

# Modelling and Scheduling of Flexible Manufacturing System

K. Amarnath, G. Sanjeev, P. Surendernath, V. Kumar

**Abstract:** Production scheduling of an FMS is formulated as a multi-level integer program. The structure proposed includes machine loading, part input sequence and operation scheduling. Flexible manufacturing system is the better option to meet the effective utilization of resources, for which scheduling is the only solution. A simple numerical problem approach is proposed, and some computational results of simulation are analyzed and an attempt is made in arriving general conclusions.

**Keywords:** The Structure Proposed Includes Machine Loading,

## I. INTRODUCTION

Availability of alternative machines is the major flexibility in an FMS, because of which jobs need not wait for a particular machine if it is busy and it can be performed on an alternative machine, this causes reduction in waiting time and hence reduction in make span. Also it is expected that the availability of alternative machines improves the utilization of machines and AGVs.

In this paper it is aimed to perform simultaneous scheduling of machines and material handling devices in an FMS environment for two different layouts and to study the effect of alternative machines on the performance of the FMS.

A standard benchmark problem on scheduling with four work centers is considered for modeling the given FMS environment. A total of eight Job Sets are considered, which are to be processed on two different layouts. Each job set in turn is a combination of ‘n’ jobs varying from five to eight. Firstly a Dynamic analysis is done which is a simultaneous scheduling of Machines and Material handling devices.

FMS environment was modeled using Flex Sim software and simulated to evaluate its performance. Dynamic Analysis was performed to study the effect of alternative machines

## II. SIMULATION OF AN FMS

By using Flex Sim software layout is modeled and processing times and the sequence of jobs which are to be processed on them were entered at each machine center. Corresponding statistics were recorded and the same was done without considering alternative machines.

Later the same were modeled with alternative machines.

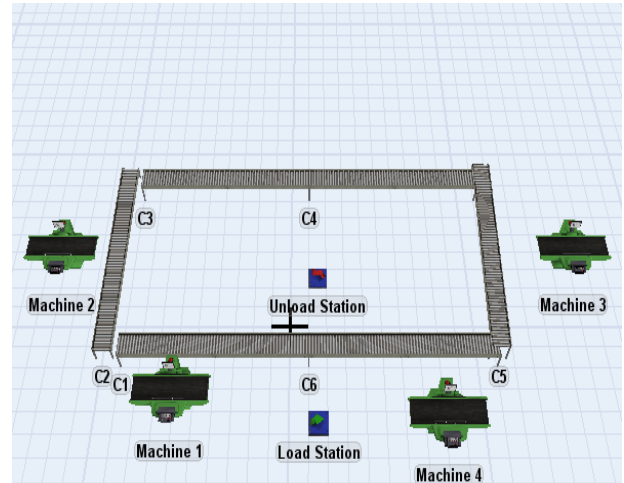
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**Figure 2: Layout 2**

In order to establish schedule for jobs, for single machine and ‘n’ jobs, there are n! choices available. When ‘m’ machines exist, the number of possible schedules is (n!)<sup>m</sup>. Table Shows Job sets with alternative machines.

<u>Job Set 1:</u>	<u>Job Set 2:</u>
JOB1: M1(8); M2(16); M4(12)	JOB1: M1(10); M4(18)
ALT: M2(9); M3(14); M1(13)	ALT: M3(12); M2(16)
JOB2: M3(10); M2(18)	JOB2: M2(10); M4(18)
ALT: M3(18); M1(13); M4(17)	ALT: M4(8); M1(20)
JOB3: M3(12); M4(8); M1(15)	JOB3: M1(10); M3(20)
ALT: M4(11); M2(10); M3(14)	ALT: M3(12); M2(18)
JOB4: M4(14); M2(18)	JOB4: M2(10); M3(15); M4(12)
ALT: M1(16); M3(16)	ALT: M4(11); M1(17); M2(9)
JOB5: M3(10); M1(15)	JOB5: M1(10); M2(15); M4(12)
ALT: M2(9); M4(16)	ALT: M4(12); M1(14); M3(11)
	JOB6: M1(10); M2(15); M3(12)
	ALT: M3(11); M4(13); M2(13)

<p><b><u>Job Set 3:</u></b>                  JOB1: M1(16); M3(15)                  ALT: M3(14); M1(17)                  JOB2: M2(18); M4(15)                  ALT: M1(17); M3(16)                  JOB3: M1(20); M2(10)                  ALT: M3(19); M4(11)                  JOB4: M3(15); M4(10)                  ALT: M4(17); M2(8)                  JOB5: M1(8); M2(10);                  M3(15); M4(17)                  ALT: M3(10); M4(12);                  M2(13); M1(15)                  JOB6: M2(10); M3(15);                  M4(8); M1(15)                  ALT: M1(8);                  M4(14);M2(10);M3(16)</p>	<p><b><u>Job Set 4:</u></b>                  JOB1: M1(6); M2(12);                  M4(9)                  ALT: M2(7); M3(10);                  M1(10)                  JOB2: M1(18); M3(6);                  M2(15)                  ALT: M2(17); M4(8);                  M3(14)                  JOB3: M3(9); M4(3);                  M1(12)                  ALT: M4(10); M2(5);                  M3(11)                  JOB4: M4(6); M2(15)                  ALT: M3(7); M1(14)                  JOB5: M3(3); M1(9)                  ALT:M2(4);M4(8)</p>	<p><b><u>Job Set 7:</u></b>                  JOB1: M3(9); M1(12);                  M2(9); M4(6)                  ALT: M4(10); M3(9);                  M1(10); M2(7)                  JOB2: M3(16); M2(11);                  M4(9)                  ALT: M1(14); M3(12);                  M2(10)                  JOB3: M1(21); M2(18);                  M4(7)                  ALT: M3(19); M4(19);                  M1(8)                  JOB4: M2(20); M3(22);                  M4(11)                  ALT: M4(21); M1(20);                  M3(12)                  JOB5: M3(14); M1(16);                  M2(13);M4(9)                  ALT: M2(15); M4(13);                  M1(14);M3(10)</p>	<p><b><u>Job Set 8:</u></b>                  JOB1: M1(11); M3(19);                  M2(16);M4(13)                  ALT: M2(13);                  M4(17);M3(14);M1(15)                  JOB2: M2(21); M3(16);                  M4(14)                  ALT: M3(19); M4(17);                  M1(15)                  JOB3: M3(8); M2(10);                  M1(14); M4(9)                  ALT: M2(10); M4(8);                  M3(16); M1(7)                  JOB4: M2(13); M3(20);                  M4(10)                  ALT: M1(15); M4(17);                  M3(11)                  JOB5: M1(9); M3(16);                  M4(18)                  ALT: M3(12); M4(14);                  M1(17)                  JOB6: M2(19); M1(21);                  M3(11);M4(15)                  ALT: M1(16); M3(22);                  M4(14);M2(14)</p>
<p><b><u>Job Set 5:</u></b>                  JOB1: M1(9); M2(11);                  M4(7)                  ALT: M3(10); M1(9);                  M2(8)                  JOB2: M1(19); M2(20);                  M4(13)                  ALT: M4(20); M3(18);                  M2(14)                  JOB3: M2(14); M3(20);                  M4(9)                  ALT: M3(12); M4(21);                  M1(10)                  JOB4: M2(14); M3(20);                  M4(9)                  ALT: M4(13); M1(19);                  M3(11)                  JOB5: M1(11); M3(16);                  M4(8)                  ALT: M2(12); M1(14);                  M3(9)                  JOB6: M1(10); M3(12);                  M4(10)                  ALT: M3(9); M4(11);                  M2(12)</p>	<p><b><u>Job Set 6:</u></b>                  JOB1: M1(6); M4(6)                  ALT: M4(5); M3(7)                  JOB2: M2(11); M4(9)                  ALT: M3(12); M1(8)                  JOB3: M2(9); M4(7)                  ALT: M4(8); M3(8)                  JOB4: M3(16); M4(7)                  ALT: M1(17); M2(6)                  JOB5: M1(9); M3(18)                  ALT: M2(10); M4(17)                  JOB6: M2(13); M3(19);                  M4(6)                  ALT: M1(14); M2(17);                  M3(7)                  JOB7: M1(10); M2(9);                  M3(13)                  ALT: M4(11); M3(10);                  M1(11)                  JOB8: M1(11); M2(9);                  M4(8)                  ALT: M4(10); M1(11);                  M3(7)</p>		

**Table 1: Job sets with Alternative Machines**

**III. RESULTS AND DISCUSSIONS**

Job Sets	Make Span for Layout1		Make Span for Layout 2	
	Without Alternative Machines	With Alternative Machines	Without Alternative Machines	With Alternative Machines
Job Set 1	145.79	139.88	150.79	146.11
Job Set 2	159.40	157.32	172.37	164.73
Job Set 3	198.83	144.02	200.69	194.94
Job Set 4	133.79	128.65	139.59	128.07
Job Set 5	167.50	115.53	188.18	187.88
Job Set 6	196.79	196.62	206.30	204.02
Job Set 7	167.24	166.49	156.76	153.80
Job Set 8	215.35	209.93	216.02	213.92
Average of all Job sets	176.64	161.33	182.52	178.12

**Table 2: Comparison of Make Span for all the Job sets without and with alternative machines**

The following table illustrates the comparison of Utilization of Machines and AGVs without and with Alternative machines for all job sets on Layout1



Job Sets	Utilization of Machines and AGVs Without Alternative Routing						Utilization of Machines and AGVs With Alternative Routing					
	M1	M2	M3	M4	AGV1	AGV2	M1	M2	M3	M4	AGV1	AGV2
Job Set 1	39.8	35.7	21.9	23.3	85.5	78.7	30	20	44.3	31.5	78.2	79.6
Job Set 2	25.1	31.4	29.5	37.6	73.8	75.8	32.4	35.6	29.2	2.8	85.6	85.5
Job Set 3	29.7	24.1	30.2	25.1	74.9	66.9	39.6	52	21.5	3.7	72.8	62
Job Set 4	33.6	13.5	31.4	13.5	87.5	85.2	18.7	25.7	32.6	2.0	84.2	83.9
Job Set 5	29.3	35.2	40.6	33.4	77.8	83.6	45	39.8	59.7	6.3	78.9	70.9
Job Set 6	18.3	25.9	33.5	21.9	86.2	79.6	31	16.8	25.9	5.9	86.5	86.7
Job Set 7	29.3	42.5	36.5	25.1	77.4	67.3	39.6	19.2	37.2	7.8	80.9	69.5
Job Set 8	25.5	36.7	41.8	36.7	79.6	73.3	40.5	17.6	44.8	4.1	86.1	81.6

**Table 3: Utilization of Machines and AGVs without and with alternative machines on Layout 1**

Job Sets	Average Machine Utilizations		Average AGV Utilizations	
	Without Alternative Machines	With Alternative Machines	Without Alternative Machines	With Alternative Machines
JobSet1	30.2	31.5	82.1	78.9
JobSet2	30.9	31.3	74.8	85.6
JobSet3	27.3	37.7	70.9	67.4
JobSet4	23.0	24.3	86.4	84.1
JobSet5	34.6	50.2	80.7	74.9
JobSet6	24.9	24.9	82.9	86.6
JobSet7	33.4	33.5	72.4	75.2
JobSet8	35.2	36.1	76.5	83.9
Average	30.4	33.9	77.4	80.5

**Table 4: Average Utilization of Machines and AGVs without and with alternative machines on**

The following table illustrates the comparison of Utilization of Machines and AGVs without and with Alternative machines for all job sets on Layout 2

Job Sets	Without Alternative Machines						With Alternate Machines					
	M1	M2	M3	M4	AGV1	AGV2	M1	M2	M3	M4	AGV1	AGV2
Job Set 1	38.5	34.5	21.5	22.5	84.9	92.7	18.5	32.9	44.5	19.8	87.0	86.2
Job Set 2	23.3	29.1	27.3	34.9	77.2	76.0	31.0	34	27.9	26.7	84.8	88.0
Job Set 3	29.4	24	29.9	25	69.1	69.3	23.1	29.2	25.6	31.8	81.3	70.3
Job Set 4	32.2	30.1	12.9	12.9	91.4	89.8	18.7	25.8	32.8	20.3	85.8	88.6
Job Set 5	26.0	31.4	25.5	29.8	73.2	74.3	27.7	24.5	36.7	34.6	91.2	92.7
Job Set 6	17.5	24.7	32.0	20.8	83.1	81.0	29.9	16.2	25.0	25.0	91.7	90.3
Job Set 7	25.5	36.6	41.7	36.6	82.7	82.3	42.9	20.8	40.3	41	83.8	82.9
Job Set 8	31.3	45.3	38.9	26.8	81.4	74.0	39.8	17.3	44	40.8	89.3	89.9

**Table 5: Utilization of Machines and AGVs with and without alternative machines on Layout 2**

Job Sets	Average Machine Utilizations		Average AGV Utilizations	
	Without Alternative Machines	With Alternative Machines	Without Alternative Machines	With Alternative Machines
JobSet1	29.3	28.9	88.8	86.6
JobSet2	28.7	29.9	76.6	86.4
JobSet3	27.1	27.4	69.2	75.8
JobSet4	22.0	24.4	90.6	87.2
JobSet5	28.2	30.9	73.8	92.0
JobSet6	23.8	24.0	82.1	91.0
JobSet7	35.1	36.3	82.5	83.4
JobSet8	35.6	35.5	77.7	89.6
Average	29.2	30.1	78.8	86.8

**Table 6: Average Utilization of Machines and AGVs without and with alternative machines on Layout 2**



The utilization is increased to a good proportion when alternative machines are included in the layouts.

### IV. CONCLUSION

In this paper two FMS environments were considered with 8 job sets and it was aimed to schedule both the machines and AGVs simultaneously.

Availability of alternative machines is an important flexibility in FMS environment. In this project, the effect of alternative machines was also used. It was observed that the average make span was on Layout 1 reduced from 176.64 to 161.33 which can be considered as 8.667 % reduction. Similarly the average utilization of machines for all job sets was improved from 30.40 % to 33.93 % and average utilization of AGVs was improved from 77.40% to 80.52 %. And on Layout 2 the averages make span of all job sets was reduced from 182.52 to 178.12 which can be considered as 2.413% reduction. Similarly the average utilizations of machines for all job sets were improved from 29.15 % to 30.06% and average utilization of AGVs was improved from 78.84 % to 86.76 %.

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