ADVANCED MODELISTIC APPROACH OF FLOWSHOP SCHEDULING PROBLEM FOR 10-JOBS, 10-MACHINES BY HEURISTICS MODELS USING MAKESPAN CRITERION

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Abstract*— Production scheduling is generally considered to be the one of the most significant issue in the planning and operation of a manufacturing system. Better scheduling system has significant impact on cost reduction, increased productivity, customer satisfaction and overall competitive advantage. In addition, recent customer demand for high variety products has contributed to an increase in product complexity that further emphasizes the need for improved scheduling. Proficient scheduling leads to increase in capacity utilization efficiency and hence thereby reducing the time required to complete jobs and consequently increasing the profitability of an organization in present competitive environment. There are different systems of production scheduling including flowshop in which jobs are to be processed through series of machines for optimizing number of required performance measures. In modern manufacturing there is the trend of the development of the Computer Integrated Manufacturing (CIM is computerized integration of the manufacturing activities (Design, Planning, Scheduling and Control)) which produces right product(s) at right time to react quickly to the global competitive market demands. The productivity of CIM is highly depending upon the scheduling of Flexible Manufacturing System (FMS). Machine idle time can be decreased by sorting the makespan which results in the improvement in CIM productivity. Conventional methods of solving scheduling problems based on priority rules still result schedule, sometimes with idle times. To optimize these, this paper models the problem of a flowshop scheduling with the objective of minimizing the makespan. The work proposed here deal with the production planning problem of a flexible manufacturing system. This paper model the problem of a flowshop scheduling with the objective of minimizing the makespan. The objective is to minimize the makespan of batch-processing machines in a flowshop. The processing times and the sizes of the jobs are known and non-identical. The machines can process a batch as long as its capacity is not exceeded. The processing time of a batch is the longest processing time among all the jobs in that batch. The problem under study is non-polynomial (NP)-hard for make span objective. Consequently, comparisons based on RA's heuristics, CDS's heuristics are proposed in this work. Gantt chart is generated to verify the effectiveness of the proposed approaches.

***Keywords*— CIM; FMS; Flowshop scheduling problem; Makespan; Heuristic models; Gantt chart.**

I. INTRODUCTION

A Flexible manufacturing system (FMS) consists of a collection of numerically controlled machines with multifunction ability, an automatic material handling system and an online computer network. This network is capable of controlling and directing the whole system. An FMS combines the advantages of a traditional flow line and job-shop systems to meet the changing demands. Thus, it involves many problems, which can be divided into four stages: (a) design, (b) system set-up, (c) scheduling and (d) control. FMS Scheduling system is one of the most important information-processing subsystems of CIM system. The productivity of CIM is highly depending upon the quality of FMS scheduling. The basic work of scheduler is to design an optimal FMS schedule according to a certain measure of performance, or scheduling criterion. This work focuses on productivity oriented-makespan criteria. Makespan is the time length from the starting of the first operation of the first demand to the finishing of the last operation of the last demand. The inherent efficiency of a flexible manufacturing system (FMS) combined with additional capabilities, can be harnessed by developing a suitable production plan. Machine scheduling problems arises in diverse areas such as flexible manufacturing system, production planning, computer design, logistics, communication etc. A common feature of many of these problems is that no efficient solution algorithm is known yet for solving it to optimality in polynomial time.

The classical flowshop scheduling problem is one of the most well known scheduling problems. Informally the problem can be described as follows:

There are set of jobs and a set of machines. Each job consists of chain of operation, each of which needs to be processed during an uninterrupted time period of a given length on a given machine. Each machine can process at most one operation at a time. A schedule is an allocation of operations to time intervals of the machines. The problem is to find the schedule of minimum length. This work tries to minimize the makespan of batch-processing machines in a flowshop. The processing times and the sizes of the jobs are known and non-identical. The machines can process a batch as long as its capacity is not exceeded. The processing time of a batch is the longest processing time among all the jobs in that batch. The problem under study is NP-hard for makespan objective. Consequently, comparisons based on RA's heuristics, CDS's heuristics, are proposed. Gantt chart is generated to verify the effectiveness of the proposed approaches.

II. SEQUENCING AND SCHEDULING

Sequencing refers to arranging items or events in a particular order. In other words Sequencing is a technique to order the jobs in a particular sequence. In industries there are different types of sequencing which are followed such as first in first out basis, priority basis, job size basis and processing time basis etc. In processing time basis sequencing for different sequence, we will achieve different processing time. The sequence is adapted which gives minimum processing time.

Scheduling is a decision making process and it concerns the allocation of the limited resources to tasks over time By Scheduling, we assign a particular time for completing a particular job. The main objective of scheduling is to arrive at a position where we will get minimum processing time.

III. SIGNIFICANCE OF WORK

By establishing the timing of the use of equipment, facilities and human activities in an organization can:

i. Determine the order in which jobs at a work center will be processed.
ii. Results in an ordered list of jobs
iii. Sequencing is most beneficial when we have constrained capacity (fixed machine set; cannot buy more) and heavily loaded work centers
iv. Lightly loaded work centers = no big deal (excess capacity)
v. Heavily loaded
   a) Want to make the best use of available capacity.
   b) Want to minimize unused time at each machine as much as possible.

IV. PARAMETERS OF THE WORK

i. Average job flow time
   a) Length of time (from arrival to completion) a job is in the system, on average
   b) Lateness
ii. Average length of time the job will be late (that is, exceeds the due date by)
iii. Makespan
iv. Total time to complete all jobs
v. Average number of jobs in the system
vi. Measure relating to work in process inventory
vii. Equals total flow time divided by makespan.

V. OBJECTIVE

1) *Minimizing the make span.* To deal with the production planning problem of a flexible manufacturing system, I model the problem of a flowshop scheduling with the objective of minimizing the makespan.
2) *To provide a schedule for each job and each machine.* Schedule provides the order in which jobs are to be done and it projects start time of each job at each work center.
3) *Comparative study.* To select appropriate heuristics approach for the scheduling problem through a comparative study.
4) *To solve FMS scheduling problem in a flowshop environment.* Considering the comparison based on RA's heuristics, CDS's heuristics are proposed. Gantt chart is generated to verify the effectiveness of the proposed approaches.

My objective of scheduling can yield:

1. Efficient utilization …
   a) staff
   b) equipment
   c) facilities
2. Minimization of …
   a) customer waiting time
   b) Inventories.
   c) Processing time.

VI. METHODOLOGY

Operations planning and scheduling (OPS) problems in flexible manufacturing systems (FMSs), are composed of a set of interrelated problems, such as part-type batching, machine grouping, part routing, tool loading, part input sequencing, and resource assignment. The performance of an FMS is highly dependent on the efficient allocation of the limited resources to the tasks, and it is strongly affected by the effective choice of scheduling rules.

In this study, a heuristic ruled based approach for dynamic scheduling of FMSs, which integrates loading, part inputting, routing, and dispatching issues of the OPS is presented, and the implementation results are compared with several dispatching rules. Manufacturing scheduling theory is concerned with the right allocation of machines to operations over time. The basic work of scheduler is to design an optimal FMS schedule according to a certain measure of performance, or scheduling criterion. This work focuses on productivity oriented-make span criteria. Makespan is the time length from the starting of the first operation of the first demand to the finishing of the last operation of the last demand. The approach used in this work was the comparisons based on four heuristic algorithms namely RA's algorithm, CDS's algorithm are proposed. Here the main objective is to compare and find the efficient heuristics algorithm for minimizing the makespan. In this work hierarchical approach were used to determine the optimal makespan criteria.

VII. PROBLEM STATEMENT

There is a flowshop scheduling problem in which all the parameters like processing time, due date, re-fixturing time, and set-up time are given. The value of the makespan of batch-processing machines in a flowshop based on comparisons of RA's, CDS's heuristics, are proposed. Analytic solutions in all the heuristics are investigated. Gantt chart is generated to verify the effectiveness of the proposed approaches. Here the heuristics approaches for planning problems are proposed which provides a way to optimize the makespan which is our objective function.

VIII. FLOWSHOP SCHEDULING

It is a typical combinatorial optimization problem, where each job has to go through the processing in each and every machine on the shop floor. Each machine has same sequence of jobs. The jobs have different processing time for different machines. So in this case we arrange the jobs in a particular order and get many combinations and we choose that combination where we get the minimum makespan.

In an m-machine flowshop, there are m stages in series, where there exist one or more machines at each stage. Each job has to be processed in each of the m stages in the same order. That is, each job has to be processed first in stage 1, then in stage 2, and so on. Operation times for each job in different stages may be different. We classify flowshop problems as:

1. Flowshop (there is one machine at each stage).
2. No-wait flowshop (a succeeding operation starts immediately after the preceding operation completes).
3. Flexible (hybrid) flowshop (more than one machine exist in at least one stage) and
4. Assembly flowshop (each job consists of specific operations, each of which has to be performed on a pre-determined machine of the first stage, and an assembly operation to be performed on the second stage machine).

IX. FLOWSHOP SCHEDULING METHODS

Heuristics for general *m*-Machine Problems

1. *CDS's Heuristic Algorithm.*
2. *RA's Heuristic Algorithm.*

X. GENERAL DESCRIPTION

1. There are *m* machines and *n* jobs.
2. Each job consists of *m* operations and each operation requires a different machine
3. *n* jobs have to be processed in the same sequence on *m* machines.
4. Processing time of job *i* on machine *j* is given by t_{ij} (where i =1, …, n ; j =1, …, m)
5. Makespan: find the sequence of jobs minimizing the maximum flow time.

XII. MAIN ASSUMPTIONS

1. Every job has to be processed on all machines in the order (j = 1,2,….,m).
2. Every machine processes only one job at a time.
3. Every job is processed on one machine at a time.
4. Operations are not preemptive.
5. Set-up times for the operations are sequence-independent and are included in the processing times.

Operating sequences of the jobs are the same on every machine, and the common sequence has to be determined.

XII. THREE CATEGORIES OF FSP

1. *Deterministic flow-shop scheduling problem:*

¾ Assume that fixed processing times of jobs are known.

2. *Stochastic flow-shop scheduling problem:*

¾ Assume that processing times vary according to chosen probability distribution.

3. *Fuzzy flow-shop scheduling problem:*

¾ Assume that a fuzzy due date is assigned to each job to represent the grade of satisfaction of decision makers for the completion time of the job.

XIII. ADVANCED HEURISTICS FOR GENERAL 10-MACHINES AND 10-JOBS PROBLEMS

1. *CDS's Heuristic Algorithm.*
2. *RA's Heuristic Algorithm.*

1. CDS's Heuristic Rule:

Algorithm: CDS's Heuristic
Procedure: CDS's Heuristic
Input: job list i, machine m;
Output: schedule s;
begin
for i = 1 to n
for j = 1 to m-1
    Calculate $t_{i1}' = t_{i1} + t_{ij}$;
for j= m-1 to m
    Calculate $t_{i2}' = t_{i2} + t_{ij}$;
end
calculate $U = \{i | t_{i1}' < t_{i2}'\}$ and
    $V = \{i | t_{i1}' \geq t_{i2}'\}$; // step 1
sort jobs in U with non-decreasing order of t_{i1}';
    //step 2
sort jobs in V with non-increasing order of t_{i2}';
    //step 3

Output optimal sequence is obtained as schedule s by U and V
// step 4

end

Consider an 10-job problem:

Table1: General 10-Jobs, 10-Machines Problem

Job ⇨ / M/c ⇩	1	2	3	4	5	6	7	8	9	10
1	5	2	1	7	6	3	7	5	7	4
2	2	6	2	5	6	7	2	1	8	3
3	3	4	2	6	1	5	4	7	6	5
4	5	2	1	3	8	2	6	1	9	8
5	7	6	3	2	6	2	5	7	1	3
6	9	2	7	3	4	1	5	3	8	1
7	7	5	2	2	3	5	1	6	2	3
8	8	2	5	4	9	3	2	6	1	8
9	2	6	4	2	6	2	5	2	6	3
10	7	1	4	2	4	6	2	2	6	7

The solution constructed as follows:
Step 1:

Job	t_{i1}’	t_{i2}’
1	48	50
2	35	34
3	27	30
4	34	29
5	49	47
6	30	33
7	37	32
8	38	35
9	48	47
10	38	41

Jobs sets are:
U = {1, 3, 6, 10} and V = {2, 4, 5, 7, 8, 9}
Step 2: Sort jobs in U as follows:

Job i :	3	6	10	1
t_{i1}’ :	27	30	38	48

Step 3: Sort jobs in V as follows:

Job i	9	5	8	2	7	4
t_{i2}’	47	47	35	34	32	29

Step 4: Output optimal sequence is
{3, 6, 10, 1, 9, 5, 8, 2, 7, 4}

Thus total processing time can be calculated as:

Table 2. Total Processing Time for 10-Jobs, 10-Machines by CDS's Heuristic Model

Job i	M/c 1 Time In	M/c 1 Out	M/c 2 Time In	M/c 2 Out	M/c 3 Time In	M/c 3 Out	M/c 4 Time In	M/c 4 Out	M/c 5 Time In	M/c 5 Out	M/c 6 Time In	M/c 6 Out	M/c 7 Time In	M/c 7 Out	M/c 8 Time In	M/c 8 Out	M/c 9 Time In	M/c 9 Out	M/c 10 Time In	M/c 10 Out
3	0	1	1	3	3	5	5	6	6	9	9	16	16	18	18	23	23	27	27	31
6	1	4	4	11	11	16	16	18	18	20	20	21	21	26	26	29	29	31	31	37
10	4	8	11	14	16	21	21	29	29	32	32	33	33	36	36	44	44	47	47	54
1	8	13	14	16	21	24	29	34	34	41	41	50	50	57	57	65	65	67	67	74
9	13	20	20	28	28	34	34	43	43	44	50	58	58	60	65	66	67	73	74	80
5	20	26	28	34	34	35	43	51	51	57	58	62	62	65	66	75	75	81	81	89
8	26	31	34	35	35	42	51	52	57	64	64	67	67	73	75	81	81	83	89	91
2	31	33	35	41	42	46	52	54	64	70	70	72	73	78	81	83	83	89	91	92
7	33	40	41	43	46	50	54	60	70	75	75	80	80	81	83	85	89	94	94	96
4	40	47	47	52	52	58	60	63	75	77	80	83	83	85	85	89	94	96	96	98

Therefore, total processing time = **98 (Units)**
Total Idle Time for M/c 1 = 98-47 = 51 (Units)
Total Idle Time for M/c 2
= 1+1+4+4+(98-52) = 56 (Units)
Total Idle Time for M/c 3
= 3+6+4+2+(98-58) = 55 (Units)
Total Idle Time for M/c 4
= 5+10+3+(98-63) = 53 (Units)
Total Idle Time for M/c 5
= 6+9+9+2+2+7+(98-77) = 56 (Units)
Total Idle Time for M/c 6
= 9+4+11+8+2+3+3+(98-83) = 55 (Units)
Total Idle Time for M/c 7
= 16+3+7+14+1+2+2+2+2+(98-85) = 62 (Units)
Total Idle Time for M/c 8
= 18+3+7+13+(98-89) = 50 (Units)
Total Idle Time for M/c 9
= 23+2+13+18+2+(98-96) = 60 (Units)

Total Idle Time for M/c 10
= 27+10+13+1+2 = 53 (Units)

The **Gantt chart** according to **Table 2**. is shown in **Figure 1.**

2. RA's Heuristic Rule:
Algorithm: RA's Heuristic
Procedure: RA's Heuristic
Input: job list i, machine m;
Output: schedule *s*;
begin
for i = 1 to n
for j =1 to m-1
$w_{j1} = m-(j-1)$, $w_{j2} = j$;

$$t_{i1}' = \sum_{j=1}^{m} w_{j1}.t_{ij} \text{ and } t_{i2}' = \sum_{j=1}^{m} w_{j2}.t_{ij}$$

where weights are defined as follows:
$W_1 = \{w_{j1} \mid j=1, 2,\ldots,m\}=\{m,m-1,\ldots,2,1\}$
$W_2 = \{w_{j2} \mid j=1, 2,\ldots,m\}=\{1,2,\ldots,m-1,m\}$
Calculate U = $\{i \mid t_{i1}' < t_{i2}'\}$ and V = $\{i \mid t_{i1}' \geq t_{i2}'\}$;
// step 1
sort jobs in U with non-decreasing order of t_{i1}';
// step 2
sort jobs in V with non-increasing order of t_{i2}';
// step 3
output : optimal sequence is obtained as schedule s by U and V // step 4
end

Consider the above 10-job and 10-machine problem:

The solution constructed as follows:
Step 1:

Job	t_{i1}'	t_{i2}'
1	277	328
2	205	191
3	139	202
4	237	159
5	289	294
6	203	193
7	239	190
8	227	213
9	328	266
10	235	260

Jobs sets are:
U = {1, 3, 5, 10} and V = {2, 4, 6, 7, 8, 9}

Step 2: Sort jobs in U as follows:

Job i :	3	10	1	5
t_{i1}' :	139	235	277	289

Step 3: Sort jobs in V as follows:

Job i	9	8	6	2	7	4
t_{i2}'	266	213	193	191	190	159

Step 4: Output optimal sequence is
{3, 10, 1, 5, 9, 8, 6, 2, 7, 4}

Thus total processing time can be calculated as:

Table 3. Total Processing Time for 10-Jobs, 10-Machines by RA's Heuristic Model

Job i	M/c 1 Time In	M/c 1 Time Out	M/c 2 Time In	M/c 2 Time Out	M/c 3 Time In	M/c 3 Time Out	M/c 4 Time In	M/c 4 Time Out	M/c 5 Time In	M/c 5 Time Out	M/c 6 Time In	M/c 6 Time Out	M/c 7 Time In	M/c 7 Time Out	M/c 8 Time In	M/c 8 Time Out	M/c 9 Time In	M/c 9 Time Out	M/c 10 Time In	M/c 10 Time Out
3	0	1	1	3	3	5	5	6	6	9	9	16	16	18	18	23	23	27	27	31
10	1	5	5	8	8	13	13	21	21	24	24	25	25	28	28	36	36	39	39	46
1	5	10	10	12	13	16	21	26	26	33	33	42	42	49	49	57	57	59	59	66
5	10	16	16	22	22	23	26	34	34	40	42	46	49	52	57	66	66	72	72	80
9	16	23	23	31	31	37	37	46	46	47	47	55	55	57	66	67	72	78	80	86
8	23	28	31	32	37	44	46	47	47	54	55	58	58	64	67	73	78	80	86	88
6	28	31	32	39	44	49	49	51	54	56	58	59	64	69	73	76	80	82	88	94
2	31	33	39	45	49	53	53	55	56	62	62	64	69	74	76	78	82	88	94	95
7	33	40	45	47	53	57	57	63	63	68	68	73	74	75	78	80	88	93	95	97
4	40	47	47	52	57	63	63	66	68	70	73	76	76	78	80	84	93	95	97	99

Therefore, total processing time = **99 (Units)**
Total Idle Time for M/c 1 = 99-47 = 52 (Units)
Total Idle Time for M/c 2
= 1+2+2+4+1+(99-52) = 57 (Units)
Total Idle Time for M/c 3
= 3+3+6+8+(99-63) = 56 (Units)
Total Idle Time for M/c 4
= 5+7+3+2+2+2+(99-66) = 54 (Units)

Total Idle Time for M/c 5
= 6+12+2+1+6+1+(99-70) = 57 (Units)
Total Idle Time for M/c 6
= 9+8+8+1+3+4+(99-76) = 56 (Units)
Total Idle Time for M/c 7
= 16+7+14+3+1+1+(99-78) = 63 (Units)
Total Idle Time for M/c 8
= 18+5+13+(99-84) = 51 (Units)
Total Idle Time for M/c 9
= 23+9+18+7+(99-95) = 61 (Units)
Total Idle Time for M/c 10
= 27+8+13+6 = 54 (Units)

The **Gantt chart** according to **Table 3**. is shown in **Fig. 2**

XIV. RESULTS

Makespan for the applied heuristics rules are:

Rule	CDS's	RA's
Makespan	98 Units	99 Units

"**Makespan** is the time length from the starting of the first operation of the first demand to the finishing of the last operation of the last demand."

XV. CONCLUSION AND FUTURE SCOPE

We assign a particular time for completing a particular job only by Scheduling. The main objective of scheduling is to arrive at a position where we will get minimum processing time. The problem examined here is the n-job, m-machine problem in a flow shop .This work arrange the jobs in a particular order and get many combinations and choose that combination where we get the minimum make span. This study try to solve the problem of a flow shop scheduling with the objective of minimizing the makes pan. Here the objective is to minimize the make span of batch-processing machines in a flow shop. Comparisons based on RA's heuristics, CDS's heuristics, are proposed here. Analytic solutions in these heuristics are investigated. Gantt chart is generated to verify the effectiveness of the proposed approaches. As a result of the work proposed here the researcher found that out of the CDS's Heuristic Model and RA's Heuristic Model, earlier model yields efficient result because of makespan is minimum than that of later. This is explained with the help of example and their performances are examined with the help of Gantt charts. The algorithm is written in a very few lines of code, and requires only specification of the problem and a few parameters in order to solve it.

Further research may be conducted to investigate the applications of other meta-heuristics to the lot-streaming flowshop problem. Future research should address problems with different shop environments, including parallel machines flowshop, jobshop, and openshop. Problems with other performance measures, such as minimum due dates, maximum lateness, and multi-criteria measures should also be studied. Future research should be directed to generalize the method to multipart, multi machine group cases.

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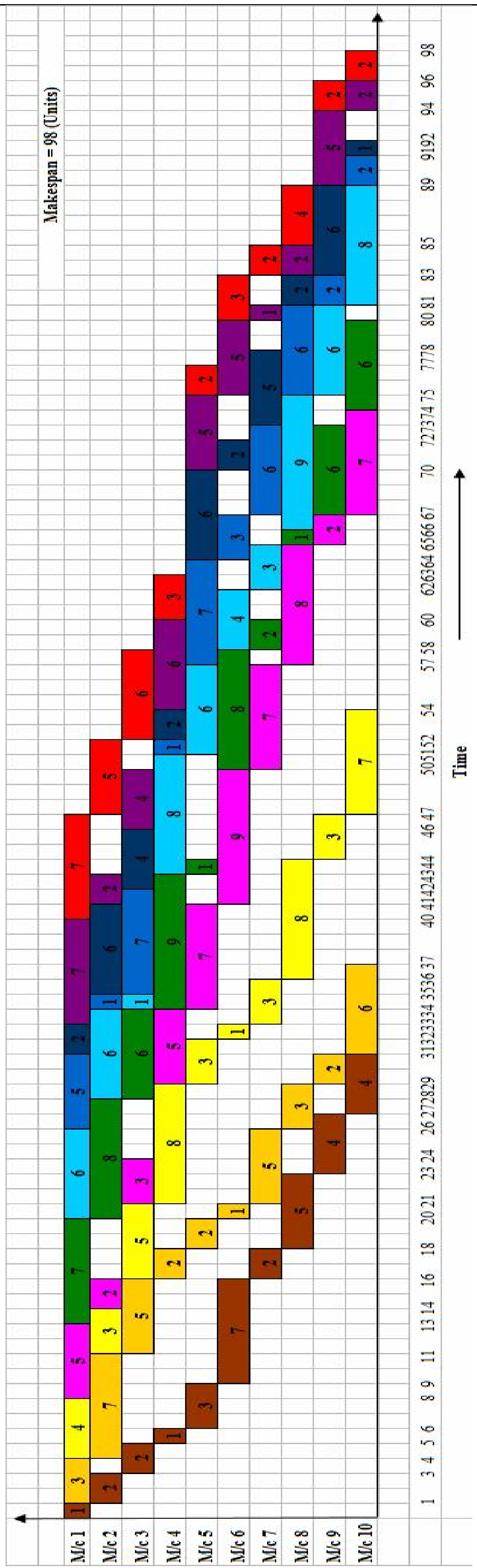

Fig.1: Gantt Chart for 10-Jobs, 10-Machines Problem by CDS's Heuristic Model

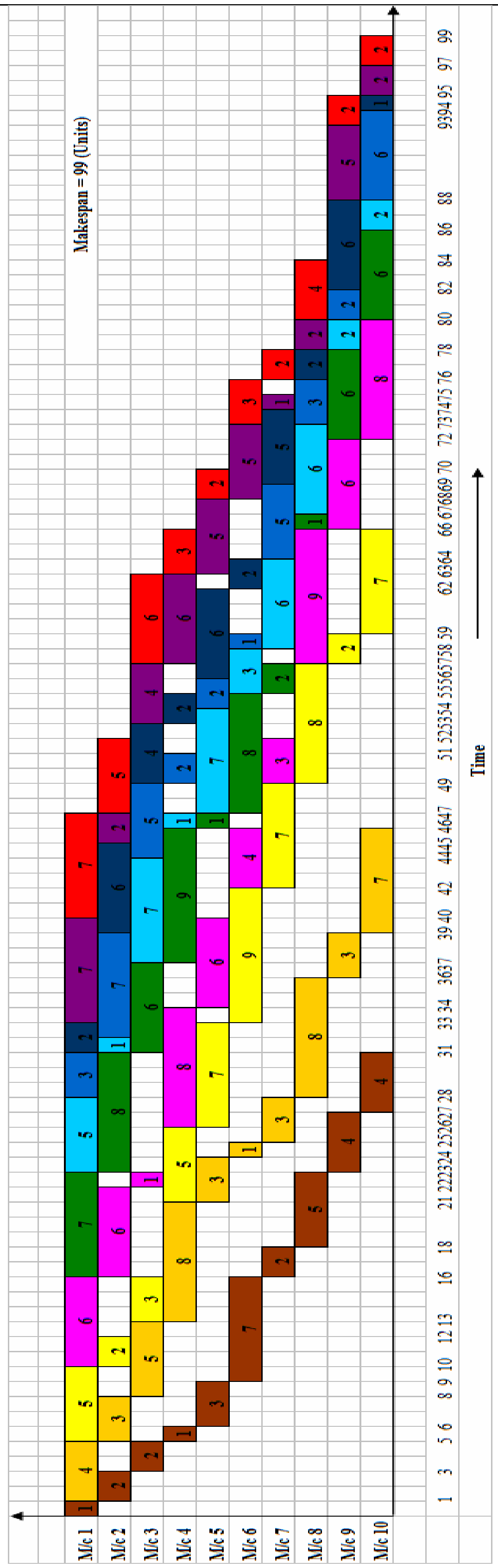

Fig.2: Gantt Chart for 10-Jobs, 10-Machines Problem by RA's Heuristic Model