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Simultaneous Scheduling of Machines and AGVs in Flexible Manufacturing System with Minimization of Tardiness Criterion

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Abstract

Optimum Automated Guided Vehicles (AGVs) operation plays a crucial role in improving the performance of Flexible Manufacturing System (FMS). One of the main elements in the implementation of AGV is task scheduling. This will enhance the productivity, Minimize delivery cost and optimally utilize the entire fleet. This enhance article Deals with Binary particle swarm Vehicle Heuristic Algorithm (BPSVHA) for simultaneous Scheduling of machines and AGVs adopting Rebust factor function and minimization of mean tardiness. The method is found to provide better solution

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

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1. Introduction

Developments in information technology Manufacturers are in a Position to deliver products with in a short period. Scientific Advancement Have been made over the past few years on the implementation of flexible manufacturing system (FMS), One of the major problems to be resolved is related to the simultaneous scheduling of machines and the automated guided vehicle (AGVs) operation. There are many elements of FMS scheduling. However, the more important factor that should be considered is scheduling of multiple AGVs. This is due to the fact that in a typical shop floor environment, AGV is shared by several machines. Assigning of a non-optimal delivery results would put other machines in longer idle time where as delaying of the delivery signifies delay on the

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processing chain of the material. Efficient AGV well reduce delivery cost and optimally utilize the entire fleet by Anh and De Koster [2005]. Studies are mostly on the hybrid approach to address scheduling and routing of AGV s by Bish,et al [2005]; Correa.et al. [2005] and Desaulniers.et al. [2003], multi-attribute dispatching rules by Grunow.et al [2004]; Iris[2001] and Mariagrazia and Maria [2007] and deadlock-resolutions by Naiqi and Mengchu [2007] and Nearchou [2004].This article considers the Binary Particle swarm vehicle heuristic algorithm(BPSVHA) for simultaneous scheduling of machines and AGVs in FMS utilizing the Rebust factor maximization function

2. SCHEDULING OF MACHINES AND AGVs IN 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 functions,

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

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

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

Makespan = Max (C1, C2, C3…Cn). (3)

Rebust Factor = 1/Makespan (4)

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

Where n = number of jobs; Ti = Tardiness

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

3. Simultaneous Scheduling with BPSVHA

3.1 Particle Swarm Optimization

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. 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 (Pbest) 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 (Gbest) 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:

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

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

- 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) and 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.

3.2 Binary Particle Swarm Vehicle Heuristic Algorithm

Let the number of tasks be T and number of machines and AGVs available be M. The proposed BPSVHA for the task allocation process is summarized as the following:

- Let M be the number of machines and AGVs, T be the number of tasks and P size of BPSVHA population
- Let PSO[i] be the position of the ith particle in the entire population with T-dimensional vector, whose entries' values belong to the set {1… M}
- Then PSO[i][j] be the processor number to which the jth task in the ith particle is assigned.
- Let fitness[i] be the objective function of the ith particle according to (1)
- Let V[i] be the traveled distance (or velocity) of a ith particle represented as an M-dimensional real-coded vector.
- Let Gbest be an index to global-best position. And Pbest[i] local-best position.
- Let Pbest_fitness[i] be the local-best fitness for the best position visited by the ith particle.

3.3 *Initialization:*

- For each particle i in the population:
- For each task j, initialize PSO[i][j] randomly from the set {1,…,N}
- Initialize V[i] randomly and Evaluate fitness[i]
- Initialize Gbest with the index of the particle with the best fitness (lowest cost) among the population.
- Initialize Pbest[i] with a copy of PSO[i] ≤ P
- Step 17: Optimization Process: Repeat until a number of generations, equal to twice the total number of tasks, are passed and Find Gbest such that fitness [Gbest] ≥ fitness[i] ≤ P For each particle i:
- Pbest[i] = PSO[i] if fitness[i] Pbest_fitness [i] ≤ P Update V[i] according to (6)
- Update PSO[i] according to (6) and (7) and Evaluate fitness[i] ≤ P

3.3 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 value obtained in step 22. This will give completion time of vehicle loaded trip

4. 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 Nageswararao.et al. [2014] was originated by Reddy and Rao [2006]. 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 distance matrix of load/unload stations to machines and machine-to-machine distances for all layouts are shown in Tables 5 and 6

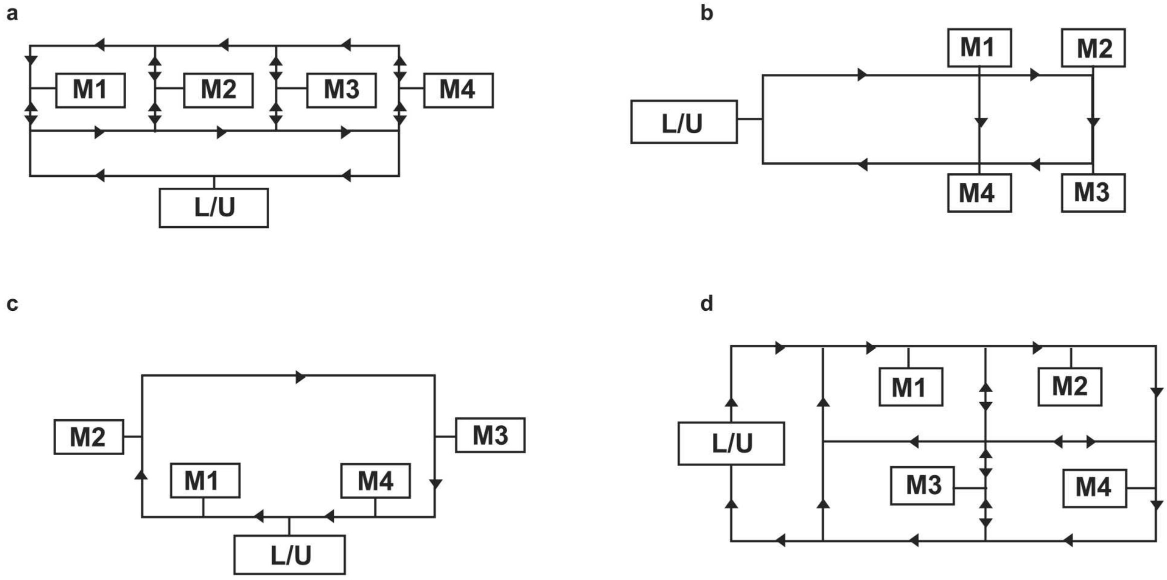


Fig.1 (a) layout 1 (b) layout 2 (c) layout 3 (d) layout 4

5. Numerical Simulations

Binary Particle Swarm Vehicle Heuristic algorithm evolutionary procedure has been implemented in C++ language. Simulations were performed on various problems 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. Results are obtained for 20 runs with 1000 iterations. The performance of Binary Particle Swarm Vehicle Heuristic Algorithm has been evaluated by testing it on 82 benchmark problems. Two types of swarm optimization algorithms. The particle swarm and the binary particle swarm are adapted to considering hybridization with vehicle heuristic. The present numerical simulations confirm the reported results of various algorithms by Tamer.et al. [2004]; Ulusoy.et al.[1997]; and Umit Bilge and Guduz Ulusoy [14].Table 1-4 provides the result of the problems with t/p>0.25 and t/p<0.25 using BPSVHA. Performances of these combinations are shown in Figure 2 and 3.

Table.1. Comparison of Performance for Job Rebust Factor (t/p>0.25)

P.No	t/p	STW	UGA	AGA	PGA	DGTHA	R M	A M	I M	S M	GVHA	BPSVHA
1.1	0.59	0.0104	0.0104	0.0104	0.0104	0.0104	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	0.0095	0.0095	0.0098	0.01	0.0099
3.1	0.59	0.0095	0.0095	0.0101	0.0101	0.0101	0.0098	0.0097	0.0098	0.01	0.01	0.0095
4.1	0.91	0.0085	0.0086	0.0089	0.0089	0.0089	0.0088	0.0087	0.0088	0.0088	0.0088	0.0085
5.1	0.85	0.0112	0.0115	0.0115	0.0115	0.0115	0.0114	0.0114	0.0111	0.0115	0.0115	0.0115
6.1	0.78	0.0083	0.0083	0.0085	0.0085	0.0085	0.0082	0.0082	0.0083	0.0083	0.0085	0.0083
7.1	0.78	0.0084	0.0085	0.0087	0.0090	0.0090	0.0087	0.0088	0.0088	0.009	0.009	0.0080
8.1	0.58	0.0062	0.0066	0.0062	0.0062	0.0062	0.0062	0.0062	0.0062	0.0062	0.0062	0.0070
9.1	0.61	0.0083	0.0085	0.0085	0.0086	0.0086	0.0084	0.0084	0.0085	0.0085	0.0086	0.0087
10.1	0.55	0.0065	0.0067	0.0068	0.0068	0.0068	0.0065	0.0065	0.0066	0.0067	0.0068	0.0065
1.2	0.47	0.0122	0.0122	0.0122	0.0122	0.0122	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	0.0125	0.0125	0.0128	0.0128	0.0132	0.0132
3.2	0.47	0.0114	0.0118	0.0118	0.0118	0.0118	0.0118	0.0114	0.0115	0.0118	0.0118	0.0125
4.2	0.73	0.0108	0.0114	0.0114	0.0115	0.0115	0.0106	0.0106	0.0109	0.0112	0.0116	0.0114
5.2	0.68	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0137	0.0137	0.0145	0.0145	0.0139

6.2	0.54	0.01	0.0102	0.0102	0.0102	0.0102	0.0098	0.0098	0.01	0.0101	0.0102	0.0111
7.2	0.62	0.0111	0.0118	0.0127	0.0127	0.0127	0.0122	0.0122	0.0122	0.0127	0.0127	0.0133
8.2	0.46	0.0066	0.007	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0073
9.2	0.49	0.0096	0.0098	0.0096	0.0098	0.0098	0.0093	0.0096	0.0095	0.0098	0.001	0.0100
10.2	0.44	0.0072	0.0073	0.0074	0.0074	0.0074	0.0072	0.0073	0.0074	0.0074	0.0074	0.0074
1.3	0.52	0.0119	0.0119	0.0119	0.0119	0.0119	0.0119	0.0116	0.0118	0.0119	0.0119	0.0119
2.3	0.54	0.0116	0.0116	0.0116	0.0116	0.0116	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	0.0111	0.0114	0.0116	0.0116	0.0119
4.3	0.8	0.0105	0.011	0.0112	0.0112	0.0112	0.0106	0.0109	0.0109	0.0111	0.0112	0.0110
5.3	0.74	0.0132	0.0133	0.0135	0.0135	0.0135	0.0132	0.0135	0.0135	0.0135	0.0135	0.0132
6.3	0.54	0.0096	0.0096	0.0096	0.0097	0.0097	0.0094	0.0094	0.0094	0.0097	0.0097	0.0099
7.3	0.68	0.011	0.0114	0.0116	0.0120	0.0116	0.0116	0.0118	0.0118	0.012	0.0122	0.0106
8.3	0.5	0.0065	0.007	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0071
9.3	0.53	0.0091	0.0095	0.0094	0.0095	0.0095	0.0093	0.0093	0.0094	0.0094	0.0095	0.0098
10.3	0.49	0.007	0.007	0.0071	0.0072	0.0072	0.0069	0.007	0.0072	0.0071	0.0072	0.0071
1.4	0.74	0.0093	0.0097	0.0097	0.0097	0.0097	0.0097	0.0096	0.0094	0.0097	0.0097	0.0097
2.4	0.77	0.0086	0.0088	0.0093	0.0093	0.0093	0.0089	0.0089	0.009	0.0093	0.0093	0.0088
3.4	0.74	0.0086	0.0088	0.009	0.0090	0.0090	0.0086	0.0089	0.0089	0.009	0.0091	0.0084
4.4	1.14	0.0079	0.0079	0.0079	0.0079	0.0083	0.0078	0.0078	0.0078	0.0079	0.0079	0.0079
5.4	1.06	0.0101	0.0103	0.0104	0.0104	0.0104	0.0102	0.0102	0.0104	0.0104	0.0104	0.0104
6.4	0.78	0.0083	0.0081	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083
7.4	0.97	0.0074	0.0078	0.0079	0.0079	0.0079	0.0078	0.0078	0.0079	0.0079	0.0079	0.0079
8.4	0.72	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0063
9.4	0.76	0.008	0.0081	0.0082	0.0082	0.0083	0.0081	0.0081	0.0082	0.0082	0.0082	0.0082
10.4	0.69	0.0058	0.0061	0.0063	0.0063	0.0063	0.0061	0.0062	0.0063	0.0063	0.0063	0.0058

Table 2. Comparison of Performance for Job Rebust Factor ($t/p<0.25$)

P.No	t/p	STW	UGA	AGA	PGA	DGTHA	R.M	A.M	I.M	S.M	HGVHA	BPSVHA
1.10	0.15	0.008	0.008	0.008	0.0079	0.0079	0.008	0.008	0.008	0.008	0.0079	0.0079
2.10	0.15	0.007	0.007	0.007	0.0068	0.0068	0.007	0.007	0.007	0.007	0.0068	0.0074
3.10	0.15	0.007	0.007	0.007	0.0067	0.0067	0.007	0.007	0.007	0.007	0.0067	0.0067
4.10	0.15	0.008	0.008	0.008	0.0084	0.0084	0.008	0.008	0.008	0.008	0.0084	0.0084
5.10	0.21	0.01	0.01	0.01	0.0098	0.0098	0.01	0.01	0.01	0.01	0.0098	0.0098
6.10	0.16	0.005	0.005	0.005	0.0054	0.0054	0.005	0.005	0.005	0.005	0.0054	0.0054
7.10	0.19	0.007	0.007	0.007	0.0073	0.0073	0.007	0.007	0.007	0.007	0.0073	0.0073
8.10	0.14	0.003	0.004	0.003	0.0034	0.0034	0.003	0.003	0.003	0.003	0.0034	0.0034
9.10	0.15	0.006	0.006	0.006	0.0057	0.0057	0.006	0.006	0.006	0.006	0.0057	0.0057
10.10	0.14	0.004	0.004	0.004	0.0042	0.0042	0.004	0.004	0.004	0.004	0.0042	0.0042
1.20	0.12	0.008	0.008	0.008	0.0081	0.0081	0.008	0.008	0.008	0.008	0.0081	0.0081
2.20	0.12	0.007	0.007	0.007	0.0070	0.0070	0.007	0.007	0.007	0.007	0.007	0.0070
3.20	0.12	0.007	0.007	0.007	0.0069	0.0069	0.007	0.007	0.007	0.007	0.0069	0.0076
4.20	0.12	0.009	0.009	0.009	0.0088	0.0088	0.009	0.009	0.009	0.009	0.0088	0.0088
5.20	0.17	0.01	0.01	0.01	0.0100	0.0100	0.01	0.01	0.01	0.01	0.01	0.0100
6.20	0.12	0.006	0.006	0.006	0.0055	0.0055	0.006	0.005	0.006	0.006	0.0055	0.0055
7.20	0.15	0.007	0.007	0.007	0.0074	0.0074	0.007	0.007	0.007	0.007	0.0074	0.0074
8.20	0.11	0.004	0.004	0.004	0.0035	0.0035	0.004	0.004	0.004	0.004	0.0035	0.0035
9.20	0.12	0.006	0.006	0.006	0.0058	0.0058	0.006	0.006	0.006	0.006	0.0058	0.0059
10.20	0.11	0.004	0.004	0.004	0.0042	0.0042	0.004	0.004	0.004	0.004	0.0042	0.0042

1.30	0.13	0.008	0.008	0.008	0.0082	0.0082	0.008	0.008	0.008	0.008	0.0082	0.0082
2.30	0.13	0.007	0.007	0.007	0.0068	0.0068	0.007	0.007	0.007	0.007	0.0068	0.0068
3.30	0.13	0.007	0.007	0.007	0.0068	0.0068	0.007	0.007	0.007	0.007	0.0068	0.0068
4.30	0.13	0.009	0.009	0.009	0.0088	0.0088	0.009	0.008	0.008	0.009	0.0088	0.0088
5.30	0.18	0.01	0.01	0.01	0.0101	0.0101	0.01	0.01	0.01	0.01	0.0101	0.0101
6.30	0.24	0.005	0.006	0.006	0.0055	0.0055	0.006	0.005	0.005	0.006	0.0055	0.0055
7.30	0.17	0.007	0.007	0.007	0.0073	0.0073	0.007	0.007	0.007	0.007	0.0073	0.0073
8.30	0.13	0.004	0.004	0.004	0.0035	0.0035	0.004	0.004	0.004	0.004	0.0035	0.0035
9.30	0.13	0.006	0.006	0.006	0.0057	0.0057	0.006	0.006	0.006	0.006	0.0057	0.0057
10.30	0.12	0.004	0.004	0.004	0.0042	0.0041	0.004	0.004	0.004	0.004	0.0042	0.0042
1.40	0.18	0.008	0.008	0.008	0.0081	0.0081	0.008	0.008	0.008	0.008	0.0081	0.0081
2.41	0.13	0.005	0.005	0.005	0.0046	0.0046	0.005	0.005	0.005	0.005	0.0046	0.0046
3.40	0.18	0.007	0.007	0.007	0.0066	0.0066	0.007	0.007	0.007	0.007	0.0066	0.0066
3.41	0.12	0.005	0.005	0.005	0.0045	0.0045	0.005	0.005	0.005	0.005	0.0045	0.0045
4.41	0.19	0.006	0.006	0.006	0.0058	0.0056	0.006	0.006	0.006	0.006	0.0058	0.0056
5.41	0.18	0.007	0.007	0.007	0.0068	0.0068	0.007	0.007	0.007	0.007	0.0068	0.0068
6.40	0.19	0.005	0.005	0.005	0.0054	0.0054	0.005	0.005	0.005	0.005	0.0054	0.0054
7.40	0.24	0.007	0.007	0.007	0.0073	0.0073	0.007	0.007	0.007	0.007	0.0073	0.0073
7.41	0.16	0.005	0.005	0.005	0.0049	0.0049	0.005	0.005	0.005	0.005	0.0049	0.0049
8.40	0.18	0.003	0.004	0.003	0.0034	0.0034	0.003	0.003	0.003	0.003	0.0034	0.0034
9.40	0.19	0.006	0.006	0.006	0.0057	0.0057	0.006	0.006	0.006	0.006	0.0057	0.0057
10.40	0.17	0.004	0.004	0.004	0.0042	0.0042	0.004	0.004	0.004	0.004	0.0042	0.0042

Table 3. Comparison of Performance for Job Tardiness (t/p>0.25)

P.No	t/p	STW	UGA	AGA	PGA	DGTHA	R M	A M	I M	S M	HGVHA	BPSVHA
1.1	0.59	0	0	0	0	0	0	0	0	0	0	0
2.1	0.61	0	0	0	0	0	0	0	0	0	0	0
3.1	0.59	0	0	0	0	0	0	0	0	0	0	0
4.1	0.91	0	0	0	0	0	0	0	0	0	0	1
5.1	0.85	0	0	0	0	0	0	0	0	0	0	0
6.1	0.78	1	4	2	3	2	4	4	3	4	2	3
7.1	0.78	0	1	0	0	0	0	0	0	0	0	8
8.1	0.58	42	35	45	48	45	43	43	43	45	45	25
9.1	0.61	1	0	2	1	0	1	1	0	2	0	0
10.1	0.55	34	34	31	32	31	36	36	34	34	32	36
1.2	0.47	0	0	0	0	0	0	0	0	0	0	0
2.2	0.49	0	0	0	0	0	0	0	0	0	0	0
3.2	0.47	0	0	0	0	0	0	0	0	0	0	0
4.2	0.73	0	0	0	0	0	0	0	0	0	0	0
5.2	0.68	0	0	0	0	0	0	0	0	0	0	0
6.2	0.54	0	1	1	1	0	2	2	1	2	1	0
7.2	0.62	0	0	0	0	0	0	0	0	0	0	0
8.2	0.46	51	45	54	54	53	51	51	52	54	54	43
9.2	0.49	4	5	7	5	4	8	4	6	5	5	6

10.2	0.44	39	40	39	38	37	38	37	37	39	38	42
1.3	0.52	0	0	0	0	0	0	0	0	0	0	0
2.3	0.54	0	0	0	0	0	0	0	0	0	0	0
3.3	0.51	0	0	0	0	0	0	0	0	0	0	0
4.3	0.8	0	0	0	0	0	0	0	0	0	0	0
5.3	0.74	0	0	0	0	0	0	0	0	0	0	0
6.3	0.54	1	3	3	2	1	3	3	4	2	2	1
7.3	0.68	0	0	0	0	0	0	0	0	0	0	0
8.3	0.5	50	42	52	52	51	50	50	51	52	52	41
9.3	0.53	7	4	5	4	3	5	4	4	5	4	2
10.3	0.49	40	42	40	38	36	41	39	37	40	38	40
1.4	0.74	0	0	0	0	0	0	0	0	0	0	0
2.4	0.77	0	0	0	0	0	0	0	0	0	0	0
3.4	0.74	0	0	0	0	0	0	0	0	0	0	0
4.4	1.14	0	0	2	2	0	2	2	3	3	2	0
5.4	1.06	0	0	0	0	0	0	0	0	0	0	0
6.4	0.78	0	0	0	0	0	0	0	0	0	0	0
7.4	0.97	8	2	3	2	2	3	2	2	3	2	0
8.4	0.72	35	37	39	39	39	39	39	38	39	39	32
9.4	0.76	0	0	0	0	0	0	0	0	0	0	0
10.4	0.69	43	38	35	34	35	37	35	35	35	35	45

Table 4. Comparison of Performance or Job Tardiness (t/p<0.25)

P.No	t/p	STW	UGA	AGA	PGA	DGTHA	R.M	A.M	I.M	S.M	HGVHA	BPSVHA
1.10	0.15	0	0	0	0	0	0	0	0	0	0	0
2.10	0.15	0	0	0	0	0	0	0	0	0	0	0
3.10	0.15	0	0	0	0	0	0	0	0	0	0	0
4.10	0.15	0	0	0	0	0	0	0	0	0	0	0
5.10	0.21	0	0	0	0	0	0	0	0	0	0	0
6.10	0.16	18	18	18	18	18	19	20	17	18	18	19
7.10	0.19	0	0	0	0	0	0	0	0	0	0	0
8.10	0.14	124	106	124	124	124	123	122	123	124	124	125
9.10	0.15	8	11	8	8	8	13	12	8	8	8	9
10.10	0.14	70	72	70	70	70	69	70	69	70	70	71
1.20	0.12	0	0	0	0	0	0	0	0	0	0	0
2.20	0.12	0	0	0	0	0	0	0	0	0	0	0
3.20	0.12	0	0	0	0	0	0	0	0	0	0	0
4.20	0.12	0	0	0	0	0	0	0	0	0	0	0
5.20	0.17	0	0	0	0	0	0	0	0	0	0	0
6.20	0.12	18	18	17	17	18	17	18	17	17	17	18
7.20	0.15	0	0	0	0	0	0	0	0	0	0	0
8.20	0.11	122	105	123	123	123	122	121	122	123	123	124
9.20	0.12	9	10	9	9	9	10	10	9	9	9	7

10.20	0.11	71	75	72	72	72	77	74	73	72	72	73
1.30	0.13	0	0	0	0	0	0	0	0	0	0	0
2.30	0.13	0	0	0	0	0	0	0	0	0	0	0
3.30	0.13	0	0	0	0	0	0	0	0	0	0	0
4.30	0.13	0	0	0	0	0	0	0	0	0	0	0
5.30	0.18	0	0	0	0	0	0	0	0	0	0	0
6.30	0.24	18	18	17	17	17	16	19	18	17	17	17
7.30	0.17	0	0	0	0	0	0	0	0	0	0	0
8.30	0.13	122	106	123	123	123	122	122	122	123	123	123
9.30	0.13	10	10	9	9	9	12	11	9	9	9	11
10.30	0.12	71	77	72	72	76	75	74	72	72	72	72
1.40	0.18	0	0	0	0	0	0	0	0	0	0	0
2.41	0.13	22	29	28	28	27	27	27	27	28	28	27
3.40	0.18	0	0	0	0	0	0	0	0	0	0	0
3.41	0.12	27	33	32	32	31	31	31	31	32	32	31
4.41	0.19	0	0	0	0	0	0	0	0	0	0	0
5.41	0.18	0	0	0	0	0	0	0	0	0	0	0
6.40	0.19	0	0	0	0	0	0	0	0	0	0	0
7.40	0.24	0	0	0	0	0	0	0	0	0	0	0
7.41	0.16	8	15	14	14	13	13	13	13	14	14	13
8.40	0.18	98	85	104	104	103	103	103	103	104	104	103
9.40	0.19	0	0	0	0	0	0	0	0	0	0	0
10.40	0.17	45	56	51	51	50	54	53	52	51	51	50

Fig..2 Performance Evaluation for (t/p>0.25)

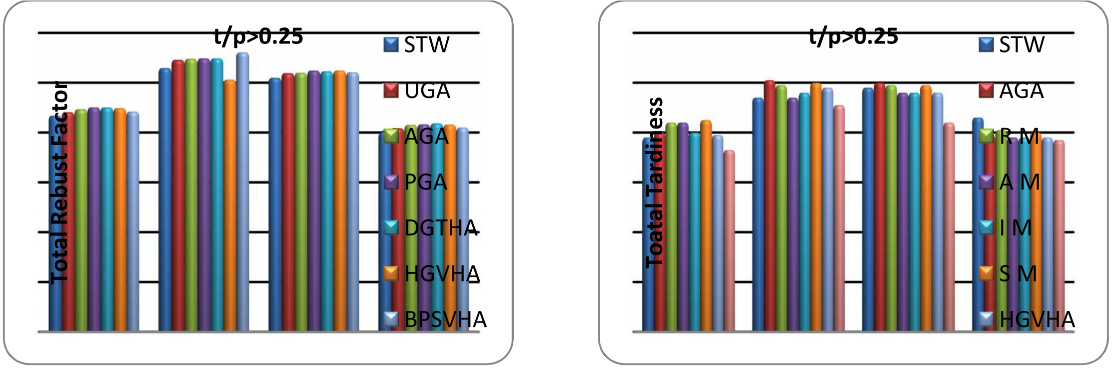
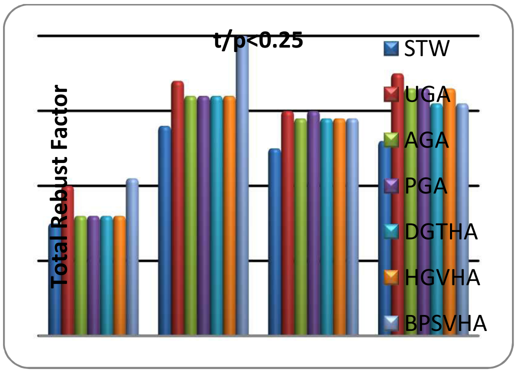
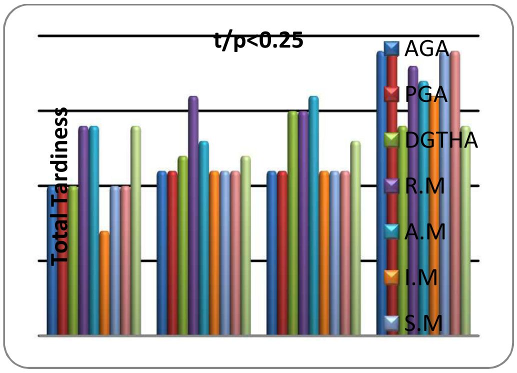


Fig..3. Performance Evaluation for (t/p<0.25)





APPENDIX-**A**

Table .No.A1 Travel Time Data [14] for the example Problems

From/To	Layout-1				
	L/U	M1	M2	M3	M4
L/U	0	6	8	10	12
M1	12	0	6	8	10
M2	10	6	0	6	8
M3	8	8	6	0	6
M4	6	10	8	6	0

From/To	Layout-2				
	L/U	M1	M2	M3	M4
L/U	0	4	6	8	6
M1	6	0	2	4	2
M2	8	12	0	2	4
M3	6	10	12	0	2
M4	4	8	10	12	0

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

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

Table .No.A2. Data for the Job Sets [14] for the 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)	**JobSet-8** Job 1: M2(12); M3(21);M4(11) Job 2: M2(12); M3(21);M4(11)

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(ll); M2(9); M4(8)	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)

6. Conclusions

From the present numerical simulations, one can conclude that BPSVHA provides better optimization solution for simultaneous scheduling of machines and automated vehicles in production environment. Performance for in t/p>0.25(Rebust Factor) indicated that BPSVHA gives the maximum rebust factor when compared to those of HGVHA, UGA and STW.For the case t/p<0.25 BPSVHA gives maximum rebust factor when compared to those of HGVHA, DGTHA, PGA, UGA and AGA it is well known fact that maximization of rebust factor implies minimization of completion time. Performance for in t/p>0.25(Tardiness) indicates that BPSVHA gives minimum lateness of due date when compared to those of AGA, PGA, DGTHA, R.M, A.M, I.M and S.M. for the case t/p<0.25(Tardiness) BPSVHA gives minimum tardiness when compared to those of R.M and A.M. Future work would consider multiple objectives so as to reflect actual industrial applications

References

Anh. T. Le., De Koster, M. B. M. (2005) "On-line dispatching rules for vehicle-based internal transport systems, *International Journal of Production Research,* vol. 43, Number 8 / April 15, 2005 pp. 1711 - 1728

Bish. E. K, Chen. F. Y. Leong., Y. T Nelson. B. L. . Ng. J. W. C, and Simchi-Levi. D. (2005) "Dispatching vehicles in a mega container terminal *OR Spectrum,* vol. 27, Number 4 pp. 491 – 506.

Corréa A. I., Langevin, A. and Rousseau, L.-M. (2005) "Scheduling and routing of automated guided vehicles: A hybrid approach, *Computers & Operations Research*

Desaulniers.G, Langevin. D, Riopel, and. Villeneuve.B (2003) "Dispatching and Conflict-Free Routing of Automated Guided Vehicles: An Exact Approach, *International Journal of Flexible Manufacturing Systems* vol. 15, Number 4, pp. 309 – 331

Grunow.M ,. Günther.H, and Lehmann.M,(2004) "Dispatching multi-load AGVs in highly automated seaport container terminals, *OR Spectrum,* vol. 26, Number 2, 211-235

Iris Vis., F.A. René de Koster, Kees Jan Roodbergen, Leon W.P. Peeters (2001). Determination of the number of AGVs required at a semi-automated container terminal. Journal of the Operational Research Society. Vol 52 pp 409-417

Mariagrazia Dotoli and Maria Pia Fanti (2007). Deadlock Detection and Avoidance Strategies for Automated Storage and Retrieval Systems. IEEE Transactions on Systems, Man and Cybernetics – Part C: Applications and Reviews, Vol 37, No 4

NaiQi Wu ., MengChu Zhou (2007).Shortest Routing of Bidirectional Automated Guided Vehicles Avoiding Deadlock and Blocking. IEEE/ASME Transactions on Mechatronics. Vol. 12 Issue 1 pp 63-72

Nearchou. A C, (2004) “The effect of various operators on the genetic search for large scheduling problems”, International Journal of Production Economics, No. 88, pp 191-203

Nageswararao.Medikondu, Dr.Narayanarao.K., Dr.Ranagajanardhana.G. “Simultaneous Scheduling of Machines and AGV’s in FMS with Rebust Factor Maximization Criteria” Advance Research and Innovations in Mechanical, Material Science, Industrial Engineering and Management - ICARMMIEM-2014 ISBN 978-93-82338-97-0 © 2014 Bonfring P.No 118-122

Reddy. B. S. P., Rao. C. S. P. (2006) “A hybrid multi-objective GA for simultaneous scheduling of machines and AGVs in FMS”, International Journal of Advanced Manufacturing Technology, 31, pp 602-613

Tamer.F., Abdelmaguid, Ashraf O Nassef, Badawia.A Kamal., Mohamed F. Hassan (2004). A Hybrid GA/ Heuristic approach to the Simultaneous Scheduling of Machines and Automated Guided Vehicle. International Research of Production Research. Vol 42, No 2, 267-281. Taylor and Francis Group.

Ulusoy, Gündüz, Sivrikaya-Serifoglu, Funda and Bilge, Ümit (1997). A genetic algorithm approach to the simultaneous scheduling of machines and automated guided vehicles. Journal of Computers Operational Research. Vol 24, No 4, pp 335-351. Elsevier Ltd.

Ümit Bilge and Gündüz Ulusoy (1995). A Time Window Approach to Simultaneous Scheduling of Machines and Material Handling System in an FMS. Journal of Operations Research. Vol. 43, No 6, pp. 1058-1070