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SPECIALLY STRUCTURED TWO STAGE FLOW SHOP SCHEDULING PROBLEM TO MINIMIZE THE RENTAL COST INCLUDING ARBITRARY LAGS

Payal Singla
Assistant Professor, Department of Mathematics, Guru Nanak College Killianwali Dist Sri Muktsar Sahib Punjab
payalsingla86@gmail.com

ABSTRACT

The present paper is attempt to develop an effective heuristic algorithm to two stage specially structured flow shop scheduling to minimize the rental cost as well as utilization time under pre-defined rental policy in which processing times are associated with respective probabilities including arbitrary lags i.e Start lag or Stop lag. In case of specially structured problem processing times are always considered to be random, but there are significant situations in which processing times are not merely random but bear a well-defined structural relationship to one another. The proposed algorithm is justified with the help of numerical illustration.

Keywords: Specially structured, Flowshop, Start Lag, Stop Lag, Transportation Time, Job Block.

INTRODUCTION

In scheduling, it is a task to find low-cost processing orders for given sets of goods. Scheduling relates to establish both time and use of resources within an industry. Scheduling have high importance for last decades because of popularity of lean manufacturing and just-in-time**.** Sequencing concerns with meeting the quality standards, satisfying customers' demands by attempting low cost processing orders for a given set of jobs over fixed machines. Sequencing is paying indispensible role for achieving the target against conflicting interests with limited resources for making the proper use of man-machinery to maximizing profit. Taking lags into account, we generally refer to minimal time lags, which means time required to elapse between two consecutive operations of a job over multi-tasking machines. Lags are of two types i.e Start lag or Stop lag. A maximal time lag describes an upper bound on the time delay b/w two consecutive operations of a job on fixed machines. The minimal or maximal time lag between two consecutive operations of a job may be job-dependent / job-independent and same criteria holds for machines too. The start lag (Di>,0) is the minimum time which must elapse between starting job i on the first machine and starting it on the second machine. The stop lag (Ei>, 0) for the job i is the minimum time which elapsed between the completion of it on second machine.

Johnson [1] gave procedure for finding the optimal schedule for n-jobs, two machine flow-shop problem with minimization of the make span (i.e. total elapsed time) as the objective. Also Mitten and Johnson [1] jointly discussed the n job, 2 machines flowshop Scheduling problem in which despite processing times some additional tags are introduced. Ignall E and Schrage L [2] implemented the concept of branch and bound in some flowshop scheduling problems Maggu and Das [4] introduced the equivalent job-block concept in the theory of scheduling which has many applications in the production management. Bagga [3],Gupta,J.N.D[4], Maggu,P.L and Das,G. [7], Szwarch [5],[6] Yoshida & Hitomi [8], etc. derived the optimal algorithm for two/ three or multistage flow shop problems taking into account the various constraints and criteria.Narain and bagga[12] continues with dealing different scheduling problems including time lags. Singh, T.P. and Gupta, D. [9], [10],[11] associated probabilities with processing time and set up time, transportation time as well as concept of breakdown interval in their studies. Later, Singh, T.P, Gupta, D [13], studied two /multiple flow shop problem to minimize rental cost under a pre-defined rental policy in which the probabilities are associated with processing time on each machine. The present paper addresses the flowshop scheduling problem in which processing times are associated with probabilities with arbitrary lags, transportation and job block for effective scheduling.

PRACTICAL SITUATIONS

Some unavoidable chances in the production are occurred which do not offer sufficient funds to an entrepreneur to purchase high in cost machinery. Therefore, such situation forces him to take machine on rent or lease. So rental cost is indispensable part of schedule. Start lag and stop lag are the defined under the term time lag and is conducive in splitting and overlapping of jobs for effective and continuous running of machines. A situation can be exercised in which each job is a batch comprises several discrete / identical units. Once the first jobs are performed on a machine A it can begin processing instantly at machine B in that case, the start symbolises the time to process one unit on machine A and the stop lag stands for the time to process one unit on machine 2. In other words, a transfer batch of size A would be used and larger transfer batches can be modelled with the use of time lags. in the case of start lags and stop lags, the optimal permutations schedule is featured by a rule analogous to Johnson's rule.

Theorem 1: Two-machine, n-job problem' with transportation times to given problem replacing three times (Start-lag, Stop-lag, transportation time) by single time t'_i

Proof: Let U_{ix} and T_{ix} denote Starting and Completion times of any job i on machine X (X = A, B, i = 1, 2, 3, ……, n) respectively in a sequence S. From definition of Start-lag D_i, we have $U_{iB} – U_{iA} \geq D_i$

Now $T_{iA} – U_{iA} + A_i$

i.e.,Hence, we have, $U_{iB} – (T_{iA} - A_i) \geq D_i$

i.e.,$U_{iB} – T_{iA} \geq D_i - A_i$ … (1)

From definition of Stop-lag E_i,

we have ,$T_{iB} - T_{iA} \geq E_i$,

Now , $T_{iB} - U_{iB} + B_i$

Hence, we have $U_{iB} + B_i - T_{iA} \geq E_i$

i.e., $U_{iB} - T_{iA} \geq E_i - B_i$ … (2)

Also, from the definition of transportation time t_i, we have

$U_{iB} - T_{iA} \geq t_i$ … (3)

Let $t'_i = \max \{D_i – A_i, E_i – B_i, t_i\}$ … (4)

From (1), (2) and (3), it is obvious that

$U_{iB} - T_{iA} \geq t'_i$

Algorithm

Step 1: Calculate expected processing time given by

$A_\alpha = A_i \times p_i$

$B_\alpha = Bi \times q_i$

Step 2: Calculate effective transportation times given by

$t'_i = \max (D_i - A_\alpha , E_i - B_\alpha , t_i)$

Step 3: Define two fictitious machines G & H with processing time G_i & H_i as below:

$G = A_\alpha + t'_i$ $H_i = B_\alpha + t'_i$

Step 4: Check the structural relationship

Either $G_i \geq H_i$ or $G_i \leq H_i$ for all i.

Step 5: Apply Johnson's (1954) technique and obtain the optimal schedule of given jobs. Let the sequence be S1. Obtain other sequences by putting 2^{nd}, 3^{rd},…..nth jobs of sequence S_1 in the 1st position and all other jobs of S1 in same order. Let these sequences be S_2 ,S_3…S_{n-1}.

Step 6: Calculate Utilization time $U_2(S_k)$ of 2^{nd} Machine

$U_2(S_k) = CT(S_K) - A_{i1}(S_k)$; K=1,2,3…r

Step 7:Find Rental cost of $R(S_i) = A_{i1}(S_k)\times C_1 + U_2(S_k)\times C_2$ are the rental cost per unit time of 1^{st} and 2^{nd} machine respectively.For all possible sequences Sk (k = 1, 2, …, n)

Step 7: Find min R(Sk); k= 1,2,….,n. let it be minimum for the sequence Sp, then sequence Sp will be the optimal sequence with rental cost R(Sp).

Numerical illustration

Obtain minimum rental cost for 5 jobs and 2 machines problem in which leasing/rentalcharge per unit for machine A are 10 units and machine B is 20 units and problem is given below as shown in Tableau 5.2.2.1

Jobs	Machine A		Machine B		Transportation Time t_i	Start Lag D_i	Stop Lag E_i
	A_i	p_i	B_i	q_i			
1	11	0.1	8	.2	5	5	3
2	15	0.3	11	.2	8	7	5
3	14	0.1	15	.1	6	3	4
4	17	0.2	16	.2	9	6	5
5	12	0.3	18	.3	7	8	7

Tableau 1

Solution: As Per Step 1: Expected processing on machines A and B are described in tableau 2

Jobs	Machine A_α	Machine B_α	Transportation Time t_i	Start Lag D_i	Stop lag E_i
1	1.1	1.6	5	5	3
2	4.5	2.2	8	7	5
3	1.4	1.5	6	3	4
4	3.4	3.2	9	6	5
5	3.6	5.4	7	8	7

Tableau 2

As Per Step 2:

t'_1 = max (5-1.1 , 3-1.6 ,5) =5

t'_2= max (7-4.5, 5-2.2, 8) = 8

t'_3= max (3-1.4, 4-1.5, 6) = 6

t'_4= max (6-3.4, 5-3.2, 9) = 9

t'_5= max (8-3.6, 7-5.4, 7)= 7

As Per Step 3: The processing time on imaginary machines are shown below in Tableau-3

Jobs	G_i	H_i
1	6.1	6.6
2	12.5	10.8
3	7.4	7.5
4	12.4	12.2
5	10.6	12.4

Tableau 3

Here all $G_i \geq H_i$ for all *i*.

As per steps 4 , Optimal sequence obtained by Johnson's technique is

S_1= 1-3-5-4-2

In- out table is shown below in Tableau 4

Jobs	Machine A	Effective transportation time	Machine B
I	In-Out	$t^1{}_i$	In-Out
1	0-1.1	5	6.1-7.7
3	1.1-2.5	6	8.5-10
5	2.5-6.1	7	13.1-18.5
4	6.1-9.5	9	18.5-21.7
2	9.5-14	8	22-24.5

Tableau 4

As per step 6,7,8,9 The sum elapsed/make span time =CT (S_1) =24.5 units.

Utilization time of Machine B =$U_2(S_1)$= 18.1 units, Also

As per step 10 Rental cost for each sequence S_1

$R(S_1)=24.5\times10+18.1\times20=502$ units

Similarly, we can find utilization for other sequences as shown in tableau 5

As per step 5, other feasible sequences are obtained

$\mathbf{S_2}$ **=** 3-1-5-4-2

S_3 = 4-1-3-5-2

S_4 **=** 2-1-3-5-4

S_5 = 5-2-3-4-2

Sequences	Total elapsed time	Utilization time	Rental cost
3-1-5-4-2	24.5	16.8	476
4-1-3-5-2	26.3	13.9	418
2-1-3-5-4	26.4	13.9	418
5-2-3-4-2	24.5	13.9	418

Tableau 5

Therefore, min $R\{S_K\}$ = R (S_3, S_4, S_5) = 418 units.

CONCLUSION

This paper deals with lags i.e Start lag and stop lag are the defined under the term time lag and is conducive in splitting and overlapping of jobs for effective and continuous running of machines. The application would be a circumstance in which every job is a bunch comprising of a few discrete/indistinguishable units. Once the first jobs are performed on a machine and it can instantly start handling at machine B. the start represents the time to process one unit on machine A and the stop lag represents the time to process one unit on machine 2. further this topic can be extended by further parameters like setup times, break-down interval etc.

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