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A Number of Operations and Time Lags in Flow Shop Scheduling

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Abstract

The idea of arbitrary delays (start lag and stop lag) in n-jobs, 3-machine flow shop scheduling problem with the influence of the breakdown interval and job block criteria including transportation time is discussed in this article. The study's goal is to provide an approach for reducing the make-span in a three-stage flow shop scheduling problem. A numerical example is provided to show the suggested algorithm's computational efficiency as a useful analytical tool for academics.

Key Words: Flow Shop, Transportation Time, Breakdown Interval, Job Block, Start Lag, Stop Lag.

1. Introduction

To succeed in today's marketing environment, every firm must focus on new manufacturing methods. To attain the goal of production optimization, one should make effective use of existing resources and establish an appropriate timetable. The scheduling theory is largely based on Johnson's two-machine result. This result may be used to investigate any flow shop scheduling issues. In the competitive market, proper scheduling in manufacturing and marketing is helpful in lowering production costs and improving product quality to meet customer expectations.We defined the time lag as the minimal amount of time that must pass between the executions of two consecutive operations on the same task. The start lag (D_i> 0) is the delay between beginning task i on the first machine and starting it on the second machine. The minimal time that passed between the completions of task i on the first machine and the completion of it on the second machine is the stop lag (E_i> 0). Johnson [1] described a technique for determining the best schedule for n tasks in a two-machine flow-shop issue with the goal of minimizing the make span (total elapsed time).Mitten and Johnson [2], [3] independently presented a solution approach for achieving an optimal sequence for a ‘n-job, 2-machine' flow shop scheduling issue with variable time delays in each task (start-lags, stop-lags). Maggu and Das [4] present a solution algorithm for determining the best sequence for a ‘n-job, 2-machine' flow shop scheduling problem in which each job requires travel time. With their expansion of Johnson's rule, Yoshida and Hitomi [5] were among the first to study the flow shop where processing periods were separated. Their approach was based on a modification of Johnson's algorithm, which was initially designed for a two-machine flow shop problem with setup time in mind.The ideal n x 2 flow shop problem solution job block, Transportation times, Arbitrary time, and Break-down machine time are presented by Singh T.P. [6]. W. Kern and W.M. Nawjin [7] demonstrate optimum production scheduling on a single machine with arbitrary time delays. The flow shop problem with time delays was explored by Riezebos, J., and Goalman, G.J.C. [8]. T.P. Singh and D. Gupta [9] worked on an optimal two-stage production plan with group job constraints, with set up and processing duration separated by probability. Singh, T.P., Gupta, D., and Kumar, R. [10] investigated the processing time and set up times associated with probability, including job block, on a three-stage production plan.Gupta, D., Bala, S., and Singla, P. [11] proposed a two-stage open shop with carefully designed scheduling to save leasing costs, processing time, and transit time. D. Gupta and P. Singla [12] production difficulty with task block conceptualization involving arbitrary delays. The breakdown interval concept is used to supplement the work of Gupta, D., and Singla, P. [14]. As a result, this study is more comprehensive and realistically useful, and it has major implications for the process sector.

2. Need for Study

Scheduling problem has become the most complex problem of todays. With the development of industrial organization, the functions in the field of Industry, Defence, Civil Government etc. have become more complex as compare to the past. We are faced with so many challenging decisions regarding planning, purchasing, production, selling, hiring and so on. It is a major problem to utilize the limited resources like machine, material and man to the best possible advantages. Only scheduling can help us to do so. Because scheduling is used to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials.

It is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility when to make, with which staff, and on which equipment. Scheduling problem are of common occurrence in our daily life e.g. ordering of jobs for processing in a manufacturing plant, waiting aircraft for landing clearances etc. The selection of an appropriate order in which to receive waiting customer or jobs is called sequencing. In some other operational research problem the objective is to optimize the use of available facilities to process the items or jobs effectively. Scheduling can be divided into sevral major areas such as Single machine scheduling, Parallel machine scheduling, Flow Shop, Job Shop, Open Shop scheduling etc.

3. Practical Situation

Many applied and experimental situations exist in our day-to-day working in factories and industrial production concerns etc. In many manufacturing companies different jobs are processed on various machines. These jobs are required to process in a machine shop M_1, M_2, M_3, ---- in a specified order. When the machines on which jobs are to be processed are planted at different places the transportation time (which include loading time, moving time and unloading time etc.) has a significant role in production concern. Further the priority of one job over the other may be significant due to the relative importance of the jobs. To be occurred as a block. It may be because of urgency or demand of that particular job. Hence, the job block criteria become important. The failure of the machine (due to material delays, changes in release and tails dates, tool unavailability, electric current failure, the facility's shift pattern, variation in processing time, certain technical interruptions, etc.) plays a key part in the production issue.

4. Assumptions

1. At any given time, no machine performs more than one action.

2. Each action on a machine must be completed once it has been begun.

3. Each machine completes work in the same order, with no jobs being passed over or overtaken.

4. Job processing time frames are unaffected by the sequence in which they are completed.

5. Jobs are separate from one another.

5. Notations

S: Job sequence 1, 2, 3,...,n.

M_j: Machine j, where j is 1, 2, 3, etc.and m is the number of the machine.

A_i: i^{th} job's processing time on machine M_1.

B_i: i^{th} job's processing time on machine M_2.

C_i: i^{th} job's processing time on machine M_3.

D_{i1}: i^{th} job's start lag from machine M_1 to M_2.

E_{i1}: i^{th} job’s stop lags from machine M_1 to M_2.

D_{i2}: i^{th} job's start lag from machine M_2 to M_3.

E_{i2}: i^{th} job's stop lags from machine M_2 to M_3.

t_i: Time spent transporting the i^{th} work from the M_1 machine to the M_2 machine.

g_i: Time spent transporting the i^{th} work from the M_2 machine to the M_3 machine.

t_i': i^{th} job's effective transportation time from M_1 to M_2 machine.

g_i': i^{th} job's effective transportation time from M_2 to M_3 machine.

6. Problem Formulation

N- Jobs are processed on three machines in this scenario, with processing time including transportation time and arbitrary time delays of jobs as shown in the table 1 below:

Jobs	Machine M_1	Transportation Time	Machine M_2	Transportation Time	Machine M_3	Start Lag		Stop Lag	
I	A_i	t_i	B_i	g_i	C_i	D_{i1}	D_{i2}	E_{i1}	E_{i2}
1.	A_1	t_1	B_1	g_1	C_1	D_{11}	D_{12}	E_{11}	E_{12}
2.	A_2	t_2	B_2	g_2	C_2	D_{21}	D_{22}	E_{21}	E_{22}
3.	A_3	t_3	B_3	g_3	C_3	D_{31}	D_{32}	E_{31}	E_{32}
….	….	….	….	….	….	….	….	….	….
n.	A_n	t_n	B_n	g_n	C_n	D_{n1}	D_{n2}	E_{n1}	E_{n2}

Table 1

We wish to determine the optimum schedule for all tasks that minimises the make span by taking (k, m) job blocks whenever the impact of break down interval (a, b) is known, using Johnson's technique.

7. Algorithm

Step1: To begin, we describe the effective transportation times t_i' and g_i' from machine M_1 to M_2 and from machine M_2 to M_3 as follows:

$t_i' = \max(D_{i1} - A_i, E_{i1} - B_i, t_i)$

$g_i' = \max(D_{i2} - B_i, E_{i2} - C_i, g_i)$

Step2: Create two factitious machines G and H with processing times G_i and H_i respectively, to calculate processing time.

$G_i = |A_i + B_i + t_i' + g_i'|$ and $H_i = |B_i + C_i + t_i' + g_i'|$

If, either $\min(A_i + t_i') \geq \max(B_i + t_i')$

Or $\min(C_i + g_i') \geq \max(B_i + g_i')$

Or both satisfied the conditions.

Step 3: Describe expected processing time for the equivalent task (job) block $\beta = (k, m)$ on factitious machine G and H as follow.

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

Step4: For the new reduced issue produced in step 3, use Johnson's (1954) approach to get the optimum string S_1.

Step5: Prepare an in-out table for the best sequence found in step 4 and examine the impact of the break down intervals (a, b) on various tasks.

Step6: Form a modified problem with processing times A_i', B_i' and C_i' on machines M_1, M_2 and M_3 respectively. If the break down interval (a, b) has effect on job i then $A_i' = A_i + L$, $B_i' = B_i + L$ and $C_i' = C_i + L$ where $L = b - a$, the length of the break down interval.

If the break down interval (a, b) has no effect on job i then $A_i' = A_i, B_i' = B_i$ and $C_i' = C_i$.

Step 7: Calculate processing time for the modified scheduling issue by building two factious machines P and Q with processing times P_i and Q_i, respectively:

$P_i = |A_i' + B_i' + t_i' + g_i'|$ and $Q_i = |B_i' + C_i' + t_i' + g_i'|$

If, either min $(A_i' + t_i') \geq$ max $(B_i' + t_i')$

Or min $(C_i' + g_i') \geq$ max $(B_i' + g_i')$

Or both satisfied the conditions.

Step 8: Describe expected processing time for the equivalent task (job) block β = (k, m) on factitious machine P and Q as follow.

$P_\beta = P_k + P_m - \min(Q_k, P_m)$ and $Q_\beta = Q_k + Q_m - \min(Q_k, P_m)$.

Step9: Apply Johnson's (1954) technique to obtain the optimal string S_2 for the new reduced problem obtained in step 8.

Step10: Prepare in-out table for the optimal sequence obtained in step 9.

8. Numerical Illustration

Consider 5 - jobs are processed on three machines with processing time including transportation time and arbitrary time lags of jobs given below in table 2:

Jobs	Machine M_1	Transportation Time	Machine M_2	Transportation Time	Machine M_3	Start Lag		Stop Lag	
I	A_i	t_i	B_i	g_i	C_i	D_{i1}	D_{i2}	E_{i1}	E_{i2}
1.	17	5	6	4	12	20	13	13	15
2.	16	4	8	3	13	19	10	11	17
3.	18	7	8	6	14	22	16	12	19
4.	14	6	9	5	15	17	12	12	20
5.	13	4	8	4	16	18	12	10	18

Table 2

We wish to determine the optimum schedule for all tasks that minimises the make span by taking (2, 5) job blocks whenever the impact of break down interval (30, 35) is known, using Johnson's technique.

Solution

Step1: To begin, we describe the effective transportation times t_i' and g_i' from machine M_1 to M_2 and from machine M_2 to M_3 as follows:

$t_i' = \max(D_{i1} - A_i, E_{i1} - B_i, t_i)$

$g_i' = \max(D_{i2} - B_i, E_{i2} - C_i, g_i)$

Jobs	Machine M_1	Effective Transportation Time	Machine M_2	Effective Transportation Time	Machine M_3
I	A_i	t_i'	B_i	g_i'	C_i
1.	17	7	6	7	12
2.	16	4	8	4	13
3.	18	7	8	8	14
4.	14	6	9	5	15
5.	13	5	8	4	16

Table 3

Step 2: Now we verify the condition mentioned earlier in the method, and both min $(A_i + t_i')$ $\geq$ max $(B_i + t_i')$ and min $(C_i + g_i') \geq$ max $(B_i + g_i')$ are satisfied. As a result, we build two factious machines, G and H, with processing times G_i and H_i, respectively:

$G_i = | A_i + B_i + t_i' + g_i'|$ and $H_i = | B_i + C_i + t_i' + g_i'|$

Jobs	Factious Machines G	Factious Machines H
I	G_i	H_i
1.	37	32
2.	32	29
3.	41	37
4.	34	35
5.	30	33

Table 4

Step 3: Describe expected processing time for the equivalent task (job) block β = (2, 5) on factitious machine G and H as follow.

$G_\beta = G_2 + G_5 - \min(H_2, G_5)$ and $H_\beta = H_2 + H_5 - \min(H_2, G_5)$

$G_\beta = 32 + 30 - \min(29, 30) = 33$ and $H_\beta = 29 + 33 - \min(29, 30) = 33$

Jobs	Factious Machines G	Factious Machines H
I	G_i	H_i
1.	37	32
β.	33	33
3.	41	37
4.	34	35

Table5

Step4: Now by adopting Johnson's technique, obtain optimal sequence is

$S_1 = 4, 3, \beta, 1$. Or $S_1 = 4, 3, 2, 5, 1$.

Step 5: Therefore the sequence S_1 is 4, 3, 2, 5, 1 and corresponding in –out table and checking the effect of breakdown interval (30, 35) on sequence S_1 is as follows.

Jobs	Machine M_1	Effective Transportation Time	Machine M_2	Effective Transportation Time	Machine M_3
I	In – Out	t_i'	In – Out	g_i'	In – Out
4.	0-14	6	20 – 29	5	**34 – 49**
3.	**14 – 32**	7	39 – 47	8	55 – 69
2.	**32 - 48**	4	52 – 60	4	64 – 77
5.	48 – 61	5	66 – 74	4	78 – 94
1.	61 – 78	7	85 – 91	7	98 – 110

Table 6

Step6: The following is the updated issue after the effect of the breakdown interval (30, 35) on machine M_1, M_2, and M_3 with processing times A_i', B_i' and C_i', respectively:

Jobs	Machine M_1	Effective Transportation Time	Machine M_2	Effective Transportation Time	Machine M_3
I	A_i'	t_i'	B_i'	g_i'	C_i'
1.	17	7	6	7	12
2.	21	4	8	4	13
3.	23	7	8	8	14
4.	14	6	9	5	20
5.	13	5	8	4	16

Table 7

Step 7: Now we verify the condition mentioned earlier in the method, and both min $(A_i' + t_i')$ $\geq$ max $(B_i' + t_i')$ and min $(C_i' + g_i') \geq$ max $(B_i' + g_i')$ are satisfied. As a result, we build two factious machines, P and Q, with processing times P_i and Q_i, respectively:

$P_i = | A_i' + B_i' + t_i' + g_i'|$ and $H_i = |B_i' + C_i' + t_i' + g_i'|$

Jobs	Factious Machines P	Factious Machines Q
I	P_i	Q_i
1.	37	32
2.	37	29
3.	46	37
4.	34	40
5.	30	33

Table 8

Step 8: Describe expected processing time for the equivalent task (job) block β = (2, 5) on factitious machine P and Q as follow.

$P_\beta = P_k + P_m - \min(Q_k, P_m)$ and $Q_\beta = Q_k + Q_m - \min(Q_k, P_m)$

$P_\beta = 37 + 30 - \min(29, 30) = 38$ and $Q_\beta = 29 + 33 - \min(29, 30) = 33$

Jobs	Factious Machines G	Factious Machines H
I	G_i	H_i
1.	37	32
β.	38	33
3.	46	37
4.	34	40

Table 9

Step9: Now by adopting Johnson's technique, obtain optimal sequence is

$S_1 = 4, 3, \beta, 1$. Or $S_1 = 4, 3, 2, 5, 1$.

Jobs	Machine M_1	Effective Transportation Time	Machine M_2	Effective Transportation Time	Machine M_3
I	In – Out	t_i'	In – Out	g_i'	In – Out
4.	0-14	6	20 – 29	5	**34 – 54**
3.	**14 – 37**	7	44 – 52	8	60 – 74
2.	**37 - 58**	4	62 – 70	4	74 – 87
5.	58 – 71	5	76 – 84	4	88 – 104
1.	71 – 88	7	95 – 101	7	108 – 120

Table 10

Minimum make-span for the given problem is 102 units.

9. Conclusion

The current research is focused on the flow shop scheduling challenge, with the goal of reducing overall work production time. When a factory/industry management has a minimum time contract with a commercial party to accomplish work, the notion of decreasing production time may be an economical component. Various factors, such as Set-Up time, weightage and so on, can be included to expand the task.

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