Chapter 16

Scheduling

Operations Management - 5th Edition

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Lecture Outline

- Objectives in Scheduling
- Loading
- Sequencing
- Monitoring
- Advanced Planning and Scheduling Systems
- Theory of Constraints
- Employee Scheduling

What is Scheduling?

- Last stage of planning before production occurs
- Specifies <u>when</u> labor, equipment, facilities are needed to produce a product or provide a service

Scheduled Operations

Scheduling function differs based on the type of operation

- Process Industry
  - Linear programming
  - EOQ with non-instantaneous replenishment
- Mass Production
  - Assembly line balancing
- Project
  - Project -scheduling techniques (PERT, CPM)
- Batch Production
  - Aggregate planning
  - Master scheduling
  - Material requirements planning (MRP)
  - Capacity requirements planning (CRP)

Objectives in Scheduling

- Meet customer due dates
- Minimize job lateness
- Minimize response time
- Minimize completion time
- Minimize time in the system
- Minimize overtime
- Maximize machine or labor utilization
- Minimize idle time
- Minimize work-in-process inventory

Shop Floor Control

- Loading
  - Check availability of material, machines and labor
- Sequencing
  - Release work orders to shop and issue dispatch lists for individual machines
- Monitoring
  - Maintain progress reports on each job until it is complete

Loading

- Process of assigning work to limited resources
- Perform work on most efficient resources
- Use assignment method of linear programming to determine allocation

Assignment Method

1. Perform row reductions
   - subtract minimum value in each row from all other row values
2. Perform column reductions
   - subtract minimum value in each column from all other column values
3. Cross out all zeros in matrix
   - use minimum number of horizontal and vertical lines
4. If number of lines equals number of rows in matrix then optimum solution has been found. Make assignments where zeros appear
5. Else modify matrix
   - subtract minimum uncrossed value from all uncrossed values
   - add it to all cells where two lines intersect
   - other values in matrix remain unchanged
6. Repeat steps 3 through 5 until optimum solution is reached

Assignment Method: Example

Initial Matrix	PROJECT 1	2	3	4
Bryan	10	5	6	10
Kari6	2	4	6	
Noah	7	6	5	6
Chris	9	5	4	10

Row reduction / Column reduction / Cover all zeros

5	0	1	5	3	0	1	4	3	0	1	4
4	0	2	4	2	0	2	3	2	0	2	3
2	1	0	1	0	1	0	0	0	1	0	0
5	1	0	6	3	1	0	5	3	1	0	5

Number lines ≠ number of rows so modify matrix

Assignment Method: Example (cont.)

Modify matrix				Cover all zeros			
1	0	1	2	1	0	1	2
0	0	2	1	0	0	2	1
0	3	2	0	0	3	2	0
1	1	0	3	1	1	0	3

Number of lines = number of rows so at optimal solution

	PROJECT			
	1	*2*	*3*	*4*
Bryan	1	0	1	2
Kari0	0	2	1	
Noah	0	3	2	0
Chris	1	1	0	3

	PROJECT			
	1	*2*	*3*	*4*
Bryan	10	5	6	10
Kari6	2	4	6	
Noah	7	6	5	6
Chris	9	5	4	10

Project Cost = (5 + 6 + 6 + 4) X \$100 = \$2,100

Sequencing

- Prioritize jobs assigned to a resource
- If no order specified use first-come first-served (FCFS)
- Many other sequencing rules exist
- Each attempts to achieve to an objective

Sequencing Rules

- FCFS - first-come, first-served
- LCFS - last come, first served
- DDATE - earliest due date
- CUSTPR - highest customer priority
- SETUP - similar required setups
- SLACK - smallest slack
- CR - critical ratio
- SPT - shortest processing time
- LPT - longest processing time

Critical Ratio Rule

CR considers both time and work remaining

$$CR = \frac{\text{time remaining}}{\text{work remaining}} = \frac{\text{due date - today's date}}{\text{remaining processing time}}$$

If CR > 1, job ahead of schedule

If CR < 1, job behind schedule

If CR = 1, job on schedule

Sequencing Jobs Through One Process

- Flowtime (completion time)
  - Time for a job to flow through the system
- Makespan
  - Time for a group of jobs to be completed
- Tardiness
  - Difference between a late job's due date and its completion time

Simple Sequencing Rules

JOB	PROCESSING TIME	DUE DATE
A	5	10
B	10	15
C	2	5
D	8	12
E	6	8

Simple Sequencing Rules: FCFS

FCFS SEQUENCE	START TIME	PROCESSING TIME	COMPLETION TIME	DUE DATE	TARDINESS
A	0	5	5	10	0
B	5	10	15	15	0
C	15	2	17	5	12
D	17	8	25	12	13
E	25	6	31	8	23

Simple Sequencing Rules: DDATE

DDATE SEQUENCE	START TIME	PROCESSING TIME	COMPLETION TIME	DUE DATE	TARDINESS
C	0	2	2	5	0
E	2	6	8	8	0
A	8	5	13	10	3
D	13	8	21	12	9
B	21	10	31	15	16

Simple Sequencing Rules: SLACK

A (10-0) – 5 = 5
B (15-0) - 10 = 5
C (5-0) – 2 = 3
D (12-0) – 8 =

SLACK SEQUENCE	START TIME	PROCESSING TIME	COMPLETION TIME	DUE DATE	TARDINESS
E	0	6	6	8	0
C	6	2	8	5	3
D	8	8	16	12	4
A	16	5	21	10	11
B	21	10	31	15	16

Simple Sequencing Rules: CR

A (10)/5 = 2.00
B (15)/10 = 1.50
C (5)/2 =

CR SEQUENCE	START TIME	PROCESSING TIME	COMPLETION TIME	DUE DATE	TARDINESS
E	0	6	6	8	0
D	6	8	14	12	2
B	14	10	24	15	9
A	24	5	29	10	19
C	29	2	31	5	26

Simple Sequencing Rules: SPT

SPT SEQUENCE	START TIME	PROCESSING TIME	COMPLETION TIME	DUE DATE	TARDINESS
C	0	2	2	5	0
A	2	5	7	10	0
E	7	6	13	8	5
D	13	8	21	12	9
B	21	10	31	15	16

Simple Sequencing Rules: Summary

RULE	AVERAGE COMPLETION TIME	AVERAGE TARDINESS	NO. OF JOBS TARDY	MAXIMUM TARDINESS
FCFS	18.60	9.6	3	23
DDATE	15.00	5.6	3	16
SLACK	16.40	6.8	4	16
CR	20.80	11.2	4	26
SPT	14.80	6.0	3	16

Sequencing Jobs Through Two Serial Process

Johnson's Rule

1. List time required to process each job at each machine. Set up a one-dimensional matrix to represent desired sequence with # of slots equal to # of jobs.
2. Select smallest processing time at either machine. If that time is on machine 1, put the job as near to beginning of sequence as possible.
3. If smallest time occurs on machine 2, put the job as near to the end of the sequence as possible.
4. Remove job from list.
5. Repeat steps 2-4 until all slots in matrix are filled and all jobs are sequenced.

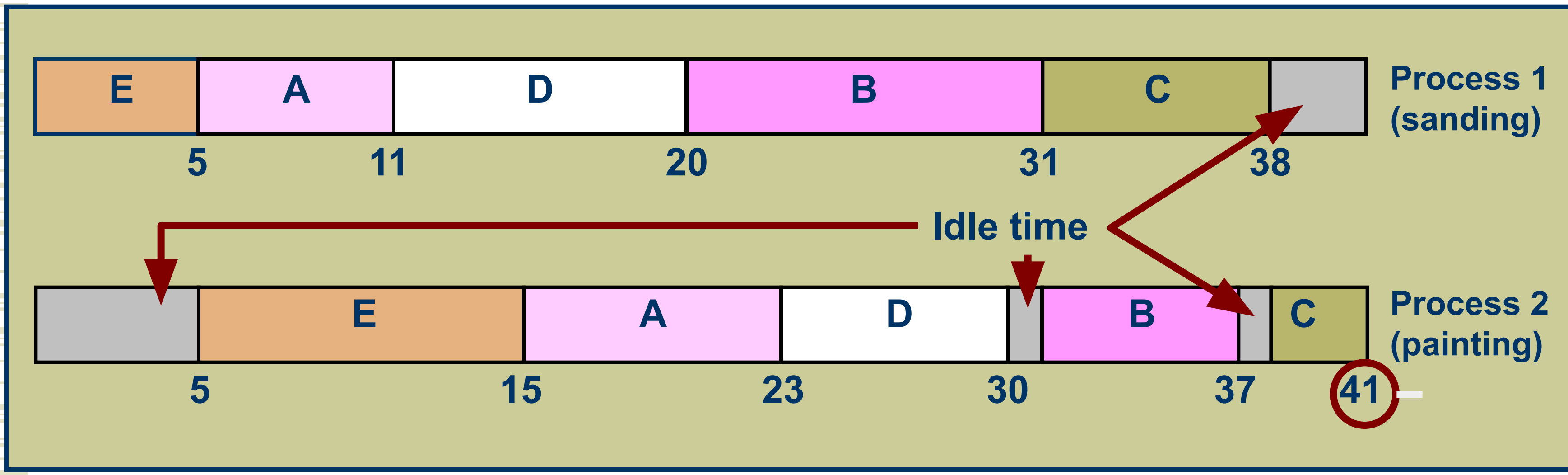
Johnson’s Rule

JOB	PROCESS 1	PROCESS 2
A	6	8
B	11	6
C	7	3
D	9	7
E	5	10

E	A	D	B	C

Johnson's Rule (cont.)

E	A	D	B	C



Completion time = 41
Idle time = 5+1+1+3=10

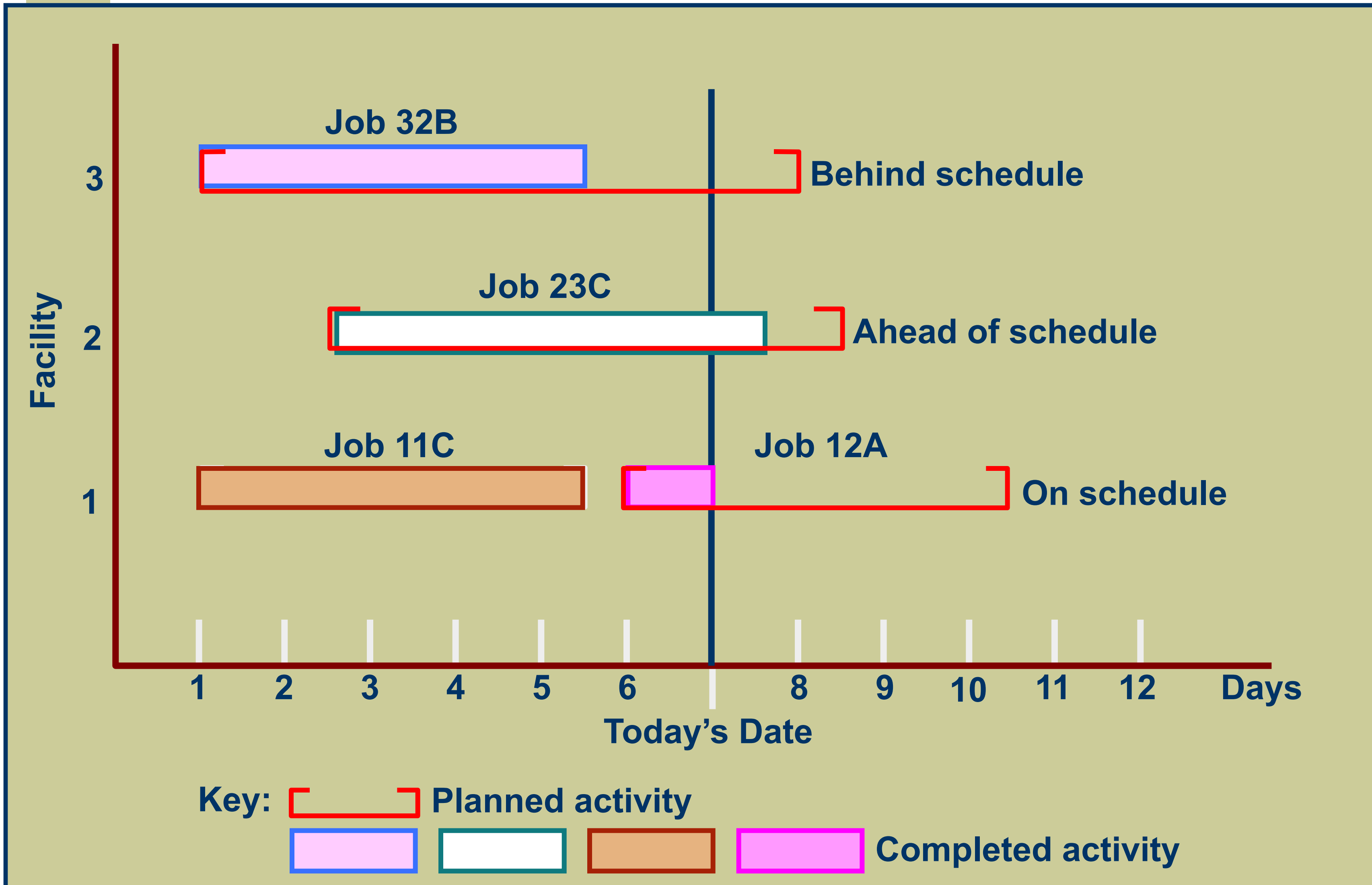
Guidelines for Selecting a Sequencing Rule

1. SPT most useful when shop is highly congested
2. Use SLACK for periods of normal activity
3. Use DDATE when only small tardiness values can be tolerated
4. Use LPT if subcontracting is anticipated
5. Use FCFS when operating at low-capacity levels
6. Do not use SPT to sequence jobs that have to be assembled with other jobs at a later date

Monitoring

- Work package
  - Shop paperwork that travels with a job
- Gantt Chart
  - Shows both planned and completed activities against a time scale
- Input/Output Control
  - Monitors the input and output from each work center

Gantt Chart



Job 32B
Behind schedule
Job 23C
Ahead of schedule
Job 11C
Job 12A
On schedule
Facility
3
2
1
1 2 3 4 5 6 8 9 10 11 12 Days
Today's Date
Key:
Planned activity
Completed activity

Input/Output Control

Input/Output Report

PERIOD	1	2	3	4	TOTAL
Planned input	65	65	70	70	
Actual input	60	60	65	65	
Deviation					
Planned output	75	75	75	75	
Actual output	70	70	65	65	
Deviation					
Backlog	30				

Input/Output Control (cont.)

Input/Output Report

PERIOD	1	2	3	4	TOTAL
Planned input	60	65	70	75	270
Actual input	60	60	65	65	250
Deviation	0	-5	-5	-10	-20
Planned output	75	75	75	75	300
Actual output	70	70	65	65	270
Deviation	-5	-5	-10	-10	-30
Backlog	30	20	10	10	10

Advanced Planning and Scheduling Systems

- Infinite - assumes infinite capacity
  - Loads without regard to capacity
  - Then levels the load and sequences jobs
- Finite - assumes finite (limited) capacity
  - Sequences jobs as part of the loading decision
  - Resources are never loaded beyond capacity

Advanced Planning and Scheduling Systems (cont.)

- Advanced planning and scheduling (APS)
  - Add-ins to ERP systems
  - Constraint-based programming (CBP) identifies a solution space and evaluates alternatives
  - Genetic algorithms based on natural selection properties of genetics
  - Manufacturing execution system (MES) monitors status, usage, availability, quality

Theory of Constraints

- Not all resources are used evenly
- Concentrate on the" bottleneck" resource
- Synchronize flow through the bottleneck
- Use process and transfer batch sizes to move product through facility

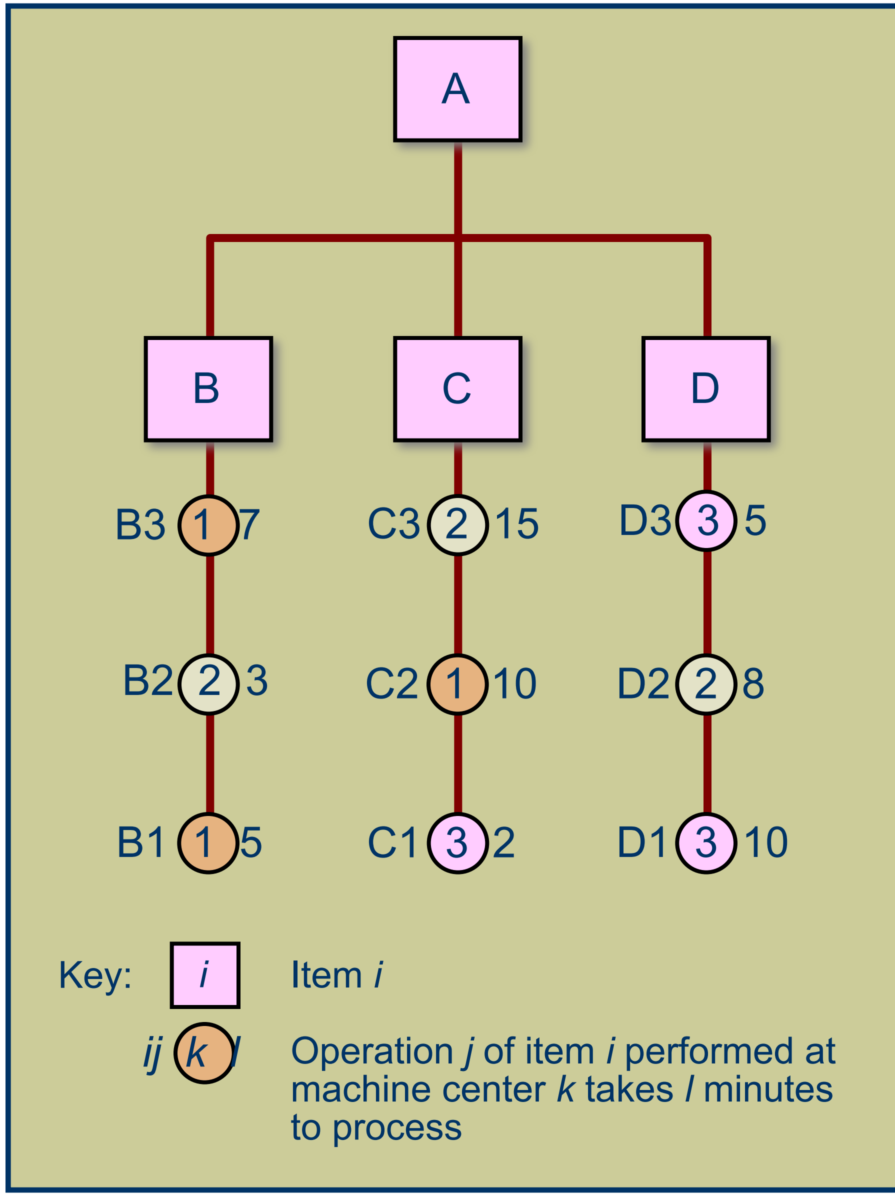
Drum-Buffer-Rope

- Drum
  - Bottleneck, beating to set the pace of production for the rest of the system
- Buffer
  - Inventory, placed in front of the bottleneck to ensure it is always kept busy
  - Determines output or throughput of the system
- Rope
  - Communication signal, tells processes upstream when they should begin production

TOC Scheduling Procedure

- Identify bottleneck
- Schedule job first whose lead time to the bottleneck is less than or equal to the bottleneck processing time
- Forward schedule the bottleneck machine
- Backward schedule the other machines to sustain the bottleneck schedule
- Transfer in batch sizes smaller than the process batch size

Synchronous Manufacturing



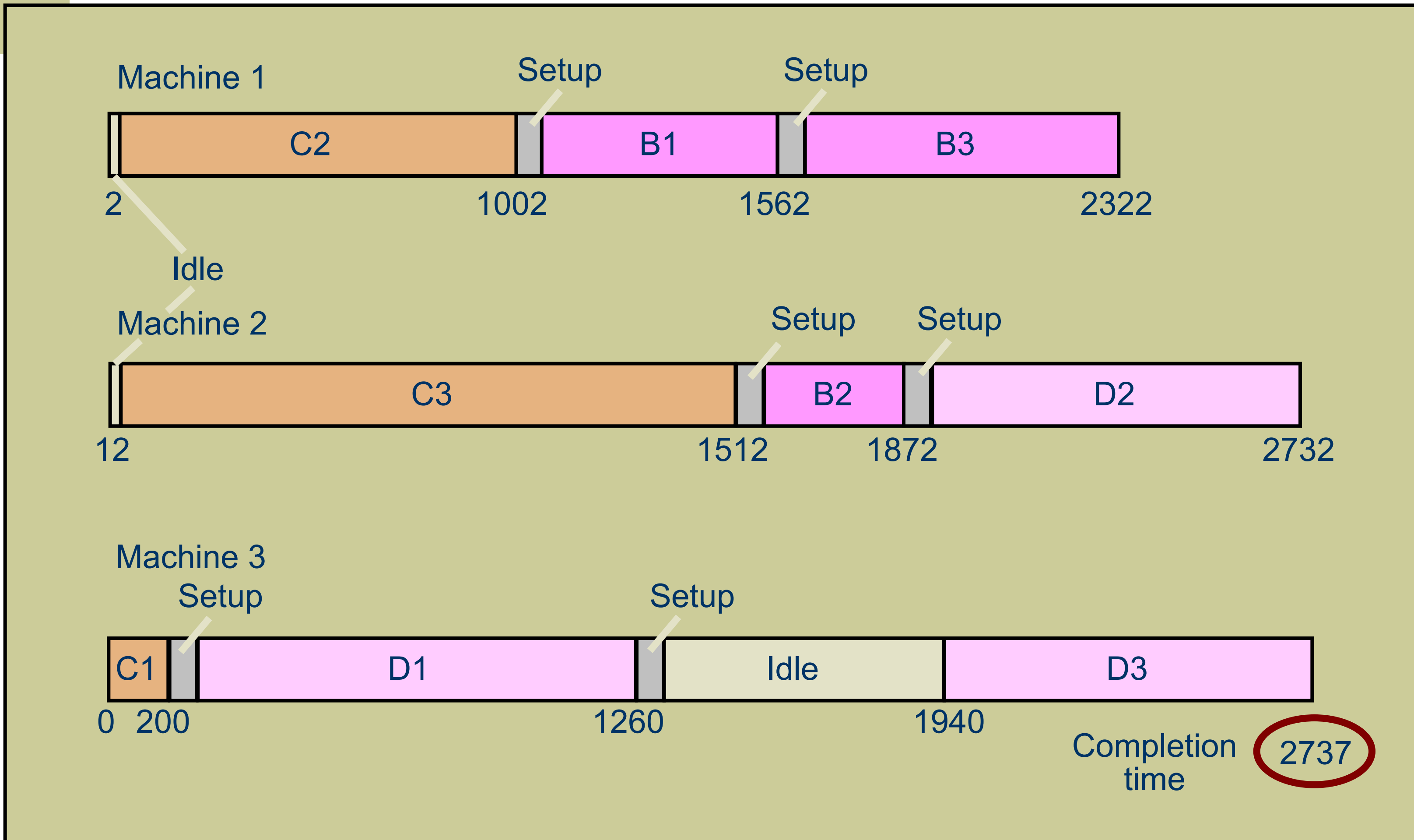
Synchronous Manufacturing (cont.)

Demand = 100 A’s
Machine setup time = 60 minutes

MACHINE 1		MACHINE 2		MACHINE 3	
B1	5	B2	3	C1	2
B3	7	C3	15	D3	5
C2	10	D2	8	D1	10
Sum	22		26*		17

* Bottleneck

Synchronous Manufacturing (cont.)



Employee Scheduling

- Labor is very flexible resource
- Scheduling workforce is complicated repetitive task
- Assignment method can be used
- Heuristics are commonly used

Employee Scheduling Heuristic

1. Let N = no. of workers available
   D_i = demand for workers on day i
   X = day working
   O = day off
2. Assign the first N - D_1 workers day 1 off. Assign the next N - D_2 workers day 2 off. Continue in a similar manner until all days are have been scheduled
3. If number of workdays for full time employee < 5, assign remaining workdays so consecutive days off are possible
4. Assign any remaining work to part-time employees
5. If consecutive days off are desired, consider switching schedules among days with the same demand requirements

Employee Scheduling

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3
Taylor							
Smith							
Simpson							
Allen							
Dickerson							

Employee Scheduling (cont.)

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3
Taylor	O	X	X	O	X	X	X
Smith	O	X	X	O	X	X	X
Simpson	X	O	X	X	O	X	X
Allen	X	O	X	X	X	X	O
Dickerson	X	X	O	X	X	X	O

Completed schedule satisfies requirements but has no consecutive days off

Employee Scheduling (cont.)

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3
Taylor	O	O	X	X	X	X	X
Smith	O	O	X	X	X	X	X
Simpson	X	X	O	O	X	X	X
Allen	X	X	X	O	X	X	O
Dickerson	X	X	X	X	O	X	O

Revised schedule satisfies requirements with consecutive days off for most employees

Automated Scheduling Systems

- Staff Scheduling
- Schedule Bidding
- Schedule Optimization