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Multi Objective Scheduling Optimization in Flexible Manufacturing System by Jaya Algorithm

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Abstract-In Flexible Manufacturing System Scheduling plays a crucial role, to meet the customer requirements and cope up with frequent fluctuations in demand. Many researchers are attempted the scheduling problem by considering the single objective, and very few researchers have applied GA, CS, PSO algorithms to solve the Multi-objective Scheduling Problems. The FMS considered in this work has Scheduling of 80 verities of products to be manufactured on 16 CNC machine tools by considering multi-objectives as Minimization of Machine Idle time and Minimization of Penalty cost. In this work Jaya Algorithm has been implemented using Mat lab, to solve Multiobjective scheduling problem to minimize the Combined Objective Function Value. The effectiveness of this algorithm is tested on benchmark problems by using different methods like Largest Processing Time (LPT) and Shortest Processing Time (SPT). The problem considered is that 80 jobs have to be manufactured by processing on 16 machines is taken from literature. COF value for the sequence obtained by Jaya Algorithm is better compared with values obtained by other algorithms. It is concluded that the proposed Jaya algorithm is better than many other earlier approaches.

Key Words - Flexible manufacturing systems, combined objective Function, Jaya Algorithm

I. INTRODUCTION

In Flexible Manufacturing system, scheduling plays a vital role because of its need to accommodate fluctuation in demands and fulfilling customers' requirements. In today's competitive world customer satisfaction is very much relevant; we need to manufacture the right quality product and deliver at a competitive price as and when the customer requires. In FMS Scheduling will be done by considering single objectives and Multi Objectives. So, researchers are trying to find solutions for FMS scheduling problem with single and multi-objective by developing the algorithms.

In FMS a group of machines which are coordinated and controlled by a common control center. FMS consists of robots, CNC machines, and material handling system. Manufacturing of each part requires a specific sequence of operations to be done on specified machines; the parts will move from one cell to another cell by material handling system. After completing the manufacturing of parts inspection will be done at an automatic inspection center, and subsequently unloaded from the Flexible Manufacturing System. The Typical layout of Flexible Manufacturing system is shown in Figure 1.

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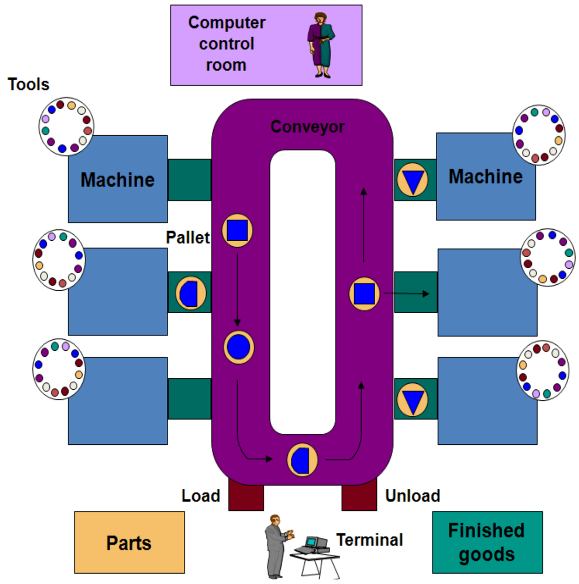

Fig1. Typical view of FMS

Following objectives are of most important in the context of an FMS

(a) Machine Idle time Minimization
(b) Penalty cost minimization
(c) Maximizing production rates
(d) Minimizing in-process inventories
(e) Minimizing setup and tool changes times
(f) Minimizing mean flow times
(g) Balancing machine utilization

The present work addresses two objectives, i.e., Machine idle time Minimization and Penalty cost minimization equal weight age is given for both the objectives and formulated combined Objective Function Value.

II.LITERATURE SURVEY

Researchers gave importance to the FMS scheduling problem with single and Multi objectives because of global completion in the manufacturing industry. Effective scheduling plays a primary function to face the competition in the market. Sateesh et al. Studied the Different FMS layouts by considering the Different number of AGV's and CART's and Suggested the Suitable Material handling system is proposed for a layout at different speeds of Material Handling Systems [1]. Mahesh successfully demonstrated the integration of scheduling with material requirement planning (MRP) and capacity requirements planning (CRP), to generate a near to optimal production schedule at low cost considering the practical difficulties in a real job shop environment [2]

Kaizhou Gao et al. Applied the Jaya Algorithm for FMS Scheduling to minimize Machine workload. Experiments conducted with real-time data. Results proved that Jaya Algorithm is giving better results than other algorithms.[3]
R.Venkat Rao proposed a Jaya algorithm for solving the optimization Problems. This algorithm is applied to the benchmark problem for testing. Results proved that this algorithm is useful for solving the optimization problems [4]
BurnwalShashikant applied the Cuckoos search algorithm for scheduling optimization in FMS results found were very effective in comparison with the results obtained by using the other algorithms like GA & PSO [5]
Deb S and Yang proposed a new Meta heuristic algorithm, i.e., CS to find an optimum solution and applied for the Benchmark problems, and it is found that Cuckoos search Algorithm is giving better results than other algorithms [6].
Jerald J made optimization procedures which are based on the various non-traditional approaches that have been implemented using C language [7].
Sankar et al. Applied MOGA for Scheduling of 16 machines and 43 jobs problem and observed good results [8].
Stephen F. Smith concluded that practical scheduling problems could be effectively solved by developing and transition techniques with better solutions. By this major technical problems can be easily solved. Still, there is a lot to be explored in this field of sequencing and scheduling. [9]
In an FMS problem multiple constraints and objectives exist. Genetic algorithms are used for solving these problems. Akhilesh Kumar proposed an FMS program and tested to get feasible solutions. [10]
A.V S. Sreedhar Kumar tried to optimize FMS problem, by using like DE & BFOA. Bacterial Foraging Optimization Algorithm BFOA has shown better results. Validation of the results plays a crucial role in taking the decision. [11]
Sunil Kumar and Sanjay Jain studied the various techniques of dynamic scheduling of FMS. They explained various techniques to study FMS like Dispatching Rule, Heuristics, G A and Artificial intelligence. They suggested combining the various techniques to get a more effective solution. [12]
FMS is a complex system with elements like workstation, ASRS, material handling. FMS can plan machine and vehicle scheduling problems simultaneously. Anshuman Mishra concluded that for an objective function PSO particle swarm optimization could give better optimization better than GA for a CPU run time. PSO does not need iterations. [13]
The manufacturing process is a mixture most unexpected uncertainties such as unexpected events, sudden or unindicated machine break downs, sudden surplus orders, order cancellations, etc. despite these complex nature, the FMS can be planned efficiently with program formulations. [14]
Rishu Sharma et al. concluded that the manufacturing industry is becoming a complex issue given the maintaining of demand and supply. It is crucial to accommodate the changes to be taken place in manufacturing processes. [15]
K.Mallikarjuna et al. studied the machines arranged in a single row assisted by AVG. The programming is made by Simulated Annealing (SA) and Genetic Algorithm. The results obtained by GA are superior to SA[16]
Nidhiry, N.M. and, Saravanan, R considered the problem of 80 products to be manufactured on 16 machines by considering the Multi-objective function and applied a modified NSGA-II algorithm. The results show that this algorithm gives better results compare to many other algorithms[17].
Jian-Hung Chen, Shinn-Ying Ho proposed an efficient multi-objective genetic algorithm EMOGA for planning flexible manufacturing system FMS. Minimizing total flow time, machine workload unbalances, greatest machine workload and total tool cost are the four objectives they considered during problem formulation. This problem solved the complex nature by using more than one product, more than one operation, more than one costs. [18]

III. PROBLEM DESCRIPTION

The main contribution of the paper

- Combined objective function considered is a combination of two objectives with equal weight ages are Machine idle time minimization and Penalty cost minimization.
- From the literature, it is revealed that no researchers are considered problem of eighty varieties of products to be manufactured on sixteen machines with particular batch size, due date, and penalty.

Problem descriptions

A sample problem is taken from the literature [17] as shown in Table 1

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Table 1- 80 parts problem showing the processing times, batch sizes, deadline and penalty cost

Part No.	Processing sequence – {Machine No., Processing time (min)}	Deadline (days)	Batch size (Nos)	Penalty cost (INR/unit/day)
45	{2, 3}, {8, 2}, {9, 5},{16, 3}	15	400	3.00
1	{6, 1}, {7, 1}, {8, 1}, {10, 2}	17	150	1.00
46	{1, 3}, {12, 5}, {13, 4}	8	250	4.00
2	{2, 1}, {6, 1}, {8, 1}, {9, 2}, {14, 4}, {16, 2}	17	200	1.00
47	{12, 3}, {13, 2}	7	440	2.00
3	{8, 1}, {11, 3}, {13, 4}	14	800	1.00
48	{5, 2}, {8, 2}, {16, 3}	10	350	2.00
4	{9, 4}	26	700	2.00
49	{1, 3}, {11, 5}	9	300	1.00
5	{4, 5}, {5, 3}, {15, 4}	11	150	1.00
50	{2, 1}, {6, 3}, {9, 2}, {16, 2}	8	300	1.00
6	{6, 5}, {14, 1}	16	700	1.00
51	{7, 3}, {10, 2}	20	250	2.00
7	{3, 5}, {6, 3}, {16, 5}	26	250	2.00
52	{1, 2}, {4, 1}	18	300	3.00
8	{5, 4}, {6, 5}, {8, 1}	26	850	2.00
53	{14, 3}	10	275	4.00
9	{4, 1}, {5, 5}, {8, 1}, {11, 1}	1	100	0.00
54	{7, 2}, {10, 6},	13	375	2.00
10	{2, 2}, {9, 1}, {16, 4}	20	150	2.00
55	{5, 3}, {6, 2}, {9, 4}, {16, 3}	15	220	5.00
11	{8, 4}, {12, 2}	1	250	1.00
56	{1, 7}, {11, 3}, {13, 2},	12	200	3.00
12	{6, 2}, {8, 4}, {10, 1}	19	1000	3.00
13	{6, 1}, {7, 5}, {10, 4}	25	700	4.00
14	{4, 2}, {5, 3}, {6, 2}, {15, 2}	22	1000	4.00
16	{5, 3}	27	750	3.00
15	{5, 4}, {8, 3}	15	700	5.00
17	{3, 1}, {6, 4}, {14, 1}	20	650	4.00
18	{9, 2}, {16, 3}	24	250	5.00
19	{4, 1}, {5, 5}, {6, 2}, {8, 2}, {15, 5}	5	450	1.00
20	{8, 2}, {11, 4}	11	50	5.00
21	{4, 5}, {5, 5}, {6, 2}, {8, 2}, {15, 5}	16	850	3.00
22	{12, 5}	24	200	5.00
23	{4, 2}, {5, 1}, {6, 5}, {8, 4}	14	50	4.00
24	{8, 4}, {11, 4}, {12, 5}, {13, 4}	7	200	5.00
25	{7, 3}, {10, 2}	24	350	1.00
26	{10, 2}	27	450	0.00
27	{8, 5}, {11, 5}, {12, 4}	22	400	1.00
28	{2, 1}, {8, 1}, {9, 2}	3	950	5.00
29	{4, 1}, {5, 5}	7	700	1.00
30	{11, 3}, {12, 5}	18	1000	1.00
31	{8, 2}, {10, 2}	2	800	2.00
32	{2, 3}, {6, 4}, {9, 3}	15	800	1.00
33	{5, 4}, {6, 5}, {15, 3}	27	500	4.00
34	{3, 2}, {6, 2}	12	300	4.00
35	{3, 4}, {14, 1}	9	900	2.00
36	{3, 2}	20	700	2.00
37	{1, 5}, {2, 2}, {6, 3}, {8, 3}, {9, 2}, {16, 4}	22	250	4.00
38	{2, 4}, {8, 3}, {9, 2}, {16, 5}	8	50	1.00
39	{6, 5}, {10, 5}	9	500	1.00
40	{2, 2}, {6, 4}, {9, 4}	7	250	5.00
41	{5, 1}, {8, 2}, {15, 1}	22	800	4.00
42	{2, 5}, {6, 4}, {9, 3}, {16,1}	19	400	2.00
43	{1, 3}, {5, 2}, {6, 2}, {8, 2}, {15, 3}	15	550	3.00
44	{2, 5}, {6, 4}, {9, 3}	12	350	1.00
57	{2, 1},{5, 3}, {6, 2}, {9, 3},	5	150	1

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58	{7, 5}	7	550	1
59	{7, 8},{10, 4},	8	150	2
60	{2, 1}, {9, 3}, {16, 1}	17	500	1
61	{1, 6},{12, 3}, {13, 2}	24	100	2
62	{11, 2}, {13, 4}	16	1000	2
63	{2, 11},{5, 3}	18	240	3
64	{11, 3},{13, 2}	27	800	1
65	{3, 11},{14, 3},	19	440	2
66	{1, 3},{4, 4},	14	320	2
67	{1, 3},{11, 3}, {12, 4}, {13, 2}	22	600	4
68	{6, 1},{8, 1},{9, 2}, {16, 2}	14	700	1
69	{2, 2},{5, 3}, {6, 3}, {8, 1}, {9, 2},	16	150	2
70	{7, 5}, {10, 1}	15	230	1
71	{3, 14}	7	450	2
72	{11, 6}, {12, 10}	18	570	3
73	{1, 5},{4, 1},	9	250	4
74	{2, 2},{9, 2}, {16, 3}	13	200	3
75	{16, 1}	3	230	1
76	{1, 2}, {5, 3}, {12, 1}	6	310	2
77	{2, 2}, {5, 1}, {6, 11}	12	330	3
78	{5, 3},{6, 2}, {9, 3}	14	280	2
79	{2, 1}, {9, 3}	14	210	1
80	{8, 3}, {9, 3}	10	50	3

IV. PRAPOSED METHODOLOGY FOR SCHEDULING OPTIMIZATION OF FMS

Jaya algorithm

The Jaya algorithm is developed by Dr. R.Venkat Rao in 2015 [4]. The Jaya algorithm is a met heuristic which is capable of solving both constrained and unconstrained optimization problems. It is a population-based method which repeatedly modifies a population of individual solutions. It is a gradient-free optimization algorithm. There are a number of optimization algorithms like genetic algorithm, particle swarm optimization algorithm, artificial bee colony optimization algorithm, firefly optimization algorithm, bio-geography based optimization algorithm, cuckoo search, etc. but what distinguishes Jaya from the

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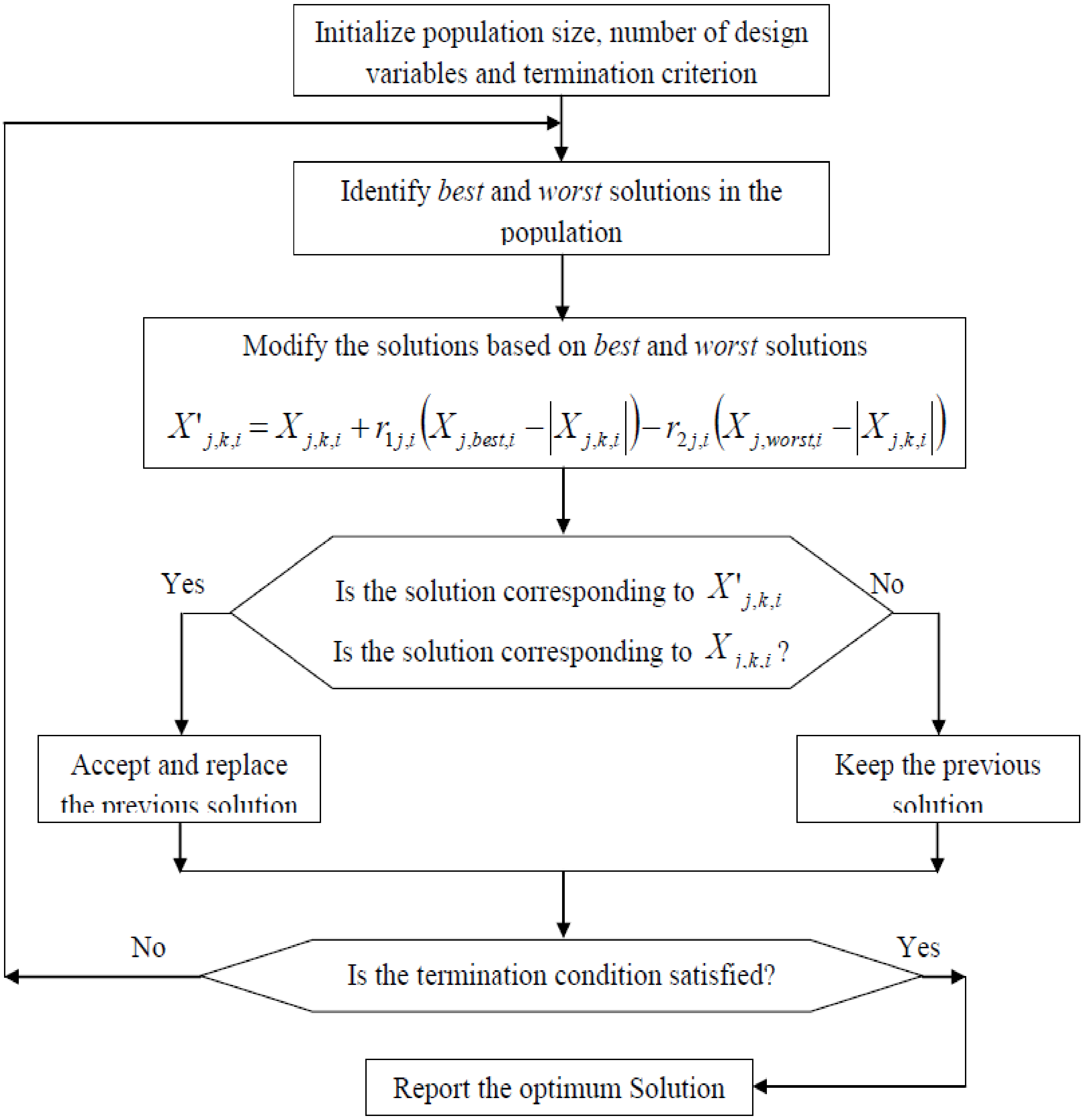

Fig 2 Jaya Algorithm

other is the fact that it does not contain any hyper parameters [4]. Jaya algorithm attempts every time to find the best solution and ignore the worst solution and move forward to find the optimum solution. The main advantage of Jaya algorithm is that it always tries to find an optimum solution and takes less time for iterations. In Jaya algorithm following Eq (1) is used to find the near-optimum solution

$$X'_{j,k,i} = X_{j,k,i} + r_{1j,i}\left(X_{j,best,i} - \left|X_{j,k,i}\right|\right) - r_{2j,i}\left(X_{j,worst,i} - \left|X_{j,k,i}\right|\right) \text{ - --- } \quad (1)$$

Flow chart of the Jaya algorithm is shown in Fig. 2. It always tries to get closer to the optimum solution and tries to avoid the worst possible solution.

Implementation of the proposed Jaya Algorithm for scheduling optimization

CombinedObjectiveFunction

$$COF = W_1 \times \left(\frac{PC}{MP}\right) + W_2 \times \left(\frac{X_q}{TE}\right) \text{------------} \quad (2)$$

W1=Weight age factor for minimizing the total penalty cost

W2=Weight age factor for minimizing the total elapsed time

PC= Total penalty cost

MP=Maximum Penalty

Xq=Total machines idle time

TE=Total Elapsed time.

The steps in the implementation of Jaya Algorithm are summarized as follows: 1. One excel file is prepared where each part job, its processing time in each machine and due date, penalty cost, and batch size are put in various columns. Mat lab can load this file during coding. 2. Then Code written for Mat lab to calculate CoF value by using equation-(2) for different possible sequences 3. In this Matlab code, Jaya algorithm is incorporated to find the best sequence which gives the best CoF Value. 4. Matlab Program was run for different iterations and obtained the CoF value.

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V. RESULTS

This developed program has been run for 10 iterations. 20 Iterations 30 Iterations,40 iterations,50 iterations, 60 and finally for 100 iterations It has been found that for less number of iterations results are not good, but as we increase the iteration number, it started giving better results, but after 40 iterations 50,60 and 100 iterations results are getting same results; therefore we have stopped at 100 iterations we got COF =0.1083 . Also calculated CoF Values by SPT and LPT methods. Results obtained by different algorithms and sequences are tabulated for the comparison purpose. Results show that Jaya Algorithm is giving better COF value.

Table 2 Sequence and CoF values obtained by different Algorithms

Algorithm/ Method	Sequence	CoF Value
SPT	79,75,20,80,23,38,1,9,53,26,52,22,10,61,34,18,51,57,70,36,11,73,69,25,5,59 76,74,47,78,66,16,2,49,50,56,48,40,60,55,58,4,46,54,41,31,7,63,24,28,17,64 29,6,44,68,35,77,37,15,39,42,27,33,62,65,71,3,43,19,12,13,67,30,32,8,14,72,21	**0.1658**
LPT	79,75,20,80,23,38,1,9,53,26,52,22,10,61,34,18,51,57,70,36,11,73,69,25,5,59,76,74,47,78 66,16,2,49,50,56,48,40,60,55,58,4,46,54,41,31,7,63,24,28,17,64,29,6,44,68,35,77,37,15 39,42,45,27,33,62,65,71,3,43,19,12,13,67,30,32,8,14,72,21	**0.1658**
Jaya	80,4,14,59,15,9,3,17,47,12,30,2,28,37,8,68,10,52,27,33,11,13,32,35,63,16,29,40,22,23 24,25,26,31,21,70,39,58,20,42,44,50,43,45,65,46,34,48,72,49,51,53,55,36,6,56,5 60,62,19,38,54,64,66,67,69,71,76,73,57,41,78,18,7,74,75,77,61,1,79	**0.1083**

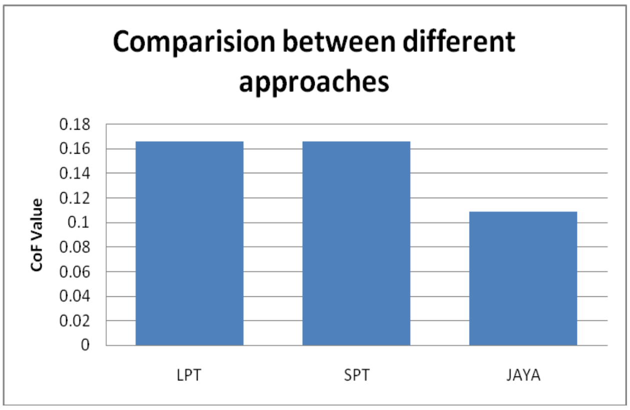

Fig-3 Comparison of Various Approaches for Multi Objective Function

V. CONCLUSIONS

In this work, the optimization process has been developed based on the Jaya Algorithm. This method is implemented successfully for solving the Multi-objective scheduling optimization problem of FMS. The code was written in Mat Lab for calculating the combined objective function. The result obtained by Jaya algorithm is analyzed for combined objective function value which is the combination of two combined objectives, i.e., Total penalty minimization and Machine idle time Minimization. After 4000 generation best solution is obtained. The procedure developed in this work can be suitably modified to any Multi-objective scheduling problem in FMS with a large number of components and machines. In the present work, we have observed that Jaya algorithm is giving the better-combined objective function value than SPT & LPT methods.

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