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Simultaneous Scheduling of Machines and AGVs in Flexible Manufacturing System by Using Particle Swarm Vehicle Heuristic Algorithm

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ABSTRACT

Scheduling of machines and transportation devices like Automated Guided Vehicles (AGVs) in a Flexible Manufacturing System (FMS) is a typical N-P hard problem. Even though several algorithms were employed to solve this combinatorial optimization problem, most of the work concentrated on solving the problems of machines and material handling independently. In this paper the authors have attempted to schedule both the machines and AGVs simultaneously, with Rebust Factor Maximization as objective, for which Particle Swarm Vehicle Heuristic (PSVHA) is applied. Operations based coding is employed to represent the solution vector. We have developed a separate heuristic for assigning the vehicles and this is integrated with the traditional PSVHA approach. The hybridized approach is tested on a number of benchmark problems whose results outperformed those available in the literature.

Keywords— Scheduling, Flexible Manufacturing System, Automated Guided Vehicle, Particle swarm Vehicle Heuristic Algorithm

INTRODUCTION

Flexible Manufacturing System can be treated as the promising technology which has the capability not only to produce parts at lower cost but also to face challenge of demand for variety of products in mid volumes, with shorter lead times. A number of advantages like increased utilization of resources, reduction in work in- progress inventory, improvement in productivity, better utilization of floor space are possible in an FMS. To achieve all these goals and to perform well FMS should be properly designed and operated. One of the important aspects in FMS operation is its scheduling policy, by which its resources like machines and automated material handling system can be utilized properly. In this paper the authors have applied a new evolutionary algorithm, Particle Swarm Vehicle Heuristic Algorithm (PSVHA) to schedule the FMS under consideration. The heuristic developed for vehicle assignment is integrated with the PSVHA, for simultaneous scheduling of machines and automated guided vehicles in FMS utilizing the Rebust Factor maximization function several researchers have laid thrust on the importance of the material handling system (2, 6,8,11 and 13). Some of the researchers reported material handling system scheduling as a comparison of a set of vehicle dispatching rules in relation to a pre specified schedule and on a particular layout (4). Equal importance was attributed for making scheduling of AGVs an integral part of the overall scheduling activity. The outcome of the co-ordination of machines and material handling system during the machine scheduling phase would be expected to raise the performance of the FMS. Simultaneous scheduling of machines and AGVs was attempted in different ways like developing on line dispatching and control rules (14, 17, 18 and 23). A beam search based algorithm was developed for the simultaneous scheduling of machines and AGVs (10 and 22) have applied sliding time windows approach to this problem. Operation sequencing and AGV assignment. (20) Studied the job shop scheduling problem, while considering the loading and unloading processes they emphasized on the importance of addressing material handling. (21) Have developed a hybrid GA procedure, which uses operation based coding for scheduling machines. They have also developed a heuristic to solve the vehicle scheduling, because of which they have reduced the length of the chromosome to half that created by Ulusoy.(4) addressed the job input sequencing and vehicle dispatching in a single vehicle automated guided vehicle system. They have coupled the heuristic branch and bound approach with discrete event simulation model. (19) Have attempted the same problem set as that of Ulusoy and Tamer with a modified GA approach. (9) Have used an adoptive genetic algorithm for solving the simultaneous scheduling of parts and AGVs problem.

MATERIALS AND METHODS

FMS is a highly automated machine cell, consisting of a group of processing workstations (usually CNC machine tools), interconnected by an automated material handling, automated storage system and controlled by a distributed computer System. This is based on the minimization of single objective functions,

Total operation completion time,

$$Oij = Tij + Pij \qquad (1)$$

Where *i*= job, *j*= operation, *Tij*= traveling time, and *Pij*= operation processing time.

$$\text{Job Completion Time, } C_i = \sum_{i=1}^{n} Oij \qquad (2)$$

$$\text{Makespan} = \text{Max}\,(C1, C2, C3\ldots Cn). \qquad (3)$$

$$\text{Rebust Factor} = 1/\text{Makespan} \qquad (4)$$

$$\text{Mean Tardiness: } \frac{1}{n}\sum_{i=1}^{n} T_i \qquad (5)$$

n = number of jobs; Ti = Tardiness

Population Size: 2XNo of Operations and No of Iterations are 1000 as the scheduling involves combinatorial problem, it is important to ensure that a suitable methodology is selected to optimize the problem. In addition to the ability of finding optimal solution, the method also has to be capable to find the solution as quick as possible.

Simultaneous Scheduling with PSVHA

Particle Swarm Optimization (PSO)

PSO is categorized as swarm intelligence algorithm. It is a population based algorithm that is inspired by the social Dynamics and emergent behavior that arises in socially organized colonies (16).It exploits a population of particles to search for promising regions of the search space (swarm). While each particle randomly moves within the search space with a specified velocity, it stores data of the best position it ever encountered. This is known as personal best (P best) position. Upon finishing each iteration, the Pbest position obtained by all individuals of the swarm is communicated to all of the particles in the population. The best value of Pbest will be selected as the global best position (G best) to represent the best position within the population. Each particle will search for best solution until it find stopping criteria. The movement of the particles towards the optimum is governed by equations similar to the following:

$V_{id}(t+1) = \omega V_{id}(t) + C_1 \text{ X Rand X } [P_{best}(t) - X_{id}(t)] + C2 \text{ X Rand X } [G_{best}(t) - X_{id}(t)]$ (6)

$X_{id}(t+1) = X_{id}(t) + V_{id}(t)$ (7)

- Initialize a population of particles with random positions and velocities on *d* dimensions in the search space.
- Update the velocity of each particle, using equation (6).
- Update the position of each particle, using equation (7).
- Map the position of each particle into solution space and evaluate its fitness value according to the desired optimization fitness function. At the same time, update pbest and gbest position if necessary.
- Loop to step 2 until a criterion is met, usually a sufficiently good fitness or a maximum number of iterations.

Vehicle Assignment Heuristic (VHA)

- Identify the position (vehicle previous location) and ready time (VRT) of the vehicle.
- Compute the traveling time (TRT1) from the position of the vehicle to the machine, where job is present (previous operation machine number).
- Add this traveling time to VRT, to know the completion time of vehicle empty trip (VET).
- Check whether the job has completed its previous operation or not. If necessary vehicle waits for the job.
- Compare the previous operation completion time and VET. Consider maximum value of these two for further calculations.
- Calculate the vehicle travel time (TRT2) from previous operation machine to present operation machine.
- Add this travel time to the value obtained in step 10. This will give completion time of vehicle loaded trip (VLT).

Experimental Setup

The FMS selected as the case in this work has the configuration as shown in Fig.No.1. The case and data set is adopted from (7) was originated by (5). In the case study, there are 10 job sets with each possessing four to eight different job sequences, dedicated machines and numbers were specified within the parenthesis is the processing time of a particular job in Table. No 2. Based on the job sets and four different layouts, 82 problems are generated. The problems are grouped into two categories. The first category contain problem sets which ti/pi ratios are greater than 0.25 while second category consists problems whose ti/pi ratios are lesser than 0.25. The digits indicate the job set and the layout respectively. Meanwhile, for second category, another digit is appended to the code. In this case, having a 0 or 1 as the last digit implies that the process times had been doubled or tripled, respectively.

RESULT AND DISCUSSION

Particle Swarm Vehicle Heuristic algorithm evolutionary procedure has been implemented in **java** language and simulated for various problems sets. The code is developed for different modules of the algorithm and also for the vehicle assignment heuristic. To study the effect of swarm optimization we consider hybridization with vehicle heuristic our observation concurs with the findings discussed with various algorithms (3) for flow shop scheduling problems. The experimental results, for the problems with t/p>0.25 and also with t/p <0.25, using PSVHA given in Table. No 1-2 Performance of these combinations are shown graphically in Fig.No.2and 3 gives the test results for the same problems and also results are compared with various algorithms (1)(15).

Table.No.1 Result Comparison for Job Rebust Factor (t/p>0.25)

PROB.No	t/p	STW	UGA	AGA	PGA	IACGA	PSVHA
1.1	0.59	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104
2.1	0.61	0.0095	0.0096	0.0098	0.0100	0.0100	0.0095
3.1	0.59	0.0095	0.0095	0.0101	0.0101	0.0101	0.0100
4.1	0.91	0.0085	0.0086	0.0089	0.0089	0.0089	0.0086
5.1	0.85	0.0112	0.0115	0.0115	0.0115	0.0115	0.0115
6.1	0.78	0.0083	0.0083	0.0085	0.0085	0.0085	0.0083
7.1	0.78	0.0084	0.0085	0.0087	0.0090	0.0087	0.0087
8.1	0.58	0.0062	0.0066	0.0062	0.0062	0.0062	0.0062
9.1	0.61	0.0083	0.0085	0.0085	0.0086	0.0086	0.0085
10.1	0.55	0.0065	0.0067	0.0068	0.0068	0.0067	0.0067
1.2	0.47	0.0122	0.0122	0.0122	0.0122	0.0122	0.0122
2.2	0.49	0.0125	0.0132	0.0132	0.0132	0.0132	0.0132
3.2	0.47	0.0114	0.0118	0.0118	0.0118	0.0118	0.0118
4.2	0.73	0.0108	0.0114	0.0114	0.0115	0.0114	0.0111
5.2	0.68	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145
6.2	0.54	0.0100	0.0102	0.0102	0.0102	0.0102	0.0102
7.2	0.62	0.0111	0.0118	0.0127	0.0127	0.0123	0.0118
8.2	0.46	0.0066	0.0070	0.0066	0.0066	0.0066	0.0066
9.2	0.49	0.0096	0.0098	0.0096	0.0098	0.0098	0.0096
10.2	0.44	0.0072	0.0073	0.0074	0.0074	0.0071	0.0073
1.3	0.52	0.0119	0.0119	0.0119	0.0119	0.0119	0.0119
2.3	0.54	0.0116	0.0116	0.0116	0.0116	0.0116	0.0116
3.3	0.51	0.0116	0.0116	0.0116	0.0116	0.0116	0.0116
4.3	0.8	0.0105	0.0110	0.0112	0.0112	0.0112	0.0111
5.3	0.74	0.0132	0.0133	0.0135	0.0135	0.0135	0.0135
6.3	0.54	0.0096	0.0096	0.0096	0.0097	0.0096	0.0096
7.3	0.68	0.0110	0.0114	0.0116	0.0120	0.0111	0.0111
8.3	0.5	0.0065	0.0070	0.0065	0.0065	0.0065	0.0065
9.3	0.53	0.0091	0.0095	0.0094	0.0095	0.0095	0.0094
10.3	0.49	0.0070	0.0070	0.0071	0.0072	0.0071	0.0073
1.4	0.74	0.0093	0.0097	0.0097	0.0097	0.0097	0.0097
2.4	0.77	0.0086	0.0088	0.0093	0.0093	0.0093	0.0088
3.4	0.74	0.0086	0.0088	0.0090	0.0090	0.0090	0.0088
4.4	1.14	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079
5.4	1.06	0.0101	0.0103	0.0104	0.0104	0.0104	0.0104
6.4	0.78	0.0083	0.0081	0.0083	0.0083	0.0082	0.0083
7.4	0.97	0.0074	0.0078	0.0079	0.0079	0.0077	0.0079
8.4	0.72	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061
9.4	0.76	0.0080	0.0081	0.0082	0.0082	0.0083	0.0081
10.4	0.69	0.0058	0.0061	0.0063	0.0063	0.0063	0.0061

Table.No.2. Result Comparison for Job Rebust Factor (t/p<0.25)

PROB.No	t/p	STW	UGA	AGA	PGA	IACGA	PSVHA
1.10	0.15	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079
2.10	0.15	0.0068	0.0068	0.0068	0.0068	0.0068	0.0068
3.10	0.15	0.0067	0.0068	0.0067	0.0067	0.0067	0.0067
4.10	0.15	0.0083	0.0084	0.0084	0.0084	0.0084	0.0084
5.10	0.21	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098
6.10	0.16	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054
7.10	0.19	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073
8.10	0.14	0.0034	0.0037	0.0034	0.0034	0.0034	0.0034
9.10	0.15	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057
10.10	0.14	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042

1.20	0.12	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081
2.20	0.12	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070
3.20	0.12	0.0068	0.0069	0.0069	0.0069	0.0069	0.0069
4.20	0.12	0.0086	0.0088	0.0088	0.0088	0.0088	0.0088
5.20	0.17	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
6.20	0.12	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055
7.20	0.15	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074
8.20	0.11	0.0035	0.0037	0.0035	0.0035	0.0035	0.0035
9.20	0.12	0.0057	0.0058	0.0058	0.0058	0.0058	0.0058
10.20	0.11	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
1.30	0.13	0.0082	0.0082	0.0082	0.0082	0.0082	0.0082
2.30	0.13	0.0068	0.0068	0.0068	0.0068	0.0068	0.0068
3.30	0.13	0.0067	0.0068	0.0068	0.0068	0.0068	0.0068
4.30	0.13	0.0086	0.0088	0.0088	0.0088	0.0088	0.0088
5.30	0.18	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
6.30	0.24	0.0054	0.0055	0.0055	0.0055	0.0055	0.0055
7.30	0.17	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073
8.30	0.13	0.0035	0.0037	0.0035	0.0035	0.0035	0.0035
9.30	0.13	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057
10.30	0.12	0.0042	0.0041	0.0042	0.0042	0.0042	0.0042
1.40	0.18	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081
2.41	0.13	0.0046	0.0046	0.0046	0.0046	0.0046	0.0046
3.40	0.18	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066
3.41	0.12	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
4.41	0.19	0.0056	0.0058	0.0058	0.0058	0.0058	0.0058
5.41	0.18	0.0065	0.0068	0.0068	0.0068	0.0068	0.0068
6.40	0.19	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054
7.40	0.24	0.0072	0.0073	0.0073	0.0073	0.0073	0.0073
7.41	0.16	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
8.40	0.18	0.0034	0.0037	0.0034	0.0034	0.0034	0.0034
9.40	0.19	0.0056	0.0057	0.0057	0.0057	0.0057	0.0057
10.40	0.17	0.0042	0.0041	0.0042	0.0042	0.0042	0.0041

Fig.No.1 Layouts for the Example Problem

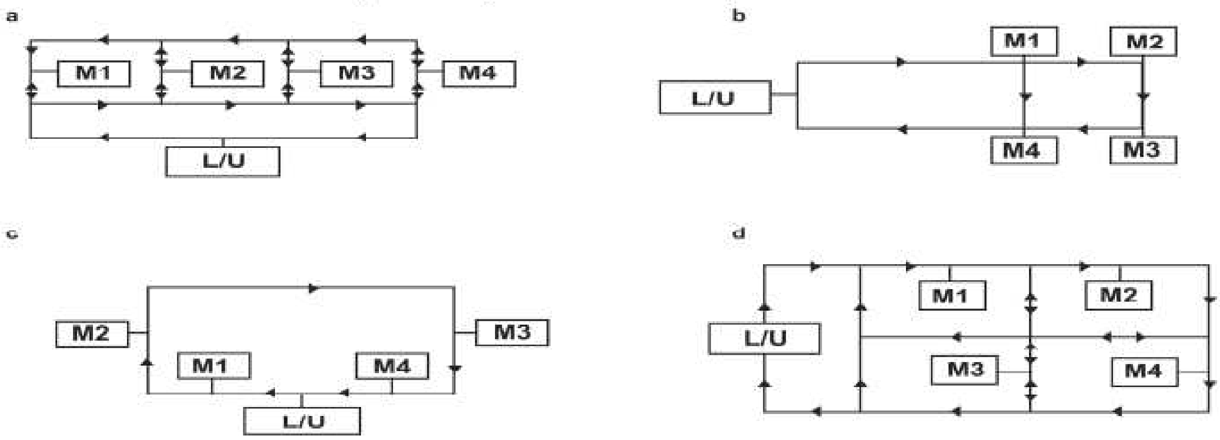

Fig.No.2 Performance Comparision (t/p>0.25)

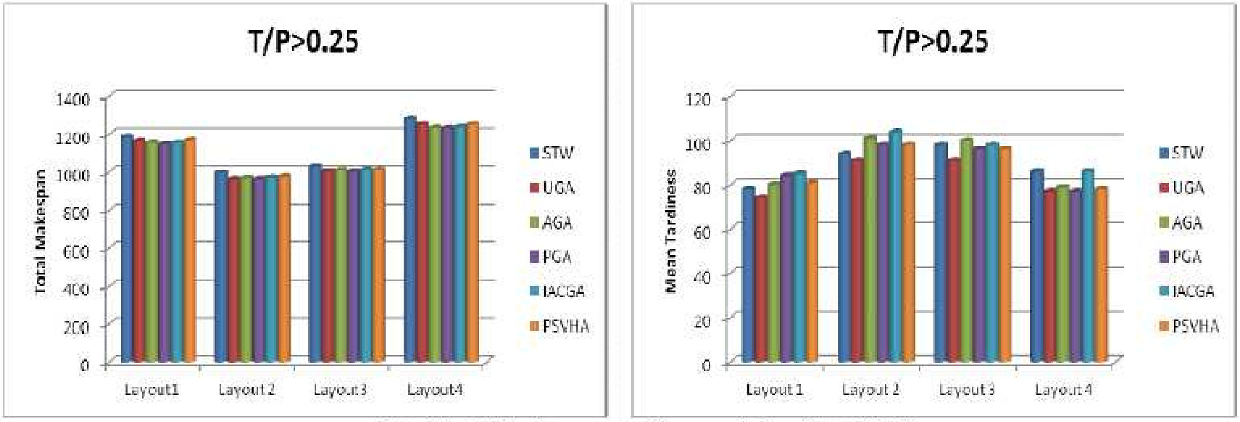

Fig.No.3 Performance Comparision (t/p<0.25)

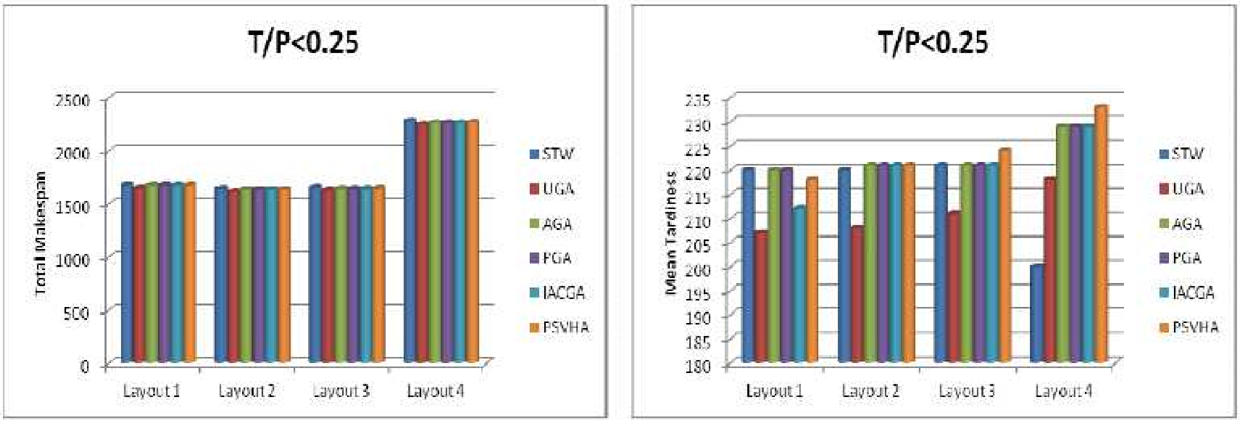

Table .No.5 Travel Time Data for the Example Problem

From/To	Layout-1					From/To	Layout-2				
	L/U	M1	M2	M3	M4		L/U	M1	M2	M3	M4
L/U	0	6	8	10	12	L/U	0	4	6	8	6
M1	12	0	6	8	10	M1	6	0	2	4	2
M2	10	6	0	6	8	M2	8	12	0	2	4
M3	8	8	6	0	6	M3	6	10	12	0	2
M4	6	10	8	6	0	M4	4	8	10	12	0
From/To	Layout-3					From/To	Layout-4				
	L/U	M1	M2	M3	M4		L/U	M1	M2	M3	M4
L/U	0	2	4	10	12	L/U	0	4	8	10	14
M1	12	0	2	8	10	M1	18	0	4	6	10
M2	10	12	0	6	8	M2	20	14	0	8	6
M3	4	6	8	0	2	M3	12	8	6	0	6
M4	2	4	6	12	0	M4	14	14	12	6	0

Table .No.6 Data for the Job Sets Used in Example Problems

JobSet-1	**JobSet-2**	**JobSet-3**	**JobSet-4**
Job 1: Ml(8); M2(16); M4(12) Job 2: Ml(20); M3(10); M2(18) Job 3: M3(12); M4(8); Ml(15) Job 4: M4(14); M2(18) Job 5: M3(10); Ml(15)	Job 1: Ml(10); M4(18) Job 2: M2(10); M4(18) Job 3: Ml(10); M3(20); Job 4: M2(10); M3(15); M4(12) Job 5: Ml(10); M2(15); M4(12) Job 6: Ml(10); M2(15); M3(12)	Job 1: Ml(16); M3(15) Job 2: M2(18); M4(15) Job 3: Ml(20); M2(10) Job 4: M3(15); M4(10) Job 5: Ml(8); M2(10); M3(15);M4(17) Job 6: M2(10); M3(15); M4(8);Ml(15)	Job 1: M4(11); Ml(10); M2(7) Job 2: M3(12); M2(10); M4(8) Job 3: M2(7); M3(10); Ml(9); M3(8) Job 4: M2(7); M4(8); Ml(12);M2(6) Job 5: Ml(9); M2(7); M4(8),M2(10);M3(8)

JobSet-5	JobSet-6	JobSet-7	JobSet-8
Job 1: Ml(6); M2(12); M4(9) Job 2: Ml(18); M3(6); M2(15) Job 3: M3(9); M4(3); Ml(12) Job 4: M4(6); M2(15) Job 5: M3(3); Ml(9)	Job 1: Ml(9); M2(11); M4(7) Job 2: Ml(19); M2(20); M4(13) Job 3: M2(14); M3(20); M4(9) Job 4: M2(14); M3(20); M4(9) Job 5: Ml(11); M3(16); M4(8) Job 6: Ml(10); M3(12); M4(10)	Job 1: Ml(6); M4(6) Job 2: M2(11); M4(9) Job 3: M2(9); M4(7) Job 4: M3(16); M4(7) Job 5: Ml(9); M3(18) Job 6: M2(13); M3(19); M4(6) Job 7: Ml(10); M2(9); M3(13) Job 8: Ml(l1); M2(9); M4(8)	Job 1: M2(12); M3(21);M4(11) Job 2: M2(12); M3(21);M4(11) Job 3: M2(12); M3(21);M4(11) Job 4: M2(12); M3(21);M4(11) Job 5: Ml(10); M2(14);M3(18); M4(9) Job 6: Ml(10); M2(14); M3(18); M4(9)
JobSet-9		**JobSet-10**	
Job 1: M3(9); Ml(12); M2(9); M4(6) ; Job 2: M3(16); M2(11); M4(9) Job 3: Ml(21); M2(18); M4(7) ; Job 4: M2(20); M3(22); M4(11) Job 5: M3(14); Ml(16); M2(13); M4(9)		Job 1: Ml(11); M3(19); M2(16);M4(13) ; Job 2: M2(21); M3(16); M4(14) Job 3: M3(8); M2(10); Ml(14); M4(9) ;Job 4: M2(13); M3(20); M4(10) Job 5: Ml(9); M3(16); M4(18) ;Job 6: M2(19); Ml(21); M3(11);M4(15)	

CONCLUSION

Based on the analysis conducted, it is found that PSVHA managed to provide a better optimization solution particularly for simultaneous scheduling of machines and automated vehicles in production environment. For future study, more consideration would be given on establishing unique PSVHA optimization method. Other PSVHA variations would be considered not only to shorten the tasks completion time but also to shorten calculation time. in the performance comparison graphs in t/p>0.25(Rebust Factor) when compared to various algorithms PSVHA gives the maximum rebust factor with comparison of STW and when compared in t/p<0.25 PSVHA gives maximum Rebust Factor when compared to various algorithms like STW it means minimization of completion time. and also in t/p>0.25(Tardiness) lateness of due date is minimized in PSVHA when compared to all the algorithms like AGA, PGA, STW and IACGA Future work would consider multiple objectives so as to reflect actual industrial applications Another limitation of the work is that it deals with single objective problem.

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