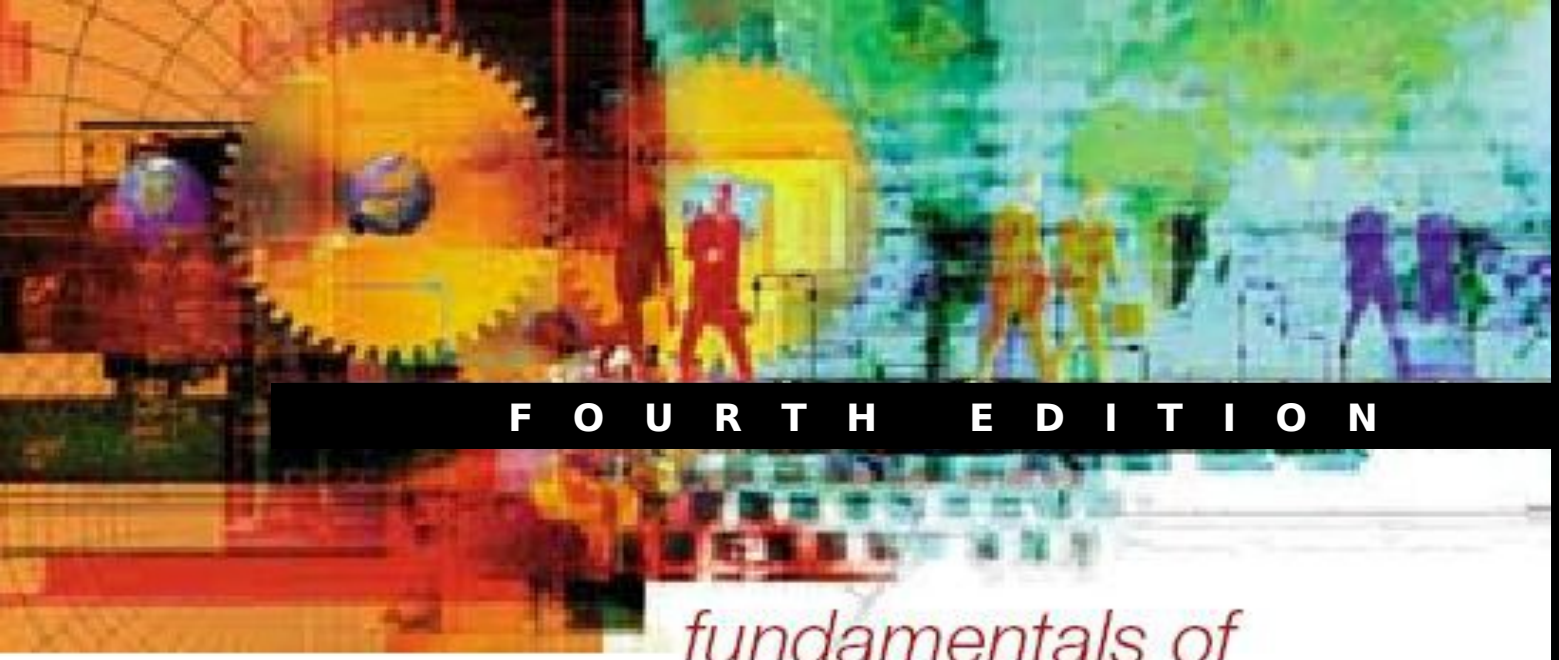


FOURTH EDITION

fundamentals of

operations MANAGEMENT

DAVIS

AQUILANO

CHASE

chapter 12 Scheduling

PowerPoint Presentation by Charlie Cook

Chapter Objectives

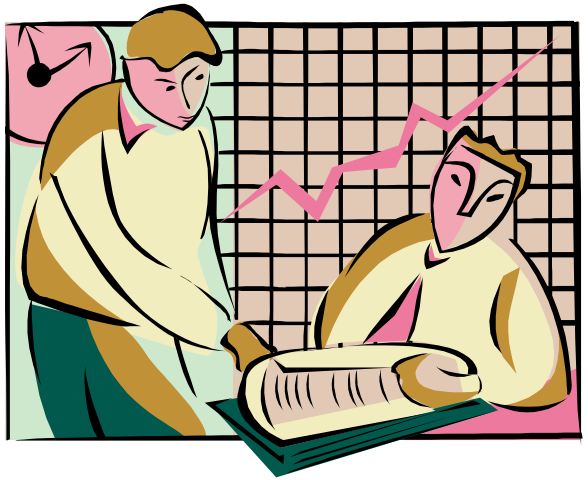
- Provide insight into the scheduling of intermittent processes.
- Emphasize the prevalence of job shops, especially in service operations.
- Present examples showing the importance of worker scheduling in service sector job shops.
- Identify the major elements of scheduling workers in service operations.
- Illustrate how technology can facilitate the scheduling of workers.

The Job Shop Defined

- Job Shop
  - **An organization whose layout is process-oriented (vs. product-oriented) and that produces items in batches.**
  - **A functional organization whose departments or work center are organized around particular processes that consist of specific types of equipment and/or operations.**

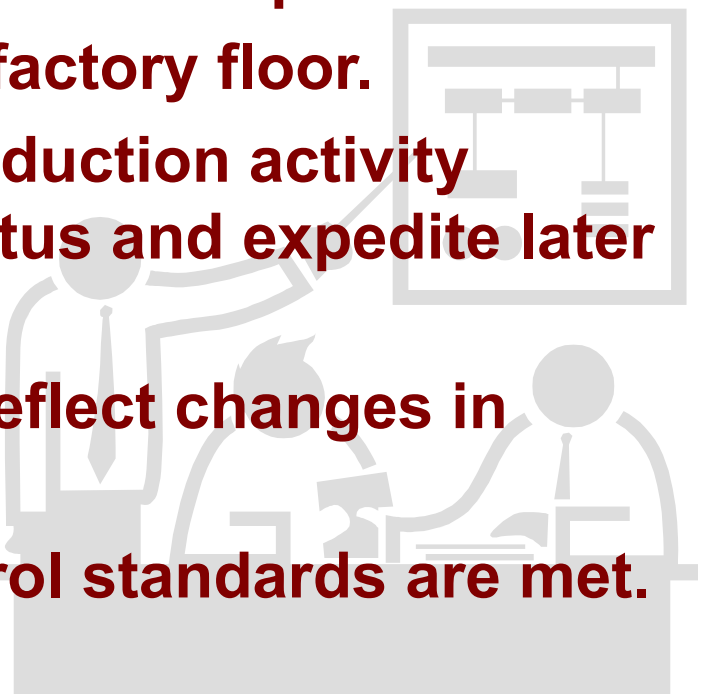
Scheduling in a Job Shop

- Disaggregating the master production schedule (MPS)
  - **Specifying time-phased activities (weekly, daily, and hourly).**
  - **Controlling job-order progress, expediting orders, and adjusting capacity.**



Scheduling in a Job Shop (cont'd)

- Scheduling and control system must capable of:
  - **Allocating orders, equipment, and personnel to work center or other specified locations.**
  - **Determining the sequence of order performance.**
  - **Dispatching orders to the factory floor.**
  - **Maintaining shop floor/production activity control to review order status and expedite later or critical orders.**
  - **Revising the schedule to reflect changes in order status.**
  - **Assuring that quality control standards are met.**



Typical Scheduling Process

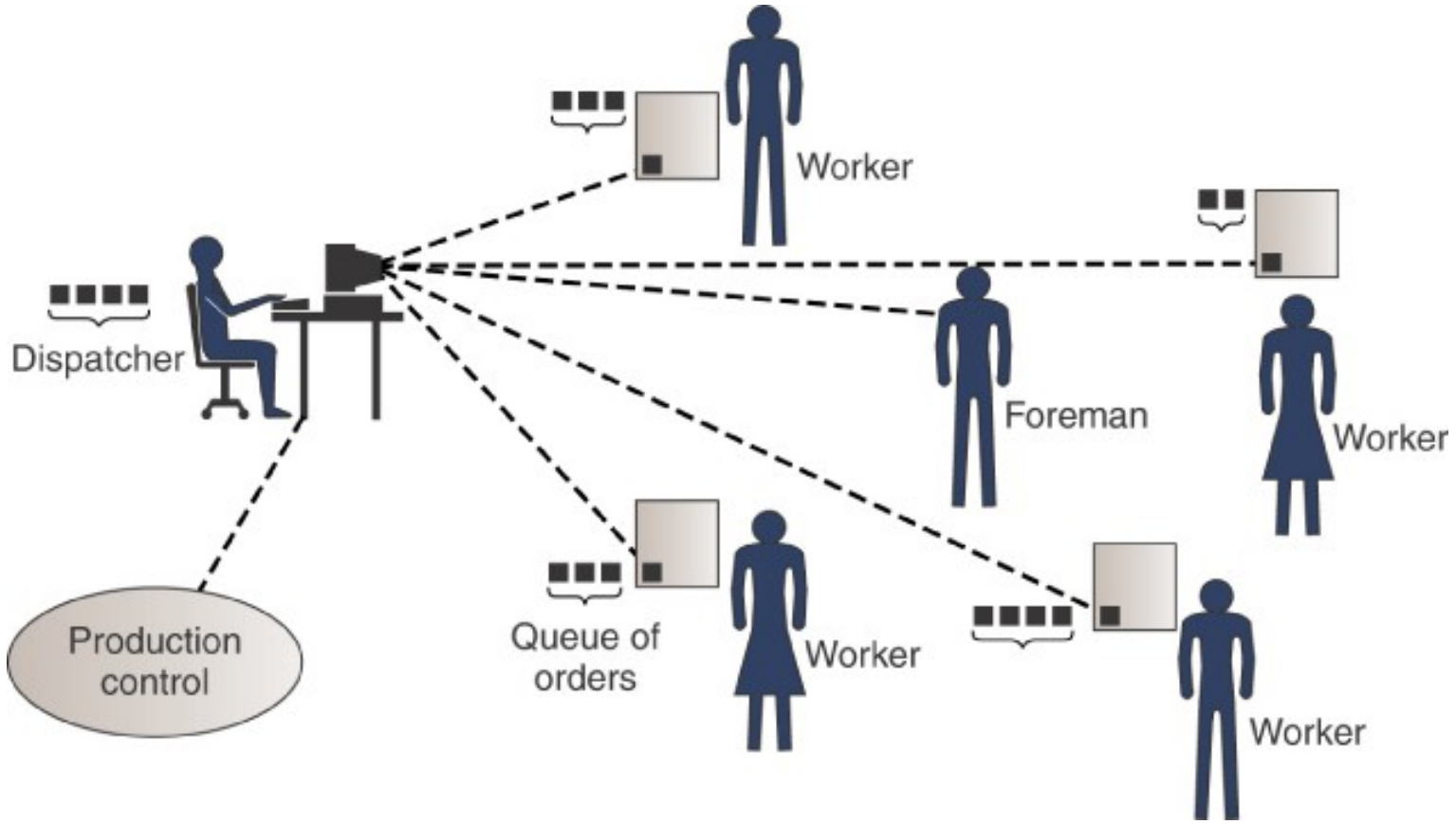


Exhibit 12.1

Scheduling in a Job Shop

- Job Arrival Patterns
  - **Constant or random arrivals**
  - **Singly or in batches (bulk or lot arrivals)**
- The "Machinery" in the Shop
- The Ratio of Skilled Workers to Machines
  - **Machine-limited systems: capacity is determined by the number of machines.**
  - **Labor-limited systems: capacity is determined by the number of workers.**
- The Flow Pattern of Jobs through the Shop

Material Flows through a Job Shop

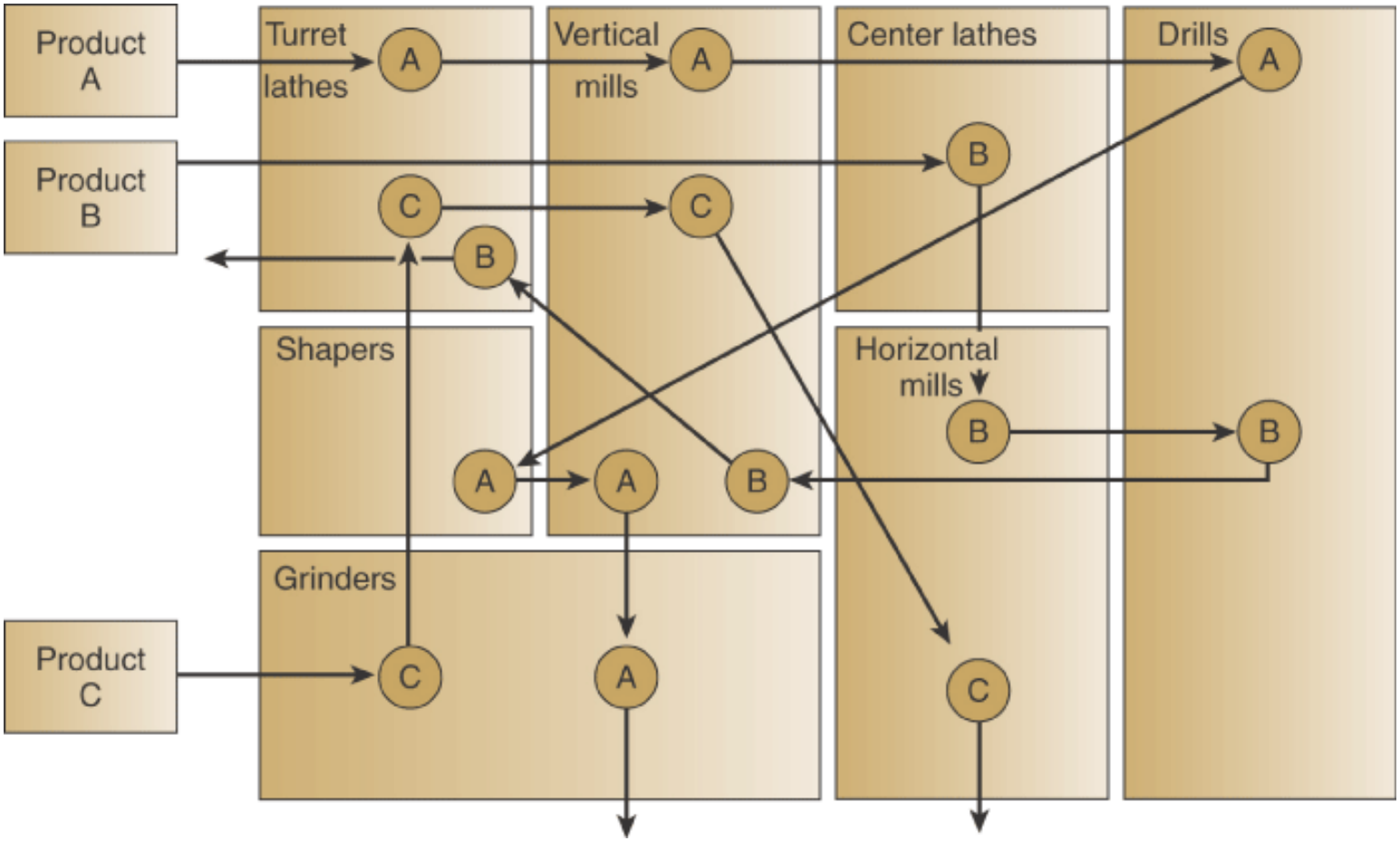


Exhibit 12.2

Allocating Jobs to Machines

- Priority Rules
  - FCFS—first-come, first-served
  - SPT—shortest processing (completion) time
  - Due date—earliest due date first
    - DDate—entire job
    - OPNDD—next operation
  - Start date—due date minus normal lead time
  - STR—slack time remaining
  - STR/OP—slack time remaining per operation
  - CR—due date-current date/work remaining
  - QR—slack time remaining/planned queue time
  - LCFS—last-come, first-served
  - Random order—whim operator's choice of job to run

Schedule Evaluation Criteria

- Standard measures of schedule performance used to evaluate priority rules:
  - **Meeting due dates of customers or downstream operations.**
  - **Minimizing flow time (throughput or cycle time) that the job spends in the shop.**
  - **Minimizing work in process.**
  - **Minimizing idle time of machines and workers.**

Scheduling *n* Jobs on One Machine

Job (in order of arrival	Processing Time (days)	Due Date (days hence)
A	3	5
B	4	6
C	2	7
D	6	9
E	1	2

Scheduling *n* Jobs on One Machine

FCFS Schedule

Job (in order of arrival	Processing Time (days)	Due Date (days hence)	Start		Job Time	Finish
A	3	5	0	+	3	3
B	4	6	3	+	4	7
C	2	7	7	+	2	9
D	6	9	9	+	6	15
E	1	2	15	+	1	16

Total flow time = 3+7+9+15+16 = 50 days

Mean flow time = 50/5 = 10 days

Scheduling *n* Jobs on One Machine

SPT Schedule

Job	Processing Time (days)	Due Date (days)	Flow Time (days)
E	1	2	0 + 1 = 1
C	2	7	1 + 2 = 3
A	3	5	3 + 3 = 6
B	4	6	6 + 4 = 10
D	6	9	10 + 6 = 16

Total flow time = 1+3+6+10+16 = 36 days
Mean flow time = 36/5 = 7.2 days

Scheduling *n* Jobs on One Machine

DDATE Schedule

Job	Processing Time (days)	Due Date (days)	Flow Time (days)
E	1	2	0 + 1 = 1
A	3	5	1 + 3 = 4
B	4	6	4 + 4 = 8
C	2	7	8 + 2 = 10
D	6	9	10 + 6 = 16

Total flow time = 1+4+8+10+16 = 39 days
Mean flow time = 39/5 = 7.8 days

Scheduling *n* Jobs on One Machine

LCFS Schedule

Job	Processing Time (days)	Due Date (days)	Flow Time (days)
E	1	2	0 + 1 = 1
D	6	9	1 + 6 = 7
C	2	7	7 + 2 = 9
B	4	6	9 + 4 = 13
A	3	5	13 + 3 = 16

Total flow time = 1+7+9+13+16 = 46 days
Mean flow time = 46/5 = 9.2 days
Average days late/job = 4.0 days

Scheduling *n* Jobs on One Machine

Random Schedule

Job	Processing Time (days)	Due Date (days)	Flow Time (days)
D	6	9	0 + 6 = 6
C	2	7	6 + 2 = 8
A	3	5	8 + 3 = 11
E	1	2	11 + 1 = 12
B	4	6	12 + 4 = 16

Total Flow time = 6+8+11+12+16 = 53 days
Mean flow time = 53/5 = 10.6 days
Average days late/job = 5.4 days

Scheduling *n* Jobs on One Machine

STR Schedule

Job	Processing Time (days)	Due Date (days)	Flow Time (days)
E	1	2	0 + 1 = 1
A	3	5	1 + 3 = 4
B	4	6	4 + 4 = 8
D	6	9	8 + 6 = 14
C	2	7	14 + 2 = 16

Total Flow time = 1+4+8+14+16 = 43 days
Mean flow time = 43/5 = 8.6 days
Average days late/job = 3.2 days

Scheduling *n* Jobs on One Machine

Scheduling Rule	Completion Time (days)	Completion Time (days)	Average Lateness (days)
FCFS	50	10.0	4.6
SPT	36	7.2	2.4
DDate	39	7.8	2.4
LCFS	46	9.2	4.0
Random	53	10.6	5.4
STR	43	8.6	3.2

Scheduling *n* Jobs on Two Machines

- Johnson's Rule (Method)
  1. **List the operation time for each job on both machines.**
  2. **Select the job with the shortest operation time.**
  3. **If the shortest time is for the first machine, do that job first; if the shortest time is for the second machine, do the job last.**
  4. **Repeat steps 2 and 3 for each remaining job until the schedule is complete.**

Optimal Schedule of Jobs Using Johnson's Rule

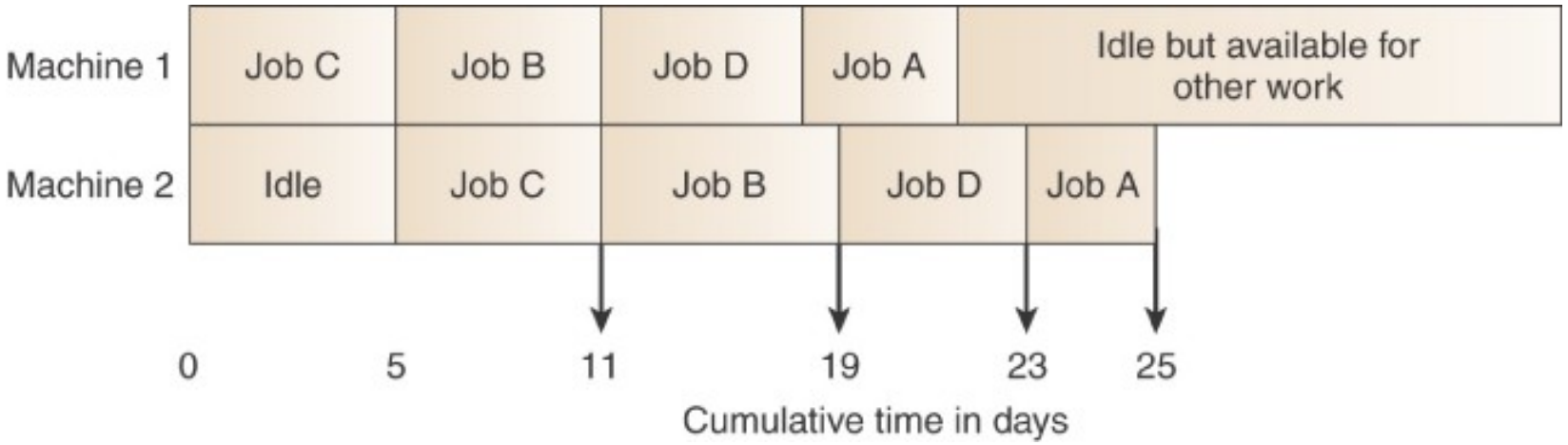


Exhibit 12.3

Scheduling *n* Jobs on *m* Machines—Complex Job Shops

- Use a simple priority scheme that embodies the following principles:
  1. **It should be dynamic, that is, computed frequently during the course of a job to reflect changing conditions.**
  2. **It should be based in one way or another on slack time (the difference between the work remaining to be done and the time remaining to do it in).**

OPT Scheduling Concepts

- OPT (optimized production technology)
  - **A proprietary software package for scheduling production.**
  - **TOC—theory of constraints**
  - **OPT/TOC**
    - **Integrated production planning and control (PPC) method to optimize scheduling by maximizing the utilization of bottlenecks in the process.**
  - **Pull systems: “kanban”**
  - **Push systems: MRP (material requirements planning)**

OPT Scheduling Concepts

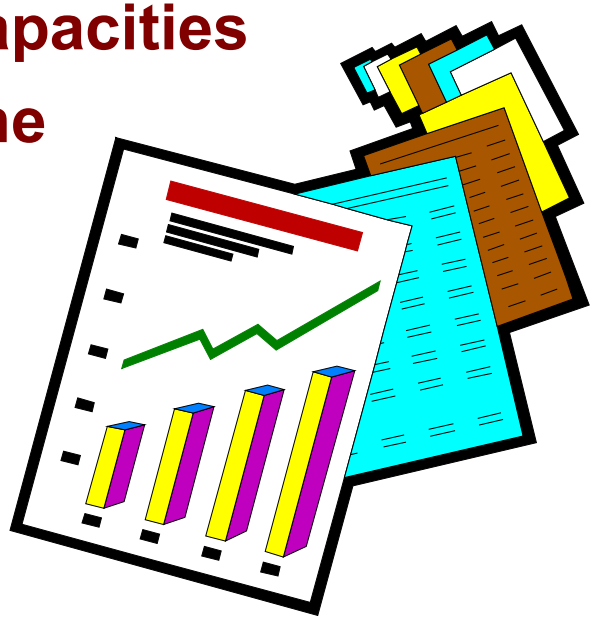
- Bottleneck systems
  - **CCR: a capacity constrained resource that is exhausted before the final product is delivered.**
  - **Bottleneck scheduling steps:**
    - **Determine the bottlenecks and CCRs.**
    - **Optimize the CCRs.**
    - **Schedule the bottleneck to its maximum.**
    - **Schedule the process located before the bottleneck.**
    - **Schedule the process located after the bottleneck.**

Control in the Job Shop

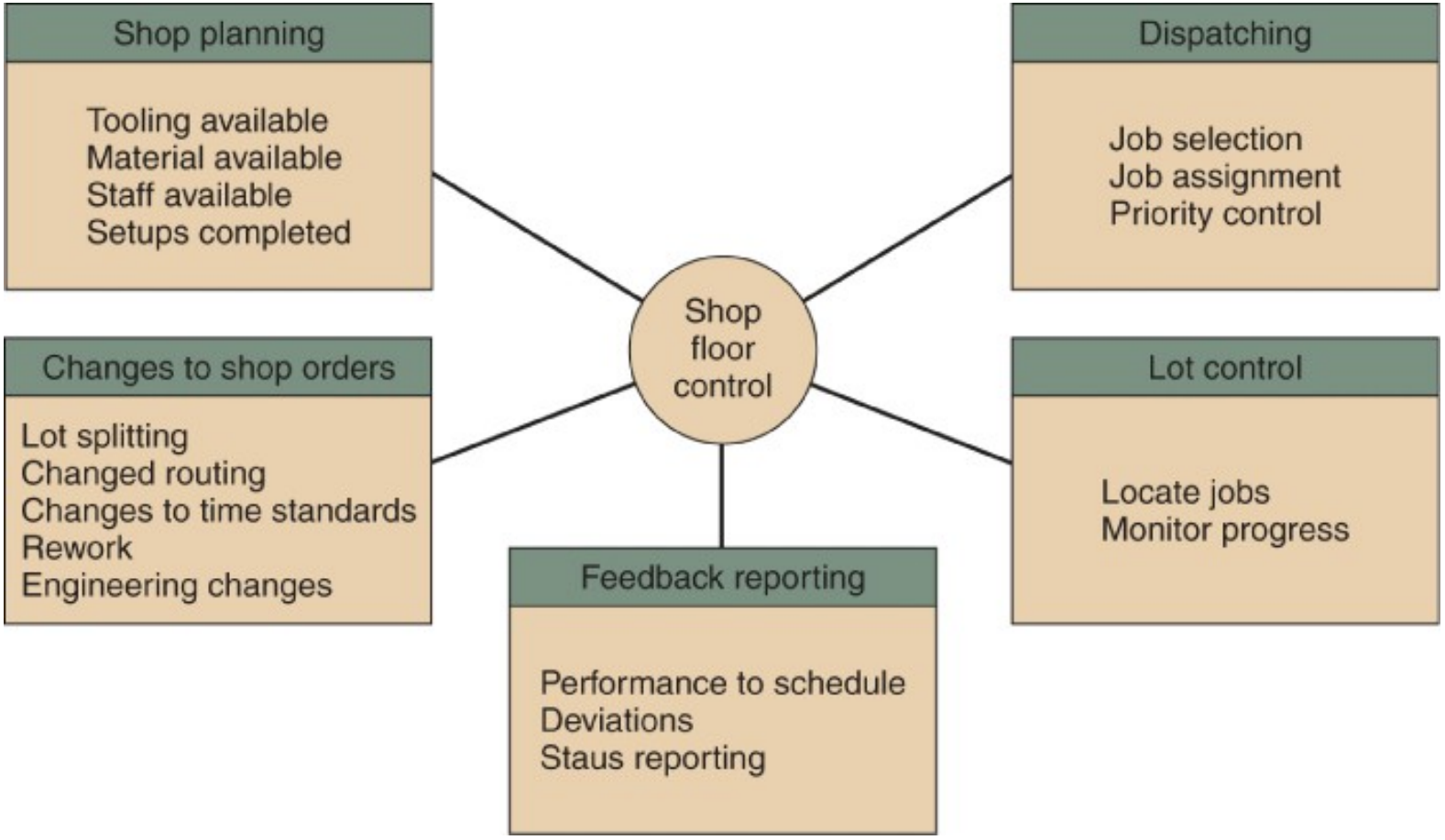
- Shop-Floor Control Functions
  - **Assigning priority to each shop order.**
  - **Maintaining work-in-process (WIP) quantity information.**
  - **Conveying shop-order status information to the office.**
  - **Providing output data for capacity control.**
  - **Providing quantity by location by shop order for WIP inventory and accounting purposes.**
  - **Providing measure of efficiency, utilization, and productivity of labor and machines.**

Control in the Job Shop (cont'd)

- Tools of Shop-Floor Control
  - **Dispatch list: job priorities**
  - **Exception report: special cases and problems**
  - **Input/output (I/O) control report: current workloads and workstation capacities**
  - **Status reports: summary of the performance of the operation**



Shop-Floor Control



Source: "Shop Floor Control—Closing the Loop," *Inventory Management Newsletter* (Stone Mountain, GA: Center for Inventory Management), August 1982.

Exhibit 12.4

Some Basic Tools of Shop-Floor Control

A. Dispatch List

Work center 1501—Day 205

Start date	Job #	Description	Run time
201	15131	Shaft	11.4
203	15143	Stud	20.6
205	15145	Spindle	4.3
205	15712	Spindle	8.6
207	15340	Metering rod	6.5
208	15312	Shaft	4.6

Note: All figures are in standard hours

Exhibit 12.5a

Some Basic Tools of Shop-Floor Control

B. Anticipated Delay Report

Dept. 24 April 8

Part #	Sched. date	New date	Cause of delay	Action
17125	4/10	4/15	Fixture broke	Toolroom will return on 4/15
13044	4/11	5/1	Out for plating—plater on strike	New lot started
17653	4/11	4/14	New part-holes don't align	Engineering laying out new jig

Note: All figures are in standard hours

Exhibit 12.5b

Some Basic Tools of Shop-Floor Control

C. Input/Output Control Report (B)

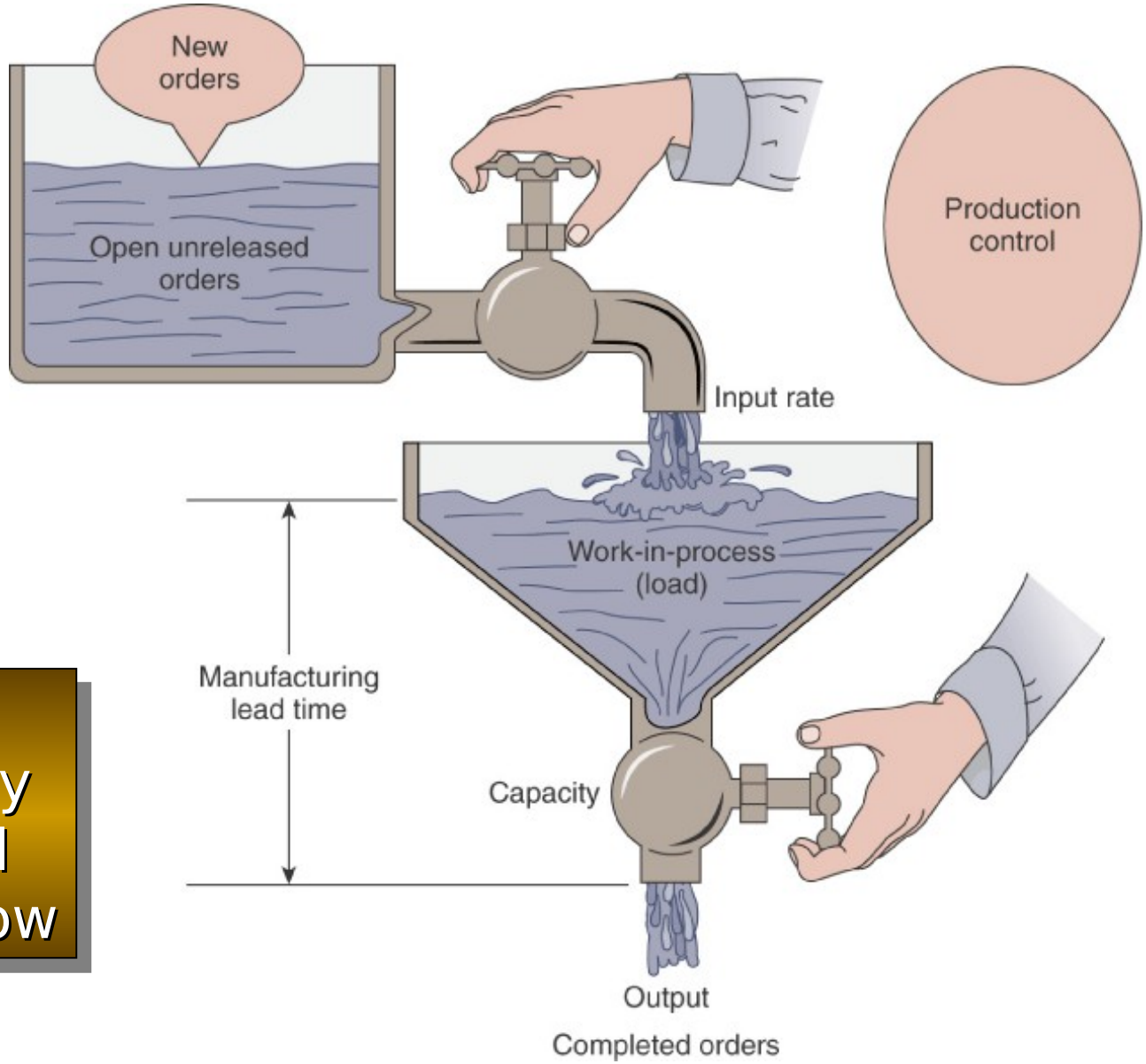
Work center 0162

Week ending	5/05	5/12	5/19	5/26
Planned input	210	210	210	210
Actual input	110	150	140	130
Cumulative deviation	−100	−160	−230	−310
Planned output	210	210	210	210
Actual output	140	120	160	120
Cumulative deviation	−70	−160	−210	−300

Note: All figures are in standard hours

Exhibit 12.5c

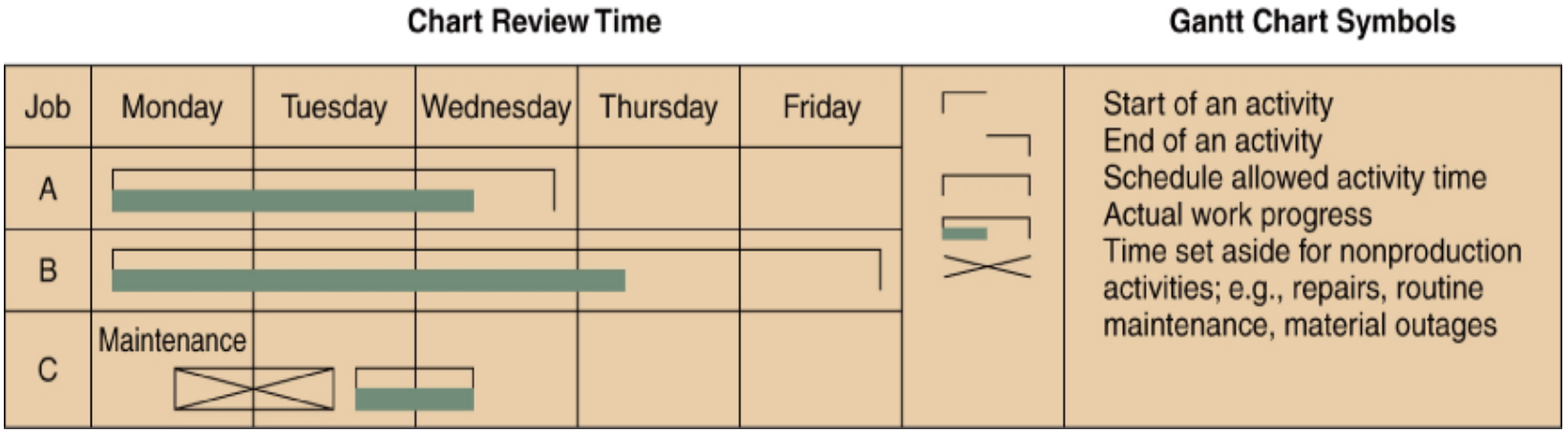
Shop Capacity Control Load Flow



Source: American Production and Inventory Control Society: "Training Aid—Shop Floor Control," undated.

Exhibit 12.6

Gantt Chart



Source: Professor Bob Parsons, Management Science Department, Northeastern University, Boston, MA. Used with permission.

Exhibit 12.7

Scheduling Workers in Service Operations

- Why Scheduling is Important in Services
  - **Determining the proper number of workers is critical to providing services to satisfy customer demand.**
  - **Having only the necessary number of workers is critical to keeping labor costs down.**

Scheduling Workers in Service Operations

- A Framework for Scheduling Service Workers
  - **Forecast customer demand.**
  - **Convert customer demand into worker requirements.**
  - **Convert worker requirements into daily work schedules.**
  - **Convert daily work schedules into weekly work schedules.**

The Required Steps in a Worker Schedule

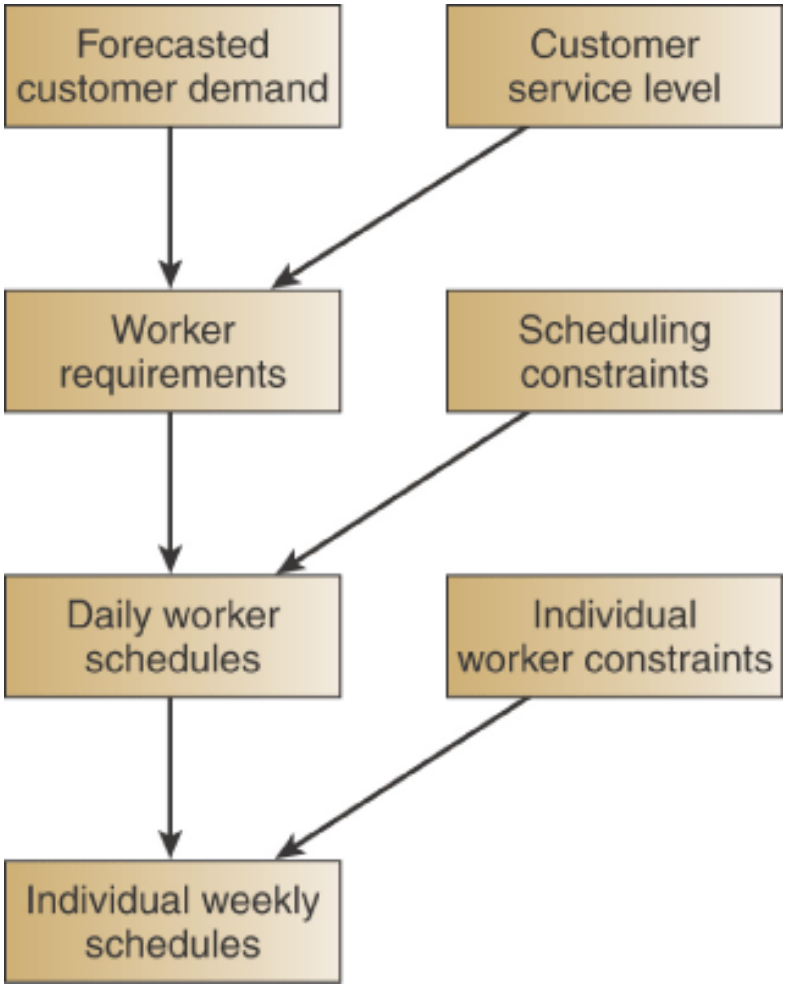


Exhibit 12.8

An Example of a Labor Requirements Table for a Fast Food Operation

Sales ($)/Hour Volume Guidelines	Total No. of Workers	Specific Worker Assignments						
		Grill	Windows	Drive-Thru	Bin	Fry	Floaters*	
$120	4	1	1	1	—	—	1	(Minimum staffing
150	5	1	1	1	—	—	2	level)
180	6	2	1	1	—	—	2	
210	7	2	2	1	—	—	2	
240	8	2	2	2	1	—	1	
275	9	2	2	2	1	—	2	
310	10	3	3	2	1	—	1	
345	11	3	3	2	1	1	1	
385	12	3	3	3	1	1	1	
425	13	4	3	3	1	1	1	
475	14	4	3	3	1	1	2	
525	15	4	4	3	1	1	2	
585	16	5	4	3	1	1	2	
645	17	5	5	3	1	1	2	(ull staf fing level)

***Floaters help out; they patrol the lot, lobby, and restrooms; restock; and cover on breaks.**

Source: Adapted from "McDonald's," Harvard Business School Case No. 681–044, 1980.

Exhibit 12.9

Scheduling Workers in Service Operations (cont'd)

- The Use of Technology in Scheduling
  - **Advantages**
    - **Reduces time managers must devote to scheduling workers.**
    - **Software algorithms reduce labor hours**
- Examples of Scheduling in Services
  - **Setting staffing levels in banks**
  - **Nurse staffing and scheduling**
  - **Scheduling consecutive days off**

Daily Staff Hours Required

Daily Staff Hours Required

Product	Daily Volume	Receive P/H	Receive H(std)	Preprocess P/H	Preprocess H(std)	Microfilm P/H	Microfilm H(std)	Verify P/H	Verify H(std)	Totals H(std)
Checks	2,000	1,000	2.0	600	3.3	240	8.3	640	3.1	16.8
Statements	1,000			600	1.7	250	4.0	150	6.7	12.3
Notes	200	30	6.7	15	13.3					20.0
Investments	400	100	4.0	50	8.0	200	2.0	150	2.7	16.7
Collections	500	300	1.7			300	1.7	60	8.3	11.7
Total Hours			14.3		26.3		16.0		20.8	77.5
Times 1.25 (absences & vacations)			17.9		32.9		20.0		26.0	96.8
Staff Required (divided by 8 hours per day)			2.2		4.1		2.5		3.2	12.1

$C11/D11

SUM(E7:E11)

G13*1.25

=E11+G11+I11+K11

K15/8

NOTE: P/H indicates production rate per hour; H(std) indicates the number of hours required.

Exhibit 12.10

Staffing Plan

Function	Staff Required	Staff Available	Variance (±)	Management Actions
Receive	2.3	2.0	−0.3	Use overtime
Preprocess	4.1	4.0	−0.1	Use overtime
Microfilm	2.5	3.0	+0.5	Use excess to verify
Verify	3.3	3.0	−0.3	Get 0.3 from microfilm

Exhibit 12.11

General Problems in Nurse Scheduling

Problem	Possible Solution
Accuracy of patient load forecast	Forecast frequently and rebudget monthly. Closely monitor seasonal demands, communicable diseases, and current occupancy
Forecasting nurse availability	Develop work standards for nurses for each level of possible demand (requires systematic data collection and analysis)
Complexity and time to rebudget	Use available computer programs
Flexibility in scheduling	Use variable staffing: Set regular staff levels slightly above minimum and absorb variation with broadskilled float nurses, part-time nurses, and overtime

Exhibit 12.12