INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Flow Shop Scheduling Problem For 10-Jobs, 8-Machines With Make Span Criterion

Ajay Kumar Agarwal
Assistant Professor, Mechanical Engineering Department
RIMT, Chidana, Gohana (Sonipat, Haryana), India

Rajan Garg
Assistant Professor & H.O.D, Mechanical Engineering Department
SDITM, Israna (Panipat, Haryana), India

Abstract:

In modern manufacturing there is the trend of the development of the Computer Integrated Manufacturing (CIM). 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 make span 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 papers model the problem of a flow shop scheduling with the objective of minimizing the makes pan. The work proposed here deal with the production planning problem of a flexible manufacturing system. The objective is to minimize the make span of batch-processing machines in a flow shop. 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 Gupta's heuristics, Palmer's heuristics are proposed in this work. Gantt chart is generated to verify the effectiveness of the proposed approaches.

Key words: *CIM; FMS; Flow shop scheduling problem; Make span; Heuristic models; Gantt chart.*

1.Introduction

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 flow shop 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 try to minimize the make span of batch-processing machines in a flow shop. 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 make-span objective. Consequently, comparisons based on Palmer's heuristics, Gupta's heuristics are proposed. Gantt chart is generated to verify the effectiveness of the proposed approaches.

2.Sequencing And Scheduling

Sequencing is a technique to order the jobs in a particular sequence. There are different types of sequencing which are followed in industries 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.

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.

3.Significance Of Work

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

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

4.Parameters Of The Work

- Average job flow time
    - Length of time (from arrival to completion) a job is in the system, on average
    - Lateness
- Average length of time the job will be late (that is, exceeds the due date by)
- Make span
- Total time to complete all jobs
- Average number of jobs in the system
- Measure relating to work in process inventory
- Equals total flow time divided by make span.

5.Objectives

- To deal with the production planning problem of a flexible manufacturing system. I model the problem of a flow shop scheduling with the objective of minimizing the make span.
- 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.

- To select appropriate heuristics approach for the scheduling problem through a comparative study.
- To solve FMS scheduling problem in a flow-shop environment considering the comparison based on Gupta's heuristics, Palmer's heuristics, are proposed. Gantt chart is generated to verify the effectiveness of the proposed approaches.

My objective of scheduling can yield

- Efficient utilization …
  - Staff
  - equipment
  - facilities
- Minimization of …
  - customer waiting time
  - Inventories.
  - Processing time.

6.Methodology

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. Make span 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 Palmer's algorithm, Gupta's algorithm are proposed. Here the main objective is to compare and find the efficient heuristics algorithm for minimizing the make span. In this work hierarchical approach were used to determine the optimal make span criteria.

7.Problem Statement

There is a flow shop 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 make span of batch-processing machines in a flow shop based on comparisons of Gupta's, Palmer'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 approach for planning problems are proposed which provides a way to optimize the make span which is our objective function.

8.Flow Shop 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 make span.

In an m-machine flow shop, 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 flow shop problems as:

- Flow shop (there is one machine at each stage).
- No-wait flow shop (a succeeding operation starts immediately after the preceding operation completes).
- Flexible (hybrid) flow shop (more than one machine exist in at least one stage) and
- Assembly flow shop (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).

9.Flow Shop Scheduling Methods

Heuristics for general *m*-Machine Problems

- Palmer's Heuristic Algorithm
- Gupta's Heuristic Algorithm

10.General Description

- There are m machines and n jobs.
- Each job consists of m operations and each operation requires a different machine
- n jobs have to be processed in the same sequence on m machines.

- Processing time of job i on machine j is given by t_{ij} (where i =1… n ; j =1,…,m)
- Make span: find the sequence of jobs minimizing the maximum flow time.

11.Main Assumptions

- Every job has to be processed on all machines in the order *(j* = 1,2,….,*m*).
- Every machine processes only one job at a time.
- Every job is processed on one machine at a time.
- Operations are not preemptive.
- 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.

12.Three Categories of FSP

12.1.Deterministic Flow-Shop Scheduling Problem

¾ Assume that fixed processing times of jobs are known.

12.2.Stochastic Flow-Shop Scheduling Problem

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

12.3.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.

13.Heuristics for General 8-Machines and 10-Jobs Problems

- Palmer's Heuristic Algorithm.
- Gupta's Heuristic Algorithm.

13.1.Palmer's Heuristic Rule

Algorithm: Palmer's Heuristic

Procedure: Palmer's Heuristic

Input: job list *i*, *machine m*;

Output: schedule “*s*”;

begin

for i = 1 to n

for j =1 to m

Calculate s_i= (m-1) $t_{j,m}$ +(m-3)$t_{j,(m-1)}$+(m-5)$t_{j,(m-2)}$; step 1

Permutation schedule is constructed by sequencing the jobs in Non-increasing order of s_i such as:

$s_{i1} \geq s_{i2} \geq \ldots\ldots \geq s_{in}$; step 2

end

Output optimal sequence is obtained as schedule “s”; step 3

end.

Consider a 10-job problem:

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

Table 1:General 10-Jobs, 8-Machines Problem

The solution constructed as follows:

Step 1: Set the slope index s_i for job i as:

s_1 = (m-1)$t_{1,8}$+(m-3)$t_{1,7}$…………………+(m-15)$t_{1,1}$

For 8 machines (m=8)

= (8-1)*2+(8-3)*4+(8-5)*3+(8-7)*9+(8-9)*7+(8-11)*1+(8-13)*5+(8-15)*6

= -25

Similarly

$s_2 = -34$

$s_3 = 35$

$s_4 = 39$

$s_5 = -14$

$s_6 = 17$

$s_7 = 6$

$s_8 = 9$

$s_9 = 48$

$s_{10} = 14$

Step 2: Jobs are sequenced according to decreasing order of slope values

$\boldsymbol{s_9 \geq s_4 \geq s_3 \geq s_6 \geq s_{10} \geq s_8 \geq s_7 \geq s_5 \geq s_1 \geq s_2}$

Step 3: Output optimal sequence is

{9, 4, 3, 6, 10, 8, 7, 5, 1, 2}

Thus total processing time can be calculated as:

Job i	M/c 1		M/c 2		M/c 3		M/c 4		M/c 5		M/c 6		M/c 7		M/c 8	
	Time		Time		Time		Time		Time		Time		Time		Time	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
9	0	1	1	5	5	11	11	13	13	18	18	22	22	25	25	34
4	1	5	5	11	11	14	14	15	18	23	23	29	29	36	36	43
3	5	13	13	14	14	20	20	24	24	27	29	38	38	43	43	52
6	13	16	16	18	20	24	24	27	27	34	38	40	43	46	52	57
10	16	22	22	25	25	30	30	35	35	37	40	47	47	48	57	66
8	22	24	25	33	33	42	42	43	43	49	49	52	52	56	66	74
7	24	29	33	42	42	46	46	48	49	53	53	61	61	67	74	80
5	29	38	42	50	50	52	52	61	61	63	63	68	68	77	80	86
1	38	44	50	55	55	56	61	68	68	77	77	80	80	84	86	88
2	44	47	55	64	64	69	69	76	77	79	80	85	85	91	91	92

Table 2: Total Processing Time for 10-Jobs, 8-Machines by Palmer's Heuristic Model

Therefore, total processing time = 92 (Units)

- Total Idle Time for M/c 1 = 92-47 = 45 (Units)
- Total Idle Time for M/c 2 = 1+2+2+4+(92-64) = 37 (Units)
- Total Idle Time for M/c 3 = 5+1+3+4+3+8+(92-69) = 47 (Units)

- Total Idle Time for M/c 4 = 11+1+5+3+7+3+4+1+(92-76) = 51 (Units)
- Total Idle Time for M/c 5 = 13+1+1+6+8+5+(92-79) = 47 (Units)
- Total Idle Time for M/c 6 = 18+1+2+1+2+9+(92-85) = 40 (Units)
- Total Idle Time for M/c 7 = 22+4+2+1+4+5+1+3+1+(92-91) = 44 (Units)
- Total Idle Time for M/c 8 = 25+2+3 = 30 (Units)

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

13.2.Gupta's Heuristic Rule

Algorithm: Gupta's Heuristic

Procedure: Gupta's Heuristic

Input: job list *i*, machine *m*;

Output: schedule "*s*";

begin

for $i = 1$ to n

for $k = 1$ to $m-1$

if $t_{i1} < t_{im}$ then

$e_i = 1$;

else

$e_i = -1$;

calculate $s_i = e_i / \min\{t_{i,k} + t_{i,k+1}\}$; step 1

end

Permutation schedule is constructed by sequencing the jobs in non-increasing order of s_i such as:

$s_{i1} \geq s_{i2} \geq \ldots\ldots \geq s_{in}$; step 2

end

Output optimal sequence is obtained as schedule "s" step 3

end .

Consider the above 10-jobs and 8-machines problem:

The solution constructed as follows:

Step 1: Set the slope index s_i for job i as:

$s_1 = -1/\min(35, 31) = -0.0323$

s_2 = -1/min (37, 35) = -0.0286

s_3 = 1/min (36, 37) = 0.0278

s_4 = 1/min (32, 35) = 0.0313

s_5 = -1/min (44, 41) = -0.0244

s_6 = 1/min (24, 26) = 0.0417

s_7 = 1/min (38, 39) = 0.0263

s_8 = 1/min (33, 39) = 0.0303

s_9 = 1/min (25, 33) = 0.0400

s_{10} = 1/min (29, 32) = 0.0345

Step 2: Jobs are sequenced according to decreasing order of slope values

$\mathbf{s_6 \geq s_9 \geq s_{10} \geq s_4 \geq s_8 \geq s_3 \geq s_7 \geq s_5 \geq s_2 \geq s_1}$

Step 3: Output optimal sequence is

{6, 9, 10, 4, 8, 3, 7, 5, 2, 1}

Thus total processing time can be calculated as:

Job i	M/c 1		M/c 2		M/c 3		M/c 4		M/c 5		M/c 6		M/c 7		M/c 8	
	Time		Time		Time		Time		Time		Time		Time		Time	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
6	0	3	3	5	5	9	9	12	12	19	19	21	21	24	24	29
9	3	4	5	9	9	15	15	17	19	24	24	28	28	31	31	40
10	4	10	10	13	15	20	20	25	25	27	28	35	35	36	40	49
4	10	14	14	20	20	23	25	26	27	32	35	41	41	48	49	56
8	14	16	20	28	28	37	37	38	38	44	44	47	48	52	56	64
3	16	24	28	29	37	43	43	47	47	50	50	59	59	64	64	73
7	24	29	29	38	43	47	47	49	50	54	59	67	67	73	73	79
5	29	38	38	46	47	49	49	58	58	60	67	72	73	82	82	88
2	38	41	46	55	55	60	60	67	67	69	72	77	82	88	88	89
1	41	47	55	60	60	61	67	74	74	83	83	86	88	92	92	94

Table 3: Total Processing Time for 10-Jobs, 8-Machines by Gupta's Heuristic Model

Therefore, total processing time = 94 (Units)

- Total Idle Time for M/c 1 = 94-47 = 47 (Units)
- Total Idle Time for M/c 2 = 3+1+1+(94-60) = 39 (Units)
- Total Idle Time for M/c 3 = 5+5+6+(94-61) = 49 (Units)

- Total Idle Time for M/c 4 = 9+3+3+11+5+2+(94-74) = 53 (Units)
- Total Idle Time for M/c 5 = 12+1+6+3+4+7+5+(94-83) = 49 (Units)
- Total Idle Time for M/c 6 = 19+3+3+3+6+(94-86) = 42 (Units)
- Total Idle Time for M/c 7 = 21+4+4+5+7+3+(94-92) = 46 (Units)
- Total Idle Time for M/c 8 = 24+2+3+3 = 32 (Units)

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

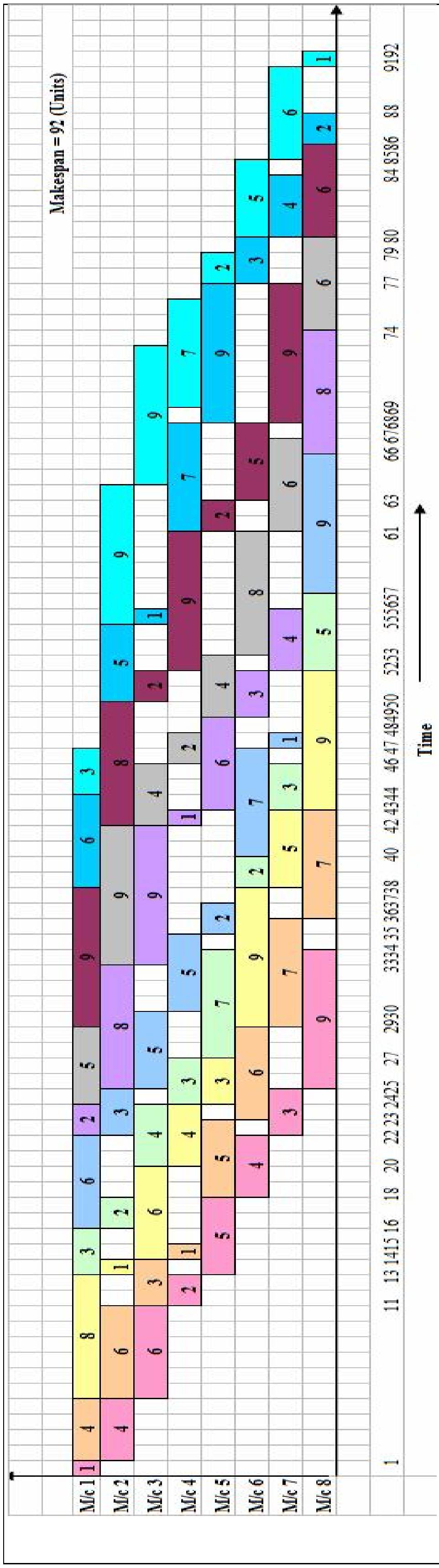

Figure.1: Gantt Chart for 10-Jobs, 8-Machines Problem by Palmer's Heuristic Model

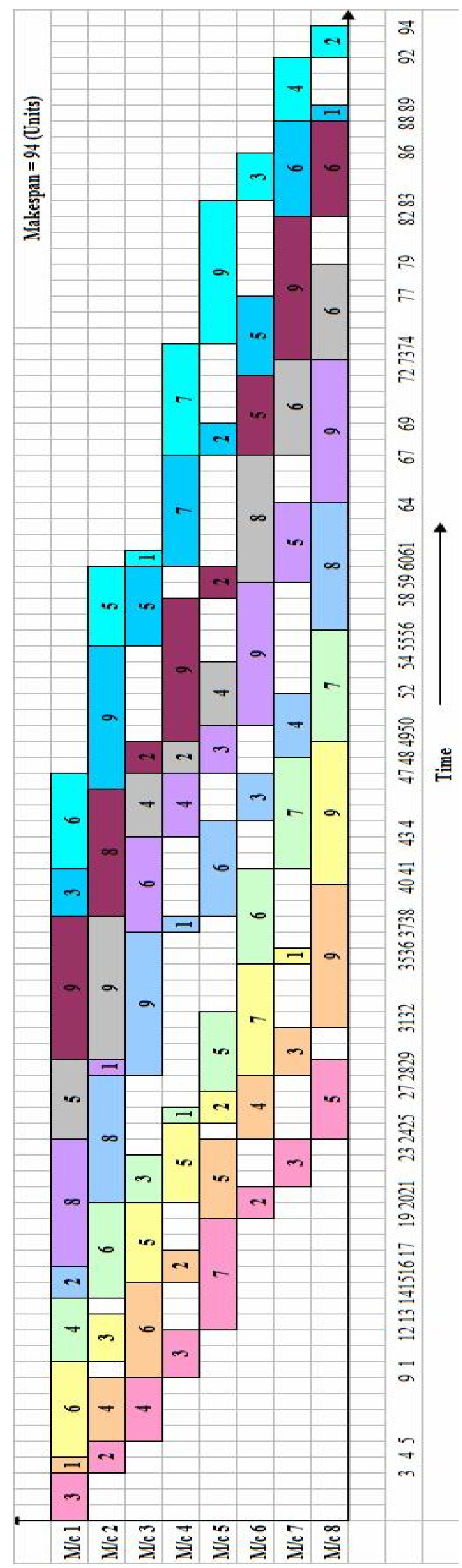

Figure.2: Gantt Chart for 10-Jobs, 8-Machines Problem by Gupta's Heuristic Model

14.Results

Makespan for the applied heuristics rules are:

Rule	Palmer's	Gupta's
Makespan	92 Units	94 Units

Table 4

"Make span 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."

15.Conclusion And Future Scope

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. 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 Palmer's heuristics, Gupta'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 Palmer's Heuristic Model and Gupta's Heuristic Model, the earlier one is the best Heuristic Model because of makespan is minimum than that of later.

Further research may be conducted to investigate the applications of other meta-heuristics to the lot-streaming flow shop problem. Future research should address problems with different shop environments, including parallel machines flow shop, job shop, and open shop. 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.

16.Reference

1. Ajay Kumar Agarwal, Rajan Garg, “Flow Shop Scheduling Problem for 10-Jobs, 10-Machines by Heuristics Models Using Make Span Criterion”, International Journal of Innovations in Engineering and Technology (IJIET) Issue 1, Vol. 2 (February 2013)
2. 28-37
3. Ajay Kumar Agarwal, Rajan Garg, “Advanced Modelistic Approach of Flow Shop Scheduling Problem for 10-Jobs, 8-Machines by Heuristics Models Using Make Span Criterion”, International Journal of Engineering, Business and Enterprises Applications (IJEBEA), Issue 3, Volume 2 (December, 2012-February, 2013) 76-84
4. Ajay Kumar Agarwal, Rajan Garg, “Advanced Modelistic Approach of Flow Shop Scheduling Problem for 8-Jobs, 3-Machines by Heuristics Models Using Make Span Criterion”, International Journal of Mechanical Science and Civil Engineering (IJMSCE), Volume 1 Issue 1 (December 2012)
5. Ajay Kumar Agarwal, “Flow Shop Scheduling Problem for 8 Jobs, 3-Machines with Make Span Criterion”, International Journal of Applied Engineering Research (IJAER), Vol. 7 No. 11(2012) 1757–1762
6. Gur Mosheiov, Assaf Sarig, “Due-date assignment on uniform machines”, European Journal of Operational Research 193 (2009) 49–58
7. K.H. Ecker, J.N.D. Gupta, “Scheduling tasks on a flexible manufacturing machine to minimize tool change delays”, European Journal of Operational Research 164 (2005) 627–638
8. Bo Chen, Chung-Yee Lee, “Logistics scheduling with batching and transportation”, European Journal of Operational Research 189 (2008) 871–876
9. Xianyi Wu, Xian Zhou, “Stochastic scheduling to minimize expected maximum lateness”, European Journal of Operational Research 190 (2008) 103–115
10. Lixin Tang, Hua Gong, “A hybrid two-stage transportation and batch scheduling problem”, Applied Mathematical Modelling 32 (2008) 2467–2479
11. Moosa Sharafali, Henry C. Co, Mark Goh, “Production scheduling in a flexible manufacturing system under random demand”, European Journal of Operational Research 158 (2004) 89–102

12. Jiaqiong Chen, Ronald G. Askin, "Project selection, scheduling and resource allocation with time dependent returns", European Journal of Operational Research 193 (2009) 23–34
13. Lixin Tang, Yufang Zhao, "Scheduling a single semi-continuous batching machine", Omega 36 (2008) 992 – 1004
14. Dirk Biskup, Jan Herrmann, "Single-machine scheduling against due dates with past-sequence-dependent setup times", European Journal of Operational Research 191 (2008) 587–592
15. Rongjun Chen, Wanzhen Huang, Guochun Tang, "Dense open-shop schedules with release times", Theoretical Computer Science 407 (2008) 389-399
16. Tiente Hsu, Ouajdi Korbaa, Re´my Dupas, Gilles Goncalves, "Cyclic scheduling for FMS: Modelling and evolutionary solving approach", European Journal of Operational Research 191 (2008) 464-484
17. T.C.E. Cheng, C.T. Ng, J.J. Yuan, "Single-machine scheduling of multi-operation jobs without missing operations to minimize the total completion time", European Journal of Operational Research 191 (2008) 320-331