Operations Management

Chapter 5 – Short-Term Scheduling

PowerPoint presentation to accompany
Heizer/Render
Principles of Operations Management,
Operations Management, 6e

Outline

- ☑ *The Strategic Importance Of Short-Term Scheduling*
- ☑ *Scheduling Issues*
  - ☑ *Forward and Backward Scheduling*
  - ☑ *Scheduling Criteria*

Outline – Continued

- ☑ *Scheduling Process-Focused Facilities*
- ☑ *Loading Jobs*
  - ☑ *Gantt Charts*
  - ☑ *Assignment Method*

Outline – Continued

- ☑ *Sequencing Jobs*
  - ☑ *Priority Rules for Dispatching Jobs*
  - ☑ *Sequencing N Jobs on Two Machines: Johnson's Rule*
  - ☑ *Limitations Of Rule-Based Dispatching Systems*

Strategic Importance of Short-Term Scheduling

- ☑ **_Effective and efficient scheduling can be a competitive advantage_**
  - ☑ **_Faster movement of goods through a facility means better use of assets and lower costs_**
  - ☑ **_Additional capacity resulting from faster throughput improves customer service through faster delivery_**
  - ☑ **_Good schedules result in more reliable deliveries_**

Scheduling Issues

- ☑ **_Scheduling deals with the timing of operations_**
- ☑ **_The task is the allocation and prioritization of demand_**
- ☑ **_Significant issues are_**
  - ☑ **_The type of scheduling, forward or backward_**
  - ☑ **_The criteria for priorities_**

Scheduling Issues

Capacity Planning
(Long term; Years)
Changes in Facilities
Changes in Equipment
See Chapter 7 and Supplement 7

Capacity Plan for New Facilities

Adjust capacity to the demand suggested by strategic plan

Aggregate Planning
(Intermediate Term; Quarterly or Monthly)
Facility utilization
Personnel changes
Subcontracting
See Chapter 13

Aggregate Production Plan for All Bikes

Month	1	2
Bike Production	800	850

Determine personnel or subcontracting necessary to match aggregate demand to existing facilities/capacity

Master Schedule
(Intermediate term; weekly)
Material requirements planning
Disaggregate the aggregate plan
See Chapters 13 and 14

Master Production Schedule for Bike Models

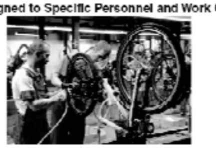
	Month 1				Month 2			
Week	1	2	3	4	5	6	7	8
Model 22		200		200		200		200
Model 24	100		100		150		100	
Model 26	100		100		100		100	

Determine weekly capacity schedule

Short Term Scheduling
(Short term; days, hours, minutes)
Work center loading
Job sequencing/dispatching
See this Chapter

Work Assigned to Specific Personnel and Work Centers

Assemble Model 22 in work center 6



Make finite capacity schedule by matching specific tasks to specific people and machines

Figure 15.1

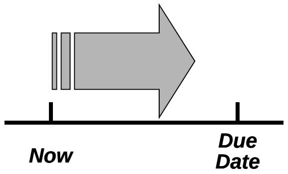
Scheduling Decisions

Organization	Managers Must Schedule the Following
Arnold Palmer Hospital	*Operating room use* *Patient admissions* *Nursing, security, maintenance staffs* *Outpatient treatments*
University of Missouri	*Classrooms and audiovisual equipment* *Student and instructor schedules* *Graduate and undergraduate courses*
Lockheed-Martin factory	*Production of goods* *Purchases of materials* *Workers*
Hard Rock Cafe	*Chef, waiters, bartenders* *Delivery of fresh foods* *Entertainers* *Opening of dining areas*
Delta Airlines	*Maintenance of aircraft* *Departure timetables* *Flight crews, catering, gate, ticketing personnel*

Table 15.1

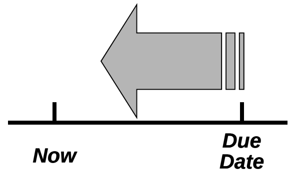
Forward and Backward Scheduling

- ☑ Forward scheduling starts as soon as the requirements are known
- ☑ Produces a feasible schedule though it may not meet due dates
- ☑ Frequently results in excessive work-in-process inventory



Forward and Backward Scheduling

- ☑ Backward scheduling begins with the due date and schedules the final operation first
- ☑ Schedule is produced by working backwards though the processes
- ☑ Resources may not be available to accomplish the schedule



Scheduling Criteria

1. Minimize completion time
2. Maximize utilization of facilities
3. Minimize work-in-process (WIP) inventory
4. Minimize customer waiting time

Optimize the use of resources so that production objectives are met

Scheduling Process-Focused Facilities

1. Schedule incoming orders without violating capacity constraints
2. Check availability of tools and materials before releasing an order
3. Establish due dates for each job and check progress
4. Check work in progress
5. Provide feedback
6. Provide work efficiency statistics and monitor times

Loading Jobs

- ☑ Assign jobs so that costs, idle time, or completion time are minimized
- ☑ Two forms of loading
  - ☑ Capacity oriented
  - ☑ Assigning specific jobs to work centers

Gantt Charts

- ☑ Load chart shows the loading and idle times of departments, machines, or facilities
- ☑ Displays relative workloads over time
- ☑ Schedule chart monitors jobs in process
- ☑ All Gantt charts need to be updated frequently

Gantt Load Chart Example

Work Center / Day	Monday	Tuesday	Wednesday	Thursday	Friday
Metalworks	Job 349	(Center not available)	Job 350		
Mechanical	(Unscheduled)	Job 349		Job 408	(Unscheduled)
Electronics	Job 408	(Unscheduled)	(Unscheduled)	Job 349	(Unscheduled)
Painting	Job 295		Job 408	(Center not available)	Job 349

Processing | Unscheduled | Center not available

Figure 15.3

Gantt Schedule Chart Example

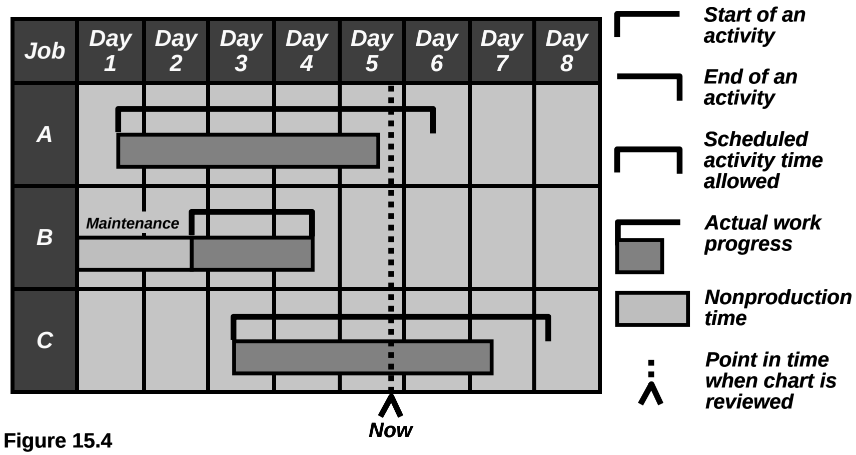


Figure 15.4

Assignment Method

- ☑ A special class of linear programming models that assign tasks or jobs to resources
- ☑ Objective is to minimize cost or time
- ☑ Only one job (or worker) is assigned to one machine (or project)

Assignment Method

- ☑ Build a table of costs or time associated with particular assignments

	Typesetter		
Job	A	B	C
R-34	$11	$14	$ 6
S-66	$ 8	$10	$11
T-50	$ 9	$12	$ 7

Assignment Method

1. Create zero opportunity costs by repeatedly subtracting the lowest costs from each row and column
2. Draw the minimum number of vertical and horizontal lines necessary to cover all the zeros in the table. If the number of lines equals either the number of rows or the number of columns, proceed to step 4. Otherwise proceed to step 3.

Assignment Method

3. Subtract the smallest number not covered by a line from all other uncovered numbers. Add the same number to any number at the intersection of two lines. Return to step 2.
4. Optimal assignments are at zero locations in the table. Select one, draw lines through the row and column involved, and continue to the next assignment.

Assignment Example

Typesetter / Job	A	B	C
R-34	$11	$14	$ 6
S-66	$ 8	$10	$11
T-50	$ 9	$12	$ 7

Step 1a - Rows

Typesetter / Job	A	B	C
R-34	$ 5	$ 8	$ 0
S-66	$ 0	$ 2	$ 3
T-50	$ 2	$ 5	$ 0

Step 1b - Columns

Typesetter / Job	A	B	C
R-34	$ 5	$ 6	$ 0
S-66	$ 0	$ 0	$ 3
T-50	$ 2	$ 3	$ 0

Assignment Example

Step 2 - Lines

Typesetter / Job	A	B	C
R-34	$ 5	$ 6	$ 0
S-66	$ 0	$ 0	$ 3
T-50	$ 2	$ 3	$ 0

Because only two lines are needed to cover all the zeros, the solution is not optimal

The smallest uncovered number is 2 so this is subtracted from all other uncovered numbers and added to numbers at the intersection of lines

Step 3 - Subtraction

Typesetter / Job	A	B	C
R-34	$ 3	$ 4	$ 0
S-66	$ 0	$ 0	$ 5
T-50	$ 0	$ 1	$ 0

Assignment Example

Step 2 - Lines

Typesetter / Job	A	B	C
R-34	$ 3	$ 4	$ 0
S-66	$ 0	$ 0	$ 5
T-50	$ 0	$ 1	$ 0

Because three lines are needed, the solution is optimal and assignments can be made

Start by assigning R-34 to worker C as this is the only possible assignment for worker C. Job T-50 must go to worker A as worker C is already assigned. This leaves S-66 for worker B.

Step 4 - Assignments

Typesetter / Job	A	B	C
R-34	$ 3	$ 4	$ 0
S-66	$ 0	$ 0	$ 5
T-50	$ 0	$ 1	$ 0

Assignment Example

From the original cost table

Minimum cost = $6 + $10 + $9 = $25

Typesetter / Job	A	B	C
R-34	$11	$14	$ 6
S-66	$ 8	$10	$11
T-50	$ 9	$12	$ 7

Step 4 - Assignments

Typesetter / Job	A	B	C
R-34	$ 3	$ 4	$ 0
S-66	$ 0	$ 0	$ 5
T-50	$ 0	$ 1	$ 0

Sequencing Jobs

- ☑ Specifies the order in which jobs should be performed at work centers
- ☑ Priority rules are used to dispatch or sequence jobs
  - ☑ FCFS: First come, first served
  - ☑ SPT: Shortest processing time
  - ☑ EDD: Earliest due date
  - ☑ LPT: Longest processing time

Sequencing Example

Apply the four popular sequencing rules to these five jobs

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

Sequencing Example

FCFS: Sequence A-B-C-D-E

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

Sequencing Example

FCFS: Sequence A-B-C-D-E

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

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

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

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

28 77 11

Sequencing Example

SPT: Sequence B-D-A-C-E

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

Sequencing Example

SPT: Sequence B-D-A-C-E

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}} = 65/5 = 13 \text{ days}$$

$$\text{Utilization} = \frac{\text{Total job work time}}{\text{Total flow time}} = 28/65 = 43.1\%$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work time}} = 65/28 = 2.32 \text{ jobs}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} = 9/5 = 1.8 \text{ days}$$

28 65 9

Sequencing Example

EDD: Sequence B-A-D-C-E

Job Sequence	Job Work (Processing) Time	Flow Time	Job Due Date	Job Lateness
B	2	2	6	0
A	6	8	8	0
D	3	11	15	0
C	8	19	18	1
E	9	28	23	5
	28	68		6

Sequencing Example

EDD: Sequence B-A-D-C-E

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}} = 68/5 = 13.6 \text{ days}$$

$$\text{Utilization} = \frac{\text{Total job work time}}{\text{Total flow time}} = 28/68 = 41.2\%$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work time}} = 68/28 = 2.43 \text{ jobs}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} = 6/5 = 1.2 \text{ days}$$

28 68 6

Sequencing Example

LPT: Sequence E-C-A-D-B

Job Sequence	Job Work (Processing) Time	Flow Time	Job Due Date	Job Lateness
E	9	9	23	0
C	8	17	18	0
A	6	23	8	15
D	3	26	15	11
B	2	28	6	22
	28	103		48

Sequencing Example

LPT: Sequence E-C-A-D-B

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}} = 103/5 = 20.6 \text{ days}$$

$$\text{Utilization} = \frac{\text{Total job work time}}{\text{Total flow time}} = 28/103 = 27.2\%$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work time}} = 103/28 = 3.68 \text{ jobs}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} = 48/5 = 9.6 \text{ days}$$

28 103 48

Sequencing Example

Summary of Rules

Rule	Average Completion Time (Days)	Utilization (%)	Average Number of Jobs in System	Average Lateness (Days)
FCFS	15.4	36.4	2.75	2.2
SPT	13.0	43.1	2.32	1.8
EDD	13.6	41.2	2.43	1.2
LPT	20.6	27.2	3.68	9.6

Comparison of Sequencing Rules

- ☑ No one sequencing rule excels on all criteria
- ☑ SPT does well on minimizing flow time and number of jobs in the system
- ☑ But SPT moves long jobs to the end which may result in dissatisfied customers
- ☑ FCFS does not do especially well (or poorly) on any criteria but is perceived as fair by customers
- ☑ EDD minimizes lateness

Sequencing N Jobs on Two Machines: Johnson's Rule

- ☑ ***Works with two or more jobs that pass through the same two machines or work centers***
- ☑ ***Minimizes total production time and idle time***

Johnson's Rule

1. ***List all jobs and times for each work center***
2. ***Choose the job with the shortest activity time. If that time is in the first work center, schedule the job first. If it is in the second work center, schedule the job last.***
3. ***Once a job is scheduled, it is eliminated from the list***
4. ***Repeat steps 2 and 3 working toward the center of the sequence***

Johnson's Rule Example

Job	*Work Center 1 (Drill Press)*	*Work Center 2 (Lathe)*
A	5	2
B	3	6
C	8	4
D	10	7
E	7	12

Johnson's Rule Example

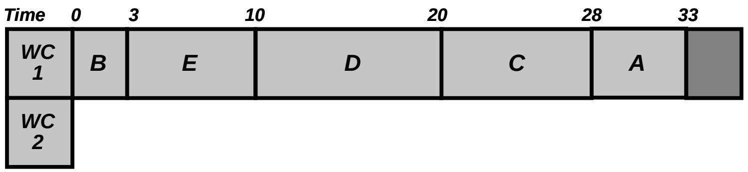
Job	*Work Center 1 (Drill Press)*	*Work Center 2 (Lathe)*
A	5	2
B	3	6
C	8	4
D	10	7
E	7	12

B	*E*	*D*	*C*	*A*

Johnson's Rule Example

Job	Work Center 1 (Drill Press)	Work Center 2 (Lathe)
A	5	2
B	3	6
C	8	4
D	10	7
E	7	12

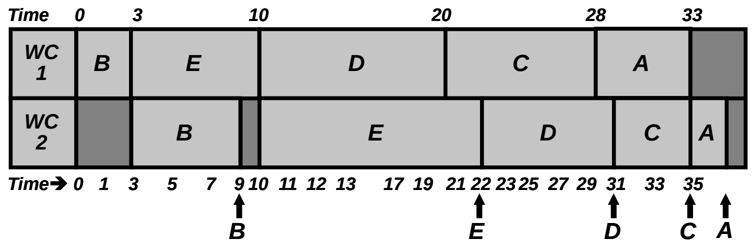
B	E	D	C	A



Johnson's Rule Example

Job	Work Center 1 (Drill Press)	Work Center 2 (Lathe)
A	5	2
B	3	6
C	8	4
D	10	7
E	7	12

B	E	D	C	A



Limitations of Rule-Based Dispatching Systems

1. Scheduling is dynamic and rules need to be revised to adjust to changes
2. Rules do not look upstream or downstream
3. Rules do not look beyond due dates

Finite Capacity Scheduling

- ☑ Overcomes disadvantages of rule-based systems by providing an interactive, computer-based graphical system
- ☑ May include rules and expert systems or simulation to allow real-time response to system changes
- ☑ Initial data often from an MRP system
- ☑ FCS allows the balancing of delivery needs and efficiency

Finite Capacity Scheduling

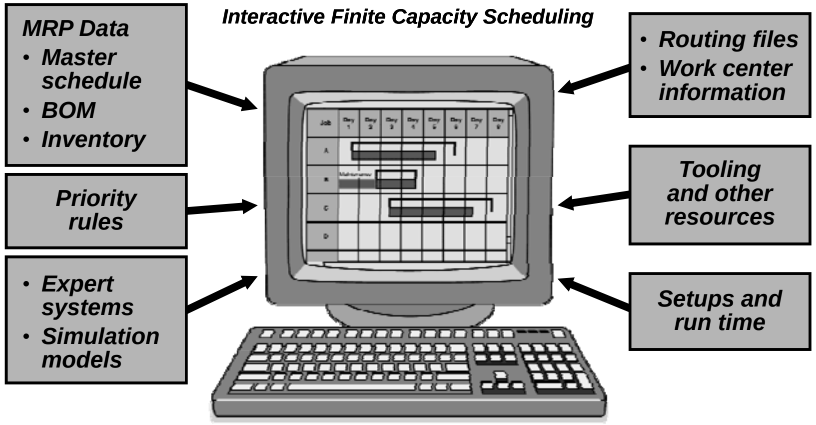
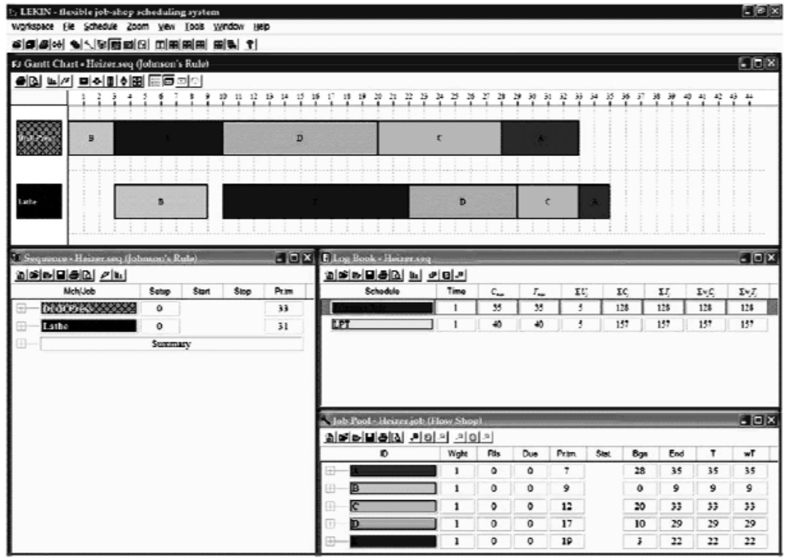


Figure 15.5

Finite Capacity Scheduling



Scheduling Services

Service systems differ from manufacturing

Manufacturing	*Services*
Schedules machines and materials	*Schedule staff*
Inventories used to smooth demand	*Seldom maintain inventories*
Machine-intensive and demand may be smooth	*Labor-intensive and demand may be variable*
Scheduling may be bound by union contracts	*Legal issues may constrain flexible scheduling*
Few social or behavioral issues	*Social and behavioral issues may be quite important*

Scheduling Services

- ☑ ***Hospitals have complex scheduling system to handle complex processes and material requirements***
- ☑ ***Banks use a cross-trained and flexible workforce and part-time workers***
- ☑ ***Airlines must meet complex FAA and union regulations and often use linear programming to develop optimal schedules***
- ☑ ***24/7 Operations use flexible workers and variable schedules***

Demand Management

- ☑ *Appointment or reservation systems*
- ☑ *FCFS sequencing rules*
- ☑ *Discounts or other promotional schemes*
- ☑ *When demand management is not feasible, managing capacity through staffing flexibility may be used*