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Non- Avaliability Of The Machines In Two- Stage Flow -Shop Scheduling ,Processing Time Associated With Probabilities Including Transportation Time And Job Block Criteria To Minimize The Hiring Cost

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Abstract

This paper deals with a herustic algorithm to minimize the rental cost of the machines for 2-stage flow shop scheduling problem under specified rental policy in which processing times are associated with their respective probabilities with break down interval and transportation time. Further ,the equivalent job block criteria is being considered. The objective of the paper is to find an algorithm to minimize the rental cost of the machines under specified rental policy with break down interval, transportation time and job block criteria. The purposed algorithm is easy to understand and provide an important tool for the decision makers.

Keywords: Equivalent -job, Flow- Shop, Rental- policy, Transportation- time , Break-down interval.

1. Introduction

Scheduling problems concern with the situation in which value of the objective function depends on the order in which tasks have to be performed. A lot of research work has been done in the area of scheduling problems for different situations and different criterions . Later on many researchers such as *Adiri* **[**4**]**, *Chandramouli* **[**6**]**, *Singh T. P.* **[**5**]** etc. have discussed the various concepts of break-down of machines. The scheduling problem practically depends upon the important factors namely, Transportation which includes loading time, moving time and unloading time, Job block criteria which is due to priority of one job over the another and machine break down due to failure of a component of machine for a certain interval of time or the machines are supposed to stop their working for a certain interval of time due to some external imposed policy such as non supply of electric current to the machines may be a government policy due to shortage of electricity production. These concepts were separately studied by various researcher *Johnson* **[***1***] ,** *Ignall* and *Scharge* **[**2**]** ,*Maggu & Das* **[**3**]** , *Singh T. P., Gupta Deepak* **[**7**]** ,*Sharma Sameer* , *Gupta Deepak, Sehgal pooja deep* etc. . Maggu & Das [3] introduced the concept of equivalent job block scriteria in the theory of scheduling.

Gupta .D &Sharma.S[8] studied n by 2 general flow shop problem to minimize the rental cost under predefined rental policy in which the probabilities have been associated with processing time on each machine including job block criteria. We have extended the study made by Singh T.P. , Gupta Deepak by introducing the concept of job block criteria. An algorithm is also developed to minimize the rental cost of the machines.

Notations

S : Sequence of jobs 1,2,3,….,n

M_j : Machine j, j=1,2,……

C_i : Processing time of i^th^ job on machine C.

D_i : Processing time of i^th^ job on machine D.

C'_i : Expected processing time of i^th^ job on machine C.

D'_i : Expected processing time of i^th^ job on machine D.

p_i : Probability associated to the processing time C_i of i^th^ job on machine C.

q_i : Probability associated to the processing time D_i of i^th^ job on machine D.

t_i : transportation time of i^th^ job from machine C to machine D

β : Equivalent job for job – block.

L : Length of the break-down interval.

C''_i: Expected processing time of i^th^ job after break-down effect on machine C.

D''_i: Expected processing time of i^th^ job after break-down effect on machine D.

S_i : Sequence obtained from Johnson's procedure to minimize rental cost.

C_j : Rental cost per unit time of machine j.

U_i : Utilization time of D (2 nd machine) for each sequence S_i

$t_1(S_i)$: Completion time of last job of sequence S_i on machine C.

$t_2(S_i)$: Completion time of last job of sequence S_i on machine D.

$R(S_i)$: Total rental cost for sequence S_i of all machines.

$CT(S_i)$:Completion time of 1 st job of each sequence S_i on machine C.

Problem Formulation

Let n jobs to be processed on two machines C and D. Let C_i and D_i (i = 1,2…..n) be the processing time of each job on machine C and D respectively. Let t_i (i= 1,2,….n) be the transportation time of moving the i^{th} job from machine C to machine D. Let p_i & q_i be the probabilities associated with their processing time C_i , and D_i respectively. Let an equivalent job β is defined as (k,m), where k and m are any jobs among the given n jobs such that k occurs before job min the order of job block (k,m) The mathematical model of the given problem in matix can be depited as:

Table - 1

Jobs	Machine C		t_i	Machine D	
I	C_i	p_i		D_i	q_i
1	C_1	P_1	t_1	D_1	q_1
2	C_2	P_2	t_2	D_2	q_2
3	C_3	P_3	t_3	D_3	q_3
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
N	C_n	P_n	t_n	D_n	q_n

Let the machines cease working in the time interval (a, b) for the length of time L = (b – a) due to break down of machines. Now, our aim is to find the optimal schedule of jobs in order to reduce the hiring cost under predefined rental policy that all the machines are taken on rent as and when they are required and are returned as when they are no longer required for processing

Practical Situation

Various practical situations occurs in real life when one has got the assignments but does not have one's own machine or does not have enough money or does not want to take risk of investing huge amount of money to purchase machine. Under such circumstances , the machine has to be taken on rent in order to complete the assignments. As a medical practitioner , in the starting of his career, does not buy any expensive machines say, X-ray, the ultrasound machine etc, but instead take them on rent. Moreover in hospitals/industries concern, sometimes the priority of one job over the other is preferred . It may be because of urgency or demand of its relative importance. Hence the job block criteria becomes significant. When the machines on which jobs are to be processed are planted at different places, the transportation time which include the loading time, moving time and unloading time etc has a significant role in production concern and hence significant. The unavailability of the machines due to delay in material, changes in release and tails date, tool unavailability, failure of electric current, the shift pattern of the facilitiy, fluctuation in processing times, some technical interruption etc have significant role in nthe production concern.

Assumptitions

- **i.** The machines will be taken on rent as and when they are required and are returned as and when they are no longer required i.e. the first machine will be taken on rent in the starting of the processing of jobs,2nd machine will be taken on rent at time when 1st job is completed on 1st machine .
- **ii.** Machines break- down gap is deterministic, . i.e. the break-down gap are well known in advance. This simplifies the problem by ignoring the stochastic cases where the break-down gap is random.
- **iii.** Jobs are independent to each other.
- **iv.** Machine break down is considered .

Algorithm

Step1: Define expected processing time $C_i^{'}$ and $D_i^{'}$ on machine C and D respectively as follows:

$$C_i^{'} = C_i \times p_i$$

$$D_i^{'} = D_i \times q_i$$

Step2: Define two fictitious machines G & H with processing time G_i & H_i for job i on machine G &H respectively

as:

$G_i = C_i^{'} + t_i$ & $H_i = t_i + D_i^{'}$

Step3: Take equivalent job β = (k,m) and define processing time as follows.

$G_\beta = G_k + G_m - \min(G_m, H_k)$, $H_\beta = H_k + H_m - \min(G_m, H_k)$

Step4: Define a new reduced problem with processing time G_i &H_i , where job –block (k,m) is replaced by single equivalent job β with processing time G_β & H_β as obtained in step3.

Step 5: Using Johnson's (1) technique and find an optimal schedule of given jobs.

Step 6: Prepare a flow time table for the sequence obtained in step 1 and read the effect of break down interval(a ,b) on different jobs on the lines of Singh T.P.

Step 7: Form a reduced problem with processing times C_i and D_i .

If the break-down interval (a, b) has effect on job i then

$C_i^{'} = C_i + L$ & $D_i^{'} = D_i + L$ where L = b – a, the length of break-down interval.

If the break-down interval (a, b) has no effect on job i then

$C_i^{'} = C_i$, $D_i^{'} = D_i$

Step 8: Now repeat the procedure to get the sequence S_i, using Johnson's two machine algorithm as in step 2.

Step 9: Observe the processing time of 1st job of S_1 on the first machine A. Let it be α.

Step 10: Obtain all the jobs having processing time on A greater than α. Put these job one by one in the 1 st position of the sequence S_1 in the same order. Let these sequences be S_2, S_3 ,……,S_r.

Step 11: Prepare in-out flow table only for those sequence S_i (i=1,2,…r) and evaluate total completion time of last job of each sequence, .i.e. $t_1(S_i)$ & $t_2(S_i)$ on machine C_i & D_i respectively.

Step 12: Evaluate completion time CT (S_i) of 1 st job of each of above selected sequence S_i on machine C_i.

Step 13: Calculate utilization time U_i of 2 nd machine for each of above selected sequence S_i as:

$U_i = t_1 (S_i) – CT (S_i)$ for i=1, 2 , 3,…r.

Step 14: Find Min $\{U_i\}$, i=1, 2, …r. let it be corresponding to i = m, then S_m is the optimal sequence for minimum rental cost. Min rental cost = $t_1(S_m) \times C_1 + U_m \times C_2$, where C_1 & C_2 are the rental cost per unit time of 1st & 2nd machines respectively

Numerical illustration

Consider 5 jobs and 2 machines problem to minimize the rental cost. The processing with their respective associated probabilities and transportation time from one machine to another machine are given as follows:

Table - 2

Jobs	Machine C		t_i	Machine D	
I	C_i	p_i		D_i	q_i
1	12	0.2	6	8	0.1
2	16	0.3	5	12	0.2
3	13	0.3	4	14	0.3
4	18	0.1	3	17	0.2
5	15	0.1	4	18	0.2

Rental costs per unit time for machines M_1 & M_2 are Rs 15 & Rs13 respectively and jobs 2, 5 are to be processed as an equivalent group job β . Also given that the break-down interval is (15,20).

Solution: As per step1:The expected processing times for two machines are in table3

As per step3&4: The processing times of equivalent job block β = (2,5) are given by

G_β = 9.8+5.5+5.5 = 9.8 and H_β= 7.4+7.6-5.5= 9.5

As per step5: Using Johnson's method, the optimal sequence is 4,3, β,1 i.e. 4,3,2,5,1 are in table4

As per step6 &7: On considering the effect of break down interval (15,20), the revised processing time C'_i and D_i' of machines C_i and D_i are in table5 & table6. As per step8&9 : Using Johnson's method, the optimal sequence is S_1 = 4,3, β,1 i.e. 4,3,2,5,1.

As per step10:Other optimal sequences for minimize rental cost, are

S_2 = 3,4,2,5,1

S_3 = 2,4,3,5,1

S_4 = 5,4,3,2,1

S_5 = 1,4,3,2,5

As per step11&12&13:The in- out table for the sequence S_1 is shown in table7

The total elapsed time = 32.3 units and utilization time for D_i = 32.3 - 4.8 =27.5 units.

The in- out table for the sequence S_2 is shown in table8

The total elapsed time = 44.3 units and utilization time for D_i = 44.3-7.9 =36.4 units.

The in- out table for the sequence S_3 is shown in table9

The total elapsed time = 34.2 units and utilization time for D_i = 34.8-9.8 =24.4 units.

The in- out table for the sequence S_4 is shown in table10

The total elapsed time = 29.9 units and utilization time for D_i = 29.9-5..5 = 24.4 units.

The in- out table for the sequence S_5 is shown in table11

The total elapsed time = 33 .9 units and utilization time for D_i = 33.9- 8.4=25.5 units.

As per step12:The total utilization of C machine is fixed 14.4 units and minimum utilization time of D machine is 24.4 units for sequence S_4. Therefore optimal sequence are S_3 = 2,4,3,5,1 and S_4 = 5,4,3,2,1 and total rental cost = 14.4 × 15 + 24.4×13= 533.2 units

Tables As per step1

Table3: The expected processing times for two machines are

Jobs	C_i'	t_i	D_i'
1	2.4	6	0.8
2	4.8	5	2.4
3	3.9	4	4.2
4	1.8	3	3.4
5	1.5	4	3.6

As per step2

Table4:

Jobs	G	H
1	8.4	6.8
2	9.8	7.4
3	7.9	8.2
4	4.8	6.4
5	5.5	7.6

As per step3&4

Table5:

Jobs	C_i'	t_i	D_i'
4	0-1.8	3	4.8-8.2
3	1.8-5.9	4	9. 7 - 13.9
2	5.7 – 10.5	5	15.5-17.9
5	10.5 -12.0	4	17.9-21.5
1	12.0-14.4	6	21.5-22.3

As per step6

Table6:

Jobs	C_i'	t_i	D_i'
1	2.4	6	0.8
2	4.8	5	7.4
3	3.9	4	4.2
4	1.8	3	3.4
5	1.5	4	8.6

As per step8

Table7

Jobs	C_i'	t_i	D_i'
4	0-1.8	3	4.8 – 8.2

3	1.8 - 5.7	4	9.7 - 13.9
2	5.7 -10.5	5	15.5-22.9
5	10.5-12.0	4	22.9 - 31.5
1	12.0-14.4	6	31.5-32.3

Table8:

Jobs	C_i'	t_i	D_i'
3	0-3.9	4	7.9-16.1
4	3.9-5.7	3	16.1-22.5
2	5.7 -10.5	5	22.5-34.9
5	10.5-12.0	4	34.9 - 37.5
1	12.0-14.4	6	37.5 - 44.3

Table9:

Jobs	C_i'	t_i	D_i'
2	0-4.8	5	9.8-12.2
4	4.8-6.6	3	17.2-20.6
3	6.6-10.5	4	20.6-24.8
5	10.5-12.0	4	24.8 - 33.4
1`	12.0-14.4	6	33.4-34.2

Table10:

Jobs	C_i'	t_i	D_i'
5	0 -1.5	4	5.5 – 14.1
4	1.5-3.3	3	14.1 - 17.5
3	3.3 – 7.2	4	17.5-

			21.7
2	7.2-12.0	5	21.7-29.1
1	12.0-14.4	6	29.1-29.9

Table11:

Jobs	$C_i^{'}$	t_i	$D_i^{'}$
1	0-2.4	6	8.4 - 9.2
4	2.4 - 4.1	3	9.2 - 12.6
3	4.1 - 8.1	4	12.6-16.8
2	8.1-12.0	5	17.9-25.3
5	12.0-14.4	4	25.3-33.9

8.Conclusion

This paper provides an heuristic algorithm which minimize total rental cost of the machines under the condition of unavailability of the machines for n×2 flow shop scheduling model with their probabilities ,job block criteriaand transportation tme.

Remarks:

1.The study may further be extended by including various parameters such as weightage of jobs etc.

2.The work an also be extended for n by 3 flow shop scheduling model..

References (APA)

1. S. M. Johnson, Optimal two & three stage production schsedules with set up times includes, *Nav. Res. Log. Quart.,* 1(1954) 61-68.
2. E. Ignall and L. Scharge, Application of branch and bound technique to some flow shop scheduling problems, *Operation Research,* **13**(1965) 400-412.
3. P. L. Maggu and G. Dass, Equivalent jobs for job block in job sequencing, *Opsearch*, **14(4)** (1977) 277-281.
4. Adiri, J. Bruno, E. Frostig, and R. A. H. G Kan, Single machine flow time scheduling with a single break-down, *Acta Information,* **26(7)** (1989) 679-696. .
5. T. P. Singh, On n x 2 flow shop problem solving job block, Transportation times, Arbitrary time and Break-down machine times, *PAMS* ***XXI*****(1-2)** (1985).
6. A. B. Chandramouli, Heuristic approach for N job 3 machine flow shop scheduling problem involving transportation time, break-down time and weights of jobs, *Mathematical and Computational Application*, **10 (2)**(2005)301-305.

7. T. P. Singh and Deepak Gupta, Minimizing rental cost in two stage flow shop , the processing time associated with probabilies including job block, *Reflections de ERA,* (2006) **1(2)** 107-120.
8 Deepak gupta and Sameer sharma , Minimizing rental cost under specified rental policy in two stage flow shop , processing time associated with probabilities including break down interval and job block criteria.(2011) 133 – 142.
9 Gupta D. and SehgalPooja deep, "An Heuristic Approach N×3 Flow Shop Scheduling Problem In Which Processing Time Are Associated With Probabilities Including With Transportation Time And Job- Block Criteria" International Journal of Innovations in Engineering and Technology,pp-25-30(2013).
10 Gupta D. and Sehgal Pooja deep, "Effect Of Break Down Interval In Three Stage Flow Shop Scheduling In Which Processing Time Associated With Probabilities Including Transportation Time And Job Block Criteria" International Journal on future Revolution in Computer Sciences & Communication Engineering, pp-257-261, Vol4,Issue 3(2018) .
11 Gupta D. and Sehgal Pooja deep, "Minimization of Hiring Cost of the machines in 2 Stage flow shop scheduling with breakdown interval" International Journal Of Advanced Research in Science, Engineering and Technology, Vol.5,Issue9(2018), pp-6927-6933
12 Gupta D. and Sehgal Pooja deep, "Unavailability In n×2 Flow Shop Scheduling To Minimize Rental Cost With Job Block Criteria" International Journal Of Advanced Research in Science, Engineering and Technology, Vol.5,Issue9(2018), pp-6975-6981
13 Gupta D. and Sehgal Pooja deep, "Unavailability Of The Machines In Two Stage Flow Shop Scheduling Model To Minimize Rental Cost With Job Block Criteria And Transportation Time" Advances in Mathematics : Scientific Journal,Vol.9,Issue9 (2020), pp -6789-6798.