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Simultaneous Scheduling of Machines and AGVs in Flexible Manufacturing Environment with Maximization of Robust Factor Criterion

M Nageswararao
Department of Mechanical Engineering
J.N.T. University
Kakinada, Andhra Pradesh, India
e-mail:medikondu@kluniversity.in

K Narayanarao
Department of Mechanical Engineering
P.G.M.R. Polytechnic College
Vishakhapatnam, Andhra Pradesh India

G Rangajanardhana
Department of Mechanical Engineering
J.N.T. University
Kakinada, Andhra Pradesh, India

Abstract -**This paper examines the simultaneous scheduling of machines and two identical automated guided vehicles (AGVs) in a flexible manufacturing system (FMS).Optimum AGVs operation plays a crucial role in improving the performance of FMS. A genetic particle swarm vehicle heuristic algorithm (GPSVHA) is proposed and developed the code in JAVA to provide optimum sequence with maximizing the robust factor and minimization of mean tardiness and AGVs schedule for ten job sets and four lay-outs. The code will enhance the productivity, minimize the delivery cost and optimally utilize the entire fleet. the code provides better performance when compared with other algorithms, namely viz; sliding time window (STW), ulusoy genetic algorithm (UGA), abdelmaguid genetic algorithm (AGA), rao and reddy genetic algorithm (PGA), deroussi hybrid algorithm (DHA), chowdary genetic algorithm (CGA), hybrid genetic vehicle heuristic algorithm(HGVHA)**

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

I. Introduction

Developments in information technology Manufacturers are beneficial to manufacturers for delivering the product without any delay. Scientific advancement have been made for the past few years to implement flexible manufacturing system (FMS).simultaneous scheduling of machines and the automated guided vehicles (AGVs) operation, is one of the major task to be resolved .There are many elements of FMS scheduling, in which the more important factor to be considered is scheduling of multiple AGVs sharing each by several machines. Non-optimal delivery process will make other machine idle for in longer time.[1] proposed an algorithm to schedule vehicles and jobs in a decision making hierarchy based on the mixed integer programming applicable only for small number of jobs and vehicles.[2] have studied the performance of machines and AGVs scheduling rules using a simulation model. [3] introduce a beam search based algorithm for the simultaneous scheduling of machines and AGVs assuming the vehicle always return to the load/ unload station [4] explains material handling in FMS. [5] Developed modern tools for the design, modeling and evaluation of FMS. [6] Explains an approach to solve hybrid flow shop scheduling problems by artificial immune system.[7] developed a multi-objective production planning model in a flexible manufacturing environment Most of the researchers have considered the machine and vehicle scheduling as two independent problems.[8] have presented a deterministic off-line scheduling model treaty it as an integer programming problem and proposed a solution based on the concepts of project scheduling under resource constraints.[9] have considered an FMS with parallel identical machines arranged in a loop greatly it as the simultaneous scheduling problem using a dynamic programming approach.[10] have tested different machine and AGV scheduling rules in FMS against the mean flow time criterion. Another off-line model for simultaneous scheduling of machines and material handling system in an FMS for the make span minimization is presented by [11]. In their formulation, a non-linear mixed integer-programming model was addressed using the sliding time window approach. [12] Have examined the same problem using genetic algorithms. In their approach the chromosome represents both the Operation number and AGV assignment which requires development of special genetic operators. [13] addressed the simultaneous scheduling of material handling operations in a trip-based material handling system and machines in JIT environment.[14] presented a new hybrid genetic algorithm for the simultaneous scheduling problem for the make span minimization objective. The hybrid GA is composed of GA and a heuristic. The GA is used to address the first part of the problem that is theoretically similar to the job shop scheduling problem and the vehicle assignment is handled by a heuristic

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called vehicle assignment algorithm (VAA). [15] Have addressed the simultaneous job input sequence and vehicle dispatching for a single AGV system. They solved the problem using the branch and bound technique coupled with a discrete event simulation model. [16] Explain how material handling should be there in a complex and difficult FMS environment by using discrete event simulation model to analyze the material handling dispatching system of an FMS. [17] Explain the active scheduling algorithm, and theorems for the production scheduling problem. [18] Have considered the real time routing method for material handling transporting in automated manufacturing shops where the performance criterion is to max throughout. [19] Have developed a SIMAN based simulation model to determine the number of AGVs needed to meet the material handling requirements. Considering the idle time of vehicle, machine. [20] Have addresses the simultaneous scheduling problem as a multi objective problem in scheduling with conflicting objectives which are more complex and combinatorial in nature. They solved the problem by non- dominating sorting evolutionary algorithm.[21]Have described the scheduling algorithm which employs discrete simulation in combination with straightforward part dispatching rules in a dynamic fashion.[22] Have explained Job shop scheduling with explicit material handling considerations. This article considers the hybrid Meta heuristic algorithm (GPSVHA) for simultaneous scheduling of machines and AGVs in FMS utilizing the robust factor and tardiness function

II. Scheduling of Machines and AGVS FMS

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 function.

Total operation completion time, Oij = Tij + Pij (1)

Job Completion Time, Ci = $\sum_{i=1}^{n} O_{ij}$ (2)

Makespan = Max (C1, C2, C3…Cn) (3)

Robust factor = 1/ make span (4)

Tardiness, Tdi = Max ((Ci - Di), 0) (5)

Mean Tardiness = $\frac{1}{n}\sum_{i=1}^{n} Tdi$ (6)

Where

i: job number

j: operation number

n: number of jobs

Oij : Time taken for *j*th operation of *i*th job

Tij : Total travelling time for *i*th job before *j*th operation

Pij : Total processing time for *i*th job and *j*th operation

Di: Due time of *i*th job

III. Experimental Setup

The FMS selected in this work has the configuration as shown in Fig-1.[23], in this case study, there are 10 job sets with each possessing four to eight different job sequences, dedicated machines and numbers were specified within the parent thesis is the travel time and processing time of a particular job in Table. 1 & 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 t_i/p_i ratios are more than 0.25 while second category consists problems whose t_i /p_i ratios are less than 0.25.In this case, having a 0 or 1 as the last digit implies that the process times had been doubled or tripled, respectively. Furthermore, travel times are halved. There are four machines consist of computer numerical machines (CNCs) and two AGVs for material delivery purpose. While the types and number of machines are fixed, the speed of the vehicles is constant at 40 m/min. Furthermore, loading and unloading times are constant (0.5 min each). It is assumed that there is sufficient buffer space for input/output operations at each machine. Loading/ unloading equipments such as pallets are sufficiently allocated. Furthermore, the machine-to-machine distance and the distance between loading/ unloading machines are known. The distance matrix of load/unload stations to machines and machine-to-machine distances for all layouts are shown in Table-1. The load/unload (L/U) station acts as the distribution center for incoming raw materials and as the collection center for outgoing finished parts. All vehicles start from the L/U station initially though it does not need to return to L/U station in between delivery job. By using above methodology

IV. SCHEDULING WITH GPSVHA

Hybrid Meta heuristic algorithm is proposed and developed the code in JAVA to provide optimum Sequence with mean tardiness and robust factor and AGVs scheduling in FMS environment. The details of GPSVHA are discussed below.

A. Particle Swarm Optimization (PSO)

PSO is categorized as swarm intelligence algorithm. It is a population based algorithm [24].Which exploits the 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 known as the personal best (Pbest) position. Upon finishing the P best position obtained by individuals of the swarm is communicated to the particles in the population. The best value of Pbest will be selected as the global best position (Gbest) to represent the best position within the population. Each particle will search for best solution until it finds the stopping criterion. The movement of particles towards the optimum is governed by

$$Vid(t+1) = \omega\ Vid(t) + C1\ \varphi 1\ (Pid\ (t) - Xid\ (t)) + C2\ \varphi 2\ (gd(t) - Xid\ (t)) \qquad (7)$$

$$X_{id}\ (t+1) = X\ (t) + V\ (t+1) \qquad (8)$$

Where

- V_{id} (t) is the velocity of i^{th} particle on d^{th} dimension (t)
- V id (t+1) is the velocity of i^{th} particle on d^{th} dimension at instance (t+1) F
- X $_{id}$ (t) is the position of i^{th} particle on d^{th} dimension at instance (t)
- X $_{id}$ (t+1) is the position of i^{th} particle on d^{th} dimension at instance (t+1)
- P $_{id}$ (t) is the best the position of i^{th} particle on d^{th} dimension found so far
- $g_d(t)$ is the global best position of the swarm on d^{th} dimension found so far
- φ_1 and φ_2 stand for a uniformly distributed random numbers in the interval [0, 1]
- ω is called the "inertia factor"
- C_1 is "self-confidence" & C_2 is "swarm confidence".

C1 and C2 whose values can be varied between 0.1 and 0.5 in general and sometimes it are tested with values between 0.1 and 1.0. It is also observed in the literature that some of the researchers gave a value of 2.0 for both the parameters.

- 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.

B. Genetic Algorithm

- Select chromosomes from the initial population for crossover operation. Here tournament selection procedure is used which picks randomly k chromosomes and the winner (based on their fitness) among them is selected for crossover
- *Single point crossover:* a cut point is selected randomly and the genes on one side of the cut point in the first parent are exchanged with the genes on the same side of the second parent.
- *Two point crossover:* two cut points are selected randomly and the genes in between are exchanged.
- *Random Mutation:* two genes are randomly selected and their positions are exchanged. chromosome is repaired whenever necessary
- *Adjacent Mutation:* two genes adjacent to each other are exchanged.
- *Inverse Mutation:* a set of successive genes are selected and reversed. If this leads to infeasible chromosome then it is repaired.

- *Shift Mutation:* a gene is selected randomly and shifted to another randomly selected position and repaired whenever necessary.

C. Vehicle Assignment Heuristic

- 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 previous VET value. To get completion time of vehicle loaded trip (VLT).

D. Genetic Particle Swarm Vehicle Heuristic Algorithm

- Generate random numbers in between 0 and 1
- Arrange these random numbers in ascending order
- Random numbers are assigned with job numbers sequentially, for all the operations of each job
- Considering again the random numbers first generated
- Job number appears for the first time, it is treated as the first operation of that job and when the same job number appears again, it is treated as second operation of the same job and so on.
- Based on above steps sequence of operations are generated
- initial chromosome is selected from the particle swarm optimization (PSO) algorithm
- After getting the initial chromosome then implement all the procedural steps of cross over and mutation up to 1000 iterations with includes vehicle heuristic algorithm.

E. Implementation of GPSVHA

To implement the algorithm job set 1 and layout1 are considered with the following representation.

Job1	Job2	Job3	Job4	Job5
M_1 M_2 M_4	M_1 M_3 M_2	M_3 M_4 M_1	M_4 M_2	M_3 M_1
8 16 12	20 10 18	12 8 15	14 18	10 15
1 2 3	4 5 6	7 8 9	10 11	12 13

Random sequence of population twenty six is generated through the precedence relation i.e., operation of the same job set must be in increasing order but anywhere in the sequence. All the above procedural steps of GPSVHA are applied. The following sequence is obtained at 970th iteration:

4 1 10 7 12 2 8 5 13 11 3 9 6

For this sequence the robust factor value is calculated and presented in Table 3.

TABLE I. TRAVEL TIME DATA FOR THE EXAMPLE PROBLEM

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

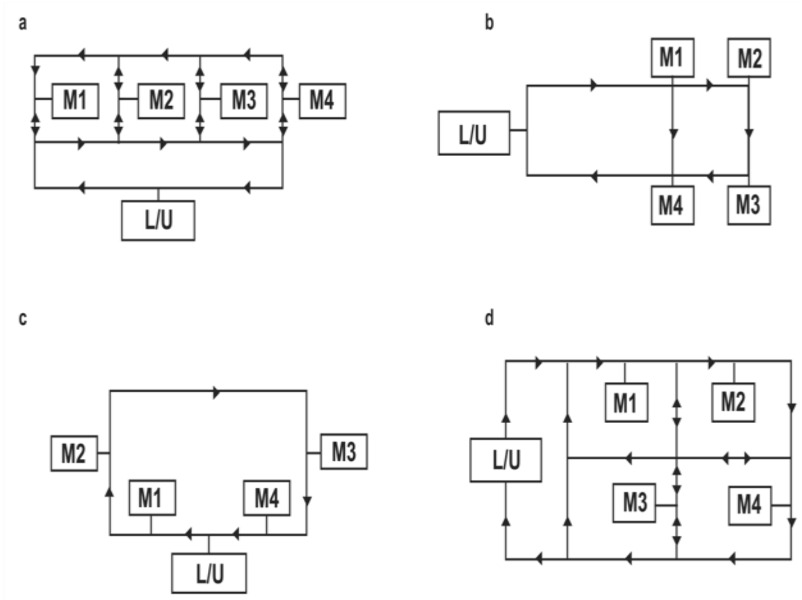


Figure 1. Layouts for the Example Problem

TABLE II. DATA FOR THE JOB SETS USED IN EXAMPLE PROBLEMS

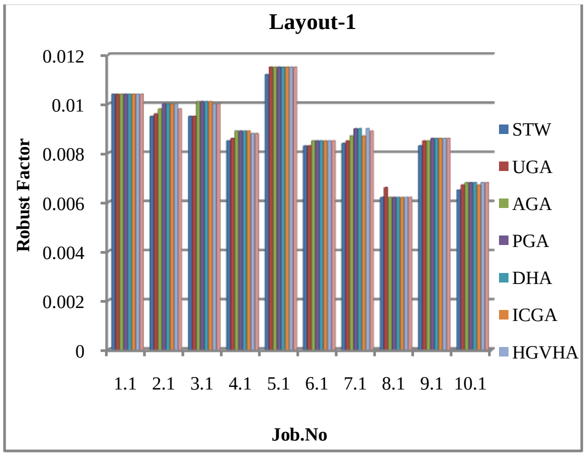
JobSet-1 Job 1: Ml(8); M2(16); M4(12) Job 2: Ml(20); M3(10); M2(18) Job 3: M3(12); M4(8); Ml(15) Job 4: M4(14); M2(18) Job 5: M3(10); Ml(15)	JobSet-2 Job 1: Ml(10); M4(18) Job 2: M2(10); M4(18) Job 3: Ml(10); M3(20); Job 4: M2(10); M3(15); M4(12) Job 5: Ml(10); M2(15); M4(12) Job 6: Ml(10); M2(15); M3(12)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

TABLE III. MODEL CALCULATION FOR ROBUST FACTOR WITH GPSVHA

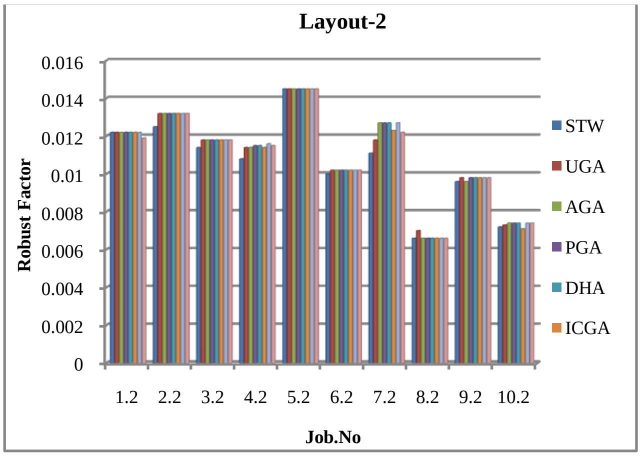
Job No	Machine Number	Vehicle Number	Travel Time	Job reach	Job ready	Process Time	Completion Time	Robust Factor
4	1	1	0	6	6	20	26	0.0384
1	1	2	0	6	26	8	34	0.0294
10	4	1	18	30	30	14	44	0.0227
7	3	2	18	28	28	12	40	0.025
12	3	1	36	46	46	10	56	0.0178
2	2	2	36	42	42	16	58	0.0172
8	4	1	46	52	52	8	60	0.0166
5	3	2	48	56	56	10	66	0.0151
13	1	2	56	64	64	15	79	0.0126
11	2	1	52	60	60	18	78	0.0128
3	4	1	60	68	68	12	80	0.0125
9	1	1	68	78	79	15	94	0.0106
6	2	2	72	78	78	18	96	0.0104

V. SIMULATION RESULTS AND DISCUSSION

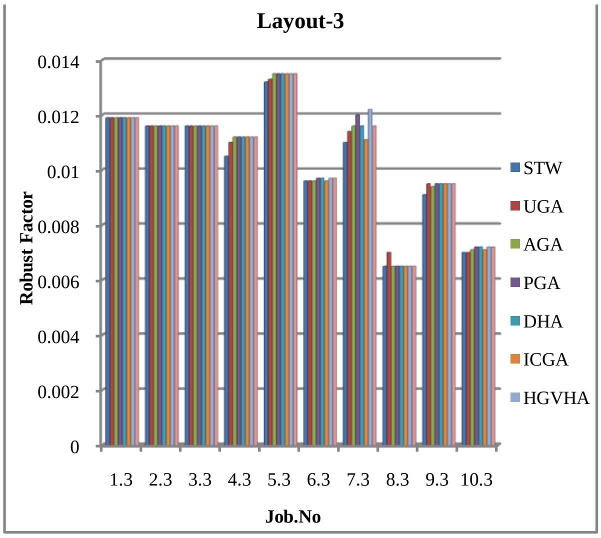
Genetic Particle Swarm Vehicle Heuristic algorithm evolutionary procedure has been implemented in JAVA language and simulated for various problem sets. The code is developed for different modules of the algorithm and also for the vehicle assignment heuristic. Population size is taken as double of the process numbers.



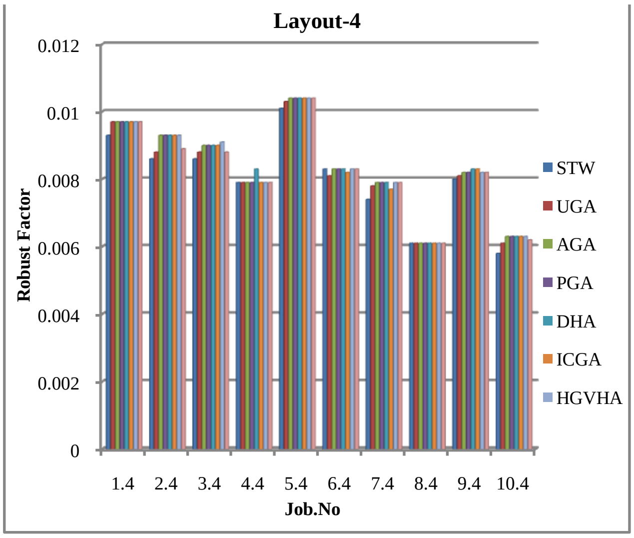
(a)



(b)



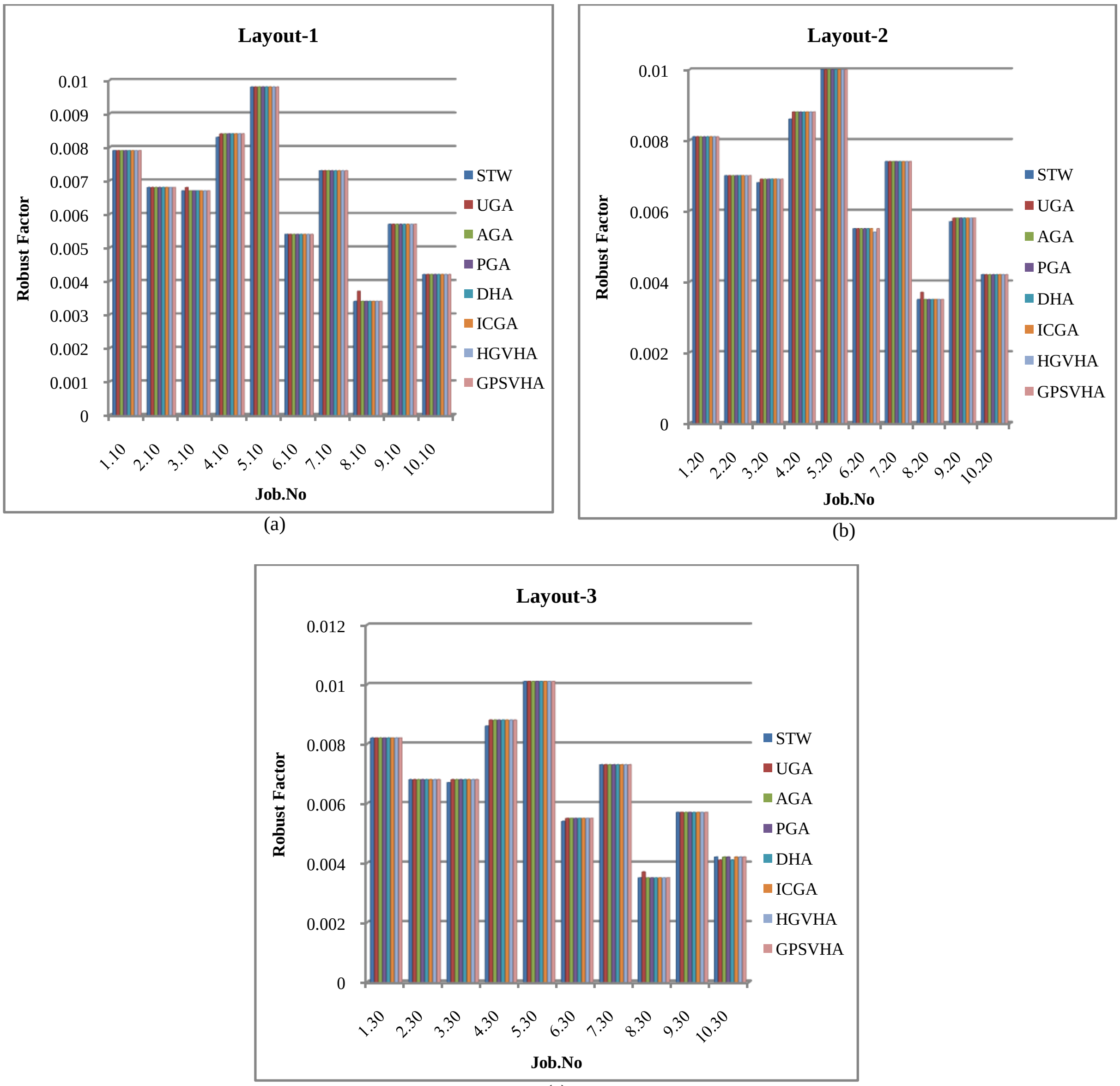
(c)



(d)

Figure 2. Performance comparison of job Robust factor (t/p>0.25)

The results are obtained after repeating the evolutionary procedure for 20 runs and the number of generations is carried out 1000 model calculation of robust factor shown in Table.3. In this work the performance of Genetic Particle Swarm Vehicle Heuristic Algorithm has been evaluated by testing it on 82 benchmark problems. To study the effect of operator's two types of swarm optimization one is particle swarm second one is Genetic particle swarm for this two algorithms we consider hybridization with vehicle heuristic our observation concurs with the findings discussed with various algorithms [25,26], for flow shop scheduling problems. The experimental results, for the problems with travel time /process time >0.25(t/p) and also with t/p <0.25, using GPSVHA given in Fig.2 to 5 which gives test results for the problems and compared results with those of various algorithms namely viz; sliding time window (STW), ulusoy genetic algorithm (UGA), abdelmaguid genetic algorithm (AGA), rao and reddy genetic algorithm (PGA), deroussi hybrid algorithm (DHA),chowdary genetic algorithm (CGA), hybrid genetic vehicle heuristic algorithm(HGVHA)



(a) (b) (c)

Figure 3. Performance Comparison of job Robust factor (t/p<0.25)

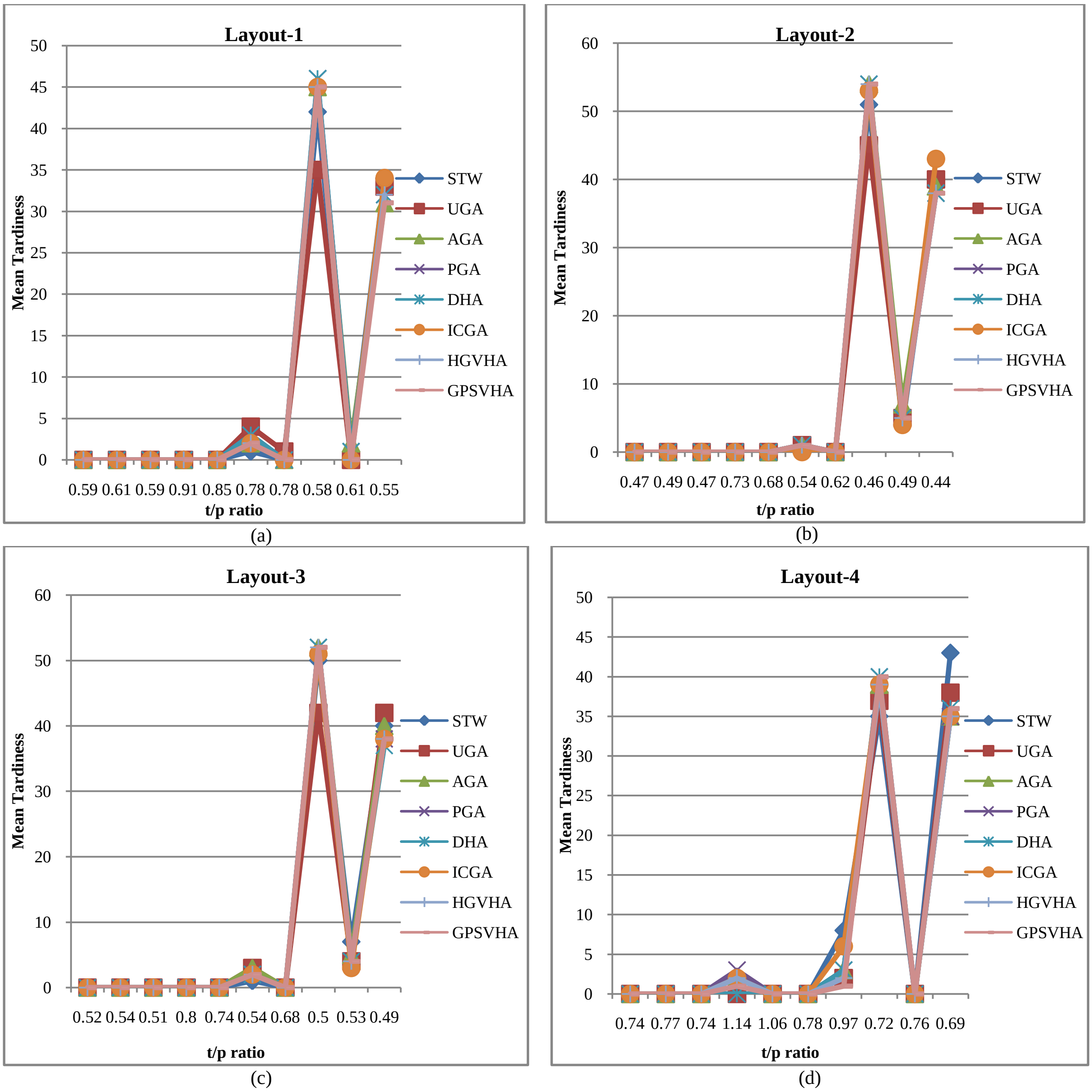


Figure 4. Performance comparison of job tardiness (t/p>0.25)

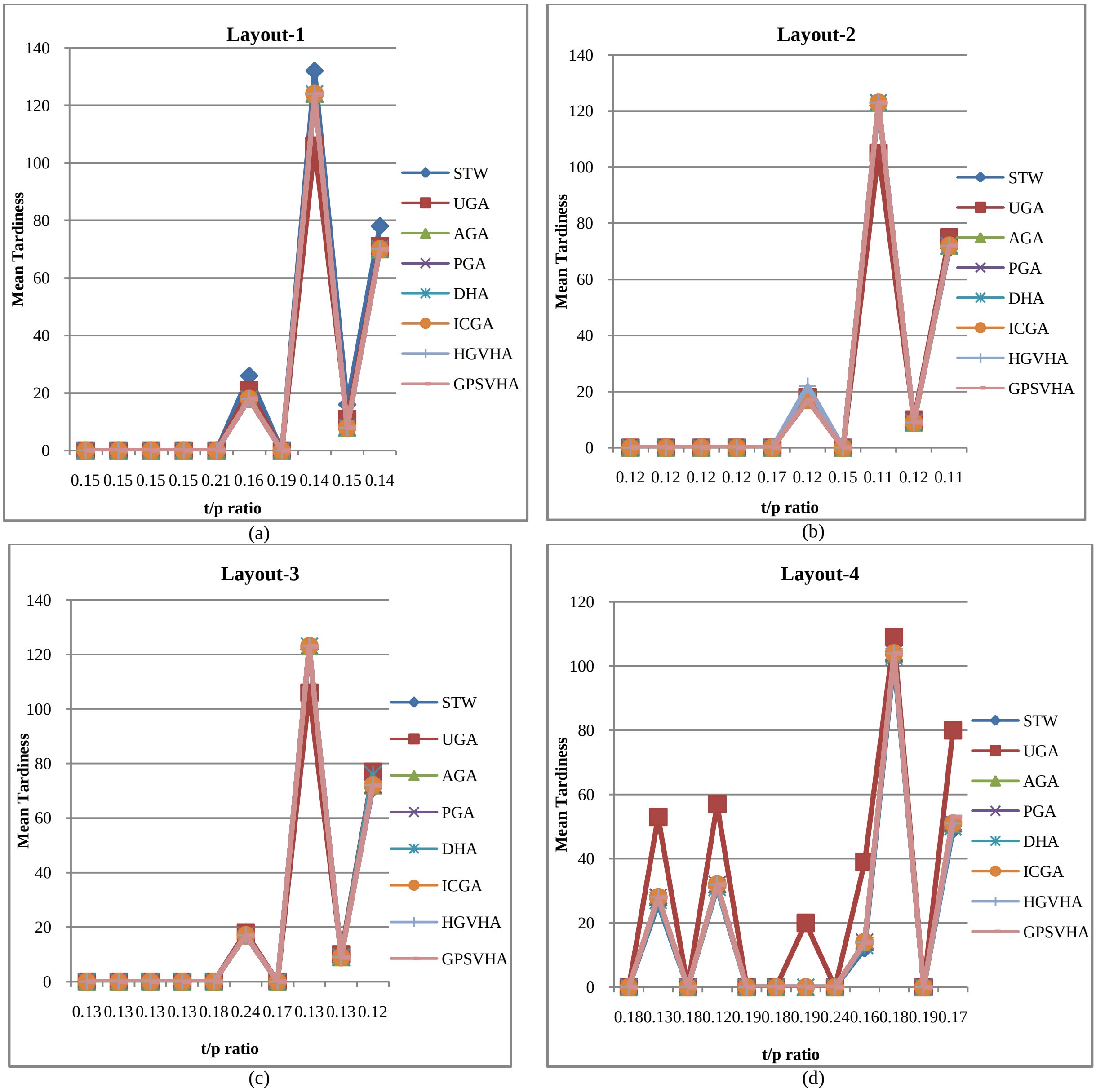


Figure 5. Performance comparison of job tardiness (t/p<0.25)

VI. CONCLUSION

From the present study, it is found that GPSVHA guided provides a better optimization solution particularly for simultaneous scheduling of machines and automated vehicles in production environment. Work is directed towards the performance GPSVHA gives maximize robust factor when compared to STW, UGA, IACGA for t/p<0.25 and HGVHA, DGTHA, STW for t/p>0.25. The performance of mean tardiness is best in GPSVHA when compared to algorithms like STW, UGA, and AGA. For t/p >0.25 and STW, DGTHA for t/p<0.25 the performance of GPSVHA is coincide with AGA, PGA, IACGA. Future work is directed towards GPSVHA variation to shorten the tasks completion time and calculation time in addition to the extension of single objective to multiple objectives for industrial applications.

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