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Optimization by Heuristic procedure of Scheduling Constraints in Manufacturing System

Bharat Chede[1*], Dr C.K.Jain[2], Dr S.K.Jain[3], Aparna Chede[4]

1. Reader, Department of Mechanical Engineering, Mahakal Institute of Technology and Management, Ujjain
2. Ex Principal, Ujjain Engineering College, Ujjain
3. Principal, Ujjain Engineering College, Ujjain
4. Lecturer, Department of Mechanical Engineering, Mahakal Institute of Technology, Ujjain

* Email of the corresponding author : bharat_chede@rediffmail.com Phone 91-9827587234

Abstract

This article provides an insight for optimization the output considering combinations of scheduling constraints by using simple heuristic for multi-product inventory system. Method so proposed is easy to implement in real manufacturing situation by using heuristic procedure machines are arranged in optimal sequence for multiple product to manufacture. This reduces manufacturing lead-time thus enhance profit.

Keywords: Optimization, Scheduling, Heuristic, Inventory, Layouts

1. Introduction

Constraints in industry lead to reduction of profit to industry especially some constraints like budgetary and space when imposed on system. These constraints has impact on cost incurred in that product basically considering the scheduling as constraints specially in case when we have to adopt in change in product mix, demand and design.

2. Traditional approach

There are many relations for EOQ

$$Q = \sqrt{\frac{2\,C_i \,.\, Y_i}{B_i}} \qquad i = 1,2,3 \_\_\_ n \quad \text{-----------------} \quad \textbf{(i)}$$

For i^{th} product Ci = order cost per unit

Yi = demand per unit

Bi = the stock holding cost per unit per unit time

There are chances when all n products have to be replenished at same time. If restriction of maximum capital investment (W) at any time in inventory is active, then (**A)** is valid if Q (i= 1.2. - - - n) satisfy the constraints

$$\sum_{i=1}^{n} Vi.\,Qi \le W \qquad \text{------------------------------} \qquad \textbf{(ii)}$$

Where V is the value of unit of product i otherwise Q (i = 1,2, ---- n)

To satisfy (ii) Lagrange multiplier technique is used to obtain modified Q

$$Q = \sqrt{\frac{2\,Ci\,.Yi}{Bi + 2\mu Vi}} \qquad i = 1,2,3\_\_\_n \qquad \text{-----------------} \qquad \textbf{(iii)}$$

μ - Lagrange multiplier associated with capital investment constraints

But by these also we may not necessarily get optimality.

The proposed simple heuristic rule for staggering of the replenishments of product under equal order interval method and provide a simple formula for obtaining the upper limit of maximum investment in inventory we assume that each product is replenished at equal time interval during common order interval T, i.e. for n product we order at a time interval of T/n and upper limit of maximum investment in inventory can be obtained by making following arrangement.

Arranging the item in descending order of demand of each item and its unit value (i.e. max [Vi,Yi] is for i=I) If INV denote the capital investment required at time (j - 1) T/n j = 1,2, --- n then INVj can be expressed as

$$INVj = T/n \sum_{k=1}^{n} rjk.\,V k\,.\,Y k \qquad j = 1,2\text{----}n$$

$$rjk = n+k-j \quad \text{if } k \le j$$
$$= k-j \quad \text{if } k \ge j$$

ML_{UL} = max (INVj) gives upper limit of maximum investment in cycle duration j.

To have exact utilization of invested budget the estimated value of T should be obtained from W = ML_{UL} Comparison of optimal result by both methods. It is clear that heuristic rule provide better cost performance than Lagrange multiplier method.(Table1)

3. **Numerical example**

Considered the company nearby Indore (India) (Table2) for the Demand rate, order cost, stock holding cost, Value and EOQ.

Maximum allowable investment W = Rs 15000/- If EOQ used ignoring budgetary constraint, the maximum investment in inventory would be 17,120/- which is greater than W. To find optimal solution by Lagrange multiplier technique which when applied gives(Table 3)

Q_{L1} = 88, Q_{L2} = 139, Q_{L3} = 98 Total cost = Rs 3541 when $\mu = 0.03$

From the result it ensures that heuristic rule performs well. Also the proposed rule in easy to implement in practice.

3.1 In case of Scheduling as constraints we can classify the Layout as

- Liner (single and double row machine layout) (Figure 1)
- Loop Layout (Figure 2)
- Ladder layout (reduces travel distance)(Figure 3)
- The Carousel Layout (Part flow in one direction around loop The Load and unload stations are placed at one end of loop)(Figure 4)
- The Open Field Layout (Consist of Ladder and Loop)(Figure 5)

Scheduling is considered as Static Scheduling where a fixed set of orders are to be scheduled either using optimization or priority heuristics also as dynamic scheduling problem where orders arrives periodically.

Process of Solution for problem

Pi be a partial schedule containing i schedule operations.

Si The set of Schedulable operation at stage i corresponding to given Pi

Pj The earliest time at which operation j and s could be started.

Q Earliest time at which operation J, sj could be completed.

4. **Priority Rule Used**

- **SPT** (Select operation with minimum processing time)
- **MWKR** (Most work remaining)

- **Random** (Select operation at random)

4.1 Algorithm

Step 1 : Let t=0 assume Pt = {Ǿ}

Step 2 : Determine q* = min {q}and corresponding machine m* on which q* could be realized.

Step 3 : For operation which belongs to S that requires machine m* and satisfy the condition $p < q^*$ identify an operation according to specified priority add this operation to pi for next stage.

Step 4 : For each new partial schedule p_{t+1} created in step 3 update the data set as follows

i) Remove operation j from Si.

ii) From S_{t+1} by adding the direct successor of operation j from si.

iii) Increment by 1

Step 5 : Repeat step 2 to step 4 for each p_{t+1} created in steps and continue in this manner until all active schedules are generated.

Step 6 : From To chart is developed from routing data the chart indicated number of parts moves between the machines.

Step 7 : Adjust flow matrix is calculated from frequency matrix, distance matrix and cost matrix.

Step 8 : From to Sums are determined from the adjusted flow matrix.

Step 9 : Assign the a machine to it on minimum from sums. The machine having the smallest sum is selected. If the minimum value is to sum, then the machine placed at the beginning of sequence. If the minimum value is from sum, then machine placed at end of sequence.

5. Example

Arrangements of machine are considered for Liner layout, loop layout and ladder layout. The input data required in inter slot distance load unload distances and unit transportation cost, processing times for different jobs, processing sequence of jobs on different machines.(Table 4)(Table 5)

- Inters lot distance and load, unload matrices for Liner layout (Table 6,7)
- Inter slot distance and load, unload matrix for Loop Layout(Table 8,9)
- Inter slot Distance and Load, Unload Matrices for Ladder Layout (Table 10,11)

6. Results

- Waiting time of machine (Table 12)
- Waiting time for Job (Table 13) Production time for a batch of component = 2600 hrs
- Sequence of job manufactured on different machine for minimum production time.(table 14)
- Machine order and total cost for different types of layouts (Table 15)

7. Conclusion

The traditional method for determining optimal order quantities and the optimal reorder points in multi-product inventory system with constraints are not easy to implement in reality but heuristic rule is not only easy to implement but also give better result than traditional method. By using heuristic procedure with scheduling as constraint layout is optimized. The other parameters such as flow time, job sequence to manufactured, Machine sequence, total transportation cost, Machine and job waiting time are determined.

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First Author. Bharat Chede has received Bachelor's degree from Amravati University, India and Masters Degree in Mechanical Engineering (Production Engineering) from Shivaji University, India, He is currently pursuing PhD from Rajiv Gandhi Proudyogiki Vishwavidyalaya Bhopal, India. He is working as Head of Department (Mechanical Engineering) at Mahakal Institute of Technology and Management Ujjain India. His Current area of research is Optimization in manufacturing techniques using fuzzy logics.

Second Author. Dr C.K.Jain Phd in Production Engineering from IIT Rourkee. A renowned academician, was responsible for making trendsetting transformations during his last stint as Principal, UEC. Having received a Gold Medal in M.Tech and an award winning research scholar during his PhD. His Current area of research is Casting methods optimization.

Third Author. Dr S.K.Jain. Phd from APS university Rewa India. He is principal Ujjain Engineering College Ujjain, India . His current areas of research are Fuzzy logic Technique in Engineering

Fourth Author. Aparna Chede has received Bachelors and Masters Degree in Mechanical Engineering from Rajiv Gandhi Proudyogiki Vishwavidyalaya Bhopal, India. She is currently working as Lecturer in Mechanical Engineering at Mahakal Institute of Technology and Science Ujjain India. Her current areas of research are Industrial Engineering techniques.

Method of solution	T	Q1	Q2	Q3	Total Cost
Langrange Multiplier	---	145	44	114	Rs 4063
Heuristic	0.108	216	54	108	Rs 3919

Table No 1: (Comparison of optimal result by both methods)

Product(i)	1	2	3
Demand rate (units per year) Y	2000	1000	1000
Order cost C (Rs per unit per year)	50	50	50
Stock holding cost B (Rs Per unit per year)	16	10	4
Value V (Rs per unit)	80	150	20
EOQ	112	100	158

Table 2: (Demand rate, order cost, stock holding cost, value and EOQ.)

Method of solution	T	Q1	Q2	Q3	Total Cost
Langrange Multiplier	---	98	88	139	Rs 3541
Heuristic	0.079	158	79	79	Rs 3716

Table 3: (Optimal solution by Lagrange multiplier technique)

Job number	J1	J2	J3	J4	J5	J6
Batch size	50	40	60	30	30	70

Table 4: (Job and Batch Size)

Job	First Operation		Second Operation		Third Operation		Fourth Operation		Fifth Operation		Sixth Operation	
	M/C	Time	M/C	Time	M/C	Time	M/C	Time	M/C	Time	M/C	Time
A	M1	8	M2	7	M3	14	M4	9	M4	3	M4	4
B	M2	10	M3	17	M3	6	M5	13	M4	4	M1	3
C	M4	18	M3	16	M4	11	M1	12	M5	3	M2	2
D	M4	16	M1	7	M2	11	M3	4	M5	4	M4	13
E	M2	12	M2	15	M4	9	M1	11	M4	3	M1	4
F	M4	8	M5	7	M4	9	M1	6	M2	11	M2	12

Table 5: (Machines with Operation time)

Slots	S1	S2	S3	S4	S5	S6
S1	0	4	6	8	10	12
S2	4	0	4	6	8	10
S3	6	4	0	4	6	8
S4	8	6	4	0	4	6
S5	10	8	6	4	0	4
S6	12	10	8	6	4	0

Table 6: (Inter slot distance for Liner Layout)

Slots	S1	S2	S3	S4	S5	S6
Load Station	3	5	7	9	11	13
Unload Station	13	11	9	7	5	3

Table 7: (Load Unload Matrices for Liner layout)

Slots	S1	S2	S3	S4	S5	S6
S1	0	4	6	8	10	12
S2	4	0	4	6	8	10
S3	6	4	0	4	6	8
S4	8	6	4	0	4	6
S5	10	8	6	4	0	4
S6	12	10	8	6	4	0

Table 8: (Inter slot distance for Loop Layout)

Slots	S1	S2	S3	S4	S5	S6
Load Station	4	6	8	10	12	14
Unload Station	14	12	10	8	6	4

Table 9: (Load Unload Matrices for Loop layout)

Slots	S1	S2	S3	S4	S5	S6
S1	0	6	8	10	12	14
S2	6	0	6	8	10	12
S3	8	6	0	6	8	10
S4	10	8	6	0	6	8
S5	12	10	8	6	0	6
S6	14	12	10	8	6	0

Table 10: (Inter Slot distance for Ladder Layout)

Slots	S1	S2	S3	S4	S5	S6
Load Station	1	5	7	9	11	13
Unload Station	13	11	9	7	5	1

Table 11: (Load unload Matrices for Ladder Layout)

Machine	M1	M2	M3	M4	M5	M6
No	4	6	6	8	8	6
Waiting time in minutes	6	8	6	8	6	4

Table 12: (Waiting Time of machine)

Job No	J1	J2	J3	J4	J5	J6
Waiting time in minutes	3210	3340	1740	3810	3840	1750

Table 13: (Waiting time for job)

M/C No	Job Sequence					
M1	J1	J6	J4	J3	J5	J2
M2	J2	J1	J4	J5	J1	J3
M3	J3	J2	J5	J1	J4	J4
M4	J3	J6	J4	J5	J1	J2
M5	J6	J2	J4	J1	J3	J5
M6	J6	J1	J2	J1	J5	J1

Table 14: (Job Sequence for minimum production time)

Type of Layout	Machine arrangement Sequence						Total Transportation Cost
Liner	M4	M6	M1	M5	M2	M1	3370
Loop	M4	M6	M1	M5	M2	M1	3382
Ladder	M4	M1	M5	M6	M2	M1	6324
Open Field	M4	M1	M5	M6	M1	M1	4212

Table 15: (Machine order and cost for different layout)

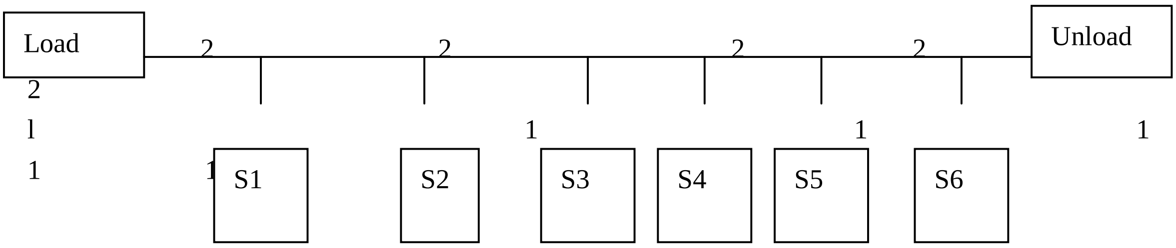

Figure 1 Liner (single and double row machine layout)