minimum flow time.

For further research, other performance measures such as due time, lateness and tardiness of the jobs can be considered.

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