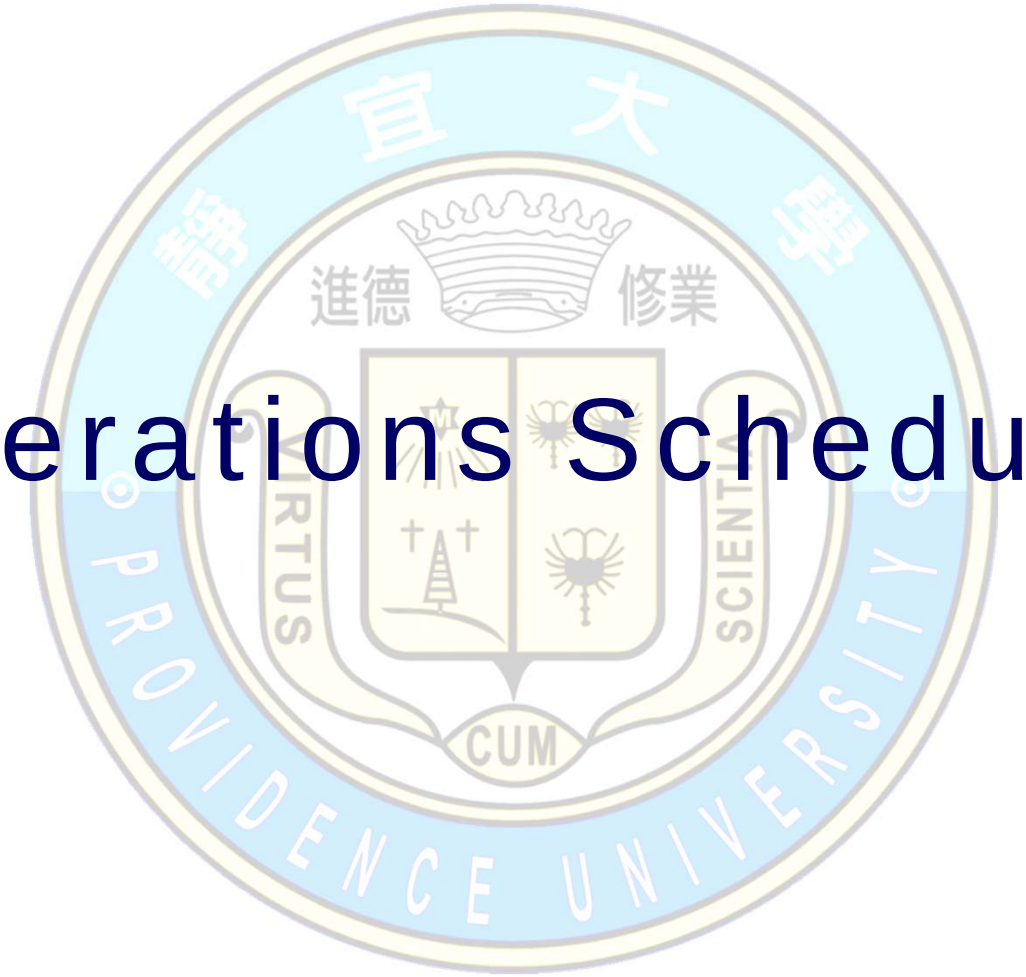


Operations Scheduling

Content

- Different kinds of scheduling operations
- Different shop loading methods
- Develop a schedule using priority rules
- Calculate scheduling for multiple workstations
- Develop a schedule performance measures

Content – con't

- Describe the theory of constraints
- Describe scheduling techniques for service applications
- Develop a workforce schedule in which each employee has two consecutive days off

Scheduling Operations

- Companies differentiate based on product volume and product variety
- Differentiation affects how the company organizes its operations
- Each kind of company operation needs different scheduling techniques
- Scheduling has specific definitions for routing, bottleneck, due date, slack and queue

Scheduling Definitions

- **Routing:** The operations to be performed, their sequence, the work centers, & the time standards
- **Bottleneck:** A resource whose capacity is less than the demand placed on it
- **Due date:** When the job is supposed to be finished
- **Slack:** The time that a job can be delayed & still finish by its due date
- **Queue:** A waiting line

Characteristics of High-Volume Operations

High-volume aka flow operations, like automobiles, bread, gasoline can be repetitive or continuous

- High-volume standard items; discrete or continuous with smaller profit margins
- Designed for high efficiency and high utilization
- High volume flow operations with fixed routings
- Bottlenecks are easily identified
- Commonly use line-balancing to design the process around the required tasks

Low-Volume Operations

- Low-volume, job shop operations, are designed for flexibility.
  - Use more general purpose equipment
  - Customized products with higher margins
  - Each product or service may have its own routing (scheduling is much more difficult)
  - Bottlenecks move around depending upon the products being produced at any given time

Gantt Charts - Low-Volume Tool

- Developed in the early 1900's by Henry Gantt
- **Load charts** illustrate the workload relative to the capacity of a resource
  - Shows today's job schedule by employee

Mechanic	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5
Bob	JOB A			JOB G		JOB I			
Sam	JOB B			JOB H		JOB J		JOB N	
Alex	JOB C		JOB E			JOB K			JOB O
J.J.	JOB D		JOB F			JOB L	JOB M		

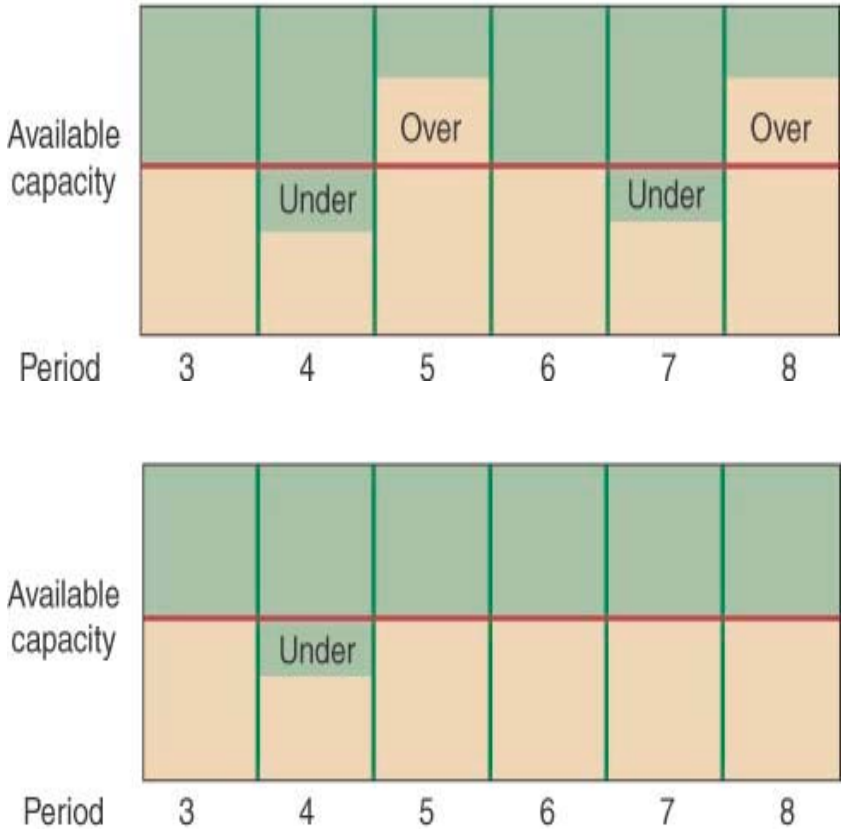
Gantt Chart con't

Progress charts:

- Illustrate the planned schedule compared to actual performance
- Brackets show when activity is scheduled to be finished. Note: design & pilot run both finish late; feedback has not started yet.

Scheduling Work - Work Loading

- **Infinite loading:**
  - Ignores capacity constraints, but helps identify bottlenecks in a proposed schedule to enable proactive management
- **Finite loading:**
  - Allows only as much work to be assigned as can be done with available capacity – but doesn't prepare for inevitable slippage



Other Scheduling Techniques

- **Forward Scheduling –** starts processing when a job is received
- **Backward Scheduling –** begin scheduling the job's last activity so that the job is finished on due date

Monitoring Workflow - Input/Output Control

- I/O control is a capacity-control technique used to monitor work flow at individual work centers
- Monitors how well available capacity is used and provides insight into process problems

Figure 15-6 Input/output report for work center 101						
Input Information (in hours)				**Period**		
		4	**5**	**6**	**7**	**8**
Planned Input		800	750	800	820	800
Actual Input		750	780	780	810	810
Deviation		-50	30	-20	-10	10
Cumulative deviation	**0**	**-50**	**-20**	**-40**	**-50**	**-40**
Output information (in hours)				**Period**		
		4	**5**	**6**	**7**	**8**
Planned output		800	800	800	800	800
Actual output		800	750	780	850	825
Deviation		0	-50	-20	50	25
Cumulative deviation	**0**	**0**	**-50**	**-70**	**-20**	**5**
Backlog (in hours)	100	50	80	80	40	25

How to Sequence Jobs

Which of several jobs should be scheduled first?

- Techniques are available to do short-term planning of jobs based on available capacity & priorities
- Priority rules:
  - Decision rules to allocate the relative priority of jobs at a work center
  - Local priority rules: determines priority based only on jobs at that workstation
  - Global priority rules: also considers the remaining workstations a job must pass through

Commonly Used Priorities Rules

- First come, first served (FCFS)
- Last come, first served (LCFS)
- Earliest due date (EDD)
- Shortest processing time (SPT)
- Longest processing time (LPT)
- Critical ratio (CR):
  - (Time until due date)/(processing time)
- Slack per remaining Operations (S/RO)
  - Slack /(number of remaining operations)

Example Using SPT, EDD

Example Using SPT and EDD at Jill's Machine Shop-Work Center 101				
	Job Time	Days to	SPT Rule	EDD Rule
Job Number	(includes Setup & Run Time)	Due Date	Sequence	Sequence
AZK111	3 days	3	EZE101	AZK111
BRU872	2 days	6	BRU872	EZE101
CUF373	5 days	8	AZK111	DBR664
DBR664	4 days	5	DBR664	BRU872
EZE101	1day	4	FID448	CUF373
FID448	4 days	9	CUF373	FID448

How to Use Priority Rules

1. Decide which priority rule to use
2. List all jobs waiting to be processed with their job time
3. Using priority rule determine which job has highest priority then second, third and so on

Measuring Performance

- **Job flow time:**
  - Time a job is completed minus the time the job was first available for processing; **avg. flow time measures responsiveness**
- **Average # jobs in system:**
  - Measures amount of work-in-progress; **avg. # measures responsiveness and work-in-process inventory**
- **Makespan:**
  - The time it takes to finish a batch of jobs; **measure of efficiency**
- **Job lateness:**
  - Whether the job is completed ahead of, on, or behind schedule;
- **Job tardiness**:
  - How long after the due date a job was completed, **measures due date performance**

Scheduling Performance Calculations

Job A finishes on day 10	Job B finishes on day 13	Job C finishes on day 17	Job D ends on day 20

- **Calculation mean flow time:**
  - MFT= (sum job flow times)/ # of jobs
    = (10+13+17+20)/4 = 60/4 = **15 days**
- **Calculating average number of jobs in the system:**
  - Average # Jobs =(sum job flow times)/ # days to complete batch
    = (60)/20 = **3 job**
- **Makespan is the length of time to complete a batch**
  - Makespan = Completion time for Job D minus start time for Job A
    = 20 – 0 = 20 days

Performance Calculations con't

- Lateness and Tardiness are both measures related to customer service
- Average tardiness is a more relevant **Customer Service** measurement as illustrated below

Example 15-5 Calculating job lateness and job tardiness				
	Completion			
Job	Date	Due Date	Lateness	Tardiness
A	10	15	-5	0
B	13	15	-2	0
C	17	10	7	7
D	20	20	0	0
		Average	0	1.75

Comparing SPT and S/RO

Performance Measures using SPT						
	Job Time at					
	Work Center		SPT			
	301	Due date	Completion	Lateness	Tardiness	Scheduling
Job	(days)	(days from now)	Date	(days)	(days)	Sequence
A	3	15	5	-10	0	2
B	7	20	27	7	7	6
C	6	30	20	-10	0	5
D	4	20	9	-11	0	3
E	2	22	2	-20	0	1
F	5	20	14	-6	0	4
Total	27	Avg. Job Flow	12.83	-8.3	1.2	
		Total Job Flow Time	77			
		Makespan	27			
		Avg. # Jobs	2.85			

E done at end of day 2	A end of day 5	D at end of day 9	F at end of day 14	C at end of day 20	B done at end of day 27

Comparing SPT and S/RO (cont.)

Performance Measures Using S/RO										
	Job Time				Remaining					
	at Work	Remaining			Number					
	Center	Job Time at		Slack	of Operations					
	301	Other Work	Due date	Time	After Work		Scheduling	Completion	Lateness	Tardiness
Job	(days)	Center (days)	(days from now)	(days)	Center 301	S/RO	Sequence	Date	(days)	(days)
A	3	6	15	6	2	2	2	10	-5	0
B	7	8	20	5	4	1	1	7	-13	0
C	6	5	30	19	3	4.75	6	27	-3	0
D	4	3	20	13	2	4.33	5	21	1	1
E	2	7	22	13	3	3.25	4	17	-5	0
F	5	5	20	10	3	2.5	3	15	-5	0
Total	27						Avg. Job Flow	16.17	-5.0	0.167
							Total Job Flow Time	97		
							Makespan	27		
							Avg. # Jobs	3.59		

B done at end of day 7	A at end of day 10	F at end of day 15	E at end of day 17	D at end of day 21	C done at end of day 27

Sequencing Jobs through Two Work Centers –Johnson's Rule

Johnson's Rule – a technique for minimizing makespan in a two-stage, unidirectional process

Step 1 – List the jobs and the processing time for each activity

Step 2 – Find the shortest activity processing time among the jobs not yet scheduled

1. If the shortest Processing time is for a 1st activity, schedule that job in the earliest available position in the job sequence
2. If the shortest processing time is for 2nd activity, schedule that job in the last available position in the job sequence
3. When you schedule a job eliminate it from further consideration

Step 3 – Repeat step 2 until you have put all activities for the job in the schedule

Johnson's Rule Example

- Vicki's Office Cleaners does the annual major cleaning of university buildings. The job requires mopping (1st activity) and waxing (2nd activity) of each building. Vicki wants to minimize the time it takes her crews to finish cleaning (minimize makespan) the five buildings. She needs to finish in 20 days.

Johnson's Rule Example

	Activity 1	Activity 2	Johnson's	Activity 1	Activity 2
Hall	Mopping (days)	Waxing (days)	Sequence	Mopping (days)	Waxing (days)
Adams Hall	1	2	Adams Hall (A)	1	2
Bryce Building	3	5	Chemistry Building (C)	2	4
Chemistry Building	2	4	Bryce Building (B)	3	5
Drake Union	5	4	Drake Union (D)	5	4
Evans Center	4	2	Evans Center (E)	4	2

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mopping	A	C	C	B	B	B	D	D	D	D	D	E	E	E	E			
Waxing		A	A	C	C	C	C	B	B	B	B	B	D	D	D	D	E	E

Scheduling Bottlenecks

- In the 1970's Eli Goldratt introduced optimized production technology (OPT)
- OPT focused on bottlenecks for scheduling & capacity planning
- Definitions:
  - **Throughput:** quantity of finished goods that can be sold
  - **Transfer batch:** quantity of items moved at the same time from one resource to the next
  - **Process batch:** quantity produced at a resource before switching to another product

OPT Principles

- Balance the process rather than the flow
- Non-bottleneck usage is driven by some other constraint in the system
- Usage and activation of a resource are not the same
- A hour lost at a bottleneck is lost forever, but an hour lost at a non-bottleneck is a mirage

OPT Principles – con't

- Bottleneck determine throughput and inventory in system
- The transfer batch does not need to be equal to the process batch
- The process batch should be variable
- Consider all constraints simultaneously. Lead times are the result of the schedule and are not predetermined.

Theory of Constraints

- TOC is an extension of OPT – theory is that a system's output is determined by its constraints

1. Identify the bottleneck(s) in the process
2. Exploit (fully utilize) the bottleneck(s)
3. Subordinate all other decisions to Step 2 - Schedule non-bottlenecks to support maximum use of bottleneck activities
4. Elevate the Bottleneck(s)
5. Do not let inertia set in

Scheduling for Service Organizations

- **Demand management:**
  - Appointments & reservations
  - Posted schedules
  - Delayed services or backlogs (queues)
- **Scheduling Employees:**
  - Staff for peak demand (if cost isn't prohibitive)
  - Floating employees or employees on call
  - Temporary, seasonal, or part-time employees

Developing a Workforce Schedule

- Tibrewala, Philippe, and Brown developed a technique for scheduling a seven day operation giving each employee two consecutive days off. This example shows how a staff of six people can be scheduled.

Developing a Workforce Schedule

- **Step 1** – Find out the minimum number of employees needed for each day of the week

(1) Day of the week	M	T	W	Th	F	Sa	Su
Number of staff needed	4	5	5	3	5	2	3

- **Step 2** – Given the above requirements, calculate the number of employees needed for each pair of consecutive days

(1) Pair of Consecutive Days	Total of Staff needed
Monday & Tuesday	9 employees
Tuesday & Wednesday	10 employees
Wednesday & Thursday	8 employees
Thursday & Friday	8 employees
Friday & Saturday	7 employees
Saturday & Sunday	5 employees

- **Step 3** - Find the pair of days with the lowest total needed

Workforce Scheduling con't

- **Step 4** – Update the number of employees you still need to schedule for each day

(2) Day of the week	M	T	W	Th	F	Sa	Su
Number of staff needed	3	4	4	2	4	2	3

- **Step 5** – Using the updated staffing needs, repeat steps 2 through 4 until you have satisfied all needs

(2) Pair of Consecutive Days	Total of Staff needed
Monday & Tuesday	7 employees
Tuesday & Wednesday	8 employees
Wednesday & Thursday	6 employees
Thursday & Friday	6 employees
Friday & Saturday	6 employees
Saturday & Sunday	5 employees

Scheduling con't

(3) Day of the week	M	T	W	Th	F	Sa	Su
Number of staff needed	2	3	3	1	3	2	3

(3) Pair of Consecutive Days	Total of Staff needed
Monday & Tuesday	5 employees
Tuesday & Wednesday	6 employees
Wednesday & Thursday	4 employees
Thursday & Friday	4 employees
Friday & Saturday	5 employees
Saturday & Sunday	5 employees

(4) Day of the week	M	T	W	Th	F	Sa	Su
Number of staff needed	1	2	3	1	2	1	2

(4) Pair of Consecutive Days	Total of Staff needed
Monday & Tuesday	3 employees
Tuesday & Wednesday	5 employees
Wednesday & Thursday	4 employees
Thursday & Friday	3 employees
Friday & Saturday	3 employees
Saturday & Sunday	5 employees

Schedule con't

(5) Day of the week	M	T	W	Th	F	Sa	Su
Number of staff needed	0	1	2	0	1	1	2

(5) Pair of Consecutive Days	Total of Staff needed
Monday & Tuesday	1 employees
Tuesday & Wednesday	3 employees
Wednesday & Thursday	2 employees
Thursday & Friday	1 employees
Friday & Saturday	2 employees
Saturday & Sunday	3 employees

(6) Day of the week	M	T	W	Th	F	Sa	Su
Number of staff needed	0	1	1	0	0	0	1

(6) Pair of Consecutive Days	Total of Staff needed
Monday & Tuesday	1 employees
Tuesday & Wednesday	2 employees
Wednesday & Thursday	1 employees
Thursday & Friday	0 employees
Friday & Saturday	0 employees
Saturday & Sunday	1 employees

Final Schedule

(7) Day of the week	M	T	W	Th	F	Sa	Su
Number of staff needed	0	0	0	0	0	0	0

Employees	M	T	W	Th	F	Sa	Su
1	x	x	x	x	x	off	off
2	x	x	x	x	x	off	off
3	x	x	off	off	x	x	x
4	x	x	x	x	x	off	off
5	off	off	x	x	x	x	x
6	x	x	x	x	off	off	x

- This technique gives a work schedule for each employee to satisfy minimum daily staffing requirements
- Next step is to replace numbers with employee names
- Manager can give senior employees first choice and proceed until all employees have a schedule

Scheduling within OM: How it all fits together

- Scheduling is the final planning that occurs before the actual execution of the plan. Production planners track the performance of operations in meeting the planned schedule. This is critical because the master scheduler (Ch 13) evaluates production planners on the level of customer service achieved for their product responsibilities.
- Schedules are essential to shop floor supervisors. The amount of time to complete a job is often determined by a time standard (Ch 11). If the time standards are inaccurate (either too stringent or too loose), the worker's morale may be affected.
- Customers often need to know when the service will be provided (cable installers) so that the customer is available. Customers often link quality of service (Ch 5) with adherence to the schedule (if the company delivers on time, everything is fine).

Scheduling Across the Organization

- Scheduling executes a company's strategic business plan and affects functional areas throughout the company
  - Accounting relies on schedule information and completion of customer orders to develop revenue projections

Scheduling Across the Organization – con't

- Marketing uses schedule effectiveness measurement to determine whether the company is using lead times for competitive advantage
- Information systems maintains the scheduling database
- Operations uses the schedule to maintain its priorities and to provide customer service by finishing jobs on time