Introduction to Operations Management
运营管理概论

4- Scheduling Sequencing

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Delta Airlines

- About 10% of Delta's flights are disrupted per year, half because of weather
- Cost is $440 million in lost revenue, overtime pay, food and lodging vouchers
- The $33 million Operations Control Center adjusts to changes and keeps flights flowing
- Saves Delta $35 million per year

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 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 Air Lines	Maintenance of aircraft Departure timetables Flight crews, catering, gate, ticketing personnel

Scheduling Flow

Capacity Planning
(Long term; years)
Changes in Facilities
Changes in Equipment

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

Aggregate Production Plan for All Bikes
(Determine personnel or subcontracting necessary to match aggregate demand to existing facilities/capacity)

Month	1	2
Bike Production	800	850

Master Schedule
(Intermediate term; weekly)
Material requirements planning
Disaggregate the aggregate plan

Master Production Schedule for Bike Models
(Determine weekly capacity schedule)

	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	

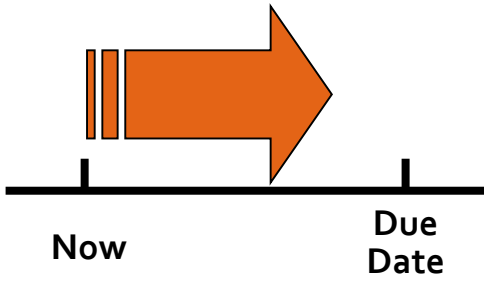
Short Term Scheduling
(Short term; days, hours, minutes)
Work center loading
Job sequencing/dispatching

Work Assigned to Specific Personnel and Work Centers
Make finite capacity schedule by matching specific tasks to specific people and machines

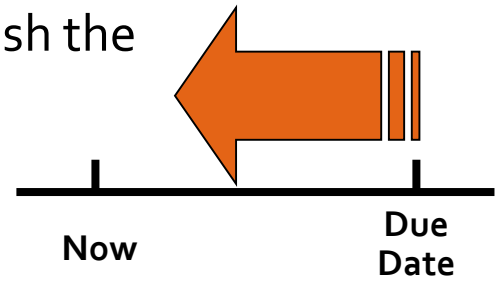
Assemble Model 22 in work center 6

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 buildup of work-in-process inventory



- 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



Performance Measures

- ***Flow time*** is the amount of time a job spends in the service or manufacturing system
- ***Past due*** (tardiness) is the amount of time by which a *job* missed its due date
- ***Makespan*** is the total amount of time required to complete a group of jobs

$$\text{Makespan} = \text{Time of completion of last job} - \text{Starting time of first job}$$

- Total inventory is used to measure the effectiveness of schedules for manufacturing processes.

$$\text{Total Inventory} = \text{Scheduled receipts for all items} + \text{On-hand inventories of all items}$$

- Utilization is the percentage of work time that is productively spent by an employee or a machine

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Sequencing Example

Summary of Rules

Rule	Average Completion Time (Days)	Utilization Metric (%)	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 maximum lateness**

Critical Ratio (CR)

- An index number found by dividing the time remaining until the due date by the work time remaining on the job
- Jobs with low critical ratios are scheduled ahead of jobs with higher critical ratios
- Performs well on average job lateness criteria

$$CR = \frac{\text{Time remaining}}{\text{Workdays remaining}} = \frac{\text{Due date - Today's date}}{\text{Work (lead) time remaining}}$$

Critical Ratio Example

Currently Day 25

Job	Due Date	Workdays Remaining	Critical Ratio	Priority Order
A	30	4	(30 - 25)/4 = 1.25	3
B	28	5	(28 - 25)/5 = .60	1
C	27	2	(27 - 25)/2 = 1.00	2

With CR < 1, Job B is late. Job C is just on schedule and Job A has some slack time.

Critical Ratio Technique

1. Helps determine the status of specific jobs
2. Establishes relative priorities among jobs on a common basis
3. Relates both stock and make-to-order jobs on a common basis
4. Adjusts priorities automatically for changes in both demand and job progress
5. Dynamically tracks job progress

Slack per remaining operations (S/RO)

$$\text{S/RO} = \frac{\left(\text{Due date} - \text{Today's date}\right) - \text{Total shop time remaining}}{\text{Number of operations remaining}}$$

- The job with the lowest S/RO is scheduled next

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

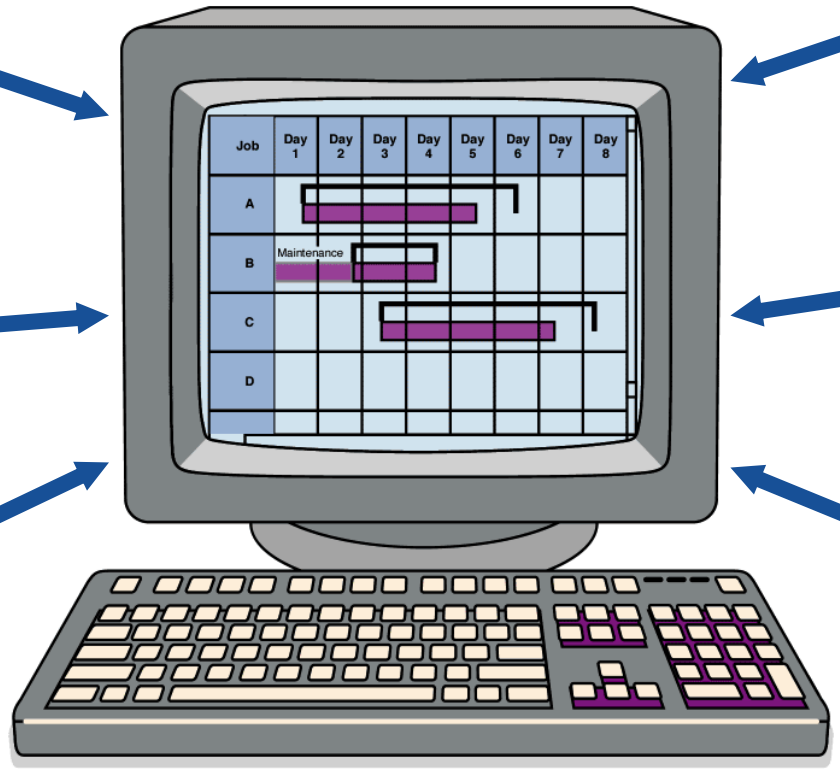
Finite Capacity Scheduling

MRP Data
- Master schedule
- BOM
- Inventory

Priority rules

- Expert systems
- Simulation models

Interactive Finite Capacity Scheduling

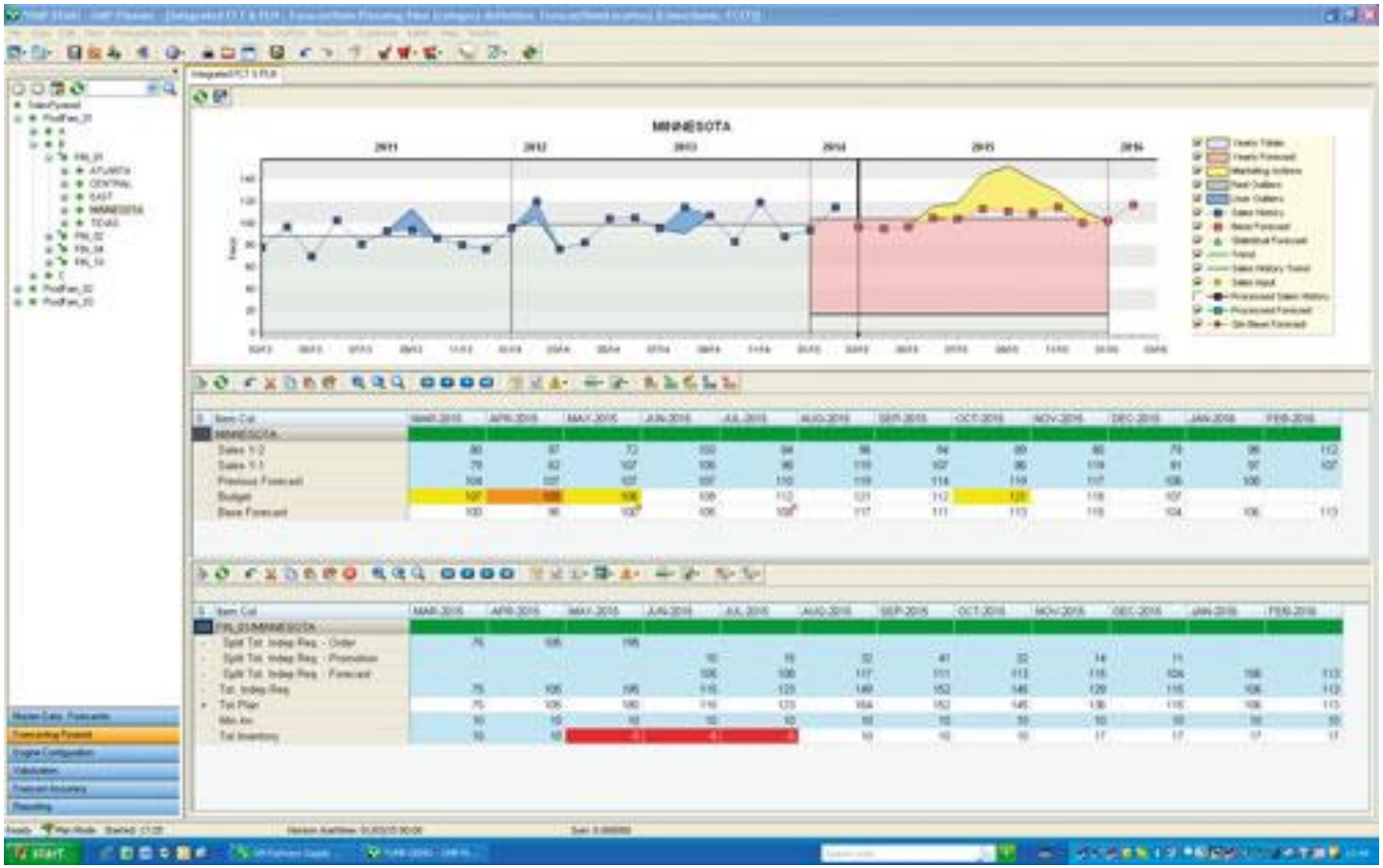


- Routing files
- Work center information

Tooling and other resources

Setups and run time

Finite Capacity Scheduling



OMP Plus

Labor-Limited Environment

- The resource constraint is the amount of labor available, not the number of machines or workstations
- The scheduler must also assign workers to their next workstations
- Some possible labor assignment rules
  - Assign personnel to the workstation with the job that has been in the system longest
  - Assign personnel to the workstation with the most jobs waiting for processing
  - Assign personnel to the workstation with the largest standard work content
  - Assign personnel to the workstation with the job that has the earliest due date