

## Unit 12 Sequencing

### 12.1 Priority Sequencing Rules

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- Priority Rules provide guidelines for the sequence in which jobs should be worked.
- In using this rules, job processing times and due dates are important pieces of information.
- Priority Rules try to minimize completion time, number of jobs in the system, and job lateness, while maximizing facility utilization.

### 12.1 Priority Sequencing Rules

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- 4 types
  - First come, first served (FCFS)
  - Shortest processing time (SPT)
  - Earlier due date (EDD)
  - Critical Ratio (CR)

## 12.1 Priority Sequencing Rules

- First come, first served (FCFS)
  - Jobs are processed in the order in which they arrive at a machine or work center.
- Shortest processing time (SPT)
  - Jobs are processed according to processing time at a machine or work center, shortest job first.
- Earlier due date (EDD)
  - Jobs are processed according to due date, earlier due date first.
- Critical Ratio (CR)
  - Jobs are processed according to smallest ratio of time remaining until due date to processing time remaining.

### 12.1.1 Sequencing Rules: First Come, First Served (FCFS) Example 1

Five jobs are to be done at custom furniture shop:

Job	Days to Finish	Date Promised
A	2	5
B	8	8
C	6	12
D	4	10
E	1	4

*Note!*

**Flow time:** is the amount of time a job spent in shop/factory  
**Total work time/makespan:** is the time needed to process given set of jobs  
**Lateness:** different between completion time and due date (if (-ve) put it zero)

Do all the jobs get done on time?

No, Jobs B, C, D and E are going to be late

#### **SOLUTION**

Measure of effectiveness:

Sequence	Work Time	Flow Time	Due Date	Lateness
A	2	2	5	0
B	8	10	8	2
C	6	16	12	4
D	4	20	10	10
E	1	21	4	17
<b>TOTALS</b>	21	69		33

### 12.1.1 Sequencing Rules: First Come, First Served (FCFS) Example 1

Performance measuring formula:

$$\# \text{Average completion time} = \text{Total flow time} \div \text{No. of jobs}$$

$$\# \text{Average number of jobs in the system} = \text{Total flow time} \div \text{Total job work time}$$

$$\# \text{Average job lateness} = \text{Total late days} \div \text{No. of jobs}$$

$$\# \text{Utilization} = \text{Total job work time} \div \text{Total flow time} = \text{in \%}$$

<b>#Average completion time</b>	<b><math>69/5 = 13.8 \text{ days}</math></b>
<b>#Average number of jobs in the system</b>	<b><math>69/21 = 3.28 \text{ jobs}</math></b>
<b>#Average lateness</b>	<b><math>33/5 = 6.6 \text{ days}</math></b>
<b>#Utilization</b>	<b><math>21/69 = 30.4\%</math></b>

### 12.1.1 Sequencing Rules: First Come, First Served (FCFS) Example 2

Five jobs are to be assemble in a plastic factory:

<b>Job</b>	<b>Job Work (Processing) Time (Days)</b>	<b>Job Due Date (Days)</b>
<b>A</b>	<b>6</b>	<b>8</b>
<b>B</b>	<b>2</b>	<b>6</b>
<b>C</b>	<b>8</b>	<b>18</b>
<b>D</b>	<b>3</b>	<b>15</b>
<b>E</b>	<b>9</b>	<b>23</b>

### 12.1.1 Sequencing Rules: First Come, First Served (FCFS) Example 2

**SOLUTION:**

Job Sequence	Job Work (Processing) Time	Flow Time	Job Due Date	Job Lateness
A	6	6	8	0
B	2	8	6	2
C	8	16	18	0
D	3	19	15	4
E	9	28	23	5
	28	77		11

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}} = 77/5 = 15.4 \text{ days}$$

$$\text{Utilization} = \frac{\text{Total job work time}}{\text{Total flow time}} = 28/77 = 36.4\%$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work time}} = 77/28 = 2.75 \text{ jobs}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} = 11/5 = 2.2 \text{ days}$$

### 12.1.2 Sequencing Rules: Shortest Processing Time (SPT)

- Shortest Processing Time. Jobs with the shortest processing time are scheduled first.
- Jobs are sequenced in increasing order of their processing time.
- Shortest processing time is optimal for minimizing:
  - Average and total flow time
  - Average waiting time
  - Average and total lateness

### 12.1.2 Sequencing Rules: Shortest Processing Time (SPT)

The steps for using this rule are :

1. Firstly, the user will input the number of jobs, the job names, the processing time and the due date of each job or use the data values given at the starting point.
2. The second step is sorting out the shortest processing time among the jobs.
3. Thirdly, calculate the flow time of each job by using the processing time. The flow time is the accumulation of processing time each job by each job.

### 12.1.2 Sequencing Rules: Shortest Processing Time (SPT) Example 1

Suppose we have the four jobs to the right arrive for processing on one machine

Jobs (in order of arrival)	Processing Time (days)	Due Date (days hence)
A	4	5
B	7	10
C	3	6
D	1	4

## 12.1.2 Sequencing Rules: Shortest Processing Time (SPT) Example 1

**Answer: Shortest Operating Time Schedule**

Sequence	Work Time	Flow Time	Due Date	Lateness
D	1	1	4	0
C	3	4	6	0
A	4	8	5	3
B	7	15	10	5
<b>TOTAL</b>	15	28		8

**Jobs A and B  
are going to  
be late**

Average completion time	$28/4 = 7$ days
Average number of jobs in the system	$28/15 = 1.867$ jobs
Average lateness	$8/4 = 2$ days
Utilization	$15/28 = 53.57\%$

## 12.1.2 Sequencing Rules: Shortest Processing Time (SPT) Example 2

- A Brake Pad have 5 process that will undergo before it will be produce at a particular point in time . The jobs are labeled A, B, C, D, and E in the order that they entered the shop. The respective processing times and due dates are given in the table below. Determine the schedule by using the SPT rule.

Job sequence	Processing Time	Due Date
A(turning)	6	8
B(drilling)	2	6
C(grinding)	8	18
D(milling)	3	15
E( facing)	9	23

### 12.1.2 Sequencing Rules: Shortest Processing Time (SPT) Example 2

Solution:

<i>Job Sequence</i>	<i>Job Work (Processing) Time</i>	<i>Flow Time</i>	<i>Job Due Date</i>	<i>Job Lateness</i>
<i>B</i>	2	2	6	0
<i>D</i>	3	5	15	0
<i>A</i>	6	11	8	3
<i>C</i>	8	19	18	1
<i>E</i>	9	28	23	5
	<u>28</u>	<u>65</u>		<u>9</u>

### 12.1.2 Sequencing Rules: Shortest Processing Time (SPT) Example 2

#Average completion time = Total flow time ÷ No. of jobs

#Average number of jobs in the system = Total flow time ÷ Total job work time

#Average job lateness = Total late days ÷ No. of jobs

#Utilization = Total job work time ÷ Total flow time = in %

Average completion time	$65/5 = 13$ days
Average number of jobs in the system	$65/28 = 2.3214$ jobs
Average lateness	$9/5 = 1.8$ days
Utilization	$28/65 = 43.08\%$

### 12.1.3 Sequencing Rules: Earliest Due Date (EDD)

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- Jobs are sequenced in increasing order of their due dates;
- The job with earliest due date is first, the one with the next earliest due date is second, and so on;
- A priority sequencing rule that specifies that the job with the earliest due date is the next job to be processed

### 12.1.3 Sequencing Rules: Earliest Due Date (EDD)

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#### **The steps for using this rule are :**

1. Firstly, the user will input the number of jobs, the job names, the processing time and the due date of each job or use the data values given at the starting point.
2. The second step is sorting out the earliest due date among the jobs.
3. Thirdly, calculate the flow time of each job by using the processing time. The flow time is the accumulation of processing time each job by each job.

### 12.1.3 Sequencing Rules: Earliest Due Date (EDD)

•The formulas for calculation are below:

#Average completion time = Total flow time ÷ No. of jobs

#Average number of jobs  
In the system = Total flow time ÷ Total job work time

#Average job lateness = Total late days ÷ No. of jobs

#Utilization = Total job work time ÷ Total flow time = in %

### 12.1.3 Sequencing Rules: Earliest Due Date (EDD) Example 1

- Five engine blocks are waiting for processing. The processing times have been estimated. Expected completion times have been agreed. The table shows the processing time and due date of those 5 engines.
- Determine the schedule by using the EDD rule.

Engine Block	Processing Time (Days)	Due Date (Days)
Ranger	8	10
Explorer	6	12
Bronco	15	20
Econoline 150	3	18
Thunderbird	12	22

### 12.1.3 Sequencing Rules: Earliest Due Date (EDD) Example 1

Engine Block Sequence	(1) Processing Time	(2) Completion Time	(3) Due Date	(2)-(3) Days Tardy (0 if negative)
Ranger	8	8	10	0
Explorer	6	14	12	2
Econoline 150	3	17	18	0
Bronco	15	32	20	12
Thunderbird	12	44	22	22
<b>Total</b>	<b>44</b>	<b>85</b>		<b>36</b>

Average completion time	$85/5 = 17$ days
Average number of jobs in the system	$85/44 = 1.9318$ jobs
Average tardiness	$36/5 = 7.2$ days
Utilization	$44/85 = 51.76\%$

### 12.1.4 Sequencing Rules: Critical Ratio (CR)

- ✓ Is an index number computed by dividing the time remaining until due date by the work time remaining.
- ✓ The critical ratio gives priority to jobs that must be done to keep shipping on schedule.
- ✓ The critical ratio is measure of urgency of any order compared to the other orders for the same facility.
- ✓ The ratio is based on when the completed order is required and how much time is required to complete.

### 12.1.4 Sequencing Rules: Critical Ratio (CR)

•The step for using this rule are:

1. At the starting program, user input the numbers of job, the jobs name, the works day remaining and the due date of each job and as well the today's date.
2. The today's date and the number of job are just inputted once time. Then, the others are followed the value of the number of jobs inputted. After that, compute the critical ratio by using the formula.
3. The formula for Critical Ratio is:  
 **$CR = \text{time remaining} / \text{works day remaining}$**
4. After calculating the CR for each job, give the priority order by using the value of the calculated critical ratio. The priority order is performed from smaller to larger.

### 12.1.4 Sequencing Rules: Critical Ratio (CR)

- There are 3 characteristics can be seen from the critical ratio:
  - ✓ A job with low critical ratio(less than 1.0) ---- falling behind schedule.
  - ✓ If CR is exactly 1.0 ---- the job is on schedule.
  - ✓ If CR is greater than 1.0 ---- the job is ahead of schedule and has some slack.

### 12.1.4 Sequencing Rules: Critical Ratio (CR)

•The critical ratio help in most production scheduling system as below:

- Determine the status of specific job.
- Establish relative priority among jobs on a common basis.
- Relate both stock and make-to-order jobs on a common basis.
- Adjust priorities (and revise schedules) automatically for changes in both demand and job progress.
- Dynamically track job progress and location.

### 12.1.4 Sequencing Rules: Critical Ratio (CR) Example 1

•A machine center in a job shop for a local fabrication company has five unprocessed jobs remaining at a particular point in time. The jobs are labeled 1, 2, 3, 4, and 5 in the order that they entered the shop. The respective processing times and due dates are given in the table below.

•Sequence the 5 jobs by CR rules.

Job number	Processing Time	Due Date
1	11	61
2	29	45
3	31	31
4	1	33
5	2	32

### 12.1.4 Sequencing Rules: Critical Ratio (CR) Example 1

Current time:  $t=0$

Job number	Processing Time	Due Date	Critical Ratio
1	11	61	61/11(5.545)
2	29	45	45/29(1.552)
3	31	31	31/31(1.000)
4	1	33	33/1 (33.00)
5	2	32	32/2 (16.00)

Current time should be reset after scheduling one job

Current time:  $t=31$

Job number	Processing Time	Due Date-Current Time	Critical Ratio
1	11	30	30/11(2.727)
2	29	14	14/29(0.483)
4	1	2	2/1 (2.000)
5	2	1	1/2 (0.500)

### 12.1.4 Sequencing Rules: Critical Ratio (CR) Example 1

Current time=60

Job number	Processing Time	Due Date-Current Time	Critical Ratio
1	11	1	1/11(0.0909)
<del>4</del>	<del>1</del>	<del>-27</del>	<del>-27/1&lt;0</del>
5	2	-28	-28/2<0

Both Jobs 4 and 5 are later, however Job 4 has shorter processing time and thus is scheduled first; Finally, job 1 is scheduled last.

### 12.1.4 Sequencing Rules: Critical Ratio (CR) Example 1

Job number	Processing Time	Completion Time	Due Date	Tardiness
3	31	31	31	0
2	29	60	45	15
4	1	61	33	28
5	2	63	32	31
1	11	74	61	13
Totals	74	289		87

Average completion time	$289/5 = 57.8$ days
Average number of jobs in the system	$289/74 = 3.905$ jobs
Average tardiness	$87/5 = 17.4$ days
Utilization	$74/289 = 25.61\%$

### 4 Rules Application - Example

Processing Time (including setup times) and due dates for six jobs waiting to be processed at a work center are given in the following table. Determine the sequence of jobs, the average flow time, average tardiness, and number of jobs at the work center, for each of these rules:

- FCFS
- SPT
- EDD
- CR

Job number	Processing Time	Due Date
A	2	7
B	8	16
C	4	4
D	10	17
E	5	15
F	12	18