Advanced Materials Manufacturing & Characterization Vol4 Issue 2 (2014)

Advanced Materials
Manufacturing & Characterization

journal home page: www.ijammc-griet.com

Machines and AGVs Scheduling in Flexible Manufacturing System With Mean Tardiness Criterion

Medikondu Nageswararao[1] K.Narayanarao[2] G.Ranagajanardhana[3]

[1]Assistant Professor, Department of Mechanical Engineering, K.L.E.F (K.L) University, Guntur, 522502, A.P, India
[2] Head of Mechanical Engineering, Govt; Polytechnic College, Paderu, Vishakhapatnam, 531024, A.P, India
[3] Director & Professor, Department of Mechanical Engineering, J.N.T.University, Kakinada, 533003, A.P, India
[1]Research Scholar U.C.E. J.N.T.University.Kakinada, Andhra Pradesh, India

ARTICLE INFO

Article history:
Received: 29-05-2014
Accepted: 10-06-2014

Keywords:
Scheduling,
FMS,
AGVs,
Vehicle Heuristic Algorithm,
Genetic Algorithm

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 Hybrid Genetic Vehicle Heuristic Algorithm (HGVHA) for simultaneous Scheduling of machines and AGVs adopting minimization of makespan and minimization of mean tardiness. The method is found to provide better solution.

1. Introduction

Developments in information technology Manufacturers are in a Position to deliver products within 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 AGV. 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 processing chain of the material. Efficient AGV well reduce delivery cost and optimally utilize the entire fleet [1]. Studies are mostly on the hybrid approach to address scheduling and routing of AGV s [2, 3, and 4], multi-attribute dispatching rules [5, 6, and 7] and deadlock-resolutions [8, 9].This article considers the Hybrid Genetic vehicle heuristic algorithm(HGVHA) for simultaneous scheduling of machines and AGVs in FMS utilizing the minimization of Makespan and mean Tardiness

2. Scheduling of Machines and AGVs

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.

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

Makespan = Max (C1, C2, C3…Cn) (3)

Mean Tardiness: $\frac{1}{n}\sum_{i=1}^{n} T_i$ (4)

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

- Corresponding author: Medikondu Nageswararao
- E-mail address: medikondu@kluniversity.in
- Doi: http://dx.doi.org/10.11127/ijammc.2014.08.04

3. Simultaneous Scheduling with HGVHA

The following are the steps to implement the Meta Heuristic Algorithm for the example problem

- ❖ Randomly generate initial population of size twice the length of the chromosome.
- ❖ Repair the invalid chromosomes, if they violate the precedence constraints.
- ❖ Assign vehicle for each operation, using the vehicle assignment heuristic,
- ❖ Evaluate the sequences obtained in step 2, by calculating their makespan. The sequence of steps for makespan calculation is explained below.
- ❖ Select randomly a sub-segment(S), of size P
- ❖ Insert any one member of the sub-segment at one of the randomly selected position, to the left or right of the sub-segment. Insertion to left creates a neighbor to the sequence and Insertion to right creates another neighbor to the sequence.
- ❖ Repeat step 2, till all the members in the sub-sequence are selected. This creates 2p neighbors.
- ❖ Compute the fitness of all the neighbors created and sorts them in the descending order of their fitness. Select the fittest
- ❖ 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. To the machine,
- ❖ 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 (VLT). Members among the neighbors and send them to the next population
- ❖ Identify the position (vehicle previous location) and ready time (VRT) of the vehicle. Compute the traveling time (TRT1) from the position of the vehicle

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 [10] was originated by [11]. 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. A code is used to represent the example problems. The digits succeeding EX 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. 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 is fixed, the speed of the vehicles is constant at 40 m/min. Furthermore, loading and unloading times are constant at 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 Appendix. 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.

5. Simulation results and discussion:

Hybrid Genetic 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. Population size is taken as double of the process numbers. The results are obtained after repeating the evolutionary procedure for 20 runs and

The number of generations is carried out 1000. In this work the performance of Hybrid Genetic Vehicle Heuristic Algorithm has been evaluated by testing it on 82 benchmark problems. To study the effect of operator's two types of algorithms one is GA second one is HGA for this two algorithms we consider hybridization with vehicle heuristic our observation concurs with the findings discussed with various algorithms [12], for flow shop scheduling problems. The experimental results, for the problems with t/p>0.25 and also with t/p <0.25, using HGVHA given in Table. No 1-4 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 [13][14]

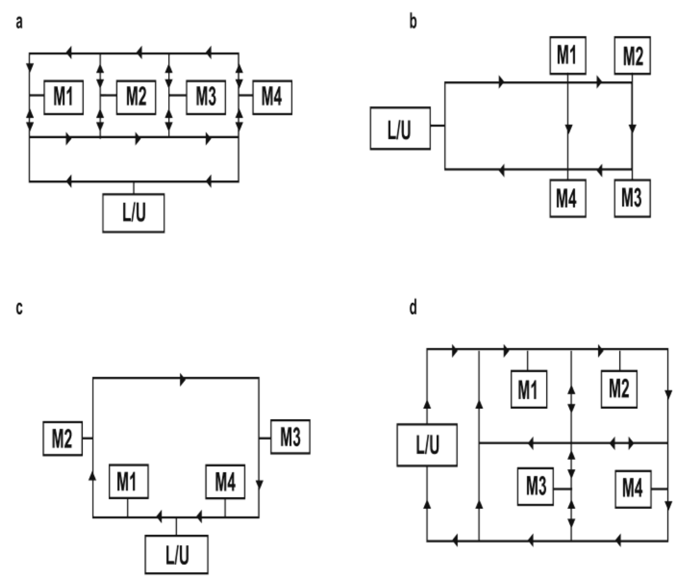

Table.No.1 Result Comparison for Various Algorithms (t/p>0.25)

	STW			UGA			AGA			DGTHA			IACGA			HGVHA	
P.NO	A*	B**	Tardi Ness	A	B	Tardi Ness	A	B	Tardi Ness	A	B	Tardi Ness	A	B	Tardi Ness	B	Tardi Ness
1.1	0	0	-23	0	0	-21	0	0	-20	0	0	-19	0	0	-20	0	-20
2.1	5	5	-14	4	4	-13	2	2	-14	0	0	-15	0	0	-16	0	-16
3.1	5	6.06	-14	5	6.06	-12	-1	0	-17	-1	0	-16	-1	0	-17	1.01	-16
4.1	3.5	5.35	-1	1.75	3.57	-1	-1.75	0	-4	-1.75	0	-3	-1.75	0	-4	1.78	-2
5.1	2.29	2.29	-30	0	0	-30	0	0	-29	0	0	-28	0	0	-29	0	-29
6.1	1.69	1.69	1	2.54	2.54	4	0	0	2	0	0	3	0	0	2	0	2
7.1	7.2	7.2	0	6.3	6.3	1	3.6	3.6	-1	0	0	-4	3.6	3.6	-1	0	-5
8.1	0	5.92	42	-5.59	0	35	0	5.92	45	0	5.92	46	0	5.92	45	5.92	45
9.1	3.44	3.44	1	0.86	0.86	0	1.72	1.72	2	0	0	1	0	0	0	0	0
10.1	3.37	4.08	34	1.35	2.04	33	-0.67	0	31	-0.67	0	32	1.35	2.04	34	0.68	32
1.2	0	0	-18	0	0	-15	0	0	-15	0	0	-15	0	0	-16	0	-15
2.2	5.26	5.26	-20	0	0	-21	0	0	-21	0	0	-21	0	0	-22	0	-21
3.2	3.52	3.52	-12	0	0	-12	0	0	-12	0	0	-12	0	0	-13	0	-12
4.2	8.13	8.13	-7	2.32	2.32	-9	2.32	2.32	-9	1.16	1.16	-10	2.32	2.32	-10	0	-11
5.2	0	0	-31	0	0	-28	0	0	-28	0	0	-28	0	0	-29	0	-28
6.2	2.04	2.04	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1
7.2	13.92	13.92	-10	7.59	7.59	-12	0	0	-18	0	0	-18	2.53	2.53	-17	0	-18
8.2	0	6.33	51	-5.96	0	45	0	6.33	54	0	6.33	54	0	6.33	53	6.33	54
9.2	1.96	1.96	4	0	0	5	1.96	1.96	7	0	0	5	0	0	4	0	5
10.2	2.96	2.96	39	1.48	1.48	40	0.74	0.74	39	0	0	38	4.44	4.44	43	0	38
1.3	0	0	-19	0	0	-17	0	0	-17	0	0	-17	0	0	-18	0	-17
2.3	0	0	-17	0	0	-15	0	0	-15	0	0	-15	0	0	-16	0	-15
3.3	0	0	-17	0	0	-15	0	0	-15	0	0	-15	0	0	-16	0	-15
4.3	6.74	6.74	-8	2.24	2.24	-10	0	0	-12	0	0	-12	0	0	-13	0	-12
5.3	2.7	2.7	-27	1.35	1.35	-26	0	0	-27	0	0	-27	0	0	-28	0	-27
6.3	0.97	0.97	1	0.97	0.97	3	0.97	0.97	3	0	0	2	0.97	0.97	2	0	2
7.3	10.9	10.9	-12	7.31	7.31	-13	4.87	4.87	-15	4.87	4.87	-15	9.75	9.75	-12	0	-19
8.3	0	6.99	50	-6.53	0	42	0	6.99	52	0	6.99	52	0	6.99	51	6.99	52
9.3	4.76	4.76	7	0	0	4	0.95	0.95	5	0	0	4	0	0	3	0	4
10.3	2.87	3.62	40	2.87	3.62	42	1.48	2.17	40	-0.72	0	37	0.72	1.44	38	0.72	38
1.4	4.85	4.85	-20	0	0	-23	0	0	-21	0	0	-20	0	0	-21	0	-21
2.4	7.4	7.4	-12	4.62	4.62	-13	0	0	-16	0	0	-15	0	0	-16	0	-16
3.4	5.45	5.45	-12	2.72	2.72	-13	0.9	0.9	-13	0.9	0.9	-12	0.9	0.9	-13	0	-14
4.4	0	4.13	-2	0	4.13	0	0	4.13	2	-3.96	0	-2	0	4.13	2	4.13	2
5.4	3.13	3.125	-29	1.04	1.04	-29	0	0	-28	0	0	-27	0	0	-28	0	-28
6.4	0	0	-8	2.5	2.5	-3	0	0	-4	0	0	-3	1.66	1.66	-2	0	-4
7.4	7.93	7.93	8	1.58	1.58	2	0.79	0.79	3	0	0	3	3.17	3.17	6	0	2
8.4	0	0	35	0	0	37	0	0	39	0	0	40	0	0	39	0	39
9.4	2.45	4.16	-3	0.81	2.5	-3	0	1.66	-2	-1.63	0	-3	-1.63	0	-4	1.66	-2
10.4	7.54	8.22	43	3.14	3.79	38	0	0.63	35	0	0.63	36	0	0.63	35	0.63	35

A* Performance Compression with Proposed Algorithm B** Performance Compression with Best Algorithm

Table.No.2. Result Comparison for Various Algorithms (t/p<0.25)

	STW			UGA			PGA			DGTHA			IACGA			HGVHA	
P.NO	A*	B**	Tardi Ness	A	B	Tardi Ness	A	B	Tardi Ness	A	B	Tardi Ness	A	B	Tardi Ness	B	Tardi Ness
1.10	0	0	-34	0	0	-39	0	0	-42	0	0	-42	0	0	-42	0	-42
2.10	0	0	-12	0	0	-17	0	0	-20	0	0	-20	0	0	-20	0	-20
3.10	0	1.35	-10	-1.33	0	-17	0	1.35	-18	0	1.35	-18	0	1.35	-18	1.35	-18
4.10	1.68	1.68	-39	0	0	-46	0	0	-49	0	0	-49	0	0	-49	0	-49
5.10	0	0	-58	0	0	-63	0	0	-66	0	0	-66	0	0	-66	0	-66
6.10	0	0	26	0	0	21	0	0	18	0	0	18	0	0	18	0	18
7.10	0	0	-23	0	0	-28	0	0	-31	0	0	-31	0	0	-31	0	-31
8.10	0	7.74	132	-7.19	7.74	106	0	7.74	124	0	7.74	124	0	7.74	124	7.74	124
9.10	0	0	16	0	0	11	0	0	8	0	0	8	0	0	8	0	8
10.10	0	0.84	78	-0.84	0	71	0	0.84	70	0	0.84	70	0	0.84	70	0.84	70
1.20	0	0	-42	0	0	-40	0	0	-41	0	0	-41	0	0	-41	0	-41
2.20	0	0	-22	0	0	-20	0	0	-21	0	0	-21	0	0	-21	0	-21
3.20	2.06	2.06	-17	0	0	-18	0	0	-19	0	0	-19	0	0	-19	0	-19
4.20	1.75	1.75	-49	0	0	-49	0	0	-50	0	0	-50	0	0	-50	0	-50
5.20	0	0	-65	0	0	-63	0	0	-64	0	0	-64	0	0	-64	0	-64
6.20	-1.61	1.1	18	-2.68	0	18	-2.68	0	17	-2.68	0	17	-2.68	0	17	2.76	22
7.20	0	0	-29	0	0	-27	0	0	-28	0	0	-28	0	0	-28	0	-28
8.20	0	7.08	122	-6.96	0	105	0	7.08	123	0	7.08	123	0	7.08	123	7.08	123
9.20	0.57	0.57	9	0	0	10	0	0	9	0	0	9	0	0	9	0	9
10.20	0	0	71	0.84	0.84	75	0	0	72	0	0	72	0	0	72	0	72
1.30	0	0	-44	0	0	-42	0	0	-43	0	0	-43	0	0	-43	0	-43
2.30	0	0	-20	0	0	-18	0	0	-19	0	0	-19	0	0	-19	0	-19
3.30	2.05	2.05	-17	0	0	-18	0	0	-19	0	0	-19	0	0	-19	0	-19
4.30	1.75	1.75	-50	0	0	-50	0	0	-51	0	0	-51	0	0	-51	0	-51
5.30	0	0	-67	0	0	-65	0	0	-66	0	0	-66	0	0	-66	0	-66
6.30	1.09	1.09	18	0	0	18	0	0	17	0	0	17	0	0	17	0	17
7.30	0	0	-29	0	0	-27	0	0	-28	0	0	-28	0	0	-28	0	-28
8.30	0	6.66	122	-6.25	0	106	0	6.66	123	0	6.66	123	0	6.66	123	6.66	123
9.30	1.15	1.15	10	0	0	10	0	0	9	0	0	9	0	0	9	0	9
10.30	0	0	71	1.68	1.68	77	0	0	72	1.68	1.68	76	0	0	72	0	72
1.40	0	0	-67	0	0	-40	0	0	-65	0	0	-66	0	0	-65	0	-65
2.41	0	0	26	0	0	53	0	0	28	0	0	27	0	0	28	0	28
3.40	0	0	-40	0	0	-13	0	0	-38	0	0	-39	0	0	-38	0	-38
3.41	0.45	0.45	31	0	0	57	0	0	32	0	0	31	0	0	32	0	32
4.41	4.67	4.67	-12	0.58	0.58	8	0.58	0.58	-17	4.67	4.67	-11	0.58	0.58	-17	0	-18
5.41	4.05	4.05	-37	0	0	-16	0	0	-41	0	0	-42	0	0	-41	0	-41
6.40	0.54	0.54	-6	0	0	20	0	0	-5	0	0	-6	0	0	-5	0	-5
7.40	0.72	0.72	-53	0	0	-27	0	0	-52	0	0	-53	0	0	-52	0	-52
7.41	0	0	12	0	0	39	0	0	14	0	0	13	0	0	14	0	14
8.40	0	7.32	102	-6.82	0	109	0	7.32	104	0	7.32	103	0	7.32	104	7.32	104
9.40	1.14	1.14	-14	0	0	11	0	0	-14	0	0	-15	0	0	-14	0	-14
10.40	0	0	49	1.66	1.66	80	0	0	51	0	0	50	0	0	51	0	51

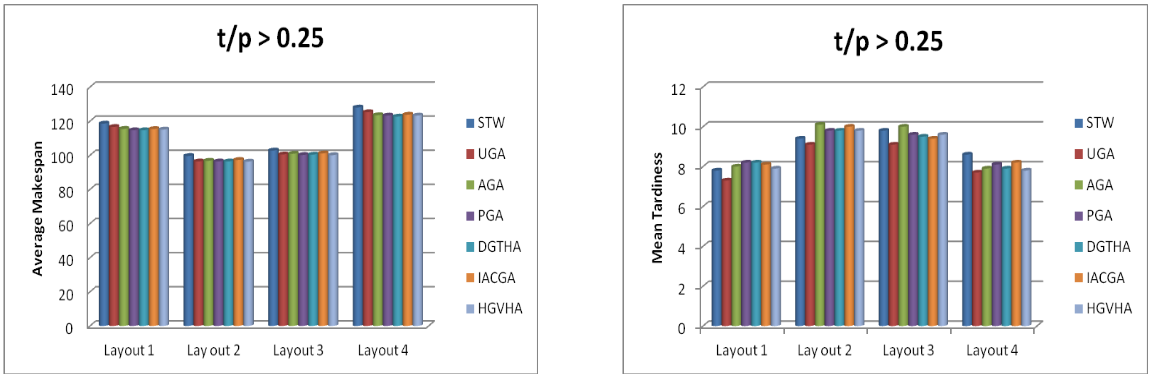

Fig.No.2 Performance Comparision (t/p>0.25)

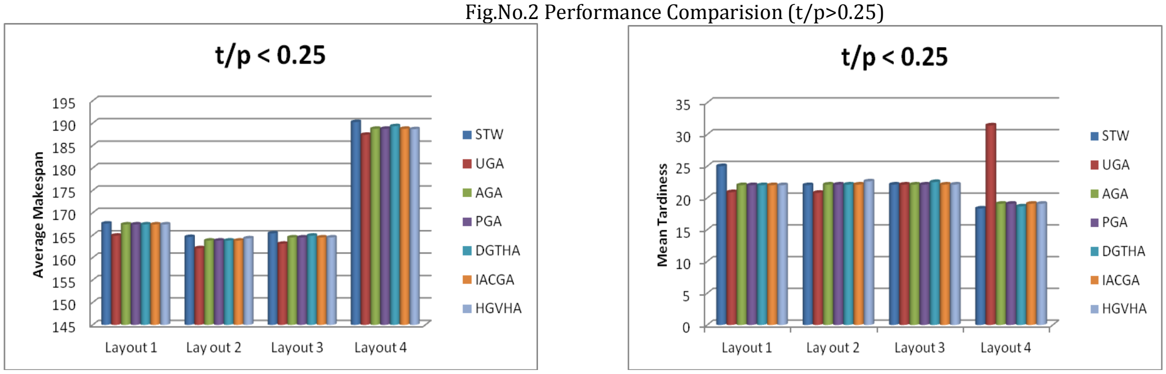

Fig.No.3 Performance Comparision (t/p<0.25)

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

From/To	Layout-1					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

Table .No.6 Process Time Data for the Example Problem

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 HGVHA 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 HGVHA optimization method. Other HGVHA 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(Makespan) when compared to various algorithms HGVHA gives the minimum makespan with comparison of STW, UGA, AGA and IACGA when compared in t/p<0.25(Makespan) HGVHA gives minimum makespan when compared to various algorithms like STW, DGTHA and also in t/p>0.25(Tardiness) lateness of due date is minimized in HGVHA when compared to all the algorithms like STW, AGA, PGA, DGTHA and IACGA. .in t/p<0.25(Tardiness) lateness of due date is minimized in proposed algorithm when compared to STW and UGA. Future work would consider multiple objectives so as to reflect actual industrial applications.

References

1. B. 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.
2. A. Corréa, I., A.Langevin, and Rousseau, L.-M. (2005) "Scheduling and routing of automated guided vehicles: A hybrid approach, Computers & Operations Research
3. G.Desaulniers, D.Langevin, Riopel, and. B.Villeneuve (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
4. De Koster. M. B. M .T. Le-Anh. (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.
5. M.Grunow,H.Günther, and M.Lehmann,(2004) "Dispatching multi-load AGVs in highly automated seaport container terminals, OR Spectrum, vol. 26, Number 2, pp.211-235
6. 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
7. 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
8. 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
9. A C .Nearchou, (2004) "The effect of various operators on the genetic search for large scheduling problems", International Journal of Production Economics, No. 88, pp.191-203
10. M.Nageswararao,K.Nrao,G.Ranagajanardhana. "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
11. B. S. P Reddy, C. S. P. Rao. (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
12. F.Tamer, 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, pp.267-281. Taylor and Francis Group.
13. 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.
14. 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.