Chapter 5

Scheduling and Controlling production Activities

Introduction

- 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.

Introduction Cont…

- **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

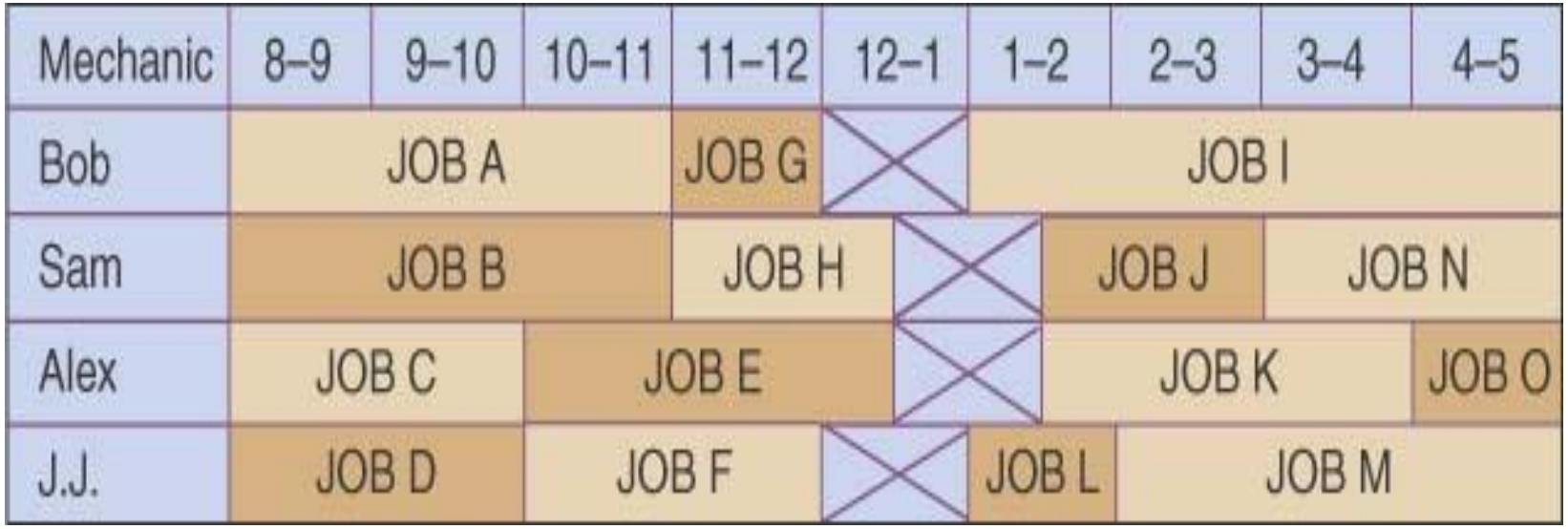
- High-volume flow operations, like automobiles, bread, gasoline can be repetitive or continuous.
  - High-volume standard items; discrete or continuous with smaller profit margins.
  - Designed for high efficiency
  - High volume flow operations with fixed routings.
  - Bottlenecks are easily identified.
  - 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.
  - ➢ 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

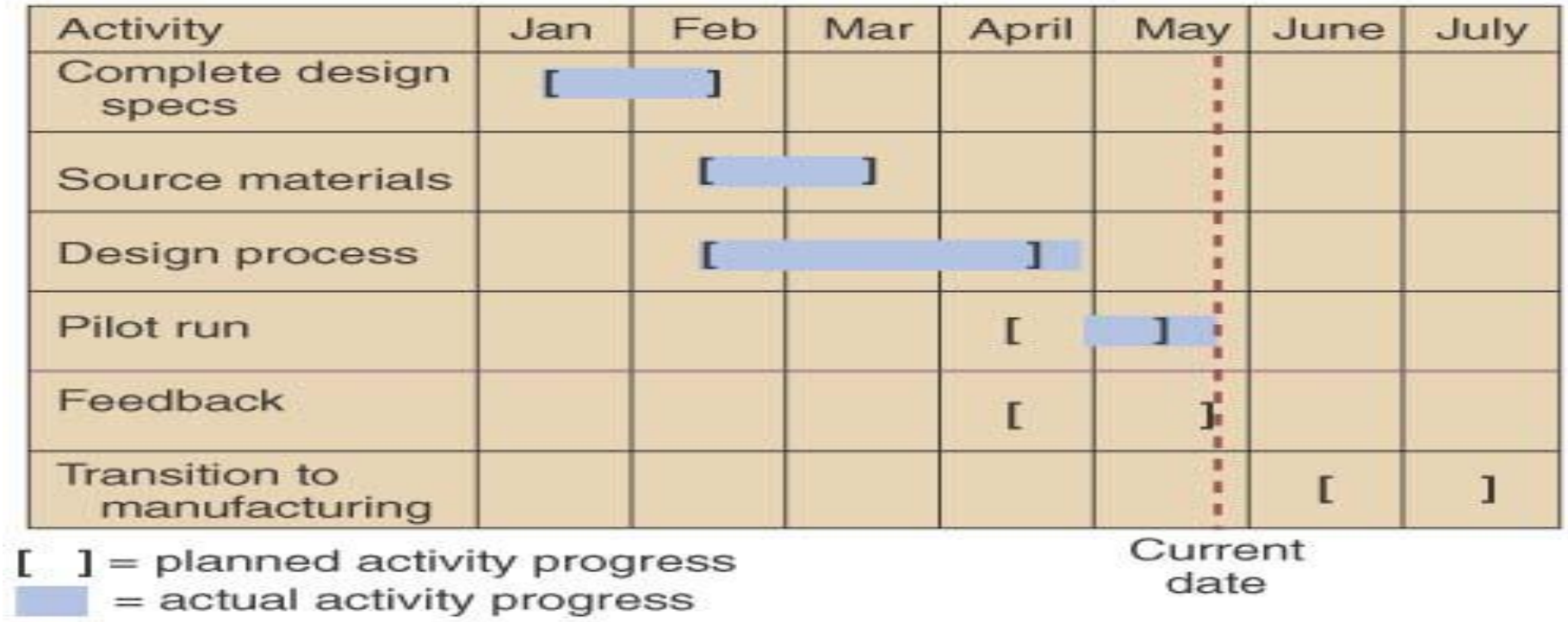
- Developed in the early 1900's by Henry Gantt
- **Load charts** illustrate the workload relative to the capacity of a resource
  - ➢ Shows today's job schedule by employee



Gantt Chart cont…

- **Progress charts:**

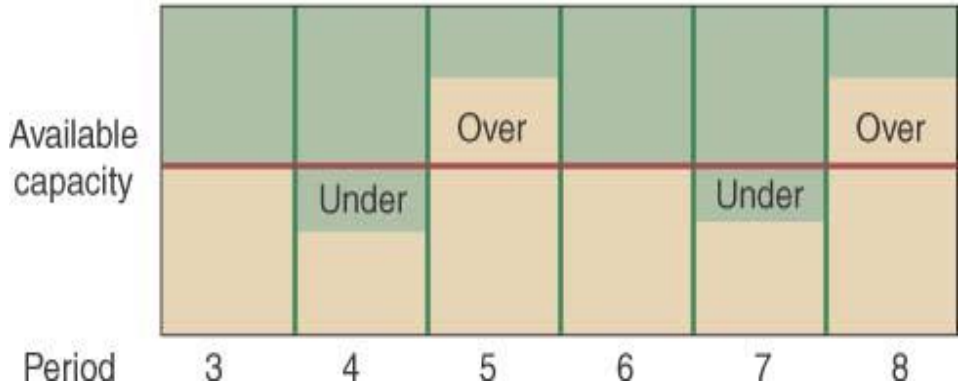
  - Illustrate the planned schedule compared to actual performance
  - Brackets show when activity is scheduled to be finished. Note: design & pilot run both finish late; feedback has not started yet.



Scheduling Work - Work Loading

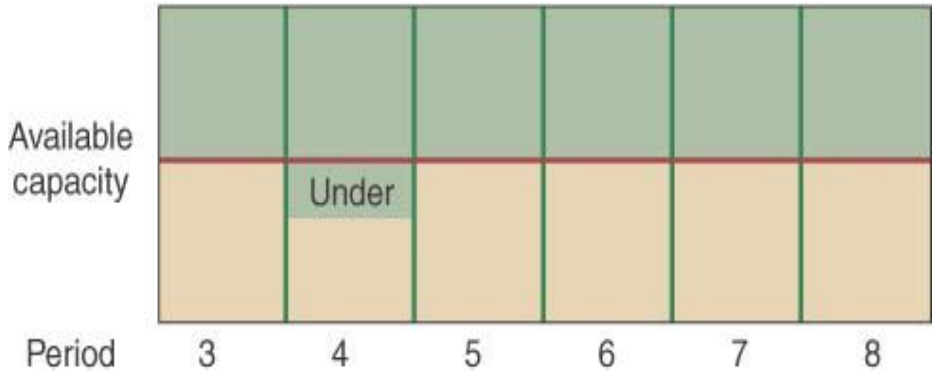
- **Infinite loading:**

➢ Ignores capacity constraints, but helps identify bottlenecks in a proposed schedule to enable proactive management.



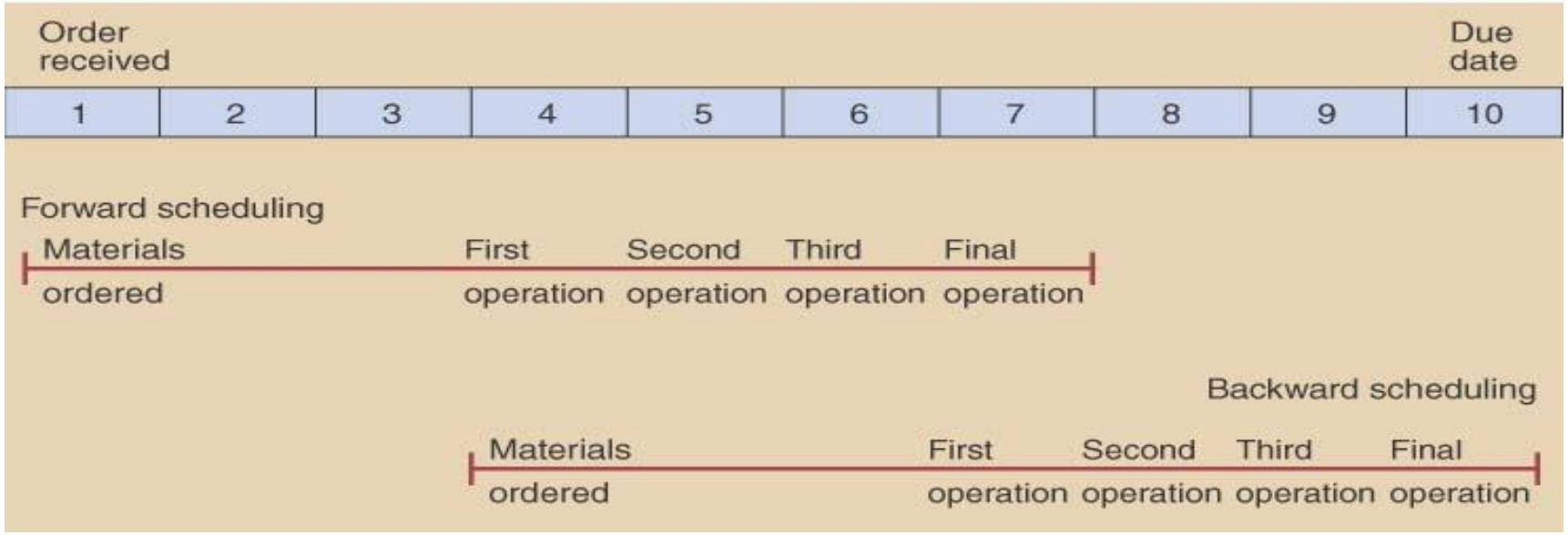
- **Finite loading:**

➢ Allows only as much work to be assigned as can be done with available capacity



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.



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 machine /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.

How to Sequence Jobs cont…

- 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)

How to Sequence Jobs cont…

- **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

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**
- **Make span:**
  - 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**

Measuring Performance cont…

- 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**
- **Makes pan is the length of time to complete a batch**
  - Make span = Completion time for Job D minus start time for Job A
    = 20 – 0 = 20 days

Measuring Performance cont…

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

	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

Measuring Performance cont…

- **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

Measuring Performance 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 *n* Jobs through Two Work Centers (machines)

- **Johnson's Rule**:

  Step 1: List all jobs with their M1 and M2 process times

  Step 2: Select the shortest processing time on the list

  - If a M1 time, schedule job 1st
  - If M2 time, schedule job LAST
  - Cross this job off list

  - Repeat Step 2 through rest of job (however, 1st means after already scheduled "1sts" and last is before already scheduled lasts).
  - Build optimal Schedule (Gantt Chart?) and compute Makes pan and Mean Flow .

Sequencing *n* Jobs.. Cont…

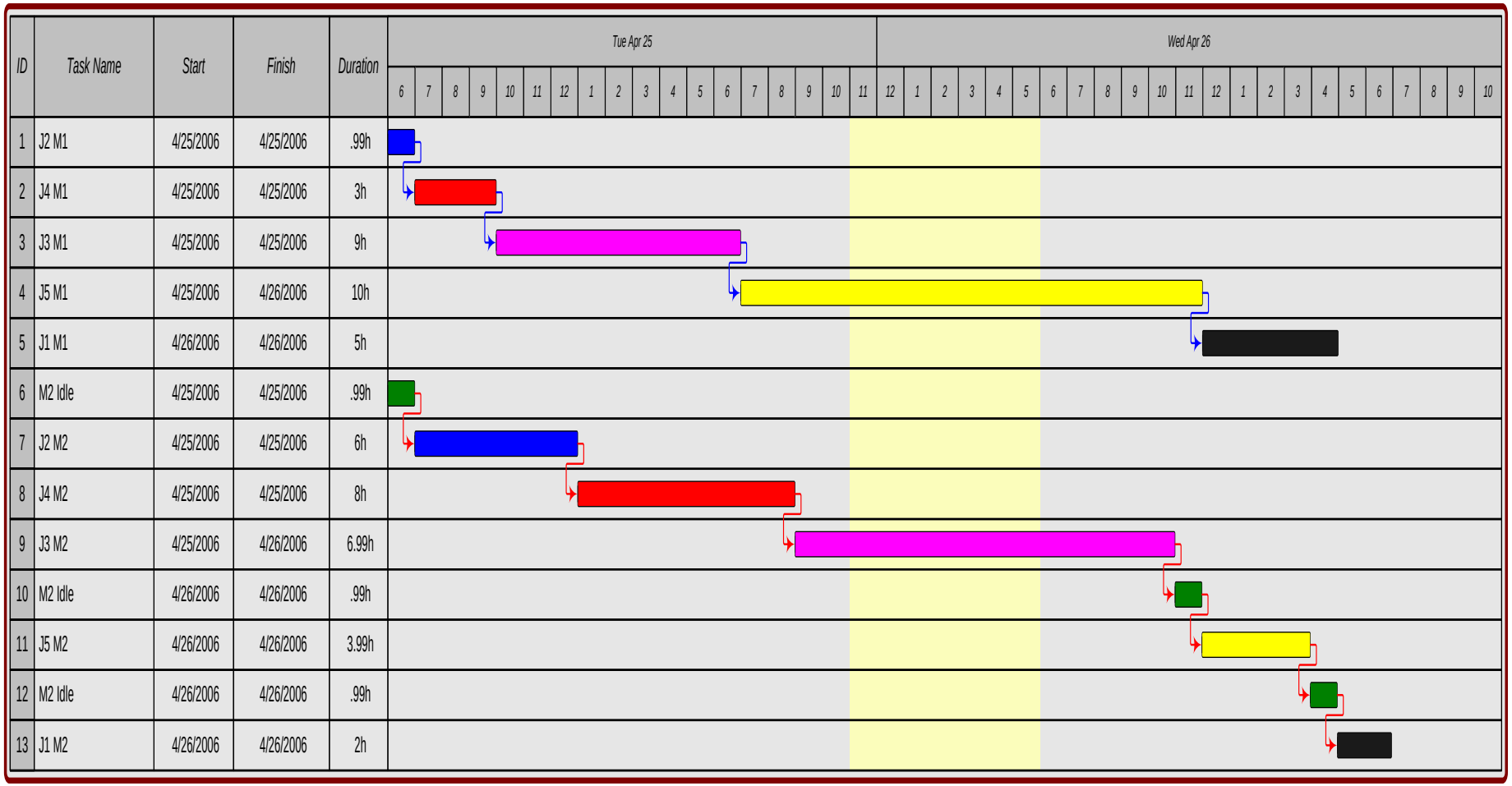
- **Lets Try an Example:**

Jobs	M1	M2
J1	5	2
J2	1	6
J3	9	7
J4	3	8
J5	10	4

- Find optimal sequence of jobs in each machine.

Sequencing *n* Jobs.. Cont…

- Solution :
- Optimal sequence is:
  - ➢ J2-J4-J3-J5-J1.



ID	Task Name	Start	Finish	Duration
1	J2 M1	4/25/2006	4/25/2006	.99h
2	J4 M1	4/25/2006	4/25/2006	3h
3	J3 M1	4/25/2006	4/25/2006	9h
4	J5 M1	4/25/2006	4/26/2006	10h
5	J1 M1	4/26/2006	4/26/2006	5h
6	M2 Idle	4/25/2006	4/25/2006	.99h
7	J2 M2	4/25/2006	4/25/2006	6h
8	J4 M2	4/25/2006	4/25/2006	8h
9	J3 M2	4/25/2006	4/26/2006	6.99h
10	M2 Idle	4/26/2006	4/26/2006	.99h
11	J5 M2	4/26/2006	4/26/2006	3.99h
12	M2 Idle	4/26/2006	4/26/2006	.99h
13	J1 M2	4/26/2006	4/26/2006	2h

Sequencing *n* Jobs.. Cont…

- Computing measures:
  - Make span: is 30 working hours of time
  - Mean Idle = (2+3)/2 = 2.5 units
  - Mean Flow Time:

$$MeanFlow = \frac{\left(\frac{1+4+13+23+28}{5}\right)+\left(\frac{7+15+22+27+30}{5}\right)}{2}$$

$$= \frac{13.8+20.2}{2} = 17$$

Sequencing n jobs on 3 machines

- The smallest processing time on machine 1 is greater than or equal the greatest processing time on machine 2, or
- The smallest processing time on machine 3 is greater than or equal the greatest processing time on machine 2.
  - If either or both of the above conditions are satisfied , we can replace the three machines by two machines namely H and G. then apply Johnson's rule.

Sequencing n jobs on 3 machines cont..

- Then, processing time will be :
  - Gi = m1 +m2
  - Hi = m2 + m3

Ex. The MDH Masala company has to process five items on three machines : A,B,C. processing times are given in the following table.

Item	A	B	C
1	4	4	6
2	9	5	9
3	8	3	11
4	6	2	8
5	3	6	7

Find optimal sequence.

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 schedule cont…

- **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

Workforce schedule cont…

-

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

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

(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) 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

Workforce schedule cont…

(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

Workforce schedule cont…

- 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

Workforce schedule cont…

THANK YOU!

END OF THE COURSE

TUTORIALS AND SELCTED PRACTICAL BASED LABS WILL CONTINUE