Scheduling

Learning Objectives

- Explain what scheduling involves and the importance of good scheduling.
- Discuss scheduling needs in high-volume and intermediate-volume systems.
- Discuss scheduling needs in job shops.

Learning Objectives

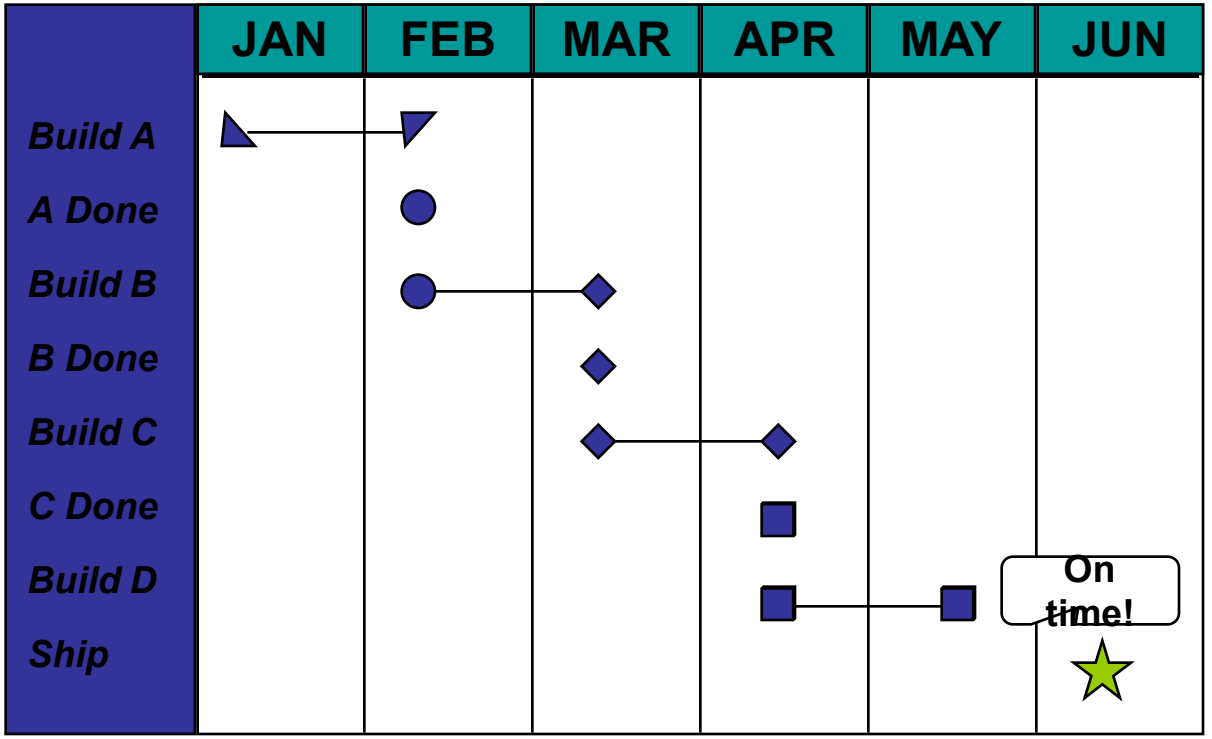
- Use and interpret Gantt charts, and use the assignment method for loading.
- Discuss and give examples of commonly used priority rules.
- Describe some of the unique problems encountered in service systems, and describe some of the approaches used for scheduling service systems.

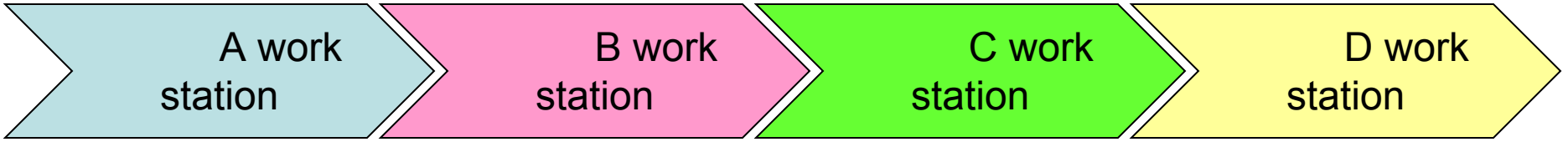
Scheduling

- Scheduling: Establishing the timing of the use of equipment, facilities and human activities in an organization
- Effective scheduling can yield
  - Cost savings
  - Increases in productivity

Scheduling Manufacturing Operations

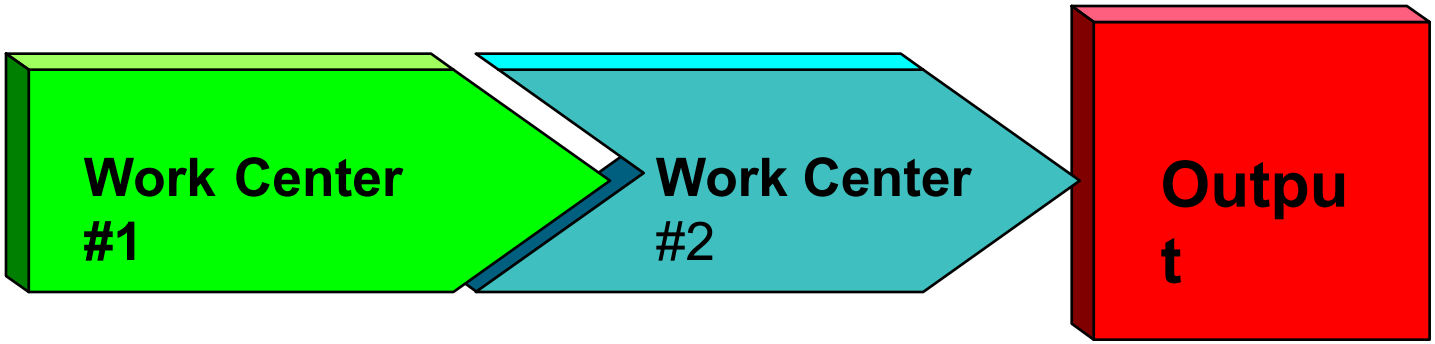
- High-volume
- Intermediate -volume
- Low-volume
- Service operations





High-Volume Systems

- *Flow system*: High-volume system with Standardized equipment and activities
- *Flow-shop scheduling*: Scheduling for high-volume flow system



High-Volume Success Factors

- Process and product design
- Preventive maintenance
- Rapid repair when breakdown occurs
- Optimal product mixes
- Minimization of quality problems
- Reliability and timing of supplies

Intermediate-Volume Systems

- Outputs are between standardized high-volume systems and made-to-order job shops
  - Run size, timing, and sequence of jobs
- Economic run size:

$$Q_0 = \sqrt{\frac{2DS}{H}} \sqrt{\frac{p}{p - u}}$$

Scheduling Low-Volume Systems

- *Loading* - assignment of jobs to process centers
- *Sequencing* - determining the order in which jobs will be processed
- *Job-shop scheduling*
  - Scheduling for low-volume systems with many variations in requirements

Job Shops

Gantt Load Chart

- *Gantt chart* - used as a visual aid for loading and scheduling

Work Center	Mon.	Tues.	Wed.	Thurs.	Fri.
1	Job 3			Job 4	
2		Job 3	Job 7		
3	Job 1			Job 6	Job 7
4	Job 10				

Loading

- *Infinite loading* – jobs are assigned to work centers without regard for the capacity of the work center.
- *Finite loading* – jobs are assigned to work centers taking into account the work center capacity and job processing times
- Vertical loading – job enlargement, need more skill for each worker

  Job rotation
- Horizontal loading – job enrichment, need more responsibility for each task

Loading (cont'd)

- *Forward scheduling* – scheduling ahead from some point in time.
- *Backward scheduling* – scheduling by working backwards in time from the due date(s).
- *Schedule chart* – a form of Gantt chart that shows the orders or jobs in progress and whether they are on schedule.

Job assignment problem: Ex 1

Table shows cost of processing job by machine		Machine			
		A	B	C	D
Job	1	8	6	2	4
	2	6	7	11	10
	3	3	5	7	6
	4	5	10	12	9

Job assignment problem

Table shows cost of processing job by machine		Machine			
		A	B	C	D
Job	1	12	16	14	10
	2	9	8	13	7
	3	15	12	9	11

Sequencing

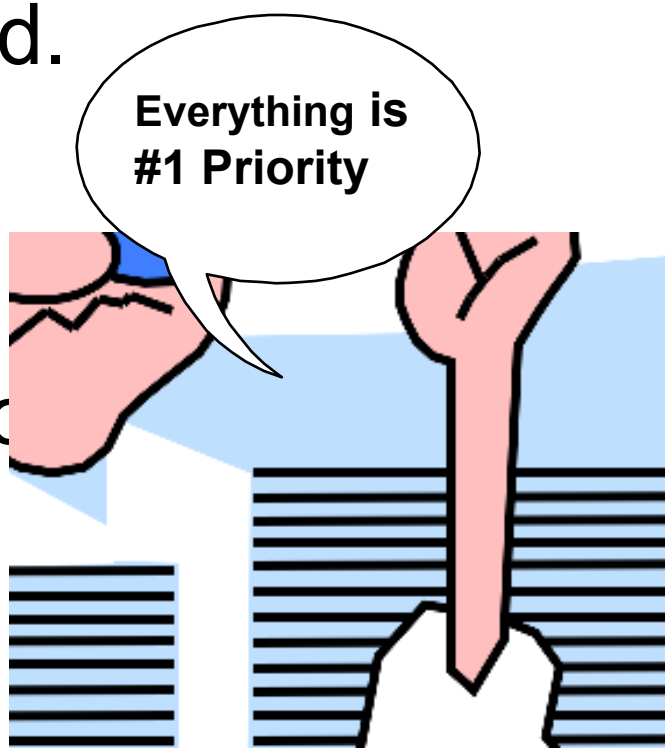
- *Sequencing*: Determine the order in which jobs at a work center will be processed.

- *Workstation*: An area where one task is assigned, usually with special equipment, on a specialized job.

Sequencing

- *Priority rules*: Simple heuristics used to select the order in which jobs will be processed.

- *Job time*: Time needed for setup and processing of a jo



Priority Rules

- FCFS - first come, first served
- SPT - shortest processing time
- EDD - earliest due date
- CR - critical ratio (smallest ratio of time remaining per processing time remaining)
- S/O - slack per operation (smallest slack time per number of remaining operations)
- Rush - emergency

Assumptions of Priority Rules

- The set of jobs is known
- Setup time is independent of processing sequence
- Setup time and processing time are deterministic
- There will be no interruptions in processing such as:
  - Machine breakdowns
  - Accidents
  - Worker illness

Example 2

Job	Processing time (days)	Due date (days)
A	2	7
B	8	16
C	4	4
D	10	17
E	5	15
F	12	18

Example 2 : FCFS

Job	Processing time (days)	Flow time (days)	Due date (days)	Tardy (days)
A	2	2	7	0
B	8	10	16	0
C	4	14	4	10
D	10	24	17	7
E	5	29	15	14
F	12	41	18	23
Total	41	120		54

Average flow time = 120/6 = 20 days
Average tardiness = 54/6 = 9 days
Makespan = 41 days
Average number of jobs at the work center = 120/41 = 2.93

Example 2 : SPT

Job	Processing time (days)	Flow time (days)	Due date (days)	Tardy (days)
A	2		7	
B	8		16	
C	4		4	
D	10		17	
E	5		15	
F	12		18	
Total	41			

Average flow time = days
Average tardiness = days
Makespan = days
Average number of jobs at the work center =

Example 2 : EDD

Job	Processing time (days)	Flow time (days)	Due date (days)	Tardy (days)
A	2		7	
B	8		16	
C	4		4	
D	10		17	
E	5		15	
F	12		18	
Total	41			

Average flow time = days
Average tardiness = days
Makespan = days
Average number of jobs at the work center =

Example 2 : CR

Job	Processing time (days)	Flow time (days)	Due date (days)	Tardy (days)
A	2		7	
B	8		16	
C	4		4	
D	10		17	
E	5		15	
F	12		18	
Total	41			

Average flow time = days
Average tardiness = days
Makespan = days
Average number of jobs at the work center =

Example 2

Rule	Average Flow Time (days)	Average Tardiness (days)	Average Number of Jobs at the Work Center
FCFS	20.00	9.00	2.93
SPT	18.00	6.67	2.63
EDD	18.33	6.33	2.68
CR	22.17	9.67	3.24

Example 3: FCFS, SPT, EDD, CR, S/O

Job	Processing time (days)	Due date (days)	Remaining number of operations
A	4	14	3
B	16	32	6
C	8	8	5
D	20	34	2
E	10	30	4
F	18	30	2

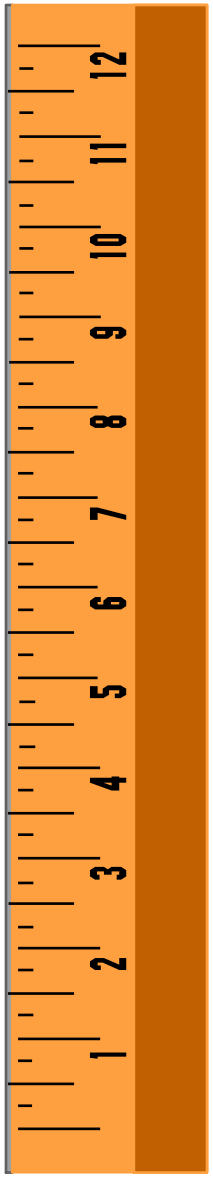
Average flow time
Average tardiness
Makespan
Average number of jobs at the work center

Two Work Center Sequencing

- *Johnson's Rule*: technique for minimizing completion time for a group of jobs to be processed on two machines or at two work centers.
- Minimizes total idle time
- Several conditions must be satisfied

Johnson's Rule Conditions

- Job time must be known and constant
- Job times must be independent of sequence
- Jobs must follow same two-step sequence
- Job priorities cannot be used
- All units must be completed at the first work center before moving to second



Johnson's Rule Optimum Sequence

1. List the jobs and their times at each work center
2. Select the job with the shortest time
3. Eliminate the job from further consideration
4. Repeat steps 2 and 3 until all jobs have been scheduled

Johnson's rule problem: Ex 4

	Processing time (hrs)	
Job	Work center 1	Work center 2
A	5	5
B	4	3
C	8	9
D	2	7
E	6	8
F	12	15

Johnson's rule problem

	Processing time (hrs)	
Job	Work center A	Work center B
a	2.5	4.2
b	3.8	1.5
c	2.2	3
d	5.8	4
e	4.5	2

Scheduling Difficulties

- Variability in
  - Setup times
  - Processing times
  - Interruptions
  - Changes in the set of jobs
- No method for identifying optimal schedule
- Scheduling is not an exact science
- Ongoing task for a manager

Minimizing Scheduling Difficulties

- Set realistic due dates
- Focus on bottleneck operations
- Consider lot splitting of large jobs

Theory of Constraints

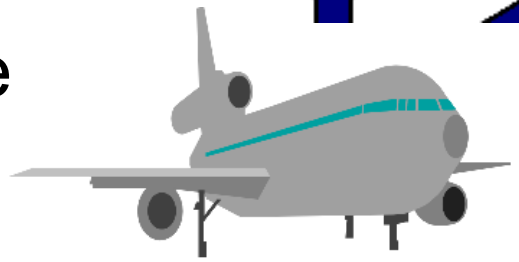
- The Theory of Constraints Goal is to maximize flow through the entire system
- Emphasizes balancing flow
- Improve performance of bottleneck:
  - Determine what is constraining the operation
  - Exploit the constraint
  - Subordinate everything to the constraint
  - Determine how to overcome the constraint
  - Repeat the process for the next constraint

Theory of Constraints Metrics

- Physical assets – the total system investment
  - Inventory
  - Buildings and land
  - Plant and equipment
- Operating expense – money the system spends to convert inventory into throughput
- Throughput – the rate at which the system generates money through sales

Scheduling Services

- Appointment systems
  - Controls customer arrivals for service
- Reservation systems
  - Estimates demand for service
- Scheduling the workforce
  - Manages capacity for service
- Scheduling multiple resources
  - Coordinates use of more than one resource



Yield Management

- *Yield Management* – the application of pricing strategies to allocate capacity among various categories of demand.
- The goal is to maximize the revenue generated by the fixed capacity
- Fixed capacity
  - Hotel, motel rooms
  - Airline seats
- Unsold rooms or seats cannot be carried over

Service Operation Problems

- Cannot store or inventory services
- Customer service requests are random
- Scheduling service involves
  - Customers
  - Workforce
  - Equipment