Operations Management (MD021)

Scheduling

Agenda

- Scheduling Basics
- Tools for Scheduling
- Scheduling Work at Two Machines
- Scheduling Problems Exhibit Many Challenges
- Scheduling Service Operations

Basics of Scheduling

Scheduling

- Scheduling
  - Establishing the timing of the use of equipment, facilities and human activities in an organization

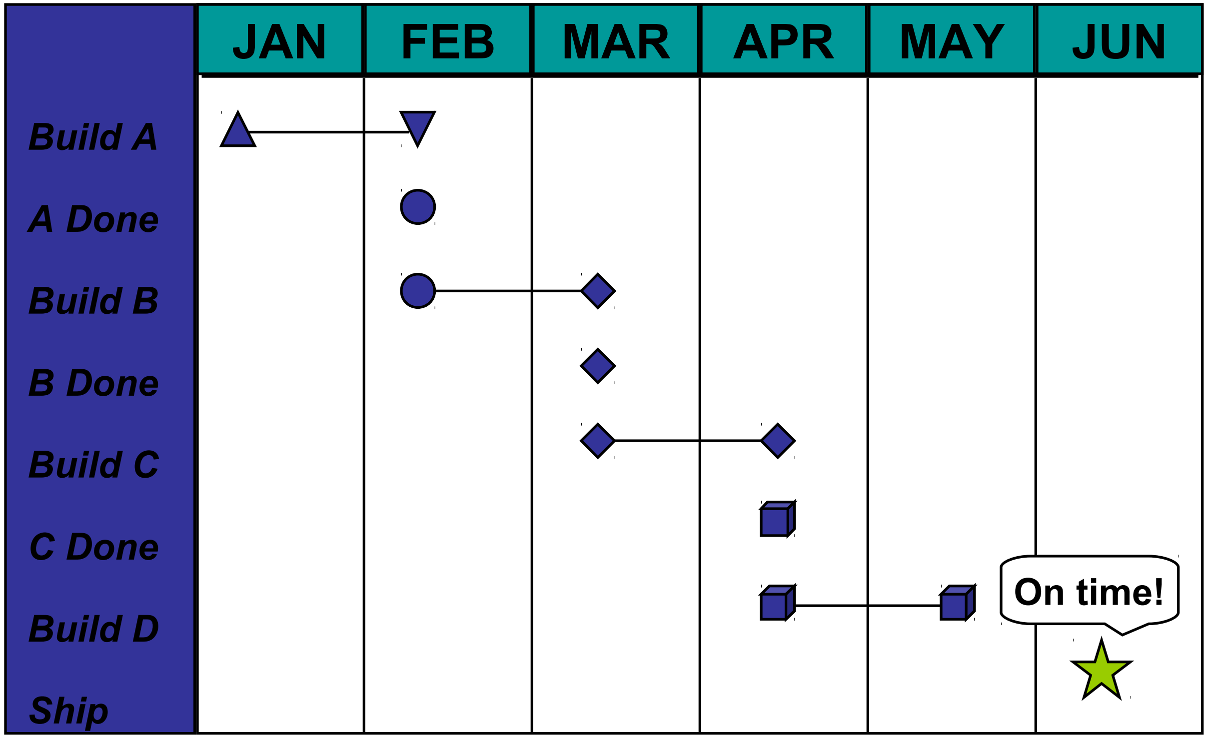
- Effective scheduling can yield …
  - Cost savings
  - Increases in productivity
  - Jobs completed on time

Goals of Scheduling

- Efficient utilization …
  - staff
  - equipment
  - facilities

- Minimization of …
  - customer waiting time
  - inventories
  - processing time

Scheduling Projects vs. Scheduling of Manufacturing/Service



If we are building a single product, we can easily plan backwards in time from the due date, and schedule activities that need to take place over time in order to reach this objective.

As we build more and different products, the different jobs compete for our resources, making scheduling much more difficult.

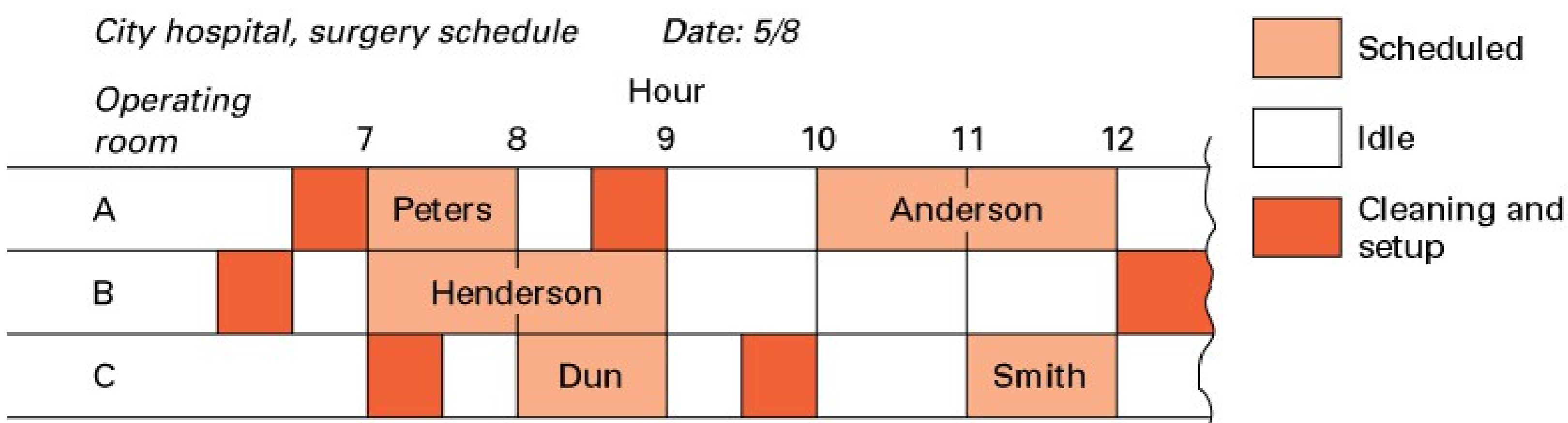
Scheduling of operations depends on the type of operations

- Manufacturing Operations
  - High-volume
  - Intermediate-volume
  - Low-volume
- Service Operations

Service scheduling examples … classroom schedules and hospital schedules

Classroom schedule: Fall   Friday

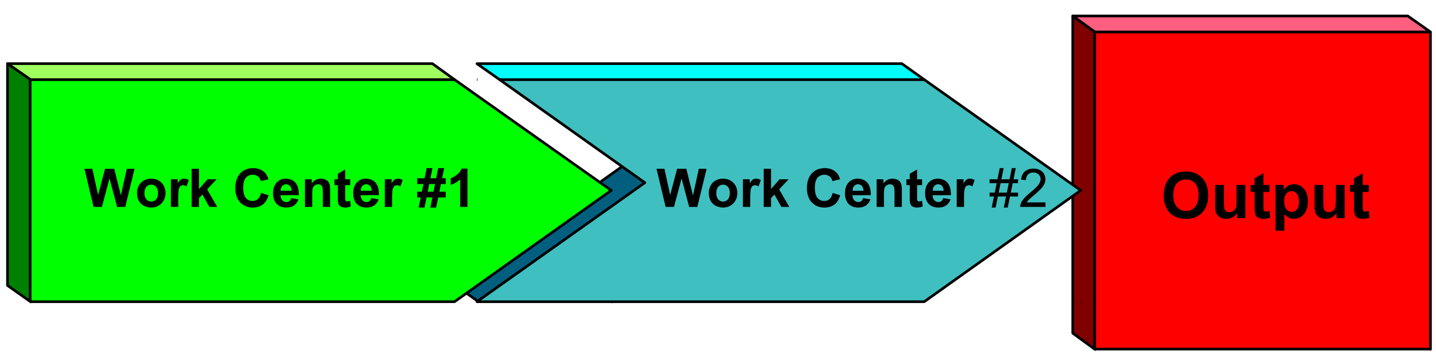
Room	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5
A100	Stat 1	Econ 101	Econ 102	Fin 201	Mar 210	Acct 212			Mar 410
A105	Stat 2	Math 2a	Math 2b			Acct 210	CCE —	— — —	— — —
A110	Acct 340	Mgmt 250	Math 3		Mar 220				
A115	Mar 440		Mgmt 230			Fin 310	Acct 360		



Scheduling of High-Volume Systems

- Flow systems
  - high-volume systems (i.e. repetitive systems)
  - standardized equipment and activities
  - identical or highly similar operations on products

- Flow-shop scheduling
  - Scheduling for high-volume flow system



Success Factors for Scheduling High-Volume Systems

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

Scheduling of Intermediate-Volume Systems

- Intermediate-volume (i.e. batch 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 of Low-Volume Systems

- Job Shops
  - products are made to order
  - orders differ considerably in their processing requirements

- Job-shop scheduling
  - Scheduling for low-volume systems with many variations in requirements

- Loading - assignment of jobs to process centers
- Sequencing - determining the order in which jobs will be processed

Tools for Scheduling

Gantt Charts are used as a visual aid for loading and scheduling

- Gantt charts organize and visually display the actual or intended use of resources in a time framework

Time Framework

A Gantt load chart

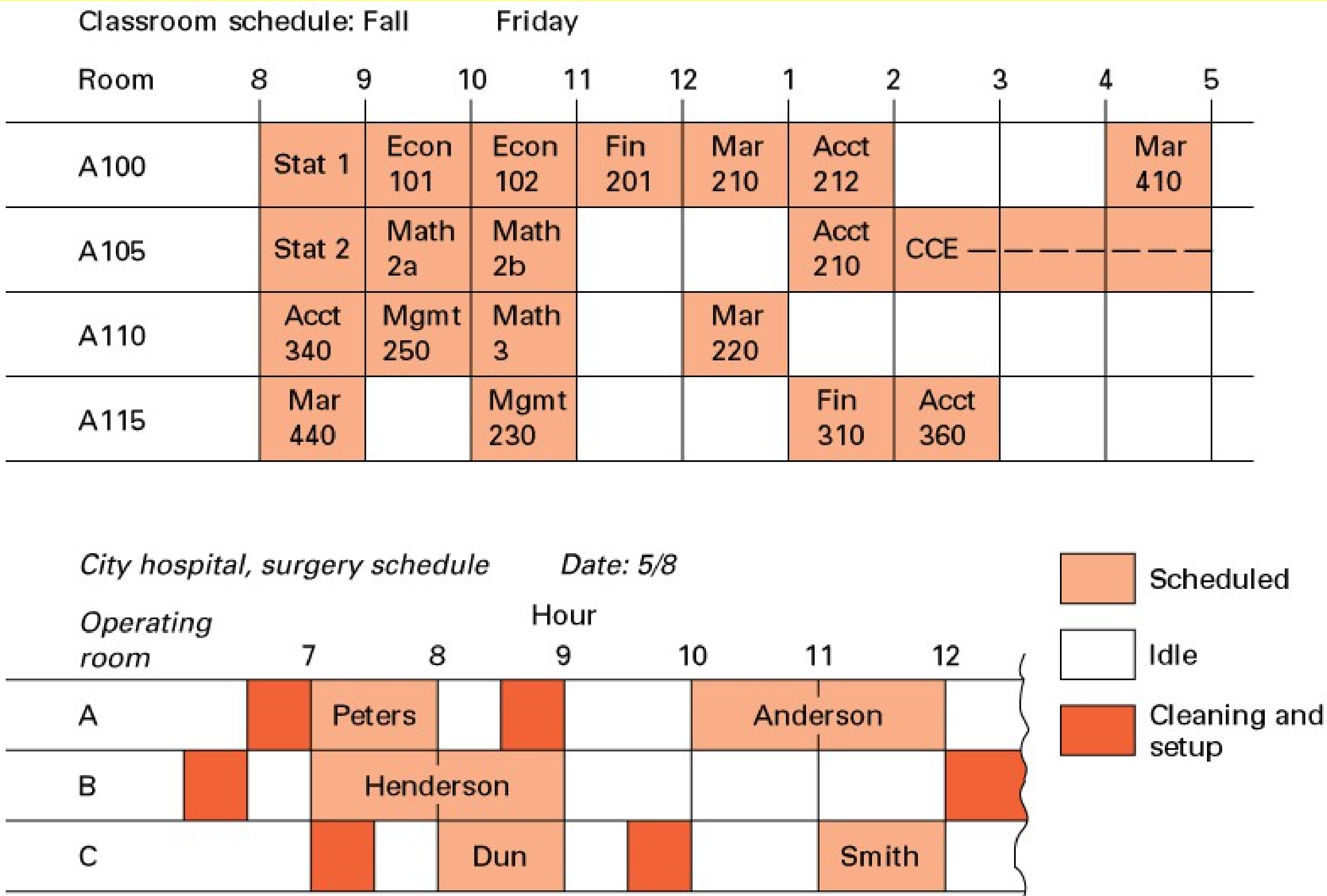
Processing Resources

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				

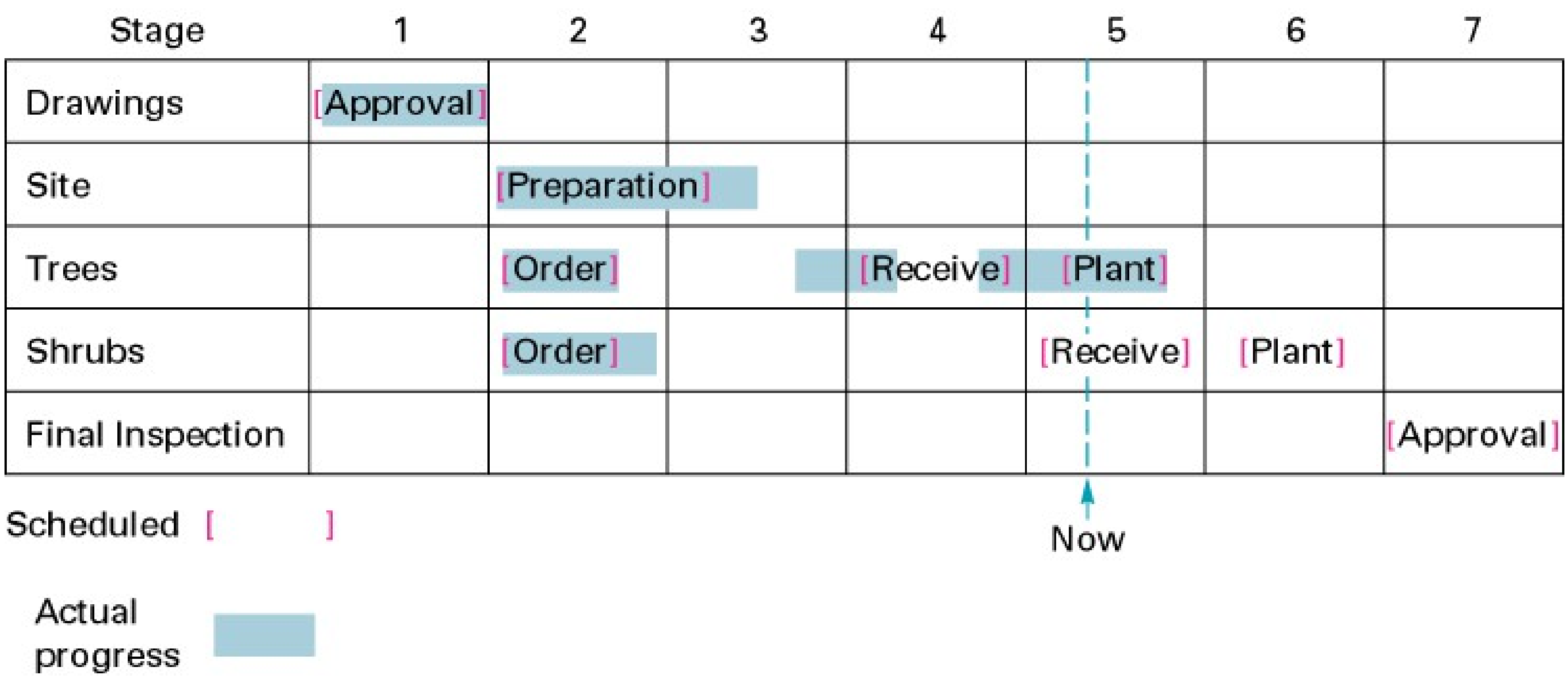
Job A = processing job

= center not available

Gantt load charts for classroom schedules and hospital schedules



Gantt schedule charts track progress of actual work relative to schedule



Decisions to be made in scheduling

- Assignment
  - need to assign a job to a machine/resource to process it
- Loading
  - need to decide how many jobs can be assigned to each machine
- Scheduling
  - need to decide on a starting time for each job at each workstation
- Sequencing
  - need to order processing of individual jobs at each workstation

Loading involves assigning jobs to processing centers

- Approaches to loading
  - Infinite loading
    - assigns jobs to work centers without regard to the capacity of the work center
    - possible to overload (exceed capacity) in some periods and underload in other periods
  - Finite loading
    - capacity is not exceeded
    - takes into account capacity of each work center and processing times of jobs; projects actual job start and stop times

Scheduling involves assigning start times to jobs at processing centers

- Approaches to scheduling
  - Forward scheduling
    - scheduling ahead from a point in time (e.g., now)
    - useful to answer the question "How long will it take to complete this job?"
  - Backward scheduling
    - scheduling backward from a future due date
    - useful to answer the questions:
      - "Can we complete this job in time?"
      - "When is the latest we can start this job and still complete it by the due date?"

Researchers have developed many linear programs to solve scheduling problems

- Assignment method
  - Assigns tasks/jobs to resources/machines
  - Special purpose linear program available for this problem
- Many linear programs for scheduling problems cannot be solved optimally in finite times for sufficiently complex (i.e. real-world) problems
  - That is, even with the fastest supercomputers, the problems cannot be completed – they run forever
  - Thus, instead of using linear programming, most companies use dispatching heuristics for sequencing

Sequencing involves ordering the processing of jobs

- Sequencing
  - Determine the order in which jobs at a work center will be processed.
  - Results in an ordered list of jobs
- Sequencing is most beneficial when we have constrained capacity (fixed machine set; cannot buy more) and heavily loaded work centers
  - Lightly loaded work centers = no big deal (excess capacity)
  - Heavily loaded
    - Want to make the best use of available capacity
    - Want to minimize unused time at each machine as much as possible

Sequencing

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

- Why use simple heuristics?
  - Problem too complex = linear programming won't work
  - Sequencing jobs often does quite well

Commonly Used Priority Rules

- FCFS
  - first come, first served
- SPT
  - job with shortest processing time is processed first
- EDD
  - job having earliest due date is processed first
- CR (critical ratio)
  - job having smallest critical ratio (time remaining until due date/processing time remaining) is processed next
- S/O (slack per operation)
  - job processed according to average slack time = (time until due date – remaining time to process)/(number of remaining operations)
- Rush
  - emergency or preferred customers go first

Example 2: Applying sequencing rules

- FCFS sequence
  - A,B,C,D,E,F
- SPT sequence
  - A,C,E,B,D,F
- EDD sequence
  - C,A,E,B,D,F

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

Sequencing rules are evaluated based on several performance measures

- Average job flow time
  - length of time (from arrival to completion) a job is in the system, on average
- Lateness
  - average length of time the job will be late (that is, exceed the due date by)
- Makespan
  - total time to complete all jobs
- Average number of jobs in the system
  - measure relating to work in process inventory
  - equals total flow time divided by makespan

Example 2: Summary of performance metrics for jobs A-F

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

SPT often performs very well, especially when trying to speed jobs through system (minimize flowtime) and minimize WIP inventories

EDD often chosen when managers are interested in meeting due dates

Scheduling Work in a Two Machine Flow Shop

Two Work Center Sequencing

- Johnson's Rule
  - A technique for minimizing total completion time (makespan) 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

- Assumptions
  - 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

- Johnson's Algorithm
  - List the jobs and their times at each work center
  - Select the job with the shortest time
  - Eliminate the job from further consideration
  - Repeat steps 2 and 3 until all jobs have been scheduled

Scheduling Problems Exhibit Many Challenges

Complexity of scheduling problems is determined by number of jobs

- Number of possible schedules can be enormous
- Scheduling decisions are combinatorial in nature
  - Choosing to process one job impacts the decisions that can be made for other jobs under consideration
- Often have a factorial (= n!) number of possible schedules
  - Toy problems in your book
    - n! = small, making them easy to solve
  - Typical problems in a factory
    - n = large
    - n! = huge, making the problem impossible to solve in a finite amount of time

Solutions for scheduling problems can involve many assumptions

- Set of Jobs to Schedule
  - Typically assume that our set of jobs is fixed
- Time
  - Need to assume times are known,
  - Usually assume times are fixed and independent of processing order or activities that take place elsewhere in the factory
- Quality
  - Assume we never produce a bad part
- Machines
  - Assume we never have breakdowns

“Optimal” scheduling methods’ assumptions can be violated in many ways

- Variability in
  - Setup times
  - Processing times
  - Interruptions
  - Changes in the set of jobs
- No method for identifying optimal schedule
- Scheduling is an ongoing (never-ending) task for a manager

Minimizing Scheduling Difficulties

- Set realistic due dates
- Focus on increasing capacity at bottleneck operations
  - Theory of Constraints approach does this
- Consider lot splitting of large jobs

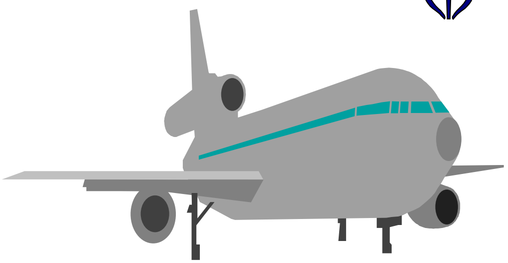
Scheduling Service Operations

Problems in Service Operations make scheduling even more difficult

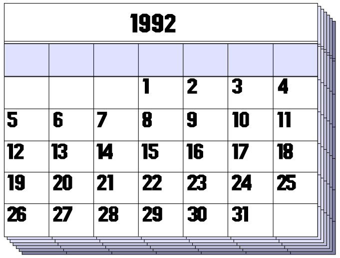
- Cannot store or inventory services
- Customer service requests are random
- Scheduling service involves
  - Customers
  - Workforce
  - Equipment

Service Operations use many scheduling tools to ensure good service

- Appointment systems
  - Controls customer arrivals for service
- Reservation systems
  - Estimates demand for service
  - Prices according to demand
  - Schedules use of service



- Scheduling the workforce
  - Manages worker capacity for service
- Scheduling multiple resources
  - Coordinates use of more than one resource



Cyclical Scheduling is used in services with similar, repeating requirements

- Hospitals, police/fire departments, restaurants, supermarkets

- Rotating schedules
  - Set a scheduling horizon
  - Identify the work pattern
  - Develop a basic employee schedule
  - Assign employees to the schedule