

# 15

## CHAPTER

### Short-Term Scheduling

#### DISCUSSION QUESTIONS

1. Scheduling's objective is to optimize the use of resources so that production objectives are met.
2. Four criteria for scheduling are: minimizing completion time, maximizing utilization, minimizing work-in-process inventory, and minimizing customer waiting time. There is a one-to-one correspondence between minimizing completion time and minimizing flowtime.
3. Loading is the assignment of jobs to work processing centers. Work centers can be loaded by capacity or by assigning specific jobs to specific work centers. Gantt charts and the assignment method are loading techniques.
4. Five priority sequencing rules are:
  - First come, first served (FCFS); or First in, first out (FIFO): Jobs are sequenced in the order in which they arrive at the workstation.
  - Earliest due date (EDD): Jobs are sequenced in the order in which they are due for delivery to the customer.
  - Shortest processing time (SPT): Jobs are sequenced in order of the processing time required at the workstation, with the job requiring the least processing time at the workstation scheduled first.
  - Longest processing time (LPT): Jobs are sequenced in order of the processing time required at the workstation, with the job requiring the longest processing time at the workstation scheduled first.
  - Critical ratio (CR): Jobs are sequenced in order of increasing critical ratio (the ratio of *time required by work left to be done to time left to do the work*).
5. SPT minimizes the average flow time, average lateness, and average number of jobs in the system. It maximizes the number of jobs completed at any point. The disadvantage is that long jobs are pushed back in the schedule.
6. A due date may range from a (meaningless) promise to a contractual obligation. It is a target with or without penalties.
7. Flow time is the length of time a job is in the system; lateness is completion time minus due date.
8. Most students will go for EDD, to gain minimum lateness. Others will go for SPT, on the grounds that the team can't afford to tackle a job with an early due date and a long processing time. Interesting to see student assumption about sequence, damage, etc.
9. Johnson's rule is used to sequence several jobs through two work centers.

10. Four effectiveness measures for dispatching rules: average completion time, average number of jobs in the system, average job lateness, and utilization.

11. The *assignment method* involves adding and subtracting appropriate numbers in the problem's table in order to find the lowest opportunity cost for each assignment. The four steps are detailed in the chapter.

12. Advantages of level material use are:

- Lower inventory costs
- Faster product throughput (shorter lead times)
- Improved component and product quality
- Reduced floor space requirement
- Improved communication between employees because they are closer together
- A smoother production process because large lots have no hidden problems

13. Input/output control keeps track of planned versus actual inputs and outputs, highlighting deviations and indicating bottlenecks.

#### ETHICAL DILEMMA

Students may not be aware of the issue from an employee's or employer's perspective, but scheduling the "graveyard" shift and achieving performance on the graveyard shift can be a problem under the best of circumstances.

Rotating shifts is very difficult and the shorter the rotation cycle the worse—a one-week cycle is a killer. Given the box the manager has gotten into, the manager may want to let the empowered employees move to a one-week rotation and simultaneously begin an education effort. The combination should result in the employees soon voting for a change to a more reasonable and intelligent schedule.

As long as the manager is doing his best to educate the employees and the short-term rotation does not last long, we see no significant ethical problem.

Not making employees aware of the literature and acquiescing to a one-week schedule does suggest an unethical position.

#### ACTIVE MODEL EXERCISE

##### ACTIVE MODEL 15.1: Job Shop Sequencing

1. Which schedule (rule) minimizes the average completion time, maximizes the utilization and minimizes the average number of jobs in the system for this example?

**SPT**

2. Use the scrollbar to change the processing time for job C and use the scrollbar to modify the due date for job C. Does the same rule always minimize the average completion time?

**Yes—SPT always minimizes the average completion time, maximizes utilization, and minimizes the average number of jobs in the system.**

3. Which schedule (rule) minimizes the average lateness for this example?

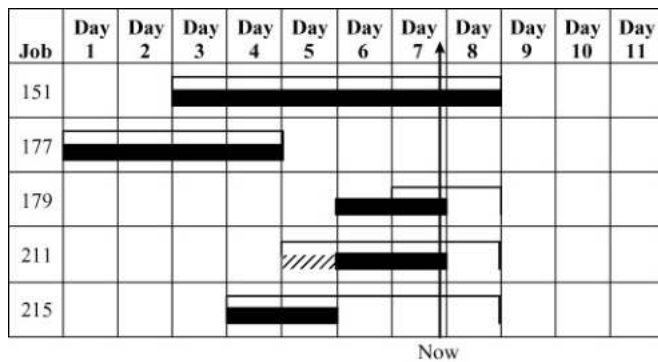
**EDD**

4. Use the scrollbar to change the due date for job C. Does the same rule always minimize the average lateness?

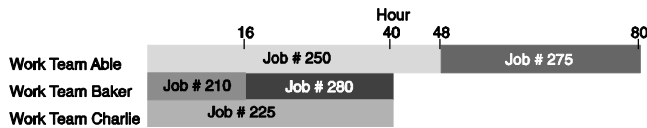
**No—if the due date for job C is 5, then FCFS and SPT minimize the average lateness.**

**END-OF-CHAPTER PROBLEMS**

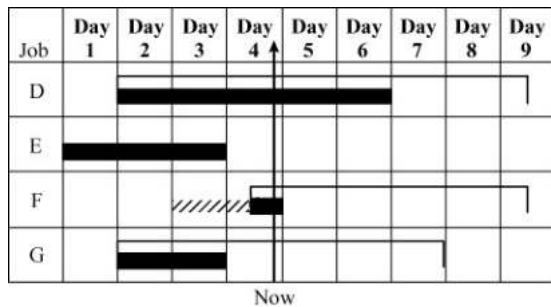
15.1 (a) Gantt scheduling chart:



(b) Gantt load chart:



15.2



15.3 Original problem:

Site/Customer	A	B	C	D
1	7	3	4	8
2	5	4	6	5
3	6	7	9	6
4	8	6	7	4

Row subtraction is done next:

Site/Customer	A	B	C	D
1	4	0	1	5
2	1	0	2	1
3	0	1	3	0
4	4	2	3	0

Column subtraction is done next:

Site/Customer	A	B	C	D
1	4	0	0	5
2	1	0	1	1
3	0	1	2	0
4	4	2	2	0

Cover zeros with lines:

Site/Customer	A	B	C	D
1	<del>4</del>	<del>0</del>	<del>0</del>	<del>5</del>
2	<del>1</del>	<del>0</del>	<del>1</del>	<del>1</del>
3	<del>0</del>	<del>1</del>	<del>2</del>	<del>0</del>
4	<del>4</del>	<del>2</del>	<del>2</del>	<del>0</del>

Optimal assignment:

- Taxi at post 1 to customer C
- Taxi at post 2 to customer B
- Taxi at post 3 to customer A
- Taxi at post 4 to customer D

Total distance traveled = 4 + 4 + 6 + 4 = 18 miles.

15.4 (a)

Original data

Job/Machine	A	B	C	D
1	7	8	8	10
2	10	9	7	6
3	11	5	9	6
4	9	11	5	8

First, we create a minimizing table by subtracting every number from 11

Job/Machine	A	B	C	D
1	4	2	3	1
2	1	2	4	5
3	0	6	2	5
4	2	0	6	3

then we do row subtraction:

Job/Machine	A	B	C	D
1	3	1	2	0
2	0	1	3	4
3	0	6	2	5
4	2	0	6	3

then we do column subtraction:

Job/Machine	A	B	C	D
1	<del>3</del>	<del>1</del>	<del>0</del>	<del>0</del>
2	<del>0</del>	<del>1</del>	<del>1</del>	<del>4</del>
3	<del>0</del>	<del>6</del>	<del>0</del>	<del>5</del>
4	<del>2</del>	<del>0</del>	<del>4</del>	<del>3</del>

Because it takes four lines to cover all zeros, an optimal assignment can be made at zero squares.

Assignment:

Job	to	Machine
1		D
2		A
3		C
4		B

(b) Total production: 40 [= 10 + 10 + 9 + 11]

15.5

Assignment	Rating
C53 at plant 1	10 cents
C81 at plant 3	4 cents
D5 at plant 4	30 cents
D44 at plant 2	14 cents
<b>Total manufacturing cost</b>	<b>58 cents</b>

15.6 Convert the minutes into \$:

	Marketing	Finance	Operations	Human Resources
Chris	\$80	\$120	\$125	\$140
Steve	\$20	\$115	\$145	\$160
Juana	\$40	\$100	\$85	\$45
Rebecca	\$65	\$35	\$25	\$75

The minimum-cost solution =

Chris	Finance	\$120
Steve	Marketing	\$20
Juana	Human Resources	\$45
Rebecca	Operations	\$25
		<b>\$210</b>

15.7 Original problem:

Squad\Case	A	B	C	D	E
1	14	7	3	7	27
2	20	7	12	6	30
3	10	3	4	5	21
4	8	12	7	12	21
5	13	25	24	26	8

(a) Row subtraction is done next:

Squad\Case	A	B	C	D	E
1	11	4	0	4	24
2	14	1	6	0	24
3	7	0	1	2	18
4	1	5	0	5	14
5	5	17	16	18	0

Column subtraction is done next:

Squad\Case	A	B	C	D	E
1	10	4	0	4	24
2	13	1	6	0	24
3	6	0	1	2	18
4	0	5	0	5	14
5	4	17	16	18	0

Cover zeros with lines:

Squad\Case	A	B	C	D	E
1	<del>10</del>	<del>4</del>	<del>0</del>	<del>4</del>	<del>24</del>
2	<del>13</del>	<del>1</del>	<del>6</del>	<del>0</del>	<del>24</del>
3	<del>6</del>	<del>0</del>	<del>1</del>	<del>2</del>	<del>18</del>
4	<del>0</del>	<del>5</del>	<del>0</del>	<del>5</del>	<del>14</del>
5	<del>4</del>	<del>17</del>	<del>16</del>	<del>18</del>	<del>0</del>

Optimal assignment:

- Squad 1 to case C
- Squad 2 to case D
- Squad 3 to case B
- Squad 4 to case A
- Squad 5 to case E

Total person-days projected using this assignment = 3 + 6 + 3 + 8 + 8 = 28 days.

(b) We can avoid the assignment of squad 5 to case E occurring by assigning a very high value to that combination. In this case, we assign 50.

Problem:

Squad\Case	A	B	C	D	E
1	14	7	3	7	27
2	20	7	12	6	30
3	10	3	4	5	21
4	8	12	7	12	21
5	13	25	24	26	50

Row subtraction is done next:

Squad\Case	A	B	C	D	E
1	11	4	0	4	24
2	14	1	6	0	24
3	7	0	1	2	18
4	1	5	0	5	14
5	0	12	11	13	37

Column subtraction is done next:

Squad\Case	A	B	C	D	E
1	11	4	0	4	10
2	14	1	6	0	10
3	7	0	1	2	4
4	1	5	0	5	0
5	0	12	11	13	23

Cover zeros with lines:

Squad\Case	A	B	C	D	E
1	<del>11</del>	4	0	4	<del>10</del>
2	<del>14</del>	1	6	0	<del>10</del>
3	<del>7</del>	0	1	2	<del>4</del>
4	<del>1</del>	5	0	5	<del>0</del>
5	<del>0</del>	12	11	13	<del>23</del>

Optimal assignment:

- Squad 1 to case C
- Squad 2 to case D
- Squad 3 to case B
- Squad 4 to case E
- Squad 5 to case A

Total person-days projected using this assignment = 3 + 6 + 3 + 21 + 13 = 46.

**15.8**

Original data:

	Barbara	Dona	Stella	Jackie
Raul	30	20	10	40
Jack	70	10	60	70
Gray	40	20	50	40
Ajay	60	70	30	90

Create the minimizing table by subtracting every number from 90:

	Barbara	Dona	Stella	Jackie
Raul	60	70	80	50
Jack	20	80	30	20
Gray	50	70	40	50
Ajay	30	20	60	0

Row subtraction:

	Barbara	Dona	Stella	Jackie
Raul	10	20	30	0
Jack	0	60	10	0
Gray	10	30	0	10
Ajay	30	20	60	0

Column subtraction:

	Barbara	Dona	Stella	Jackie
Raul	<del>10</del>	0	<del>30</del>	<del>0</del>
Jack	<del>0</del>	40	10	<del>0</del>
Gray	<del>10</del>	10	0	<del>10</del>
Ajay	<del>30</del>	0	60	<del>0</del>

Because it takes four lines to cover all zeros, an optimal assignment can be made at zero squares.

Note also that there are alternative optimal solutions.

The best pairs are assigned as follows:

- Ajay—Jackie
- Jack—Barbara
- Gray—Stella
- Raul—Dona

$$\begin{aligned} \text{Total compatibility score (overall)} &= 90 + 70 + 50 + 20 \\ &= 230 \end{aligned}$$

**15.9** Because this is a maximization problem, each number is subtracted from 95. The problem is then solved using the minimization algorithm.

(a)

Original data:

	Statistics	Management	Finance	Economics
Fisher	90	65	95	40
Golhar	70	60	80	75
Hug	85	40	80	60
Rustagi	55	80	65	55

Create the minimizing table by subtracting every number from 95:

	Statistics	Management	Finance	Economics
Fisher	5	30	0	55
Golhar	25	35	15	20
Hug	10	55	15	35
Rustagi	40	15	30	40

Row subtraction:

	Statistics	Management	Finance	Economics
Fisher	5	30	0	55
Golhar	10	20	0	5
Hug	0	45	5	25
Rustagi	25	0	15	25

Column subtraction:

	Statistics	Management	Finance	Economics
Fisher	<del>5</del>	30	0	50
Golhar	<del>10</del>	20	0	<del>0</del>
Hug	<del>0</del>	45	5	20
Rustagi	25	<del>0</del>	15	20

Because it takes four lines to cover all zeros, an optimal assignment can be made at zero squares.

Assignment	Rating
Fisher—finance	95
Golhar—economics	75
Hug—statistics	85
Rustagi—management	80
Total rating	335

(b) Since Fisher is not teaching statistics, the answer does not change. Total rating remains 335.

15.10

Job	Due Date	Duration (Days)
A	313	8
B	312	16
C	325	40
D	314	5
E	314	3

FCFS

Job	Due Date	Duration (days)	Flow	Start	End	Lateness
A	313	8	8	275	282	0
B	312	16	24	283	298	0
C	325	40	64	299	338	13
D	314	5	69	339	343	29
E	314	3	72	344	346	32
Totals:		72	237			74

EDD

Job	Due Date	Duration (days)	Flow	Start	End	Lateness
B	312	16	16	275	290	0
A	313	8	24	291	298	0
D	314	5	29	299	303	0
E	314	3	32	304	306	0
C	325	40	72	307	346	21
Totals:		72	173			21

SPT

Job	Due Date	Duration (days)	Flow	Start	End	Lateness
E	314	3	3	275	277	0
D	314	5	8	278	282	0
A	313	8	16	283	290	0
B	312	16	32	291	306	0
C	325	40	72	307	346	22
Totals:		72	131			22

LPT

Job	Due Date	Duration (days)	Flow	Start	End	Lateness
C	325	40	40	275	314	0
B	312	16	56	315	330	18
A	313	8	64	331	338	25
D	314	5	69	339	343	29
E	314	3	72	344	346	32
Totals:		72	301			104

- (a) FCFS (first come, first served):  
 Because all jobs arrived on day 275, and presumably in the order given, the FCFS sequence is:  
 A, B, C, D, E

- (b) EDD (earliest due date):

Job Sequence	Due Date
B	312
A	313
D	314
E	314
C	325

- (c) SPT (shortest processing time):

Job Sequence	Processing Time
E	3
D	5
A	8
B	16
C	40

- (d) LPT (longest processing time):

Job Sequence	Processing Time
C	40
B	16
A	8
D	5
E	3

Scheduling Rule	Average Tardiness	Average Flow Time	Average Number of Jobs in System
FCFS	14.8	47.4	3.3
EDD	4.2*	34.6	2.4
SPT	4.2*	26.2*	1.8*
LPT	20.8	60.2	4.2

\* = Best

15.11

Job	Due Date	Remaining Days	Critical Ratio
103	214	10	1.40
205	223	7	3.29
309	217	11	1.55
412	219	5	3.80
517	217	15	1.13

Jobs should be scheduled in the sequence 517, 103, 309, 205, 412 if scheduled by the critical ratio scheduling rule.

15.12

Job	Due date	Remaining Processing Time
A	212	6
B	209	3
C	208	3
D	210	8

Minimize total lateness. Comparing the scheduling efficiency of the several algorithms presented in terms of lateness:

(a) *First come, first served (FCFS):*

Job	Processing Time	Due Date	Start	End	Days Late
A	6	212	205	210	0
B	3	209	211	213	4
C	3	208	214	216	8
D	8	210	217	224	14
					Total: 26 days

(b) *Shortest processing time (SPT):*

Job	Processing Time	Due Date	Start	End	Days Late
B	3	209	205	207	0
C	3	208	208	210	2
A	6	212	211	216	4
D	8	210	217	224	14
					Total: 20 days

(c) *Longest processing time (LPT):*

Job	Processing Time	Due Date	Start	End	Days Late
D	8	210	205	212	2
A	6	212	213	218	6
C	3	208	219	221	13
B	3	209	222	224	15
					Total: 36 days

(d) *Earliest due date (EDD):*

Job	Processing Time	Due Date	Start	End	Days Late
C	3	208	205	207	0
B	3	209	208	210	1
D	8	210	211	218	8
A	6	212	219	224	12
					Total: 21 days

(e) *Critical ratio:*

Job	Due Date	Remaining Processing Time	Critical Ratio
A	212	6	$(212 - 205)/6 = 1.17$
B	209	3	$(209 - 205)/3 = 1.33$
C	208	3	$(208 - 205)/3 = 1.00$
D	210	8	$(210 - 205)/8 = 0.63$

$$\text{Critical ratio} = \frac{\text{Need date} - \text{today's date}}{\text{Days required to complete job}}$$

Job Sequence	Critical Ratio
D	0.63
C	1.00
A	1.17
B	1.33

*Critical ratio:*

Job	Processing Time	Due Date	Start	End	Days Late
D	8	210	205	212	2
C	3	208	213	215	7
A	6	212	216	221	9
B	3	209	222	224	15
					Total: 33 days

A minimum total lateness of 20 days seems to be about the least we may achieve.

Scheduling Rule	Average Lateness	Average Flow Time	Average Number of Jobs in System
FCFS	6.5	11.8	2.4
SPT	5.0	10.25	2.1
LPT	9.0	14.8	3.0
EDD	5.25	10.8	2.2
Critical ratio	8.3	14.0	2.8

SPT is best on all criteria.

15.13 (a)

Dispatching Rule	Job Sequence	Flow Time	Utilization	Average Number of Jobs	Average Late
EDD	CX-BR-SY-DE-RG	385	37.6%	2.66	10
SPT	BR-CX-SY-DE-RG	375	38.6%	2.59	12
LPT	RG-DE-SY-CX-BR	495	29.3%	3.41	44
FCFS	CX-BR-DE-SY-RG	390	37.2%	2.69	12

Starting day number: 241 (i.e., work can be done on day 241)

**Method: SPT—Shortest processing time**

	Processing Time	Due Date	Order	Flow Time	Completion Time	Late
CX-01	25	270	2	40	280	10
BR-02	15	300	1	15	255	0
DE-06	35	320	4	105	345	25
SY-11	30	310	3	70	310	0
RG-05	40	360	5	145	385	25
Total	145			375		60
Average				75		12

Sequence: BR-02,CX-01,SY-11,DE-06,RG-05 Average # in system = 2.586 = 375/145

**Method: LPT—Longest processing time**

	Processing Time	Due Date	Order	Flow Time	Completion Time	Late
CX-01	25	270	4	130	370	100
BR-02	15	300	5	145	385	85
DE-06	35	320	2	75	315	0
SY-11	30	310	3	105	345	35
RG-05	40	360	1	40	280	0
Total	145			495		220
Average				99		44

Sequence: RG-05,DE-06,SY-11,CX-01,BR-02, Average # in system = 3.414 = 495/145

**Method: Earliest due date (EDD); earliest to latest date**

	Processing Time	Due Date	Slack	Order	Flow Time	Completion Time	Late
CX-01	25	270	0	1	25	265	0
BR-02	15	300	0	2	40	280	0
DE-06	35	320	0	4	105	345	25
SY-11	30	310	0	3	70	310	0
RG-05	40	360	0	5	145	385	25
Total	145				385		50
Average					77		10

Sequence: CX-01,BR-02,SY-11,DE-06,RG-05 Average # in system = 2.655 = 385/145

**Method: First come, first served (FCFS)**

	Processing Time	Due Date	Slack	Order	Flow Time	Completion Time	Late
CX-01	25	270	0	1	25	265	0
BR-02	15	300	0	2	40	280	0
DE-06	35	320	0	3	75	315	0
SY-11	30	310	0	4	105	345	35
RG-05	40	360	0	5	145	385	25
Total	145				390		60
Average					78		12

Sequence: CX-01,BR-02,DE-06,SY-11,RG-05, Average # in system = 2.69 = 390/145

- (b) The best flowtime is SPT; (c) best utilization is SPT;
- (d) best lateness is EDD. (e) Students could support either of these choices. LPT scores poorly on all three criteria.

15.14

Job	Date Order Received	Production Days Needed	Date Order Due
A	110	20	180
B	120	30	200
C	122	10	175
D	125	16	230
E	130	18	210

- (a) FCFS (first come, first served):

Job Sequence	Date Order Received
A	110
B	120
C	122
D	125
E	130

- (b) EDD (earliest due date):

Job Sequence	Due Date
C	175
A	180
B	200
E	210
D	230

- (c) SPT (shortest processing time):

Job Sequence	Processing Time
C	10
D	16
E	18
A	20
B	30

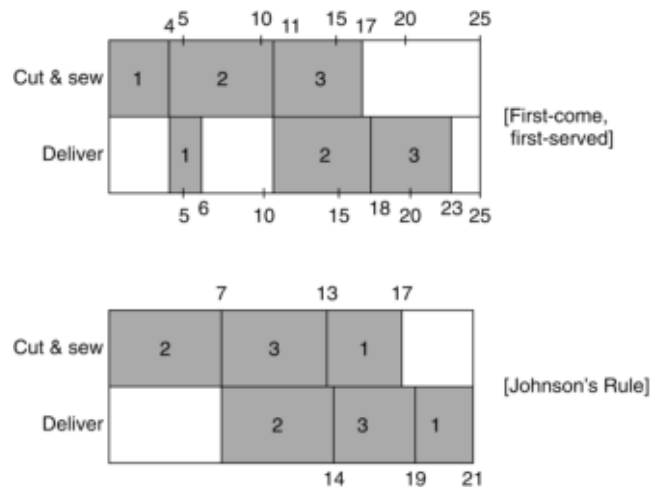
- (d) LPT (longest processing time):

Job Sequence	Processing Time
B	30
A	20
E	18
D	16
C	10

Scheduling Rule	Average Tardiness	Average Flow Time	Average Number of Jobs in System
FCFS	5.4	60.0	3.2
EDD	0.0	54.4	2.9
SPT	7.2	47.6	2.5
LPT	9.6	65.2	3.5

EDD is best for Average Lateness and SPT for the other two measures.

15.15



Johnson's Rule finishes in 21 days, 2 days faster than the First-come, First-served schedule, which finishes in 23 days.

15.16

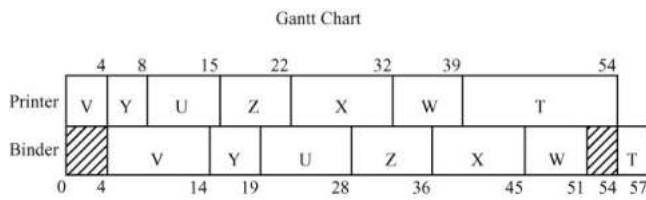
Job	Date Job Received	Production Days Needed	Date Job Due	Critical Ratio
1	215	30	260	0.33
2	220	20	290	2.00
3	225	40	300	1.25
4	240	50	320	1.40
5	250	20	340	4.50

Jobs should be scheduled in the sequence 1, 3, 4, 2, 5 if scheduled by the critical ratio scheduling rule.

15.17 (a, c) The jobs should be processed in the sequence V–Y–U–Z–X–W–T, for a total time of 57.

Job Shop Scheduling				Flow Time	
	Printer	Binder	Order	Printer	Binder
T	15	3	seventh	54	57
U	7	9	third	15	28
V	4	10	first	4	14
W	7	6	sixth	39	51
X	10	9	fifth	32	45
Y	4	5	second	8	19
Z	7	8	fourth	22	36
Time					57

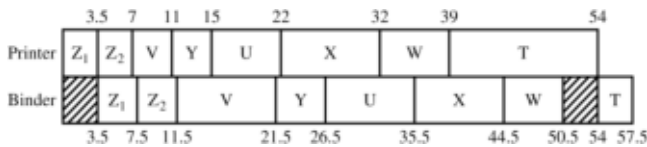
(b, c)



Note: Y could also be placed first, with no change in total times.

(d) Binding is idle from 0 to 4 and from 51 to 54 for a total of 7 hours.

(e) We split Job Z into two halves and call them Z<sub>1</sub> and Z<sub>2</sub>. The times become 3.5 hours each on the Printer and 4 hours on the Binder.

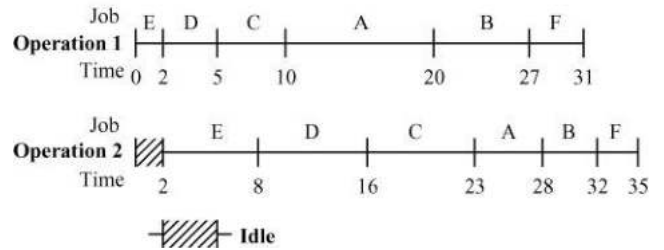


We see that the Binder idle time is now 3.5 hours plus 3.5 hours, for a total of 7 hours. So it is unchanged. T is not finished any sooner, but other jobs are completed ½ hour earlier.

Job	Operation 1 (Hours)	Operation 2 (Hours)
A	10	5
B	7	4
C	5	7
D	3	8
E	2	6
F	4	3

Using Johnson's rule, the optimal sequence is:

E, D, C, A, B, F



15.19	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Worker 1	6	5	5	5	6	4	3
Worker 2	5	4	4	4	5	4	3
Worker 3	4	3	3	3	4	4	3
Worker 4	3	3	3	2	3	③	②
Worker 5	2	2	2	1	2	③	②
Worker 6	1	①	②	1	1	2	1
Worker 7	1	1	①	0	0	④	④

Note: Seven employees are needed; six have two consecutive days off. The 7th worker has two consecutive days off but only works 4 days. Days off are circled.

**15.20**

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Worker 1	3	4	4	5	6	7	4
Worker 2	3	3	3	4	5	6	4
Worker 3	3	3	2	3	4	5	3
Worker 4	2	3	2	2	3	4	2
Worker 5	1	2	2	2	2	3	1
Worker 6	1	1	1	1	1	2	1
Worker 7	1	0	0	0	0	1	1

Note: Seven employees are needed. Six have two consecutive days off. The 7th worker has 4 days off and only works 3.

**15.21**

Period	1	2	3	4	Total
Planned input	80	80	100	100	360
Actual input	85	85	85	85	340
Deviation	+5	+5	-15	-15	-20
Planned output	90	90	90	90	360
Actual output	85	85	80	80	330
Deviation	-5	-5	-10	-10	-30
Backlog: 30	30	30	35	40	

Analysis: The completed input/output report shows that the Grinding work center did not process all the jobs that were available during the four periods; therefore, the desired output rate was not achieved. Also, rather than reducing the backlog, the backlog increased to 40 units.

**ADDITIONAL HOMEWORK PROBLEMS\***

**15.22** (a) Assign:

Job	to	Machine
1		A
2		D
3		B
4		C

(b) Total cost: 23

**15.23**

Client \ Attorney	1	2	3	Smallest in Row
Divorce	800	1100	1200	800
Felony	500	1600	1300	500
Discrimination	500	1000	2300	500

Client \ Attorney	1	2	3
Divorce	0	300	400
Felony	0	1100	800
Discrimination	0	500	1800
	0	300	400

**Smallest in Column**

Subtracting the smallest number from each column:

Client \ Attorney	1	2	3
Divorce	0	0	0
Felony	0	800	400
Discrimination	0	200	1400

Draw the minimum number of lines needed to cover the zeros:

Client \ Attorney	1	2	3
Divorce	0	0	0
Felony	0	800	400
Discrimination	0	200	1400

\*Here are solutions to the additional homework problems that are located on our Web site, at [www.myomlab.com](http://www.myomlab.com).

Subtracting the *smallest uncovered number* (200) from all uncovered numbers, and adding it to the numbers at the intersections of the lines:

	<b>Attorney</b>		
<b>Client</b>	<b>1</b>	<b>2</b>	<b>3</b>
Divorce	200	0	0
Felony	0	600	200
Discrimination	0	0	1200

Again, draw the minimum number of lines needed to cover the zeros:

	<b>Attorney</b>		
<b>Client</b>	<b>1</b>	<b>2</b>	<b>3</b>
Divorce	<del>200</del>	<del>0</del>	<del>0</del>
Felony	0	600	200
Discrimination	<del>0</del>	<del>0</del>	<del>1200</del>

The solution is now optimal, and the assignments can be made in the following manner:

Assignment	Cost
Divorce case to Attorney 3	1200
Felony case to Attorney 1	500
Discrimination case to Attorney 2	1000
	\$2700

15.24

	<b>Unit</b>				
<b>Nurse</b>	<b>Ur.</b>	<b>Ca.</b>	<b>Or.</b>	<b>Ob.</b>	<b>Smallest in Row</b>
Hawkins	28	18	15	75	15
Condriac	32	48	23	38	23
Bardot	51	36	24	36	24
Hoolihan	25	38	55	12	12

Subtracting the smallest number from each row:

	<b>Unit</b>				
<b>Nurse</b>	<b>Ur.</b>	<b>Ca.</b>	<b>Or.</b>	<b>Ob.</b>	
Hawkins	13	3	0	60	
Condriac	9	25	0	15	
Bardot	27	12	0	12	
Hoolihan	13	26	43	0	
	9	3	0	0	<b>Smallest in Column</b>

Subtracting the smallest number from every column:

Nurse \ Unit	Ur.	Ca.	Or.	Ob.
Hawkins	4	0	0	60
Condriac	0	22	0	15
Bardot	18	9	0	12
Hoolihan	4	23	43	0

The following optimal assignments can now be made:

Assignments	Cost
Nurse Condriac to Urology	32
Nurse Hawkins to Cardiology	18
Nurse Bardot to Orthopedics	24
Nurse Hoolihan to Obstetrics	12
<b>Total Cost:</b>	<b>86</b>

15.25

Plant Component	1	2	3	4	5	6	7	8	Smallest in Row
C53	10	12	13	11	10	6	16	12	6
C81	5	6	4	8	4	9	6	6	4
D5	32	40	31	30	42	35	36	49	30
D44	17	14	19	15	10	16	19	12	10
E2	6	7	10	5	8	10	11	5	5
E35	8	10	12	8	9	10	9	6	6
G99	55	62	61	70	62	63	65	59	55
Dummy	0	0	0	0	0	0	0	0	0

Subtracting the smallest number from every row:

Plant Component	1	2	3	4	5	6	7	8	Smallest in Column
C53	4	6	7	5	4	0	10	6	0
C81	1	2	0	4	0	5	2	2	0
D5	2	10	1	0	12	5	6	19	0
D44	7	4	9	5	0	6	9	2	0
E2	1	2	5	0	3	5	6	0	0
E35	2	4	6	2	3	4	3	0	0
G99	0	7	6	15	7	8	10	4	0
Dummy	0	0	0	0	0	0	0	0	0

Draw the minimum number of lines needed to cover the zeros:

Plant Component	1	2	3	4	5	6	7	8
C53	4	6	7	5	4	0	10	6
C81	1	2	0	4	0	5	2	2
D5	2	10	1	0	12	5	6	19
D44	7	4	9	5	0	6	9	2
E2	1	2	5	0	3	5	6	0
E35	2	4	6	2	3	4	3	0
G22	0	7	6	15	7	8	10	4
Dummy	0	0	0	0	0	0	0	0

Subtracting the *smallest uncovered number* (2) from all uncovered numbers, and adding it to the numbers at the intersections of the lines:

Plant Component	1	2	3	4	5	6	7	8
C53	4	4	7	5	4	0	8	6
C81	1	0	0	4	0	5	0	2
D5	2	8	1	0	12	5	4	19
D44	7	2	9	5	0	6	7	2
E2	1	0	5	0	3	5	4	0
E35	2	2	6	2	3	4	1	0
G99	0	5	6	15	7	8	8	4
Dummy	2	0	2	2	2	2	0	2

Draw the minimum number of lines needed to cover the zeros:

Plant Component	1	2	3	4	5	6	7	8
C53	<del>4</del>	<del>4</del>	<del>7</del>	<del>5</del>	<del>4</del>	<del>0</del>	<del>8</del>	<del>6</del>
C81	<del>1</del>	<del>0</del>	<del>0</del>	<del>4</del>	<del>0</del>	<del>5</del>	<del>0</del>	<del>2</del>
D5	<del>2</del>	<del>8</del>	<del>1</del>	<del>0</del>	<del>12</del>	<del>5</del>	<del>4</del>	<del>19</del>
D44	<del>7</del>	<del>2</del>	<del>9</del>	<del>5</del>	<del>0</del>	<del>6</del>	<del>7</del>	<del>2</del>
E2	<del>1</del>	<del>0</del>	<del>5</del>	<del>0</del>	<del>3</del>	<del>5</del>	<del>4</del>	<del>0</del>
E35	<del>2</del>	<del>2</del>	<del>6</del>	<del>2</del>	<del>3</del>	<del>4</del>	<del>1</del>	<del>0</del>
G99	<del>0</del>	<del>5</del>	<del>6</del>	<del>15</del>	<del>7</del>	<del>8</del>	<del>8</del>	<del>4</del>
Dummy	<del>2</del>	<del>0</del>	<del>2</del>	<del>2</del>	<del>2</del>	<del>2</del>	<del>0</del>	<del>2</del>

The following optimal assignments can now be made:

Assignments	Cost
Component G99 to Plant 1	0.55
Component E2 to Plant 2	0.07
Component C81 to Plant 3	0.04
Component D5 to Plant 4	0.30
Component D44 to Plant 5	0.10
Component C53 to Plant 6	0.06
Component E35 to Plant 8	0.06
<b>Total Cost:</b>	<b>\$1.18</b>

Plant 7 will not be given a component.

**15.26**

Job	Due Date	Duration (Days)
010	260	30
020	258	16
030	260	8
040	270	20
050	275	10

(a) FCFS (first come, first served):  
 Because all jobs arrived on day 210, and presumably in the order given, the FCFS sequence is:

010, 020, 030, 040, 050

(b) EDD (Earliest due date):

Job Sequence	Due Date
020	258
010	260
030	260
040	270
050	275

Note that the tie breaker of longest processing time was used; however, job 030 could come before job 010.

(c) SPT (shortest processing time):

Job Sequence	Processing Time
030	8
050	10
020	16
040	20
010	30

(d) LPT (longest processing time):

Job Sequence	Processing Time
010	30
040	20
020	16
050	10
030	8

Scheduling Rule	Average Tardiness	Average Flow Time	Average Number of Jobs in System
FCFS	(7.4)	6.8	57.6
EDD	(7.4)	6.8	54.8
SPT	(6.8)	6.6	39.6
LPT	(12.6)	12.0	61.2

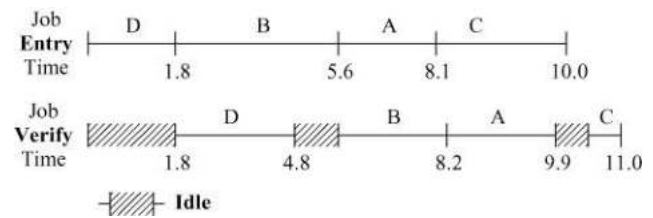
If current time is 210.

**15.27**

Job	Data Entry (Hours)	Verify (Hours)
A	2.5	1.7
B	3.8	2.6
C	1.9	1.0
D	1.8	3.0

Using Johnson's Rule, the optimal sequence is:

D, B, A, C



### CASE STUDY

#### OLD OREGON WOOD STORE

1. The assignment algorithm can be utilized to yield the fastest time to complete a table.

Person	Job	Time (Minutes)
Tom	Preparation	100
Cathy	Assembly	70
George	Finishing	60
Leon	Packaging	10
Total time		240

2. If Randy is used, the assignment problem becomes unbalanced, and a dummy job must be added. The optimum assignment would be:

Person	Job	Time (Minutes)
George	Preparation	80
Tom	Assembly	60
Leon	Finishing	80
Randy	Packaging	10
Total time		230

Cathy becomes the Backup.

3. If Cathy is given the preparation task, the solution of the assignment with the remaining three workers assigned to the remaining three tasks is:

Person	Job	Time (Minutes)
Cathy	Preparation	120
Tom	Assembly	60
George	Finishing	60
Leon	Packaging	10
Total time		250

If Cathy is assigned to the finishing task, the optimum assignment is:

Person	Job	Time (Minutes)
George	Preparation	80
Tom	Assembly	60
Cathy	Finishing	100
Leon	Packaging	10
	Total time	250

4. One possibility would be to combine the packaging operation with finishing. Then George could build an entire table by himself (in 230 minutes), and Tom could do preparation (100 minutes), Randy the assembly (80 minutes), and Leon the finishing and packaging (90 minutes). This crew would build 4.8 tables in a 480-minute workday, while George himself could build 2.09 tables—a total of almost 7 tables per day.

To utilize all five workers, George and Tom could each build entire tables, 2.09 and 1.75 per day respectively. Letting Randy do preparation (110 minutes), Cathy the assembly (70 minutes), and Leon the finishing and packaging (90 minutes) allows an additional 4.36 tables per day, for a total of 8.2 per day.

Nine tables per day could be achieved by having Tom prepare and assemble 3 tables, George prepare and finish 3 tables, Cathy assemble 6 tables, Leon finish 6 tables, and Randy prepare 3 tables and package all 9 tables. George, Cathy, and Randy would each have 60 minutes per day unutilized and could build 0.6 tables by having George do preparation (80 minutes), Cathy assembly and packaging (95 minutes), and Randy the finishing (100 minutes).

**VIDEO CASE STUDY**

**SCHEDULING AT HARD ROCK CAFE**

1. This case study works best if the 7-minute video, made specifically for this text, is shown and accompanies the written case.

Hoffman currently uses these factors in forecasting weekly cafe sales: (1) last year’s sales, (2) convention center data, (3) hotel occupancy rates, (4) concerts scheduled at Hard Rock Live. Other factors could include (1) weather forecasts (most tourists head home if a hurricane is bearing down on Florida and a rainy day will reduce sales), (2) concerts or major events at Universal Studios (which is adjacent to the cafe), (3) world events (since the restaurant is heavily tourist driven), (4) major events at the Citrus Bowl (football) or Waterhouse Arena that may bring large numbers of out-of-towners with them.

2. To lower turnover, Hard Rock tries to make schedules financially profitable to servers. It also provides a lot of flexibility in terms of shift preference. Further, the cafe provides a favorable working environment, where servers can “be themselves,” even if that means spiked, green hair and nose rings. At the end of 10 years of service, every Hard Rock employee receives a gold Rolex watch valued at over \$10,000.

3. Seniority cuts down on turnover by rewarding employees who remain a longer time with an organization. Shift and service station are critical assignments, which can make a very big difference in income to a server.

4. By not overstaffing, the software increases employee productivity. It also places senior servers at the busiest/hardest stations.

**ADDITIONAL CASE STUDY\***

**PAYROLL PLANNING, INC.**

The first step in tackling this case study is to translate the due dates into minutes. Thus, for the monthly clients, the due dates are  $9 \times 60 = 540$ ; for the biweekly clients, the due dates are  $12 \times 60 = 720$ ; and for the weekly clients, the due dates are  $15 \times 60 = 900$ . The table shows the results of running Excel OM or POM for Windows under different processing rules.

Rule	Average Number of Jobs in Systems	Average Flow Time	Average Lateness
Earliest due date (EDD)	20.80	928	193
SPT	12.03	537	135
Critical ratio	22.82	1,018	273

It can be seen from the table that the rules that seem most intuitive work least well. The best rule seems to be shortest processing time (with its well-known advantages).

\* This case study is located at our Companion Web site, at [www.pearsonhighered.com/heizer](http://www.pearsonhighered.com/heizer).