# CPIM

CERTIFIED IN PLANNING
AND INVENTORY MANAGEMENT

## MODULE 5:
## DETAILED SCHEDULES

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# Module 5 Overview

## Detailed Schedules

- Section A: Planning Detailed Schedules
- Section B: Scheduling and PAC Methods
- Section C: Creating Production and Service Schedules
- Section D: Managing Detailed Schedules and Scheduling Materials

# CPIM

CERTIFIED IN PLANNING
AND INVENTORY MANAGEMENT

## SECTION A:
## PLANNING DETAILED SCHEDULES

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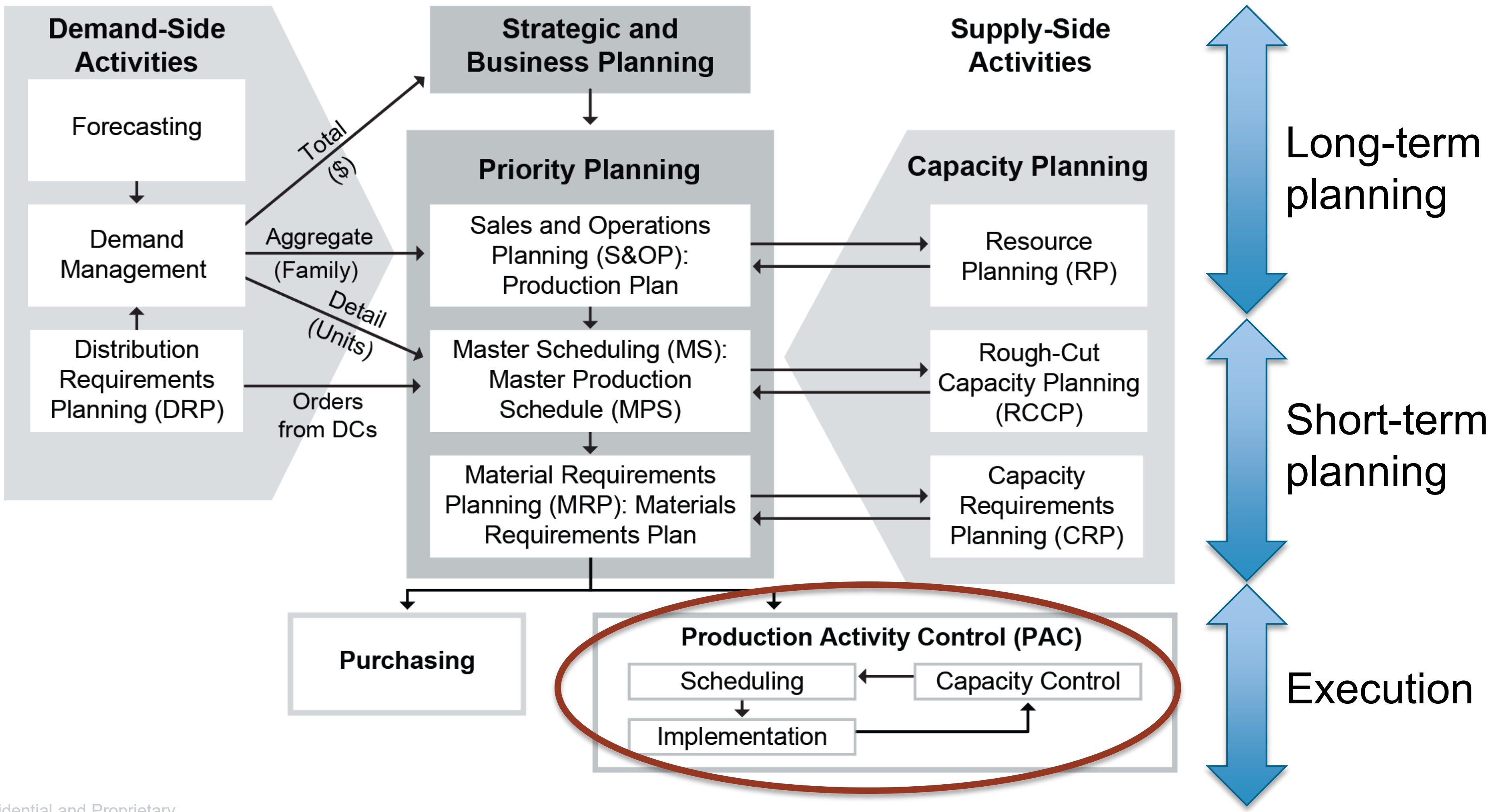
# Section A Overview

## Section A Learning Objectives

- Components of lead time
- Evaluating throughput
- Production activity control (PAC) objectives, roles, and responsibilities
- PAC inputs
- Dispatching rules
- Forward, backward, and central scheduling with finite and infinite loading
- Techniques to improve efficiency and control

## Execution in Manufacturing Planning and Control



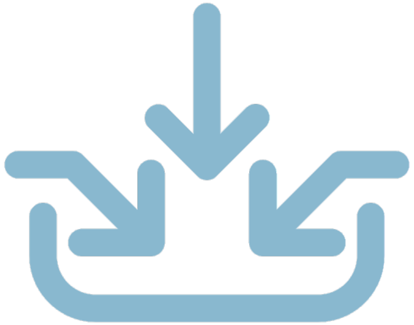

 

# Detailed Scheduling Objectives

| Objectives | Objectives provide guidance on addressing tradeoffs between: |
| --- | --- |
| ▪ Make best use of manufacturing resources to meet delivery dates.<br>▪ Ensure that resources are available when needed.<br>▪ Schedule feasible start and completion dates for each shop order at each work center.<br>▪ Utilize capacity effectively.<br>▪ Minimize lead times.<br>▪ Meet customer service goals. | ▪ Labor and equipment<br>▪ Lead time<br>▪ Inventory levels<br>▪ Processing times. |

## Detailed Scheduling Inputs and Elements

- What to make
- When to make
- Where to make
- How to make
- How much to make
- Time needed to make
- Material availability
- Due date
- Machine maintenance schedules/failure rates
- Expected rework and scrap percentages
- Other demands on facility



**Schedule**

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## Detailed Scheduling Components

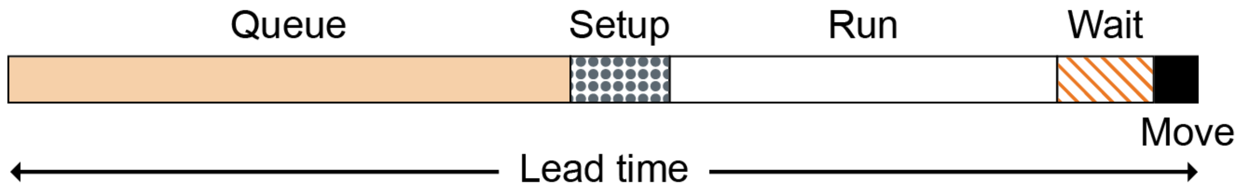
- Operations necessary to complete an item
- Sequence and routing of operations
- Start and finish dates of each operation
- Time estimates for each operation
- Work centers where operations are performed

# Lead Time for One Operation or Work Center

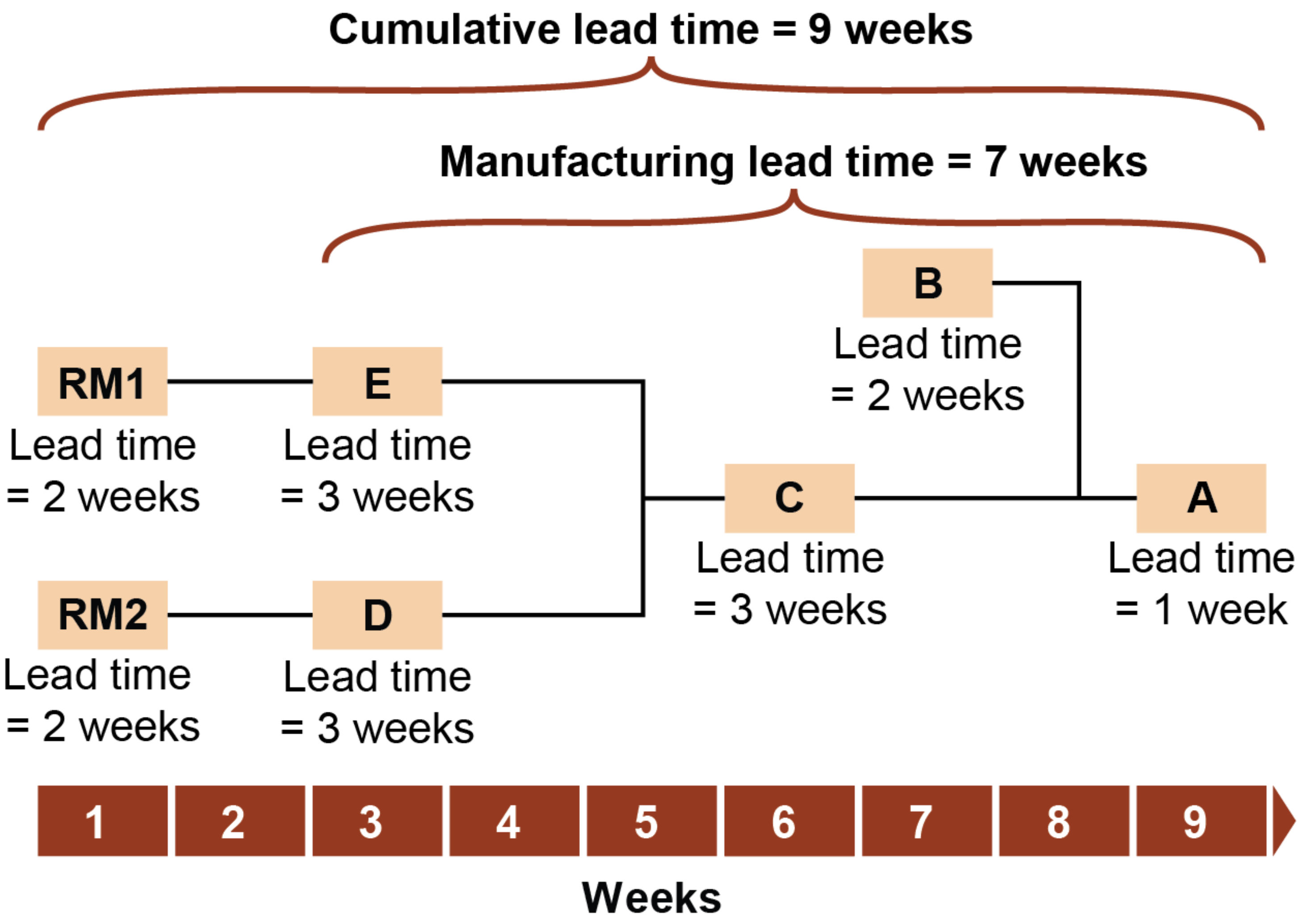
Lead time is the sum of

- Operation time (load)
  - Setup: from last good item A to first good item B
  - Run time: time doing operation (not including setup)
- Interoperation time (not load)
  - Queue: waiting to begin; often largest component
  - Wait: waiting after operation ends
  - Move: physical move time between operations



## Product Structure



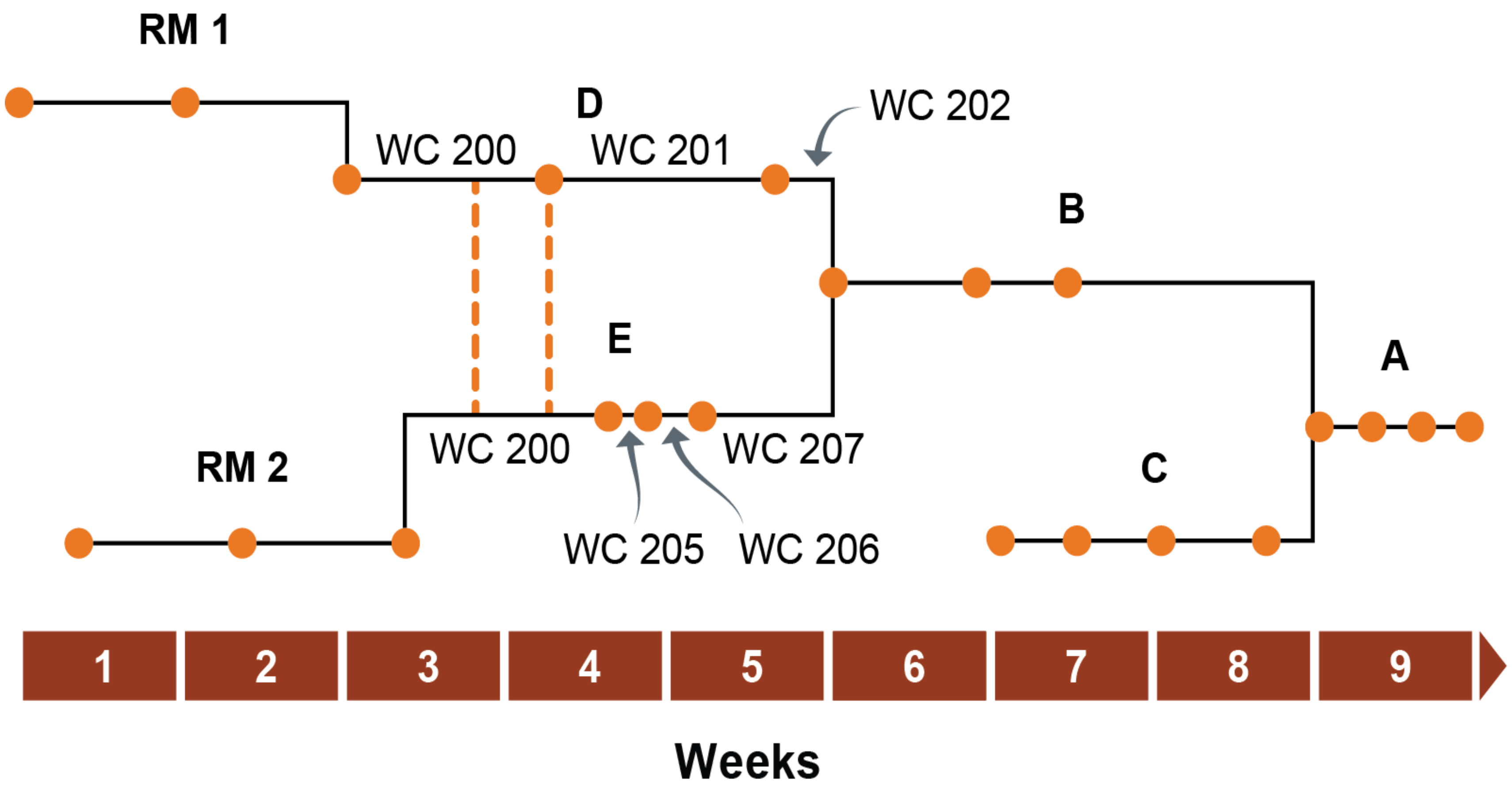
# Detailed Scheduling and Throughput

## Routing and Lead Time Data

| Part D Routing | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Operation** | **Work Center** | **Queue Time** | **Setup Time** | **Run Time** | **Move Time*** | **Total Time** | **Rounded Time** |
| 1 | 200 | 2.6 | 0.4 | 2.4 | 0.4 | 5.8 | 6.0 |
| 2 | 201 | 4.0 | 0.8 | 2.1 | 0.4 | 7.3 | 7.0 |
| 3 | 202 | 0.7 | 0.2 | 0.5 | 0.3 | 1.7 | 2.0 |
| Total lead time (days) = 15.0 (*includes wait time) | | | | | | | |

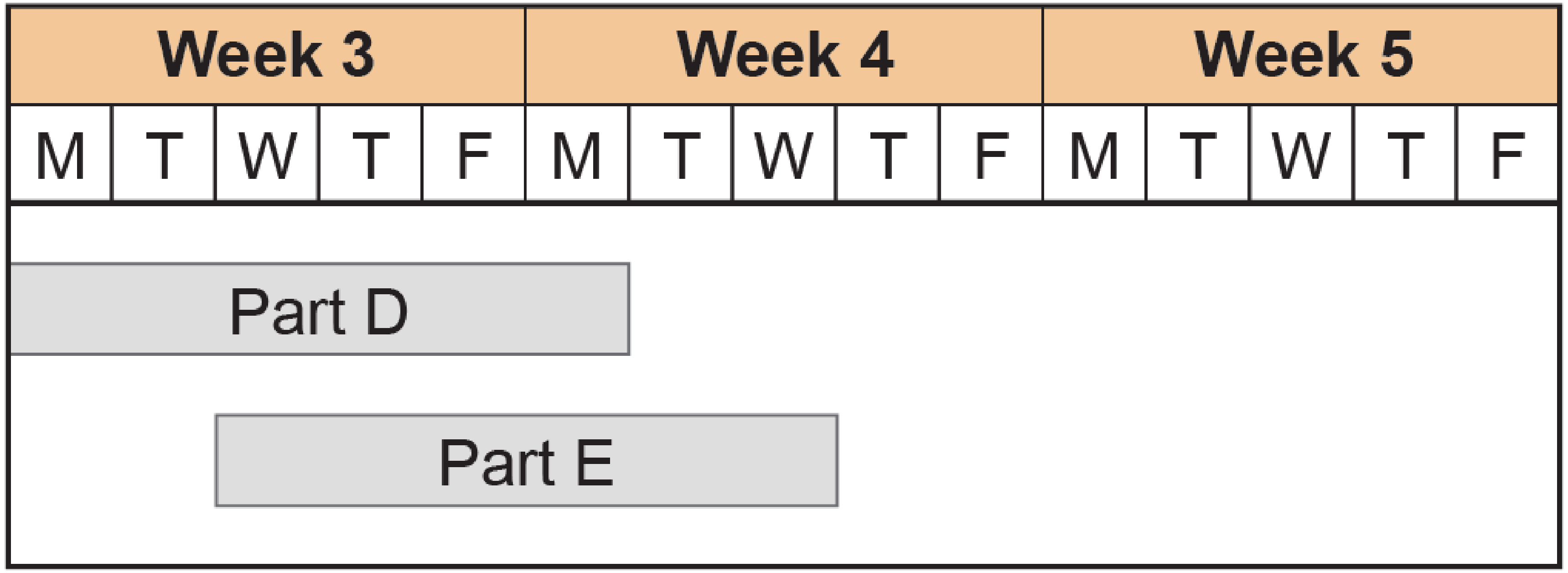
| Part E Routing | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Operation** | **Work Center** | **Queue Time** | **Setup Time** | **Run Time** | **Move Time*** | **Total Time** | **Rounded Time** |
| 1 | 200 | 2.6 | 0.6 | 2.5 | 0.3 | 6.0 | 6.0 |
| 2 | 205 | 0.5 | 0.1 | 0.2 | 0.3 | 1.1 | 1.0 |
| 3 | 206 | 1.5 | 0.2 | 0.3 | 0.1 | 2.1 | 2.0 |
| 4 | 207 | 1.5 | 0.6 | 1.0 | 0.8 | 3.9 | 4.0 |
| Total lead time (days) = 13.0 (*includes wait time) | | | | | | | |

## Operation Setback Chart



## Gantt Charts

Parts D and E with MRP lead times



# Evaluating Throughput

## Throughput metrics

- Efficiency
- Utilization
- Productivity
- Input/output control metrics
- Cycle time or throughput time
- Cycle time versus takt time
- Visual management systems related to throughput

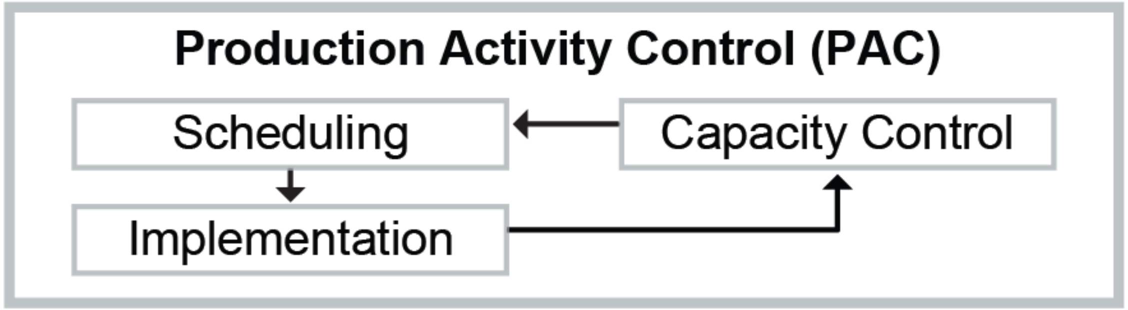
## Service industry throughput

- Value-added
  - Service provision ("run" time)
  - Set time range
- Non-value-added
  - Minimize queue, setup, wait, and move

# Production Activity Control (PAC) Road Map

If done correctly, PAC will

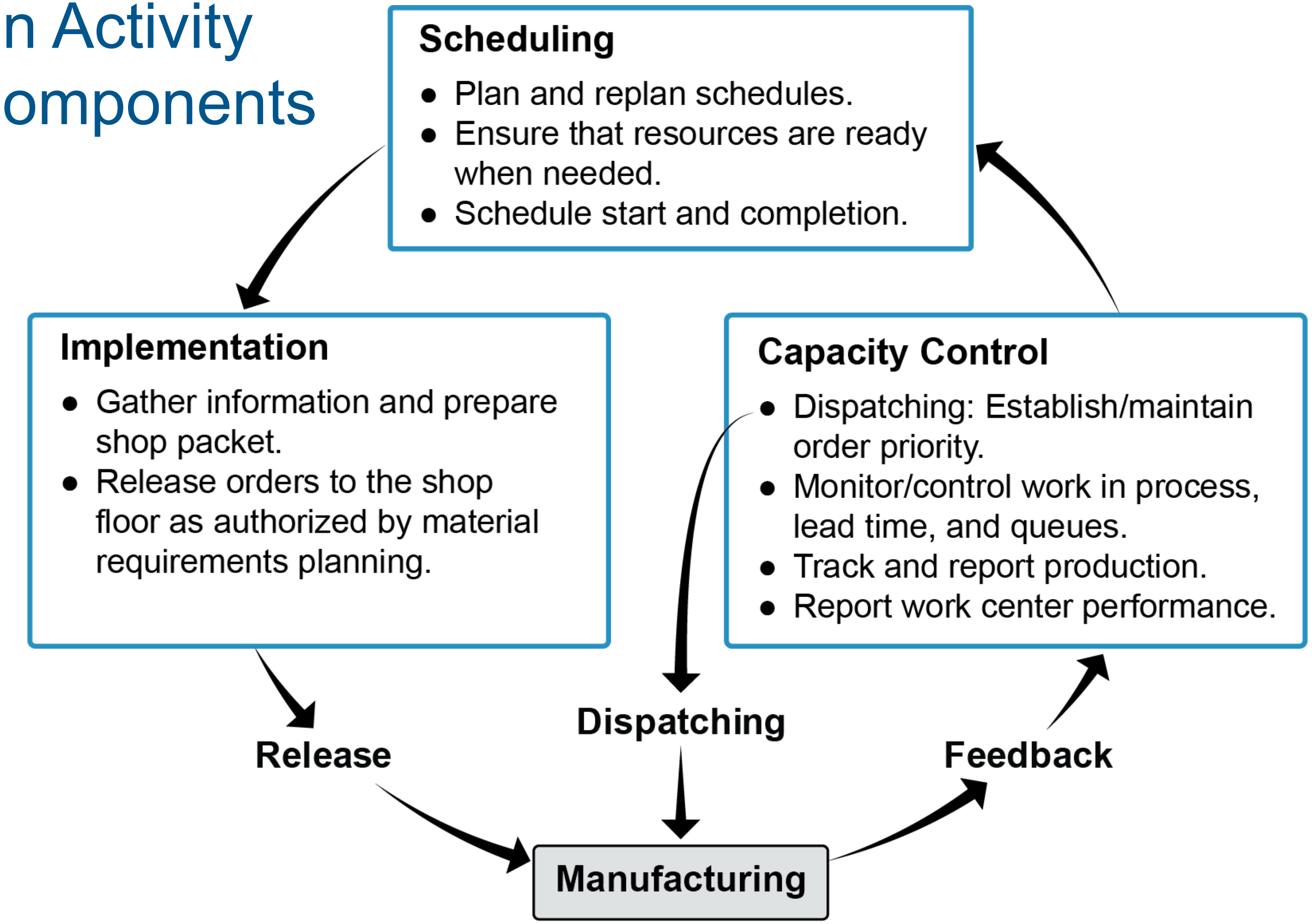
- Execute orders authorized in MPS and MRP
- Plan and release individual orders to factory and vendors
- Optimize use of resources
- Provide availability information to production coordinators
- Provide early warning signals and status information to other MPC modules
- Meet customer service targets
- Provide information on WIP inventories
- Shorten both queue and move
- Provide feedback on shop and suppliers' performance against plans.



# Production Activity Control

## Production Activity Control Components



# Inputs to Production Activity Control

| Input | Description | Information Provided |
| --- | --- | --- |
| MRP | Authorized production | Shop order quantities, due dates |
| Item master files | Database of part numbers | Part number and description; quantity on hand, available, on order; manufacturing lead times and lot sizes |
| BOMs | Options and parts per order | Shop floor pick lists for shop order packet |
| Routing files | Operations sequence | Work center sequence, manufacturing lead times, capacity required, tools required |
| Work center files | Work center information | Work center number, shifts, machine and labor hours per shift, capacity, efficiency, utilization, queue time, manufacturing lead time, alternatives |
| Shop order files | Live document per shop order | Shop order number; quantities; due dates; issued, completed, scrapped, due; planned and actual setup/run; lead times remaining; cost |

# Production Activity Control

Some of PAC's major data elements are listed in the table. Identify the sources.

| Type of information | Name of system or file source | | | | | |
|---|---|---|---|---|---|---|
| | MRP | Item master | Product structure | Routing | Work center | Shop order and detail |
| Shop order number | | | | | | x |
| Quantity on hand | | x | | | | |
| Shop order quantity | x | | | | | x |
| Order due dates | x | | | | | x |
| Operations required | | | | x | | |
| Operations work centers | | | | x | | |
| Manufacturing lead time | | x | | x | x | |
| Operation times | | | | x | | |
| Work center capacity | | | | | x | |
| On-order quantity | | x | | | | |
| BOM | | | x | | | |
| Material issue tickets | | | | | | x |
| Efficiency/utilization | | | | | x | |
| Tools required | | | | x | | |
| Quantity available | | x | | | | |
| Quantity complete/scrapped | | | | | | x |
| Actual versus planned setup/run | | | | | | x |
| Lead time remaining | | | | | | x |

## Operations Sequencing and Dispatching

- Priority control: Communicating start and end dates to work centers.
- Operations sequencing: Actual jobs to run based on capacity and priority.
- Dispatching: Executing sequencing at work center level.
- While MPS sets due dates and MRP makes into component due dates, priority control still needed.

### Supply and demand in flux:

- Customer changes: due dates, quantities, expediting
- Early or late materials
- Scrap or rejects higher than standard
- Same due date for multiple orders or work center operations

# Sequencing Priority Rules

- Due date
- Order slack
- Slack per operation
- Critical ratio
- Shortest operation next

## Dispatching and Dispatch List

- **Select and sequence jobs using dispatch list daily.**
- **Identifies plant, department, and information below.**

**Dispatch List** Work Center: 13 Description: Spot Welding Station Date: 48
Standard Hours (Available Time): 16 hours per day (8hr shift with 2 Arc Welders)

| Order # | Part # | Order Qty. | Setup (hrs.) | Run (hrs.) | Total (hrs.) | Qty. Completed | Remaining Load (hrs.) | Operation Start | Finish Date |
|---|---|---|---|---|---|---|---|---|---|
| 988 | 604 | 35 | 0.15 | 12.3 | 12.4 | 28 | 2.45 | 47 | 48 |
| 234 | 569 | 25 | 0.25 | 8.0 | 8.3 | 12 | 4.16 | 47 | 48 |
| 808 | 199 | 80 | 0.15 | 20.0 | 20.2 | 0 | 20.15 | 48 | 49 |
| | | Total Available Load in Standard Hours | | | | | 26.76 | | |
| Jobs Coming | | | | | | | | | |
| 112 | 199 | 30 | 0.15 | 4.5 | 4.7 | 0 | 4.65 | 49 | 49 |
| 115 | 989 | 50 | 0.35 | 17.5 | 17.9 | 0 | 17.85 | 49 | 51 |
| | | Total Future Load in Standard Hours | | | | | 22.50 | | |

## Dispatching Rules

- First come, first served (FCFS)
- Earliest job due date (EDD)
- Earliest operation due date (ODD)
- Shortest process time (SPT)
- Critical ratio (CR)
  - If 0 or negative: expedite, late
  - If < 1: expedite, behind schedule
  - If > 1: ahead of schedule
- Slack time

Order C due day 56, today is day 48, 16 days lead time left

**Critical Ratio (CR)**

$$= \frac{\text{(Due Date − Present Date)}}{\text{Lead Time Remaining}}$$

$$= \frac{\text{Actual Time Remaining}}{\text{Lead Time Remaining}}$$

$$= \frac{\text{(Day 56 − Day 48)}}{\text{16 Days}} = \frac{\text{8 Days}}{\text{16 Days}}$$

**= 0.5 (behind schedule)**



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## Comparison of Dispatching Rules

Today's Date: 48 (Units in Days Except CR)

| Order | Work Center 13 Process Time | Work Center 13 Operation Due Date | Order Arrival Date | Order Due Date | Lead Time Left | CR |
|---|---|---|---|---|---|---|
| A | 2 | 46 | 41 | 47 | 6 | -0.2 |
| B | 4 | 50 | 40 | 66 | 18 | 1.0 |
| C | 3 | 51 | 44 | 56 | 16 | 0.5 |
| D | 1 | 49 | 48 | 58 | 7 | 1.4 |

| Rule | Sequence | Reason |
|---|---|---|
| FCFS | B, A, C, D | Order arrival dates: 40, 41, 44, 48 |
| EDD | A, C, D, B | Order due dates: 47, 56, 58, 66 |
| ODD | A, D, B, C | Operation due dates: 46, 49, 50, 51 |
| SPT | D, A, C, B | Process times: 1, 2, 3, 4 |
| CR | A, C, B, D | CR: -0.2, 0.5, 1.0, 1.4 |

# Slack Time and Critical Ratio Exercise

1. Review the data for work orders W, X, Y, and Z and then calculate slack times and critical ratios.

| Order | Due Date | Current Operation Time | Total Operation Time Remaining | Manufacturing Lead Time Remaining | Number of Operations Remaining | Slack Time | Critical Ratio |
|---|---|---|---|---|---|---|---|
| W | 105 | 1.5 | 3.0 | 5.5 | 4 | 2.0 | .91 |
| X | 107 | 1.0 | 4.5 | 9.0 | 6 | 2.5 | .78 |
| Y | 111 | 2.0 | 4.0 | 7.0 | 5 | 7.0 | 1.57 |
| Z | 113 | 3.5 | 7.0 | 8.5 | 3 | 6.0 | 1.53 |

Current date = day 100

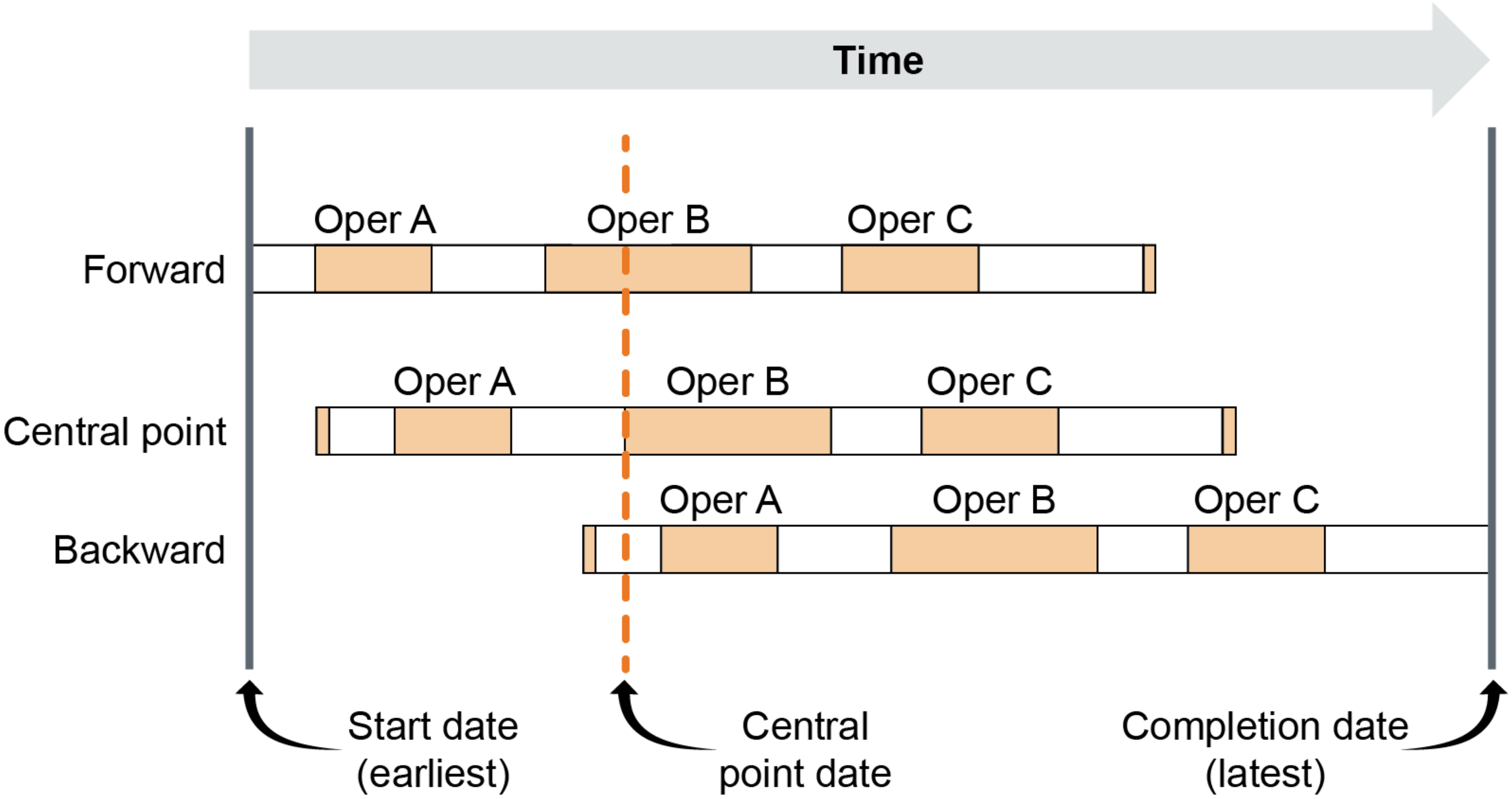
Lead time units = days

2. Calculate the sequence of orders based on slack times and critical ratios.

*Slack time:* *W-X-Z-Y*

*Critical ratios:* *X-W-Z-Y*

# Backward, Forward, and Central Point Scheduling



# Forward and Backward Scheduling

| Forward Scheduling | Backward Scheduling |
|---|---|
| Material procurement and operations scheduling start when order is received. | Uses MRP logic: works back from MRP due date to determine operation start dates. |
| Operations usually scheduled from first to last. | Last operation scheduled first; previous operations scheduled back from start of last. |
| More inventory build-up than backward scheduling. | Less inventory build-up than forward scheduling. |
| If I start now, when can I have it? | When must this be started in order to finish by [date]? |
| Used when resources are underloaded or capacity-related costs are high and load leveling is desired. | Used when low inventory is a top priority and production is synchronized with order due date. |



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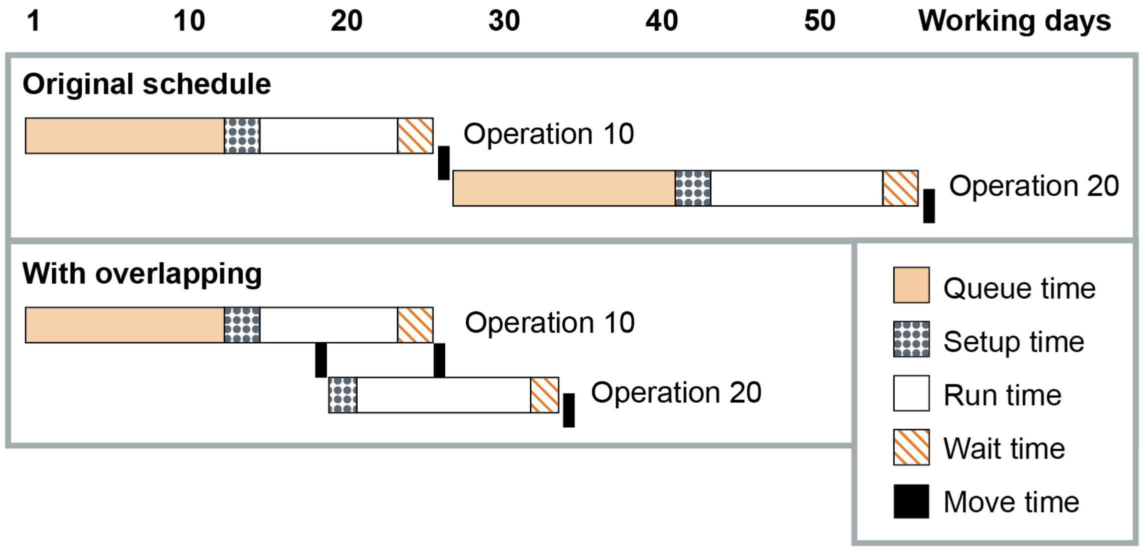
# Infinite and Finite Loading

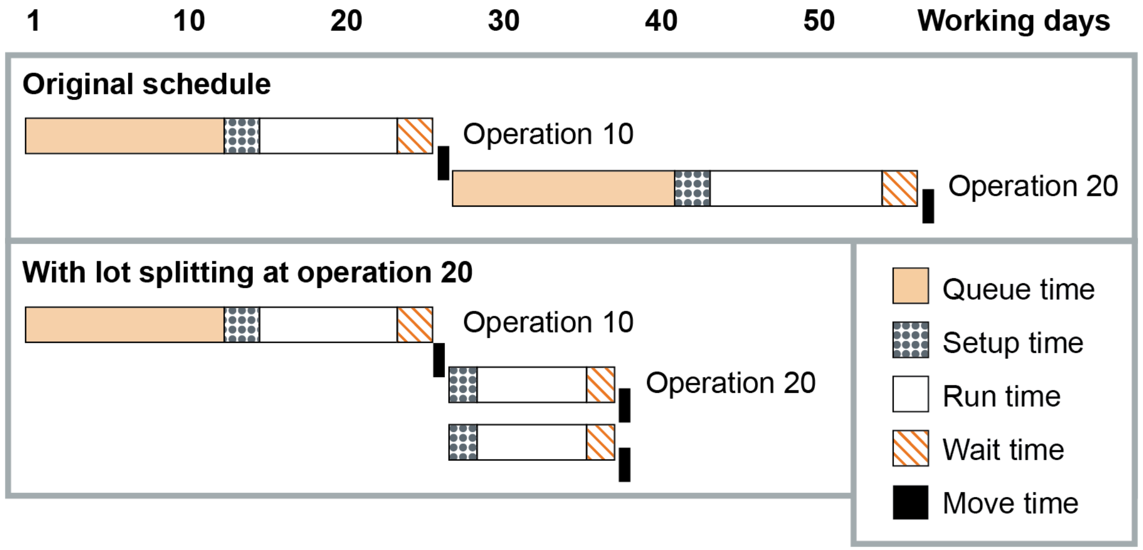
| Week | Order Received 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | Due Date 31 |
|---|---|---|---|---|---|---|---|---|---|
| **#** | **Backward Schedule with Infinite Loading** | | | | | | | | |
| 153 | | | | Materials Ordered | | | Op 1 | Op 2 | Op 3 |
| 923 | | | | Materials Ordered | | | Op 1 | Op 2 | Op 3 |
| | **Forward Schedule with Infinite Loading** | | | | | | | | |
| 153 | Materials Ordered | | | Op 1 | Op 2 | Op 3 | | | |
| 923 | Materials Ordered | | | Op 1 | Op 2 | Op 3 | | | |
| | **Backward Schedule with Finite Loading** | | | | | | | | |
| 153 | | | | Materials Ordered | | | Op 1 | Op 2 | Op 3 |
| 923 | | | Materials Ordered | | | Op 1 | Op 2 | Op 3 | |
| | **Forward Schedule with Finite Loading** | | | | | | | | |
| 153 | Materials Ordered | | | Op 1 | Op 2 | Op 3 | | | |
| 923 | Materials Ordered | | | | Op 1 | Op 2 | Op 3 | | |

# Managing Lead Time and Other Parameters

## Overlapping




## Lot splitting



## Managing Lead Time and Other Parameters

### Lot size reduction

- Lean goal can be used in MRP too
- Smallest lot that keeps good setup-to-run-time ratio
- One less at a time

### Automation and queue management

- ERP and APS
- Queue management reduces WIP

### Safety capacity (capacity cushion)

- Planned amount by which available capacity exceeds current productive capacity

Productive Capacity +
Safety Capacity +
Excess Capacity
100% of Capacity

# Shop Floor Systems: Best Suited*

| | MRP-Based (Push)* | Production-Rate Based (Pull)* |
|---|---|---|
| **Market-Facing Characteristics** | | |
| Product design | Custom | Standard |
| Product variety | Broad | Narrow |
| Individual product volume/period | Low | High |
| Ease of changing total volume | Easy/incremental | Difficult/stepped |
| Ease of changing product mix | Less difficult | More difficult |
| Delivery speed | Through schedule change | Through finished goods inventory |
| Ease of changing delivery schedules | More difficult | Less difficult |
| **Manufacturing-Related Characteristics** | | |
| Process choice | Low-volume batch | High-volume batch/line |
| Changeover cost | High | Low |
| Work-in-process | High | Low |
| Cost reduction—overheads | Fewer | More |

***There will be exceptions, but as a general rule these are considered to be “best suited” by Jacobs.**

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## SECTION B:
## SCHEDULING AND PAC METHODS

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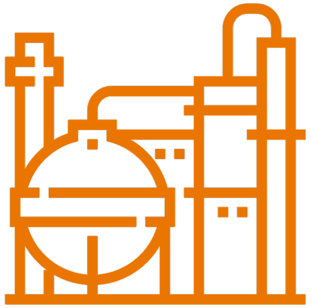
## Section B Learning Objectives

- Batch and flow processes, push or pull, and production rates/flow rates
- Calculating load
- MRP scheduling: push and flow MRP systems, input/output control, authorizing and releasing work orders
- Lean scheduling, including takt time, heijunka, pacemaker, store, production leveling, and one- and two-card kanban
- Product flow (VATI)
- Theory of constraints (TOC) scheduling: drum-buffer-rope scheduling and use in removing bottlenecks
- Process flow scheduling, process trains, and process- versus material-dominated scheduling

# Intermittent versus Flow Manufacturing

## Critical points and examples

- Intermittent critical points
  - Transfer batch
  - Lot sizing (consider scrap factor)
  - Reorder point
- Flow critical points
  - Bottlenecks
  - Resource constraints
  - Minimizing waste
  - Optimize coupling and connectivity



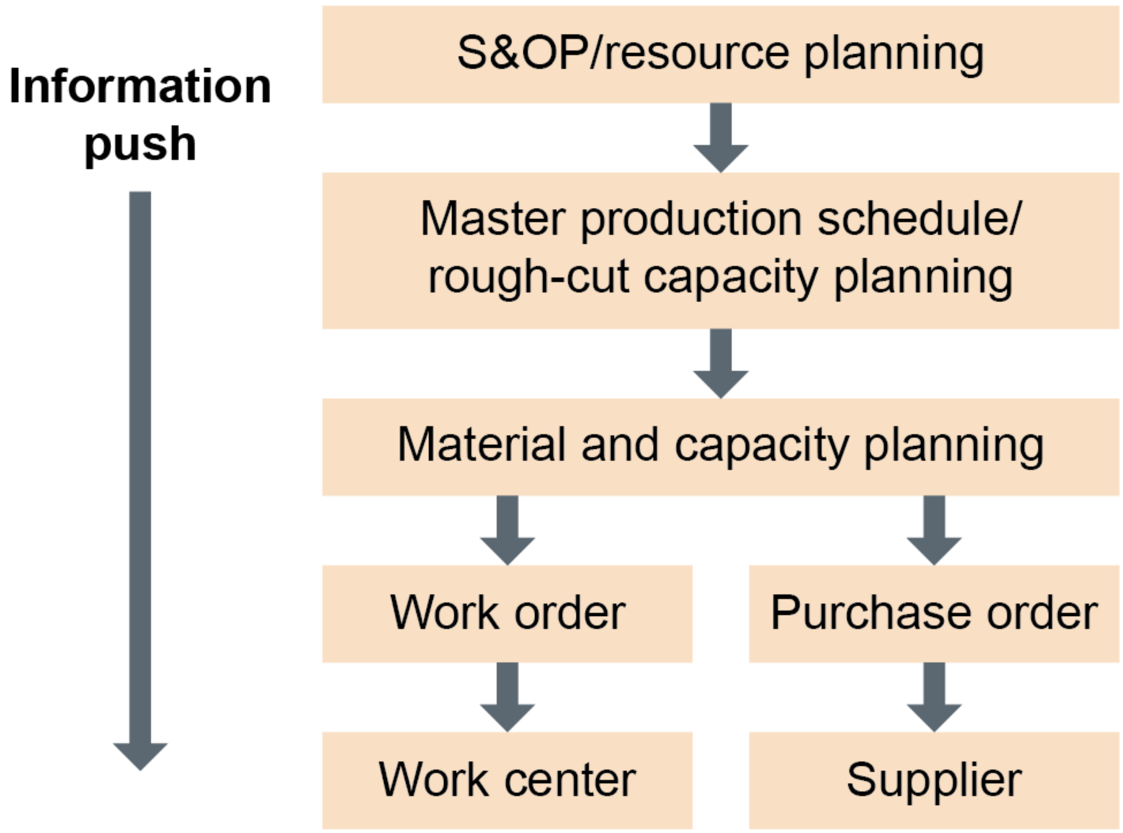
| Type | Intermittent | Flow |
|---|---|---|
| Batch | MTS shoes in batches | Pharmaceuticals made in constant flow but distinct batches |
| Line | Different car models in batches, no new setup for accessories | Pickle jarring never stops except for supply/demand issues |
| Continuous | Different chemicals in batches after cleanout | Glass factory line dedicated to one type of glass |

# Intermittent versus Flow Manufacturing

| Category | Intermittent Processes | | Flow Processes | | |
|---|---|---|---|---|---|
| **Process type** | Work center | Batch | Batch flow | Line | Continuous flow |
| **Layout** | Functional (process) | Functional (process) | Cellular/ product-based | Cellular/product-based | Product |
| **Routing** | Product-specific | Product-specific | Product-specific | Fixed | Fixed |
| **Scheduling** | Operations | Operations | Operations or rate-based | Production: rate-based | Production: rate-based |
| **Control** | MRP/PAC | MRP/PAC | MRP/PAC | MRP/PAC | MRP/process flow scheduling |
| **Transaction requirements** | Very high | Very high | Medium | Low | Low |
| **Productivity tools** | TOC/six sigma | TOC/six sigma | Lean/TOC/ six sigma | Lean/TOC/ six sigma | Lean/TOC/ six sigma |

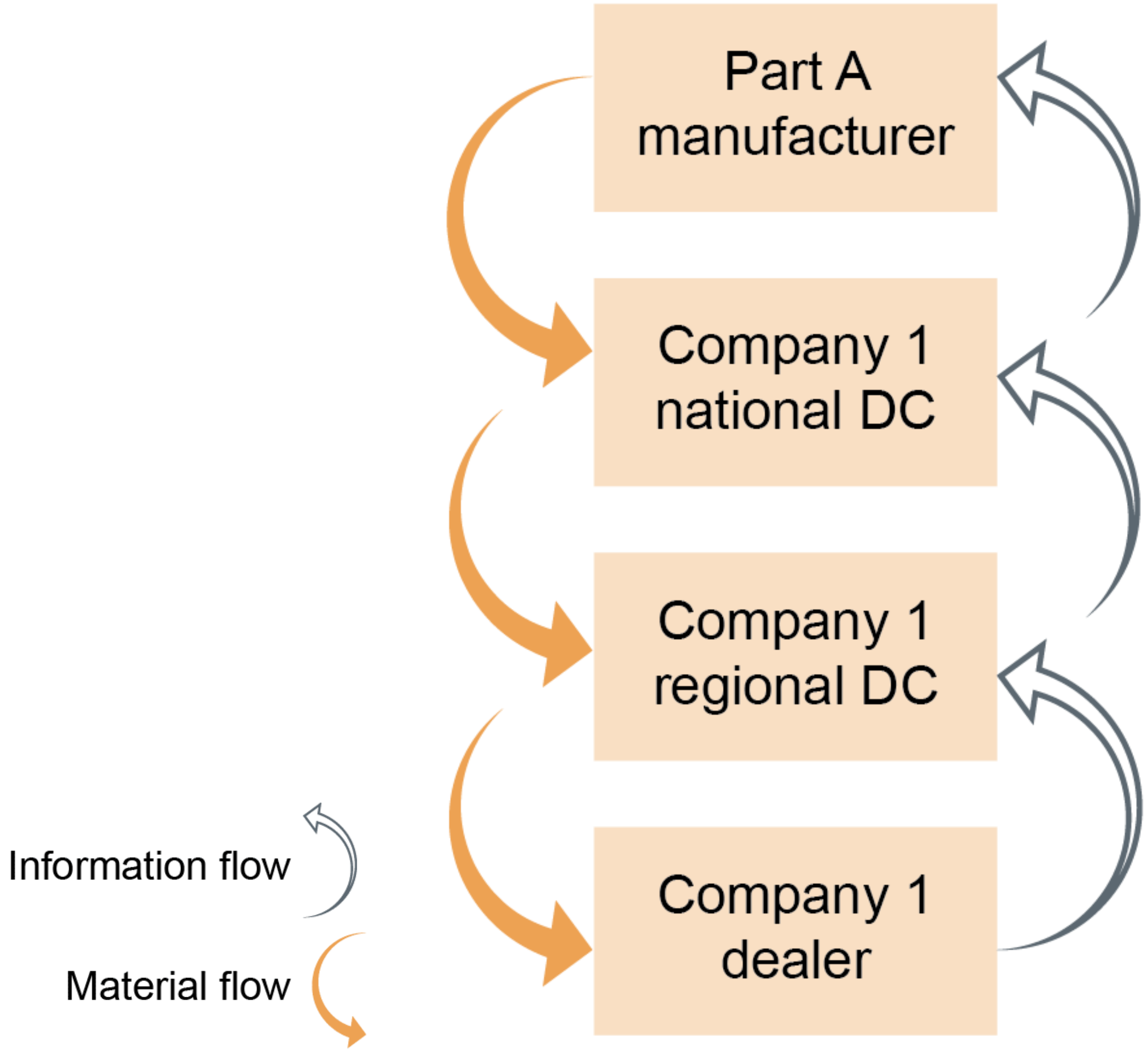
## Push System (MRP-Based Execution System)




- Sequence of work
- Setup time and changeovers
- Resource constraints
- Alternate routing
- Scheduling method
- Load leveling
- Input/output control

## Pull System Execution

- Mixed-model scheduling
- Synchronization
- Constrained resources
- Rate-based scheduling
- Line balancing



# MRP-Based, Lean, and TOC-Based Scheduling

| | MRP-Based | Lean | TOC-Based |
|---|---|---|---|
| **Primary focus** | Minimizing backlog, lead time | Raw material/finished goods velocity, very low WIP, short lead times, de-emphasize utilization | Maximizing throughput |
| **Scheduling method** | Forward, backward, or central point | Kanban signals based on demand | Finite forward schedules for bottleneck centers; backward schedules for rest |
| **Scheduling complexity** | Very detailed | Very simple: cellular, fast completion times | Exact for gateway and bottleneck; pull for rest |
| **Input priorities** | Material + capacity, level loading | Vendor scheduling multiple times a day | Material/capacity simultaneous |

# MRP-Based, Lean, and TOC-Based Scheduling

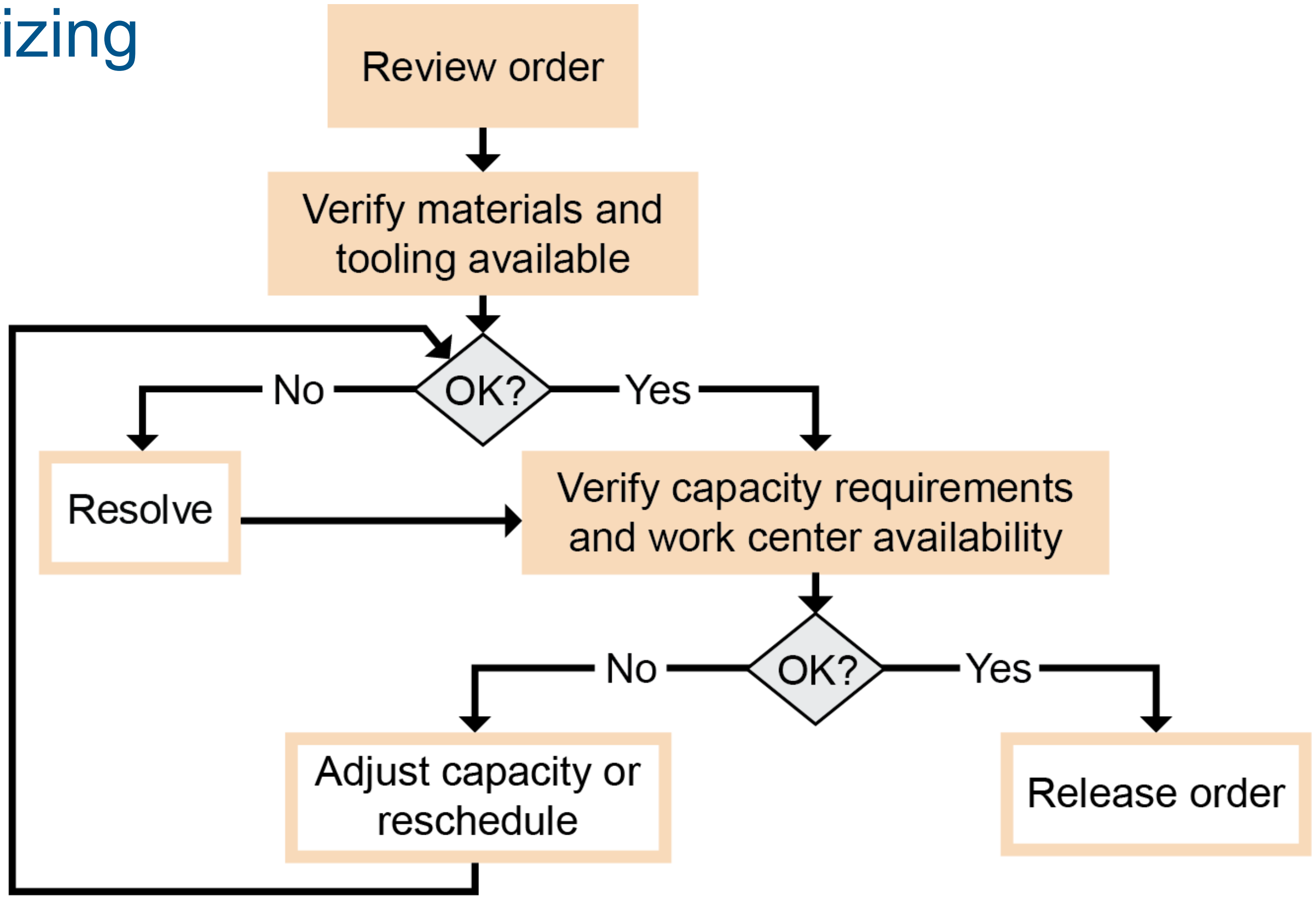
| | MRP-Based | Lean | TOC-Based |
|---|---|---|---|
| **Job sequencing** | Priority sequencing rules on dispatch list | In order of kanbans received; little sequencing needed | Prioritize on same setup as last batch; priority sequence for rest |
| **Batch/lot sizing** | Fixed | Ideally a lot size of one (as small as feasible) | Large batches for bottlenecks; order splitting at others (transfer batches) |
| **Inventory tracking** | Manufacturing, purchase orders; shipping/receiving documents | Finished goods receipt used to backflush (little paperwork) | Same as MRP-based |
| **Potential problems** | Master schedule not leveled/overcapacity | Vendor relations; supply failures | Varied routings shift bottleneck often |

## Scheduling Choice and Decoupling Point

- Point at which a supply chain or organization moves from forecast-based push to demand-based pull
- MRP, TOC, and lean systems impact the decoupling point differently.

| MRP | TOC | Lean |
| --- | --- | --- |
| ▪ Redesign processes to meet changes over life cycle. | ▪ Manage bottlenecks by coupling/ decoupling. | ▪ Move decoupling point back up supply chain as far as possible. |

# Executing: Authorizing Production



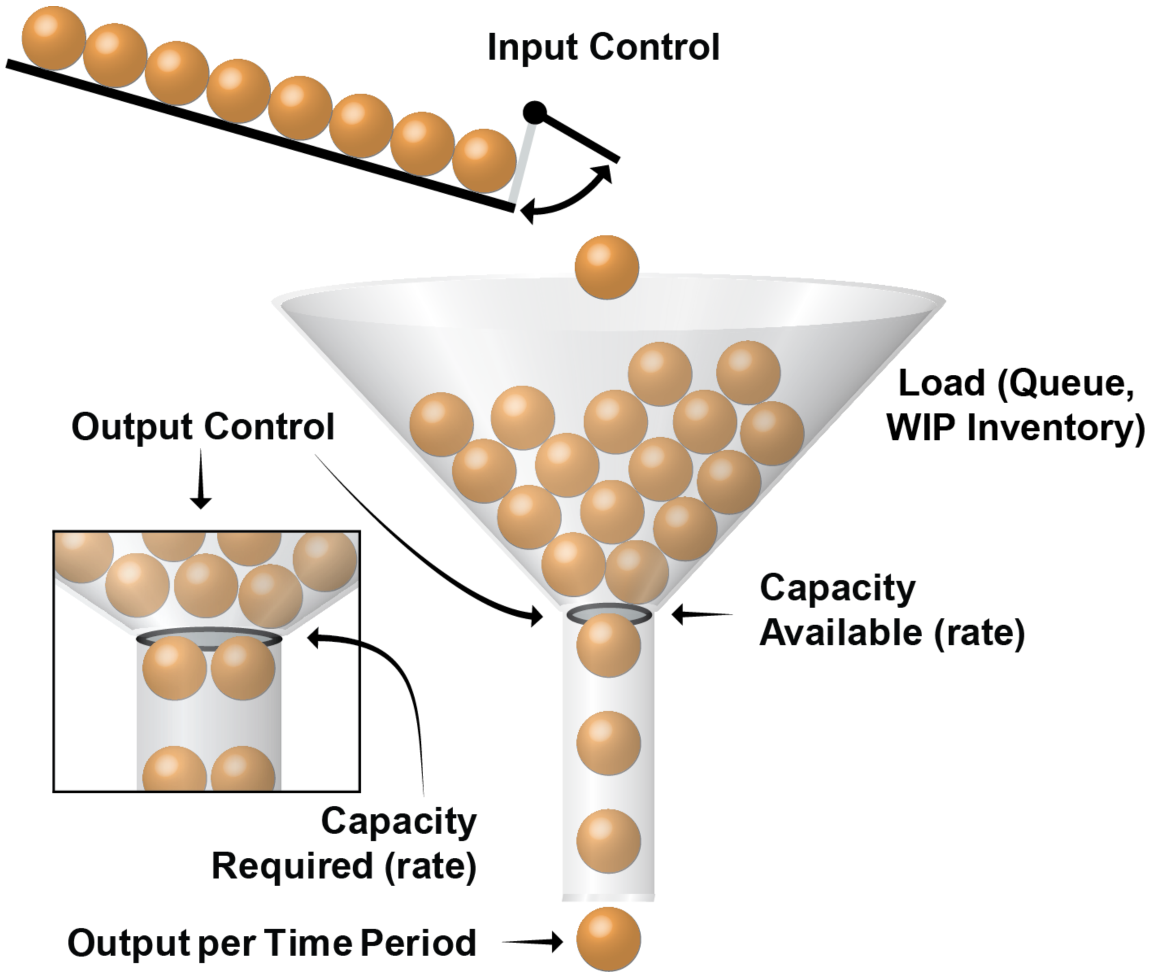
# MRP-Based PAC in Batch and Flow

| Batch Production | Flow Manufacturing |
| --- | --- |
| High-variety, low-volume ATO products. | Standard high-volume MTS products. |
| Varied routings through general purpose equipment. | Fixed routings: dedicated assembly lines or flow equipment. |
| Operations time at work centers will vary. | Operations time at work centers about the same: balanced. |
| High risk that work arrives at work centers late or early. | Flow between work centers is predictable. |
| Slow throughput. | Fast throughput. |
| WIP builds up. | Low WIP. |
| Capacity required varies by item. | Capacity fixed by line. |

## Input/Output Control in Intermittent Process Types

Objectives

- Keep WIP and queue times at desired levels.
- Control inputs (schedule, dispatch).
- Control output rate (capacity).



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# MRP-Based Scheduling and PAC

## Input/Output Report

**Cumulative Variance = Previous Cumulative Variance + Actual Output − Planned Output**

**Backlog = Previous Backlog + Input − Output**

Work Center: 13 Capacity per Day: 16 hours
(All Units in Standard Hours)

| Mfg. Calendar Day | | 48 | 49 | 50 | 51 | 52 | SUM |
|---|---|---|---|---|---|---|---|
| Planned Input | | 16 | 16 | 14 | 13 | 20 | 79 |
| Actual Input | | 14 | 16 | 12 | 15 | 16 | 73 |
| Cumulative Variance | | -2 | -2 | -4 | -2 | -6 | -6 |
| Planned Output | | 16 | 16 | 16 | 16 | 16 | 80 |
| Actual Output | | 12 | 18 | 14 | 15 | 19 | 78 |
| Cumulative Variance | | -4 | -2 | -4 | -5 | -2 | -2 |
| Planned Backlog | 8 | 8 | 8 | 6 | 3 | 7 | |
| Actual Backlog | 8 | 10 | 8 | 6 | 6 | 3 | |

8 + 16 − 16 = 8

−2 + 12 − 14 = −4

−5 + 19 − 16 = −2

8 + 14 − 12 = 10

Both input or both output
Both planned or both actual



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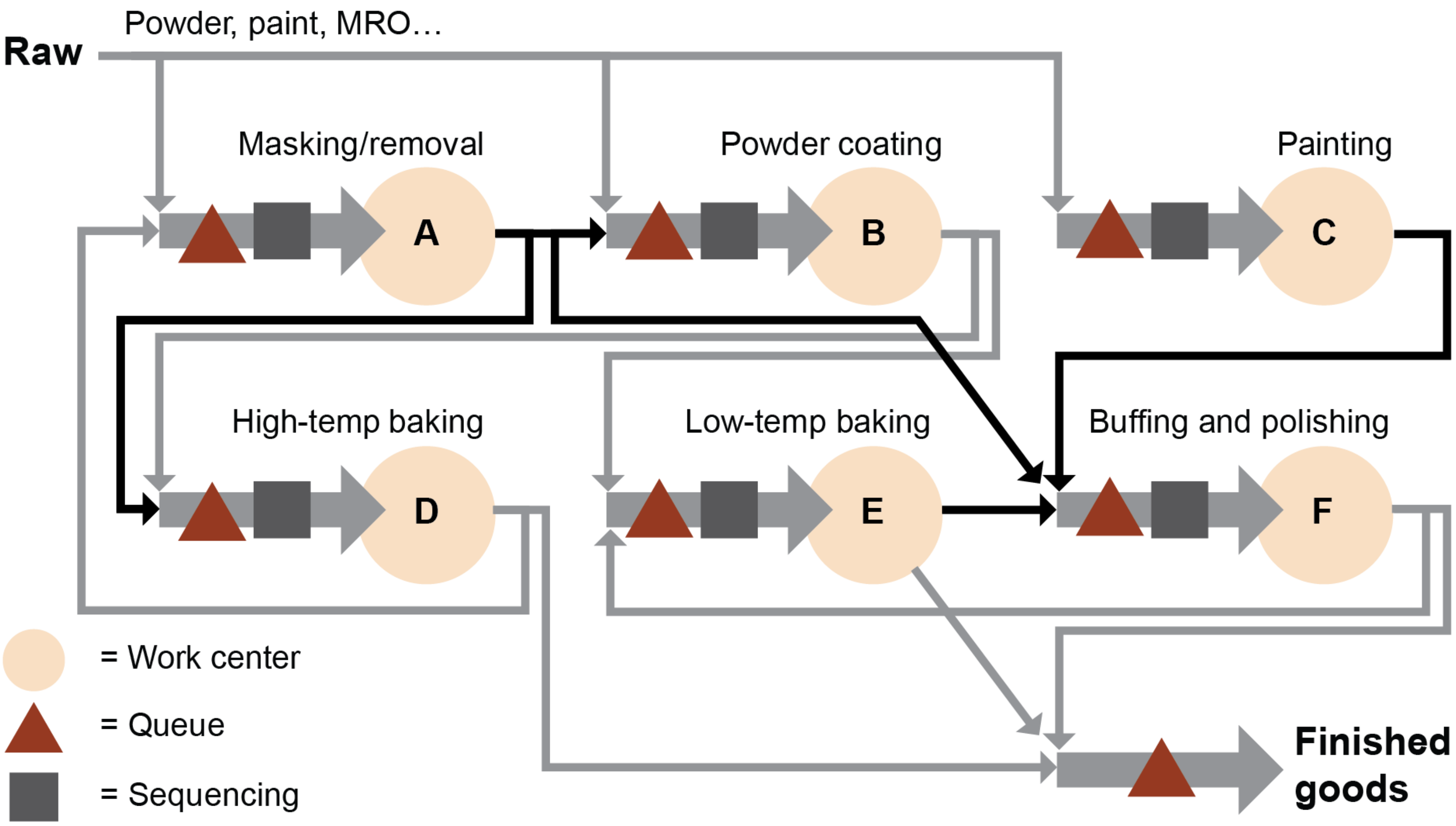
# MRP-Based Scheduling and PAC

## Input/Output Report Exercise

Work center: 20
Capacity per period: 40 standard hours

| Period | | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|---|
| Planned input | | 38 | 32 | 36 | 40 | 44 | 190 |
| Actual input | | 34 | 32 | 32 | 42 | 40 | 180 |
| Cumulative variance | | -4 | -4 | -8 | -6 | -10 | -10 |
| Planned output | | 40 | 40 | 40 | 40 | 40 | 200 |
| Actual output | | 32 | 36 | 44 | 44 | 36 | 192 |
| Cumulative variance | | -8 | -12 | -8 | -4 | -8 | -8 |
| Planned backlog | 32 | 30 | 22 | 18 | 18 | 22 | - - |
| Actual backlog | 32 | 34 | 30 | 18 | 16 | 20 | - - |

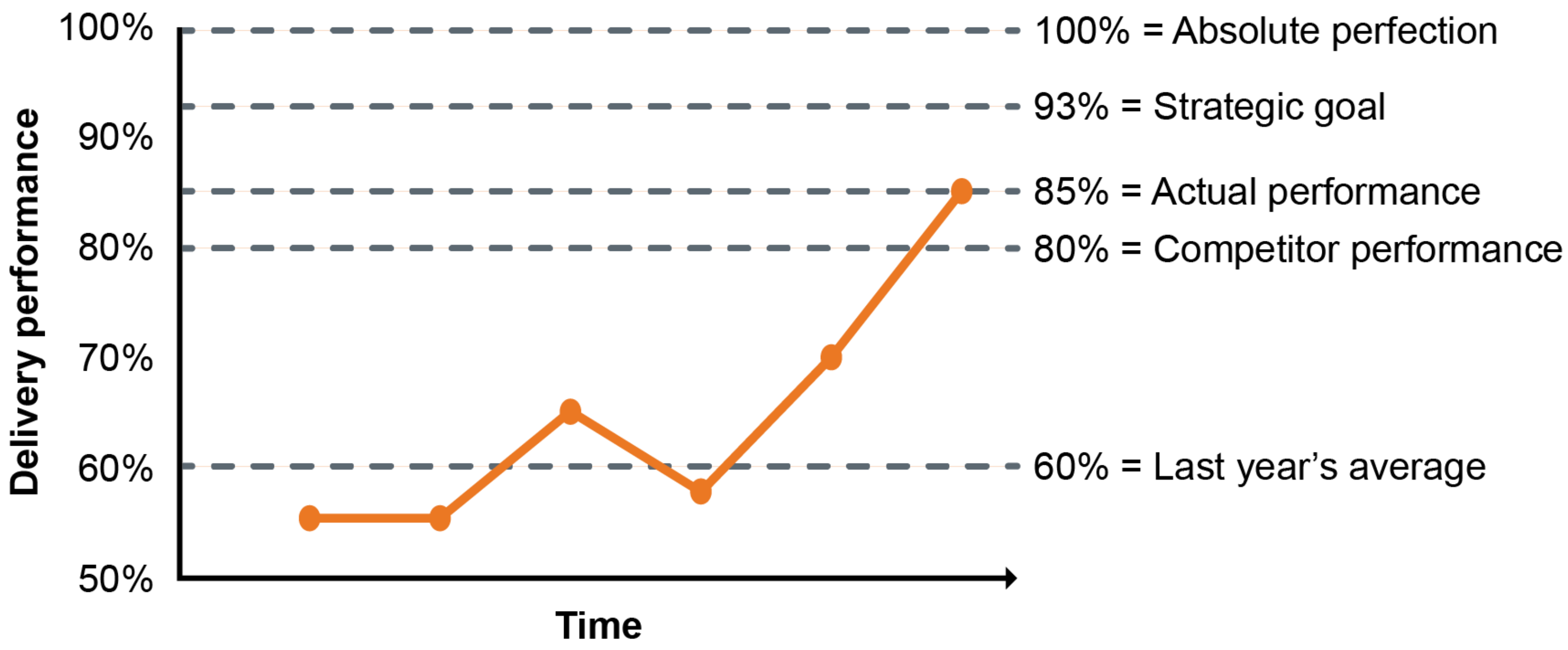
## Sequencing Rules



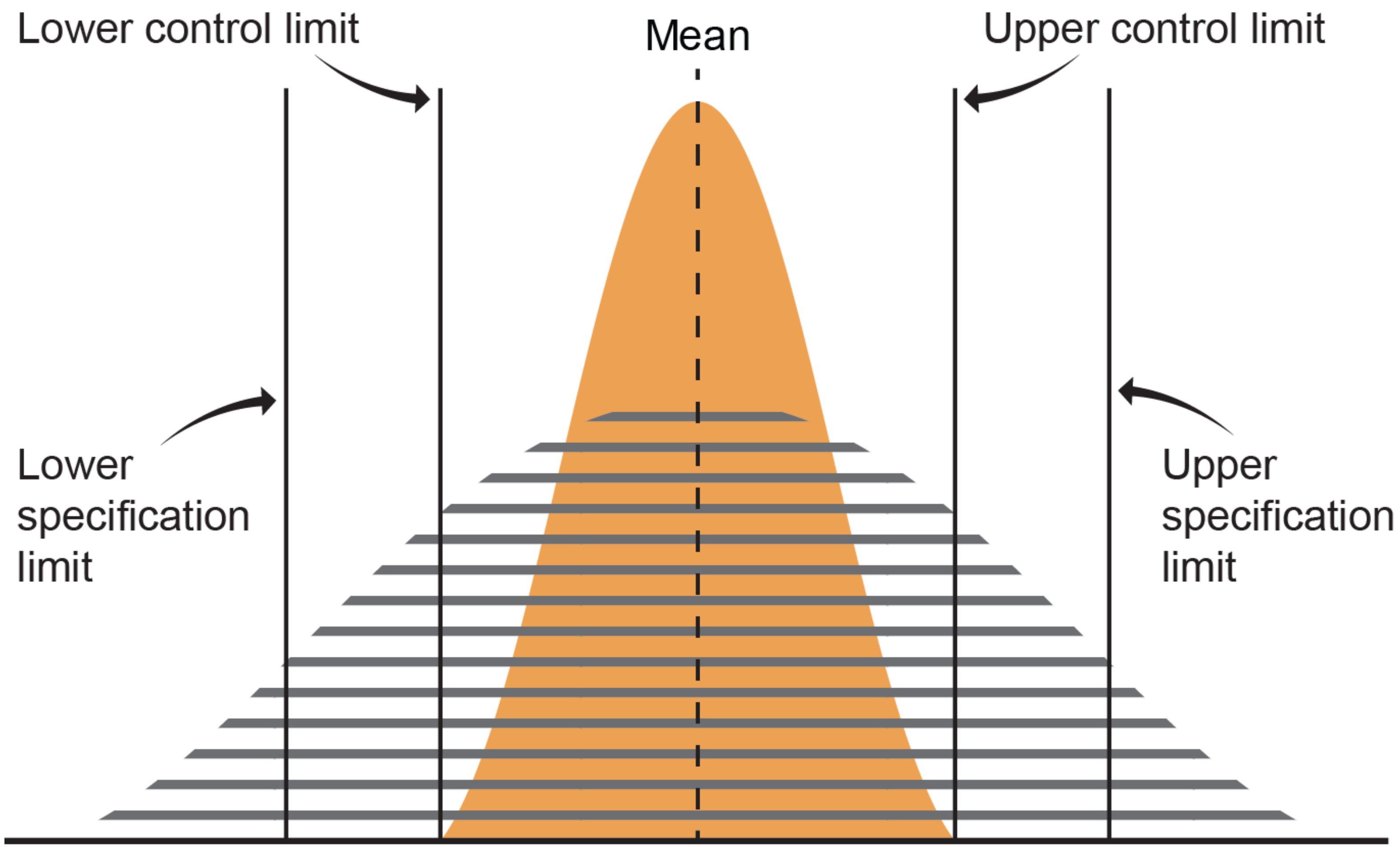
# MRP-Based Scheduling and PAC

## Control Goals

- Integrated performance measurement
- Balanced scorecard
- Performance targets



# Tolerance Limits



## Operational Capability

Key performance measurement reports

- Day-by-the-hour
- First-time-through
- WIP-to-standard WIP
- Overall equipment effectiveness

# Lean Objectives

- Make only those products and services customers actually want.
- Match the production rate to the demand rate.
- Make products and services with perfect quality.
- Make products and services with the shortest possible lead times.
- Include only features actually in demand, excluding all else.
- Keep labor, equipment, materials, and inventory continually in motion, with no waste or unnecessary movement.
- Build worker learning and growth into each operational activity.

## Lean versus MRP Scheduling

| MRP (Push-Based) System | Lean (Pull-Based) System |
|---|---|
| Process layout; complex routings | Flow layout; standard routings |
| Long lead times | Short lead times |
| High WIP | Low WIP |
| High work center utilization = goal | Work centers may have surge capacity; utilization flexes by production rate needed to meet customer orders |
| Detailed scheduling routes work through work centers | Work completed quickly; jobs easily tracked visually |



APICS

# Lean Documentation and Backflushing

| Lean Documentation | Backflushing |
| --- | --- |
| ▪ Kanban instead of order release, job packet.<br>▪ Visibility of material/tools.<br>▪ Continuous flow so no detailed routings or work center start/finish dates.<br>▪ Less feedback/reporting.<br>▪ Production reports displayed at cell level. | ▪ Used in lean systems to handle recording.<br>▪ Inventory record is automatically reduced after completion of activity on upper-level parent.<br>▪ Works best when lead times are short and BOMs are accurate. |

# Elements of Lean Scheduling

- Sufficient volume in repetitive process
- Production rate goals
- Reduction in WIP
- Level production planning
- Heijunka (or mixed-model) scheduling/production

# Level Production Planning

Takt time = rate of production/customer demand

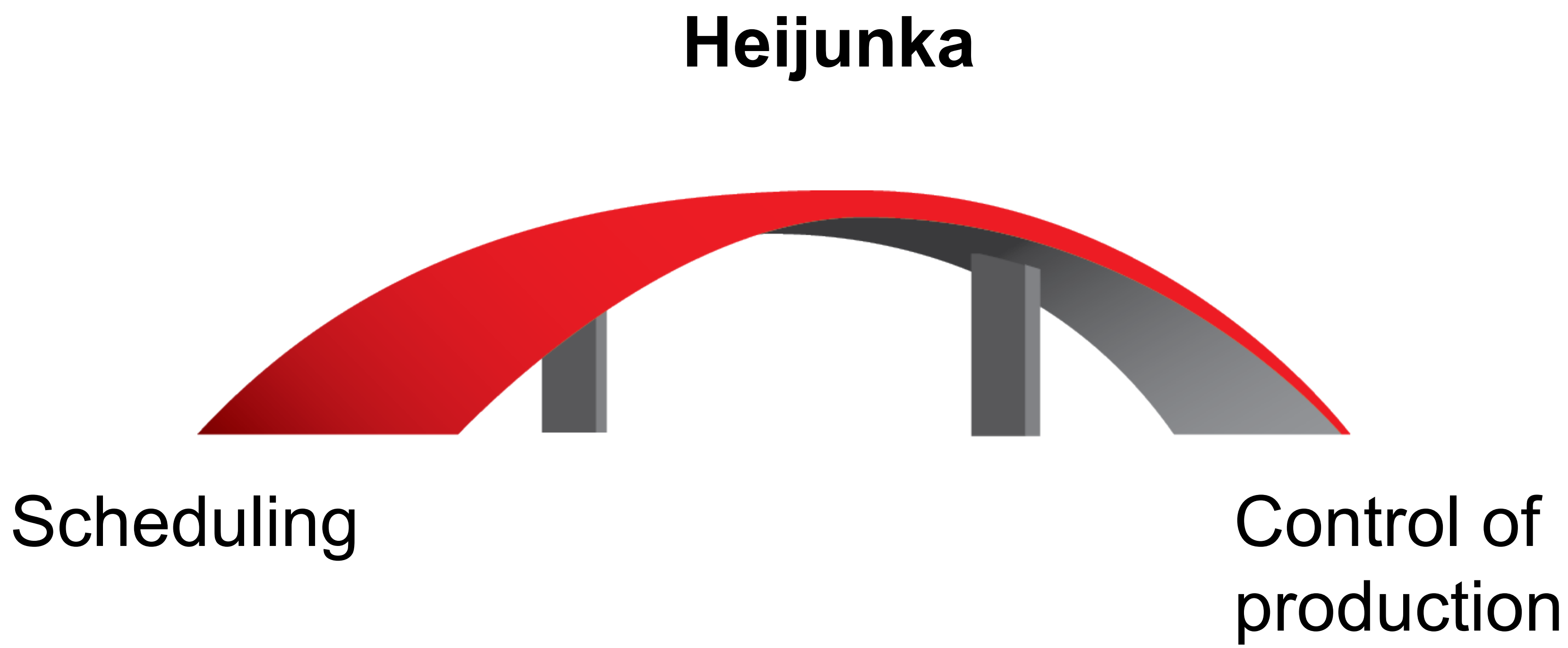
- Wood + Brass Takt Time = 100,000 Units/250 Days = 400 Units per Day

| | Model A | Model B | Model C | Model D |
|---|---|---|---|---|
| **Option configurations:** | | | | |
| Handle | Wood | Wood | Steel | Steel |
| Head | Brass | Alloy steel | Brass | Alloy steel |
| Annual forecast (units) | 100,000 | 1,250 | 12,500 | 50,000 |
| **Possible mixed production schedules:** | | | | |
| Daily batch MPS | 400 | 5 | 50 | 200 |
| Hourly batch MPS | 50 | .625 | 6.25 | 25 |

MPS: master production schedule
Assumes a 250-day work year and an 8-hour day
Total annual forecast 163,750 hammers
Total daily batch quantity is 655

# Heijunka



# Heijunka Scheduling Techniques to Improve Flow

| Using control limits | Not over-reacting to demand changes | Prioritizing regular orders | Using ATP logic | Moving to "milk runs" |
| --- | --- | --- | --- | --- |
| If demand stays within plan, plan should not change. | Use takt time to manage and control time. | Don't let large or unusual orders derail regular orders. | Logic in master scheduling software. | Frequent small batches are delivered on one vehicle. |

# Takt Time

| Store/supermarket | Pacemaker |
|---|---|
| Controlled inventory of parts or finished goods that schedules an upstream process through a kanban signal. | Raw material or other point's cycle time that sets a pace that enables all other processes to achieve the takt time objective. |

$$\text{Takt Time} = \frac{\text{Available Production Time}}{\text{Rate of Customer Demand}}$$

$$\frac{\text{445 Minutes} \times \text{2 Shifts}}{\text{890 Units per Day}} = \text{1 Minute per Unit}$$



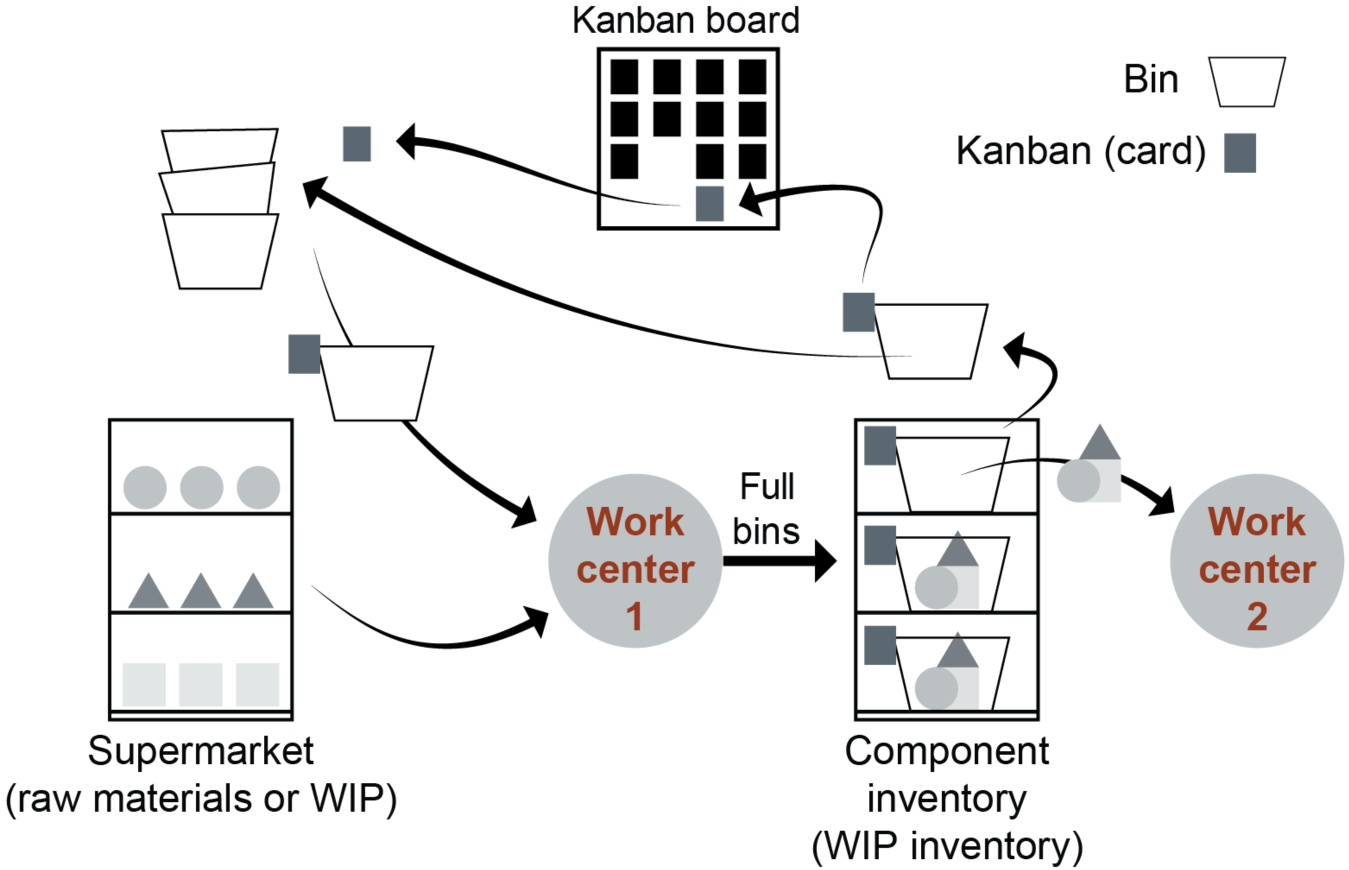
APICS

# Kanban Systems

## Process

- Authorize production at processes upstream from pacemaker.
- Pull parts through upstream processes to pacemaker based on production schedule.
- Establish number of parts containers between processes on shop floor.
- Use visual controls in fast throughput environment.

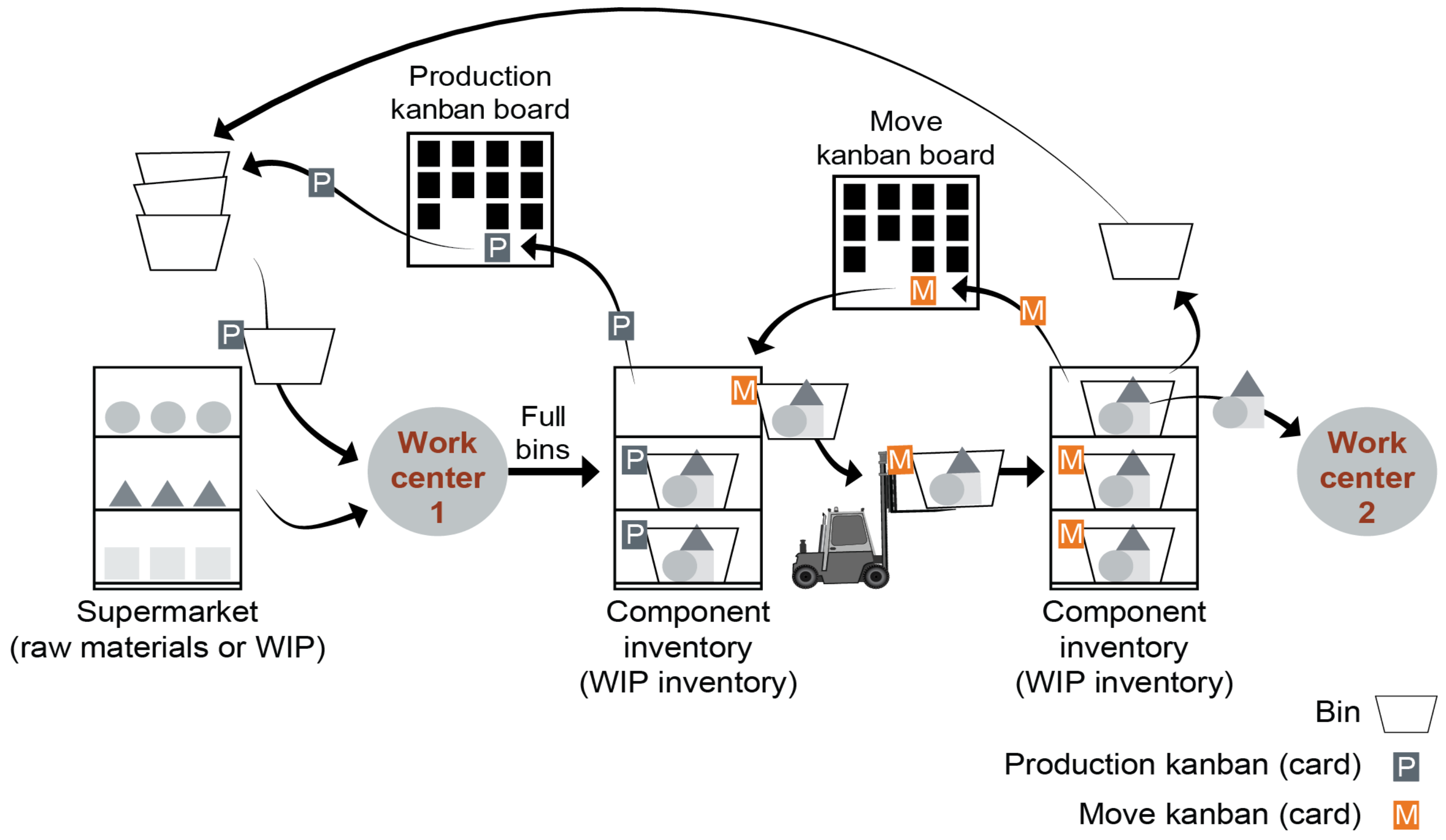
## One-card kanban system



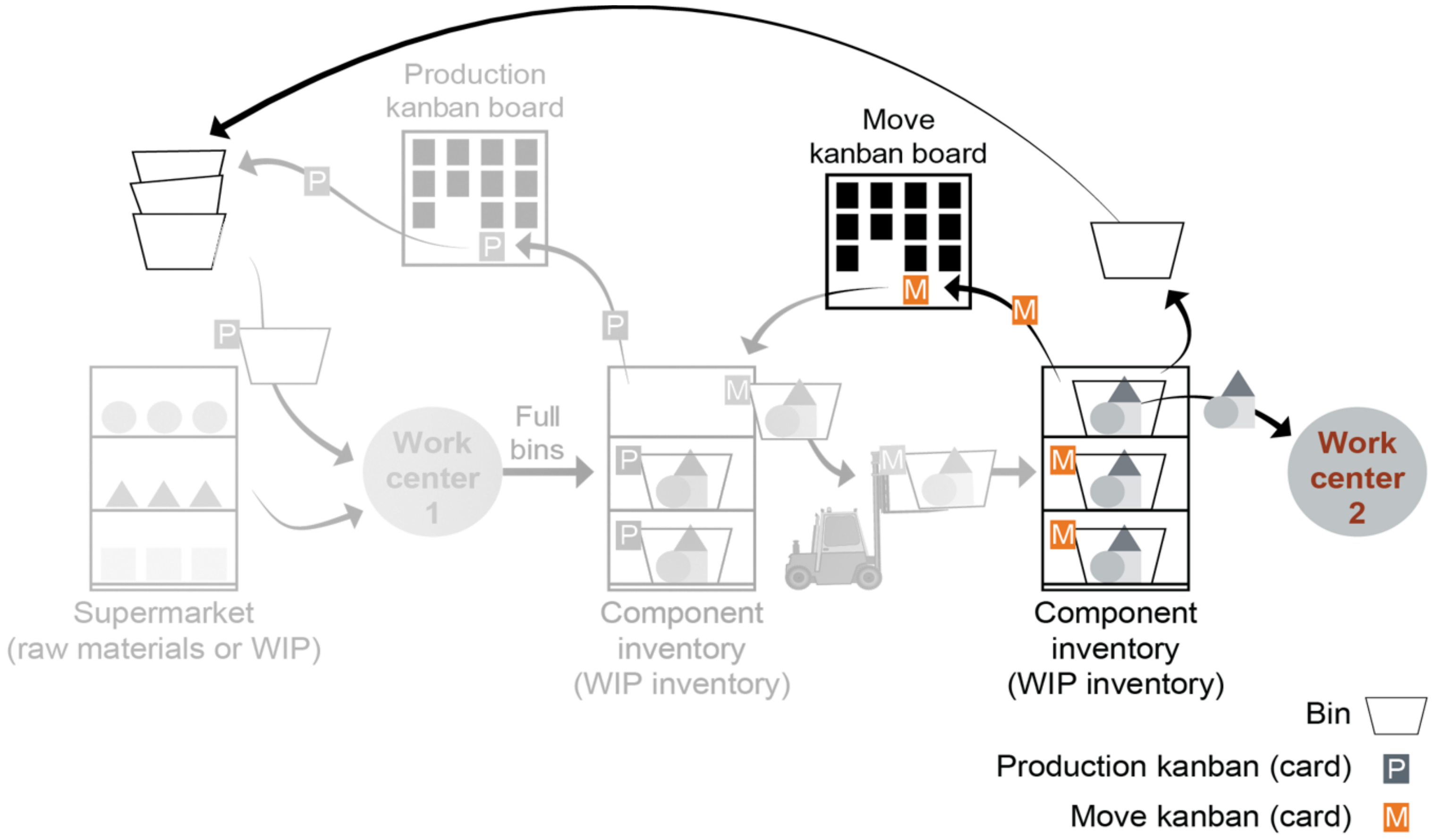
## Limiting Number of Kanban Cards

- Each container of parts must have a kanban card.
- The number of parts in a container is fixed, and no partial containers will be put into storage.
- Parts are always pulled by the user department.
- No parts are obtained without a kanban card.
- All containers contain standard quantities, and only the standard container for the part can be used.
- No extra production is permitted; production can start upon receipt of a production kanban card.

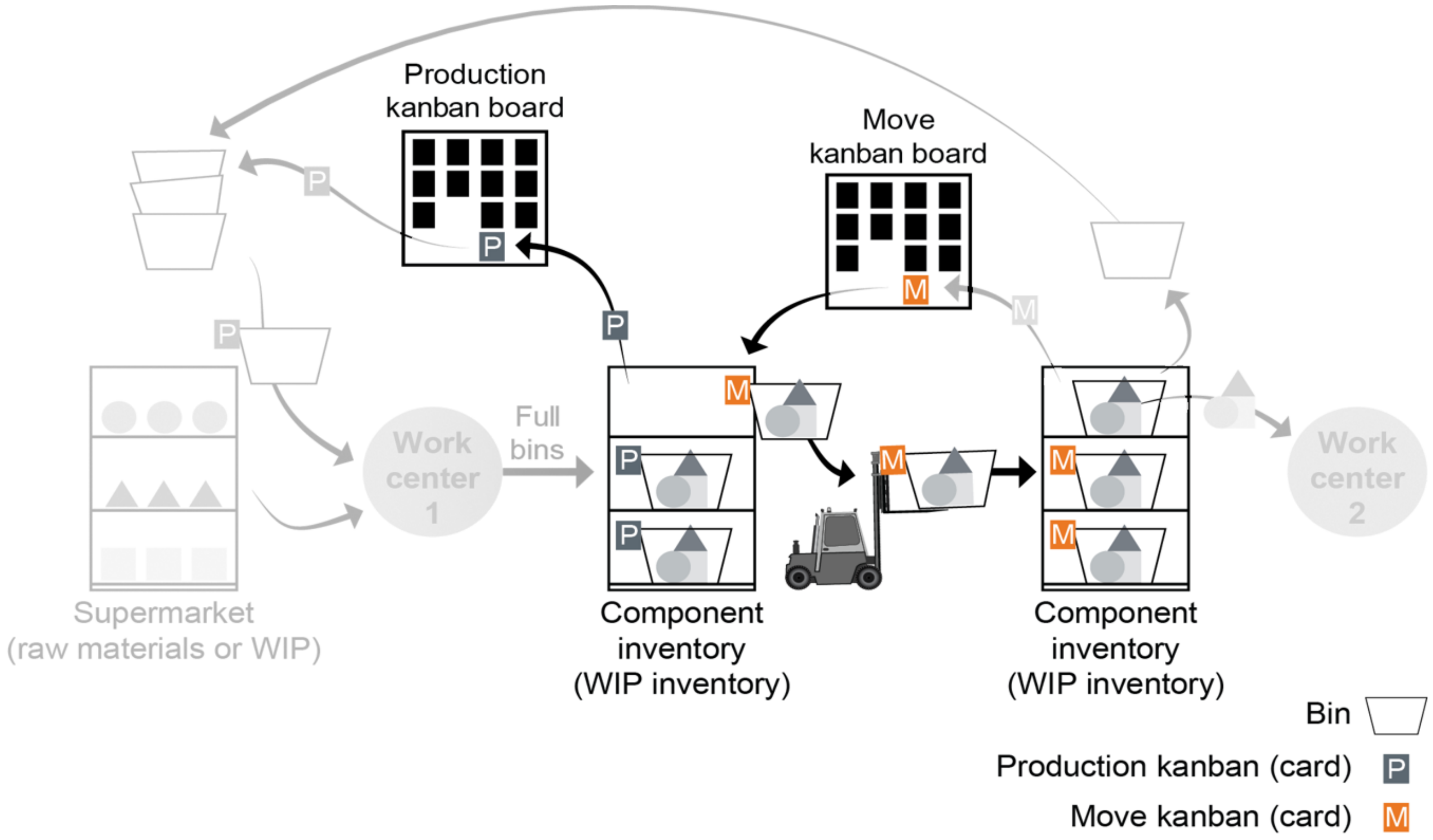
# Two-Card Kanban Systems



## Two-Card Kanban Systems



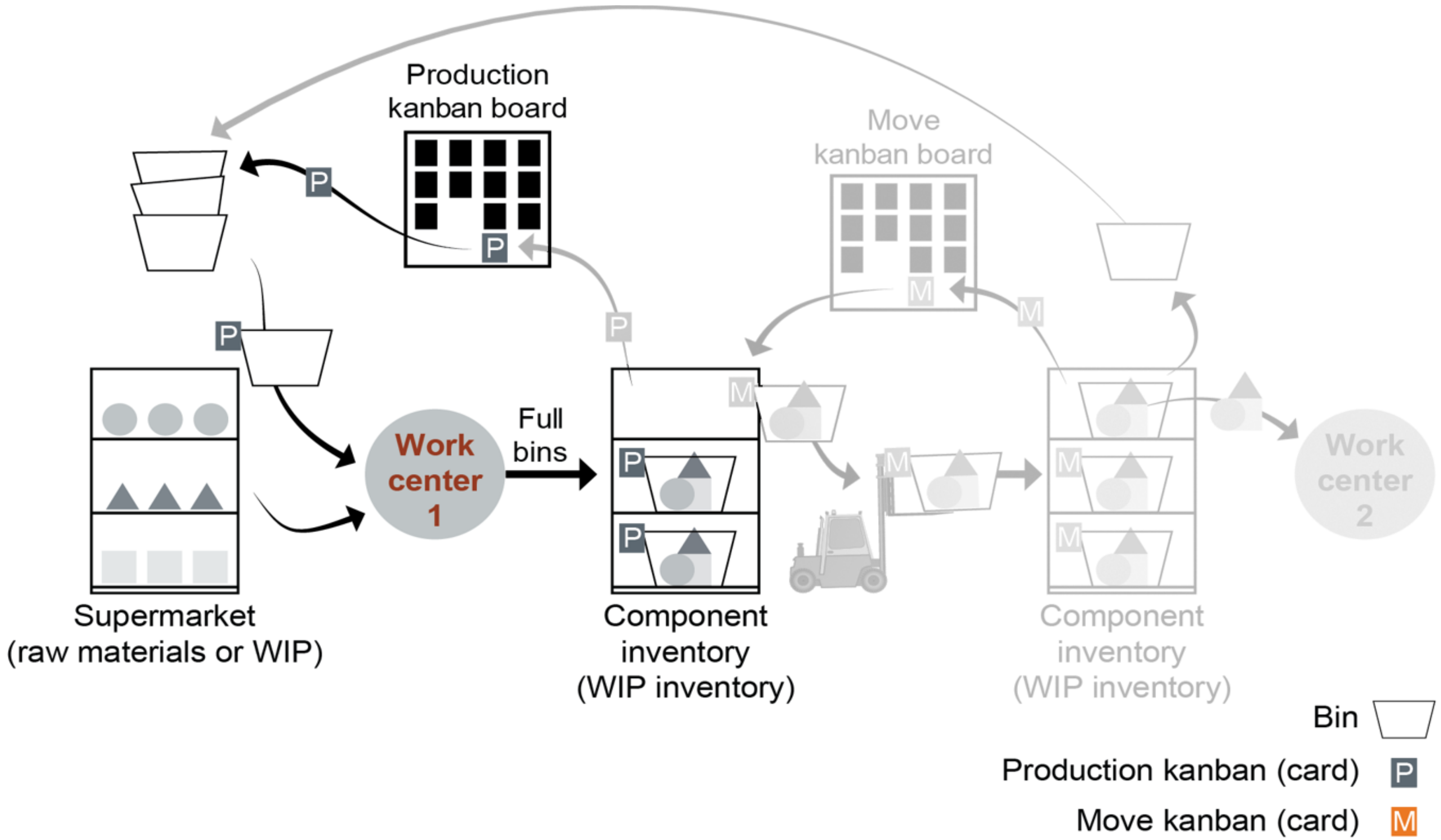
## Two-Card Kanban Systems



APICS

# Two-Card Kanban Systems



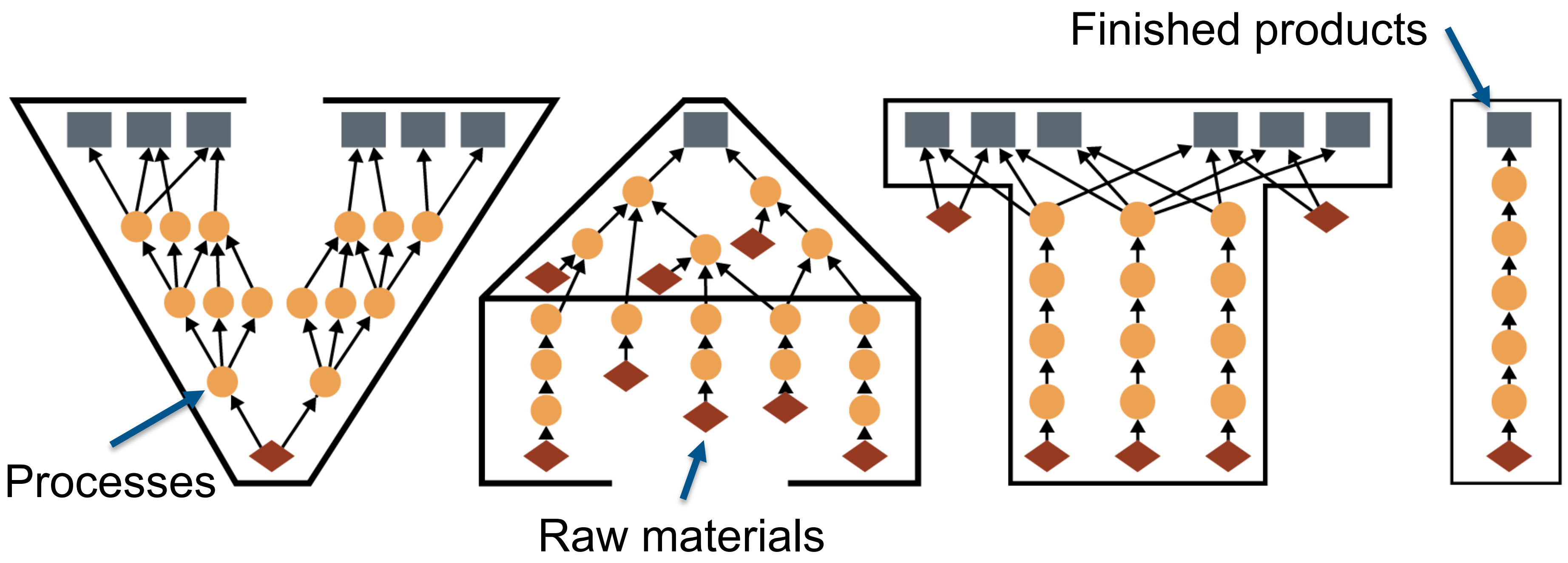
# Control Systems Exercise

Complete the “Lean-Based” column in the table.

| Element or Factor | MRP-Based | Lean-Based |
|---|---|---|
| Control objective | Work center capacity utilization | Overall product flow rate |
| Control of material flow | Push: schedules, shop orders, batches, job sequencing rules | Pull: flow production in response to customer requirements |
| Operations sequencing | Important; based on due date priorities at each work center | Not a concern; relatively quick flow-through to finished goods |
| Order tracking | Important; track production floor transactions by operation | Not necessary; minimal WIP; quick flow-through; no need for tracking |
| Monitoring and feedback | Critical; input/output control and work center load reports | Less central; focuses on the overall result |
| Preferred lot size | Large | One or small |
| WIP and safety stock | Large | Small |
| Product demand | Low/medium volume, high variety with variable demand and lead times | Best with medium/high volume, low variety, and stable demand |

## Product Flow (VATI) Analysis

- Look at routings, BOMs, and BOM explosions.
- Study in operation; watch out for spontaneous shifts.



## Theory of Constraints (TOC)

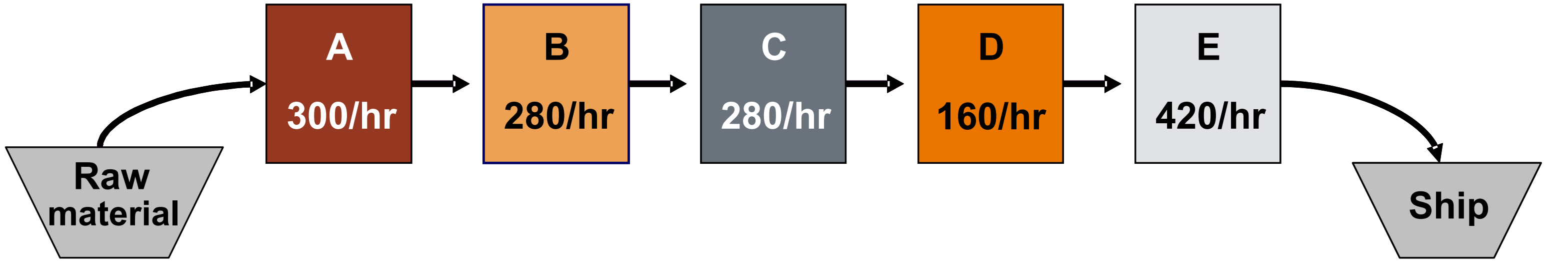
- Dr. Goldratt principle: Complex systems have simplicity.
  - Very small number of variables, maybe one, that limit higher attainment of goal.
  - Improvement at only constraint area creates net gain.
  - Strengthening other areas wastes effort, no net gain.
- Constraint often easy to see.
  - Full-capacity work center.
  - WIP accumulating.
  - Downstream work centers waiting.
- Throughput “goal units,” e.g., revenue per time period.

# Types of Constraints

| Physical constraints | Capacity-constrained resources (CCRs) | Behavior-based constraints |
| --- | --- | --- |
| ▪ Limited resources:<br>– Equipment<br>– Labor<br>– Materials<br>▪ Market constraint (Sales is the constraint.) | ▪ Resource that could become a constraint if not managed carefully | ▪ Managerial constraints<br>▪ Time-consuming administrative policies<br>▪ Personnel unaware they are working at a bottleneck<br>▪ Inability to detect need for, fund, or initiate improvements<br>▪ Complex problem |

## Constraints

a) If the market demand is 600 per hour, what is the active bottleneck?
b) If the market demand is 80 per hour, what is the constraint?
c) If the market demand is 150 per hour, what is the role of resource D?



# Principles of Bottleneck Management

## Bottlenecks

- Rate at which bottleneck processes work is rate at which inputs should be provided.
- Capacity of production process depends on bottleneck capacity, so breakdowns/slowdowns reduce throughput.
- Priority (demand) for different types of units promotes more setups, but each new setup is opportunity cost.
- Output from bottleneck areas should be provided to next work center(s) in smaller lots than full batch size.
- Goal is to maximize total plant throughput. Schedule capacity-constrained resources to avoid bottlenecks.

## Non-bottleneck areas

- Non-bottleneck capacity improvements do not improve total capacity.
- Non-bottleneck areas set maximum utilization based on rate determined at bottleneck.
- Using non-bottleneck area 100% of time does not result in 100% utilization, just more WIP.

# TOC Scheduling and PAC

## Drum-Buffer-Rope

Organizations use TOC scheduling, called drum-buffer-rope (DBR), to

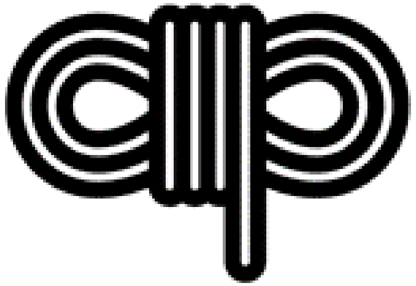
- Identify and schedule constraints carefully
- Buffer constraints with inventory
- Maximize utilization at bottlenecks or constrained resources
- Maximize system throughput.

## Drum-Buffer-Rope

- Drum schedule sets pace for entire system.
  - Like takt time but based on constraint rate (or demand).
  - Production initiated by drum to avoid queue and wait.

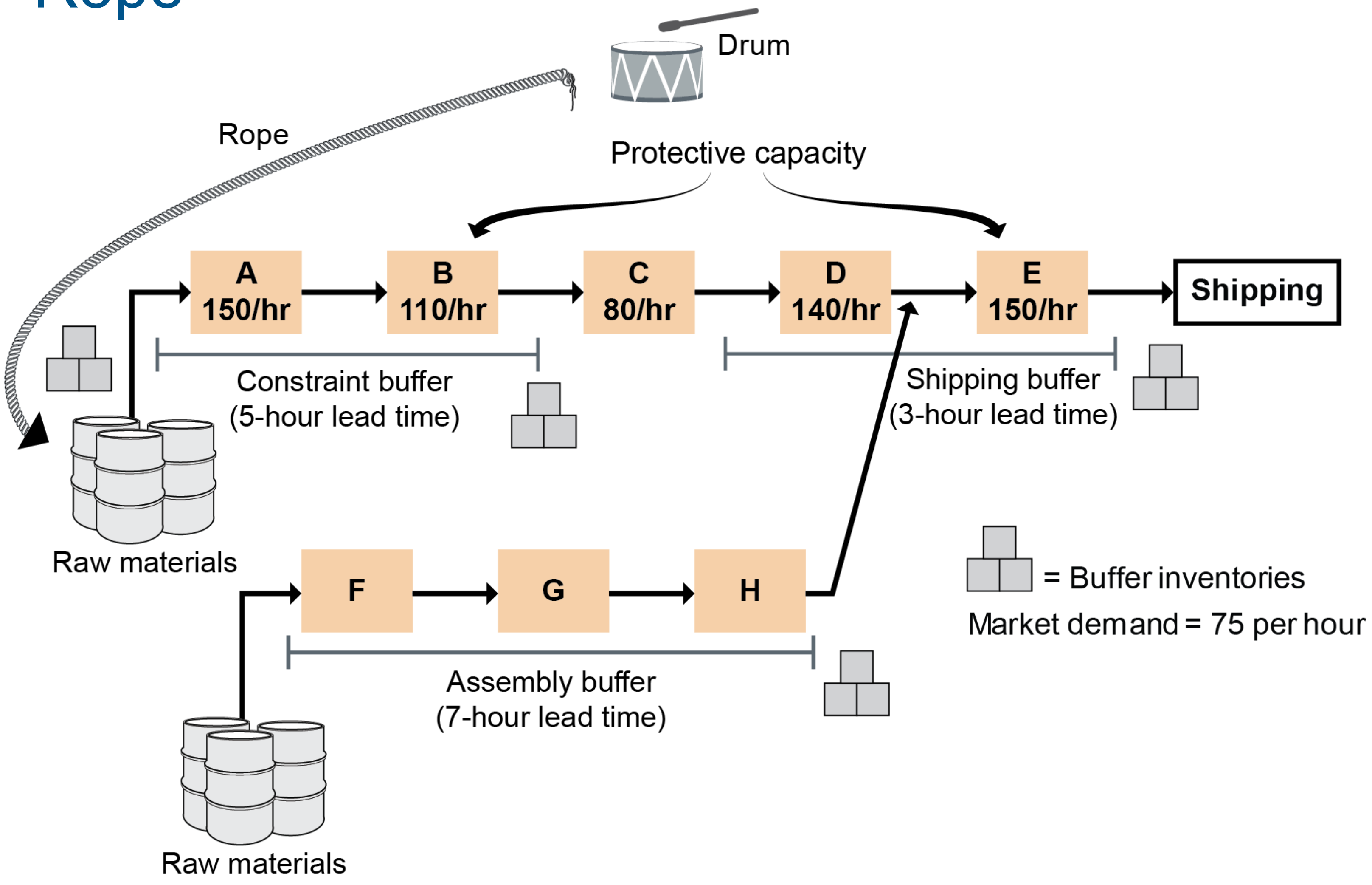
- Buffer
  - Time buffer: Materials arrive specific time before need.
  - Not general parts but parts allocated to future orders.

- Rope
  - Like demand-pull, but signal is constraint throughput rate.
  - Adjust pull to keep buffer from shrinking or growing.



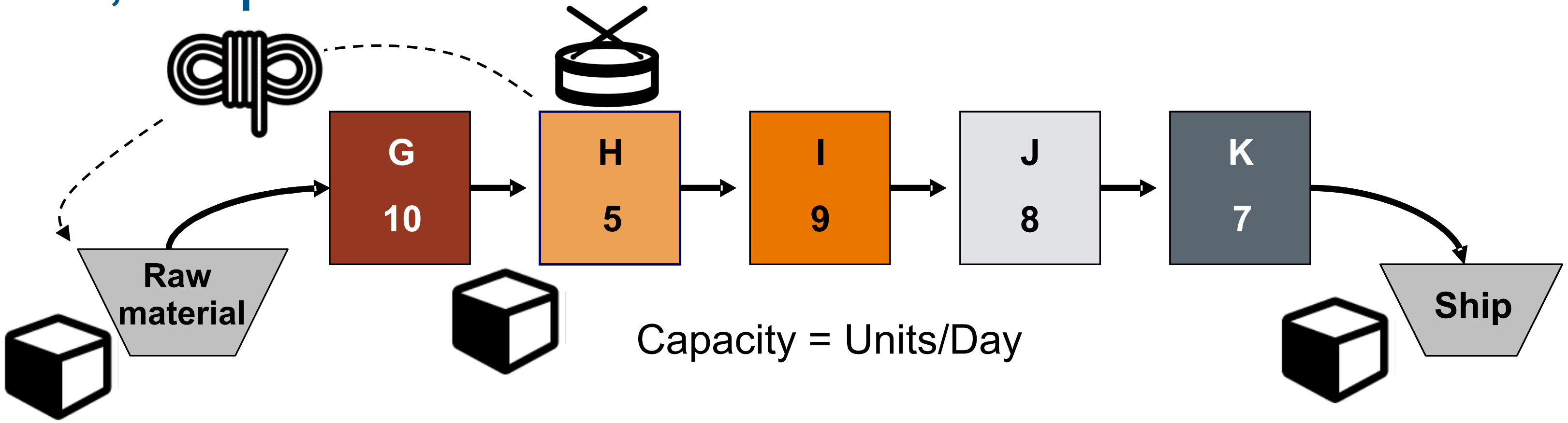
# TOC Scheduling and PAC

## Drum-Buffer-Rope



# TOC Scheduling and PAC

## Drum, Buffer, Rope

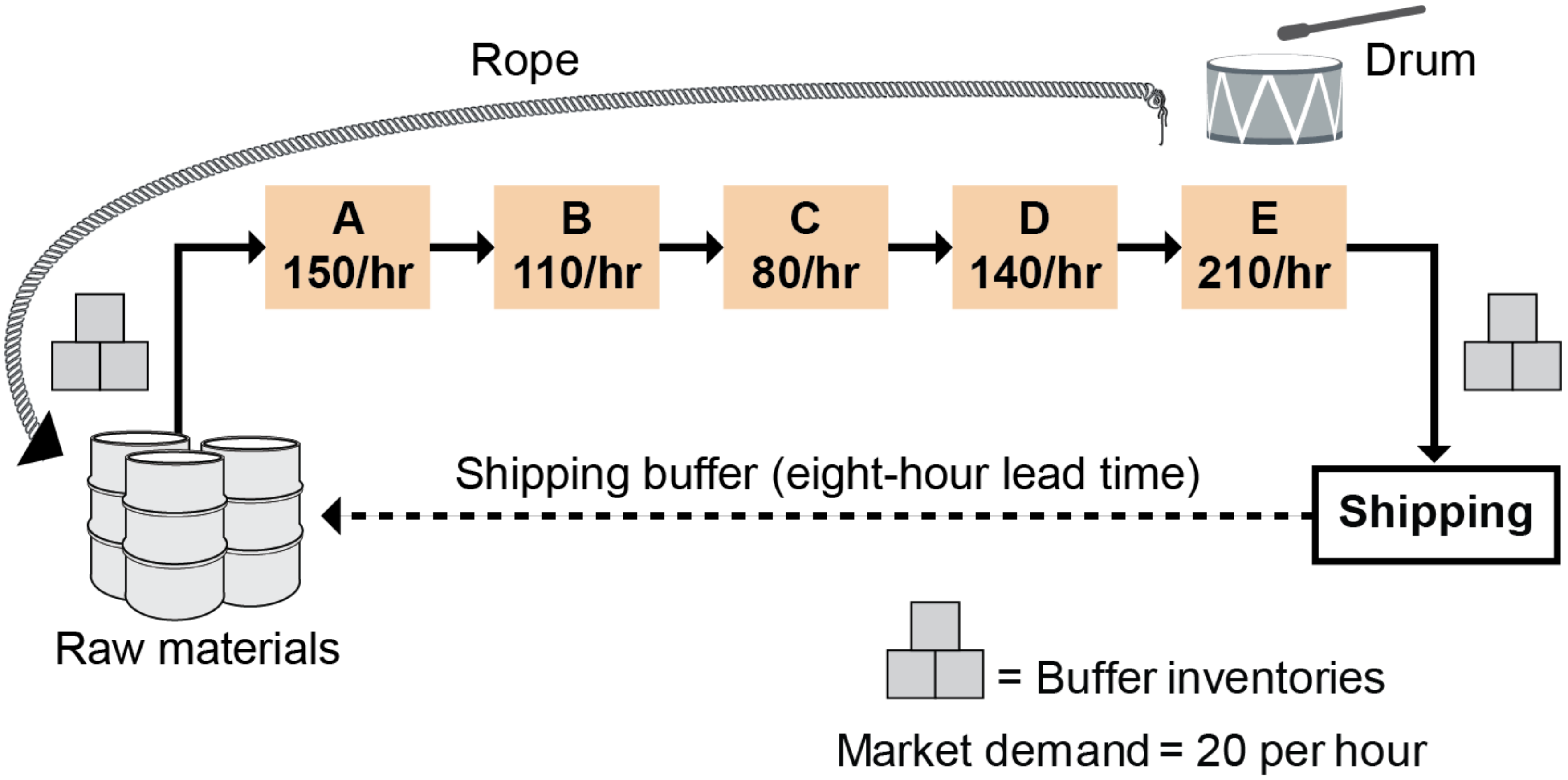



Where is the drum?

Where should stock buffers be located?

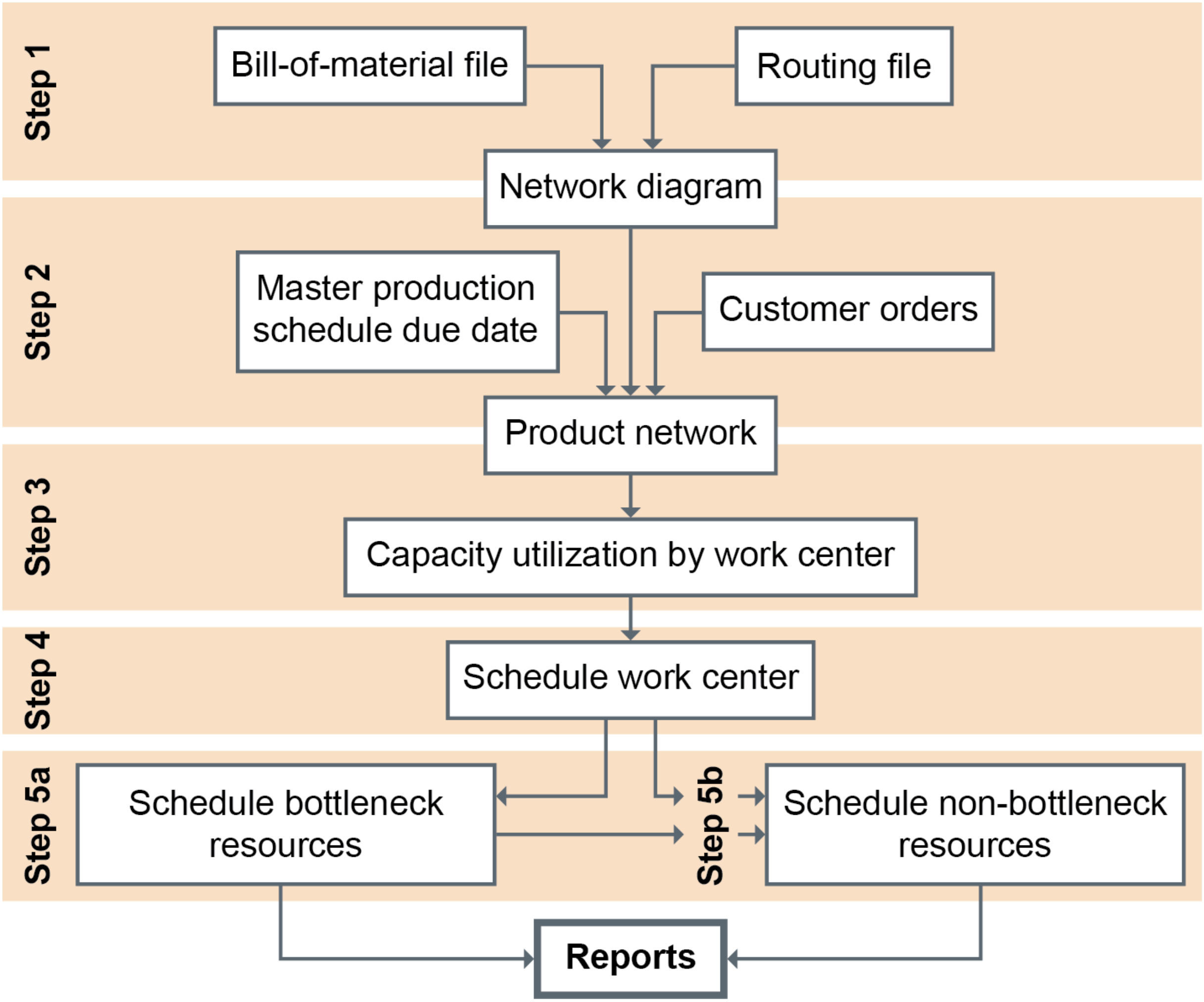
Where is the rope?

## Market Demand as Constraint: Simplified Drum-Buffer-Rope (S-DBR)



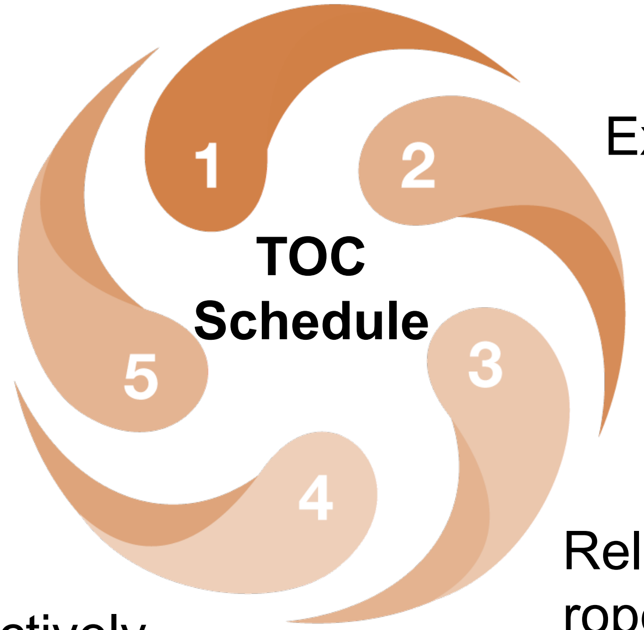
## TOC Scheduling Steps



## TOC Production Activity Control Scheduling Process

Scheduling the drum

Elevating the drum




Exploiting the drum

Releasing material using the rope

Managing buffers proactively

## Managing Bottlenecks

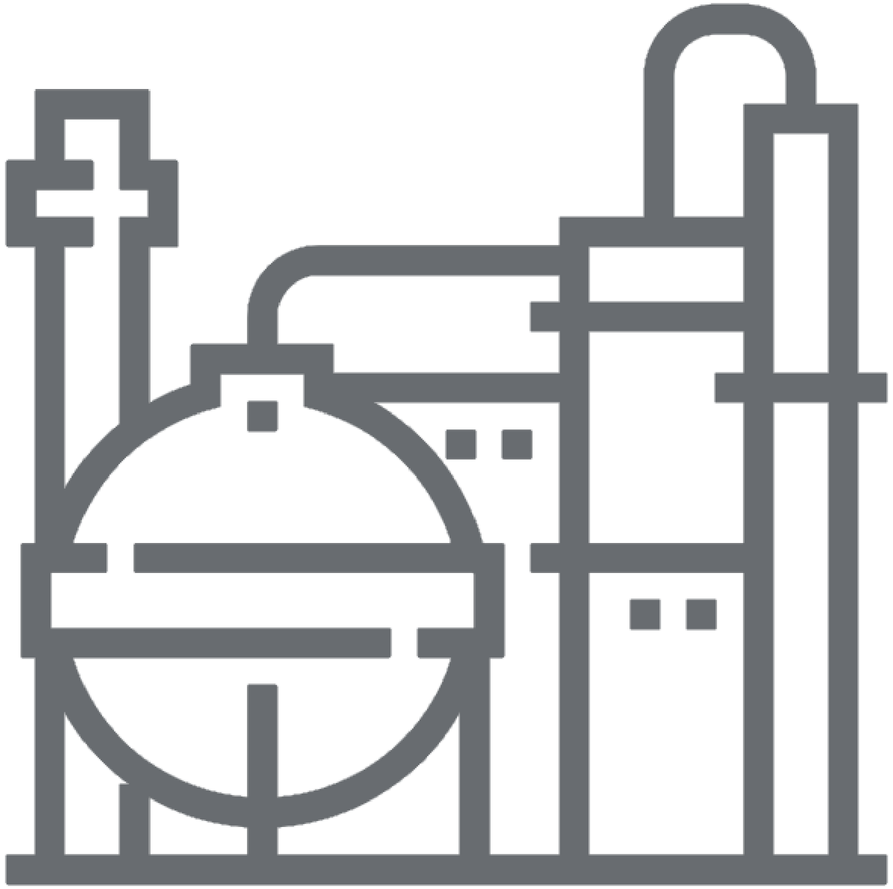
| Technique | Explanation |
|---|---|
| Establish buffer in front of bottleneck. | Create time buffer or queue before bottleneck. |
| Control rate of material flowing into bottleneck. | Keep bottleneck fed at constant rate that is equal to its capacity so time buffer remains constant. |
| Focus on maintain or increasing bottleneck capacity. | Look for ways to increase capacity of bottleneck. |
| Adjust loads. | Reduce load on bottleneck. |
| Change schedule. | Last resort is to change promised schedule for delivery. |

## Elements of Constraint Management

- Identify—Identify the capacity-constrained resource (CCR) before it becomes a bottleneck.
- Exploit—Keep the CCR working.
- Subordinate—Feed into the process only what can be handled at the CCR.
- Elevate—Accelerate and improve the CCR.
- Repeat—After fixing the CCR, return to step 1 to attack the new CCR.

# Continuous (Flow) Manufacturing Environments

- Divergent product structure
- Capacity planned first to meet forecast demand
- Continuous flow
- Focus on efficient use of capacity

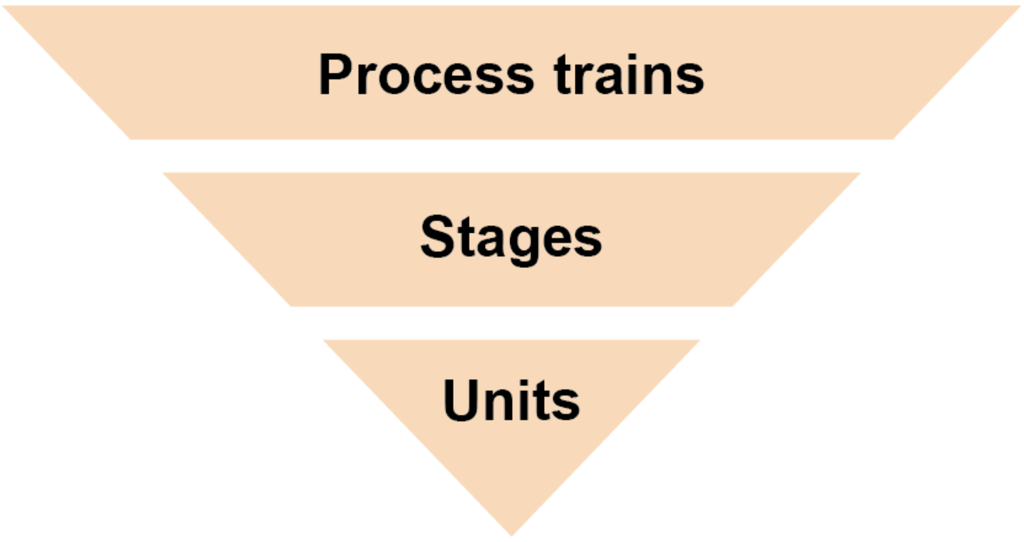


# Nonstandard Demand

## Process Flow Scheduling

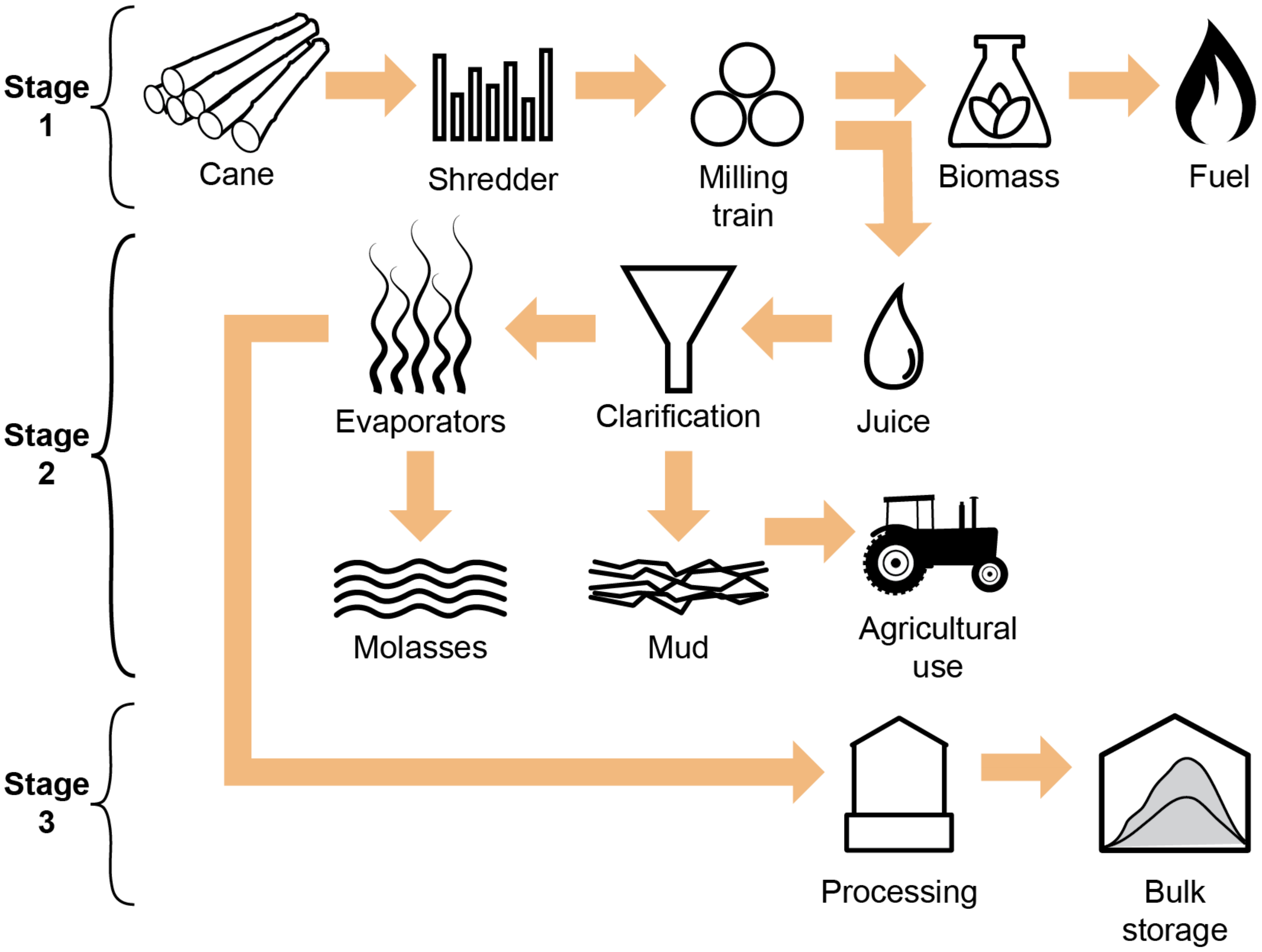
Three principles

- Scheduling is based on the process structure.
- Processor- or material-dominated scheduling can be used within a stage.
- Process trains can be scheduled with reverse flow scheduling, forward-flow scheduling, or mixed-flow scheduling.



# Nonstandard Demand

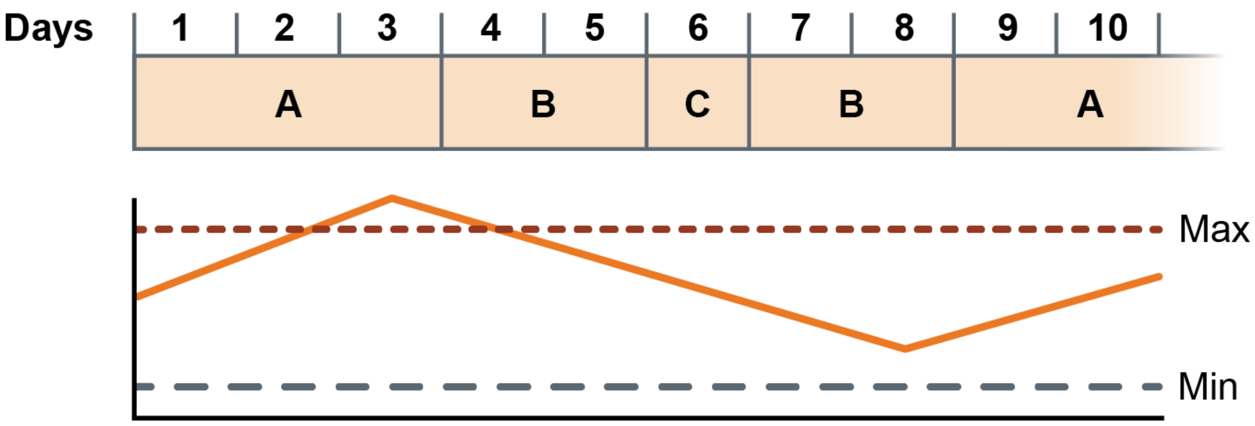
## Sugar Refinery Process Train



## Processor-Dominated Scheduling Approach

1. Prepare finite capacity schedule.
2. Check inventory against min-max levels.
3. Revise production schedule.
4. Schedule raw materials.

Processor schedule for products A, B, and C in a single-stage process train:




Inventory graph for product A

# Material-Dominated Scheduling Approach

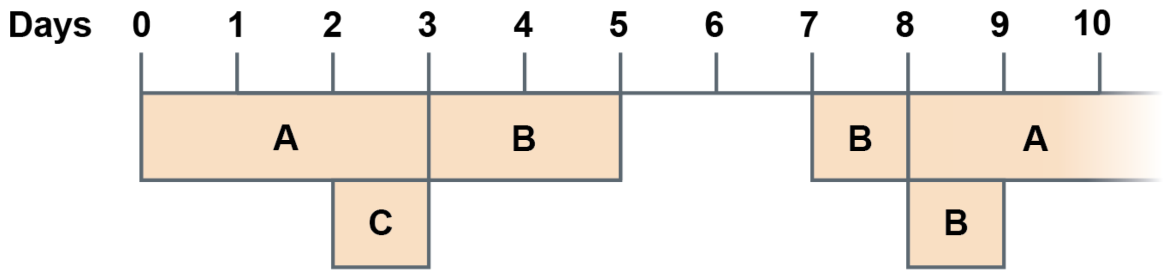
1. Create a time-phased record of material balances.
2. Add a lot when inventory falls below target.
3. Compile a load profile for the unit.
4. Analyze and reconcile incompatibilities.

**Product A**
**Minimum = 100, Maximum = 800**
**Production rate = 200/day**
**Lot size = 600**

**Material schedule**

| Day | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Requirements | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Production | | 200 | 200 | 200 | | | | | | 200 | 200 |
| Inventory | 500 | 600 | 700 | 800 | 700 | 600 | 500 | 400 | 300 | 400 | 500 |

**Processor schedule (material schedule needs adjustment)**



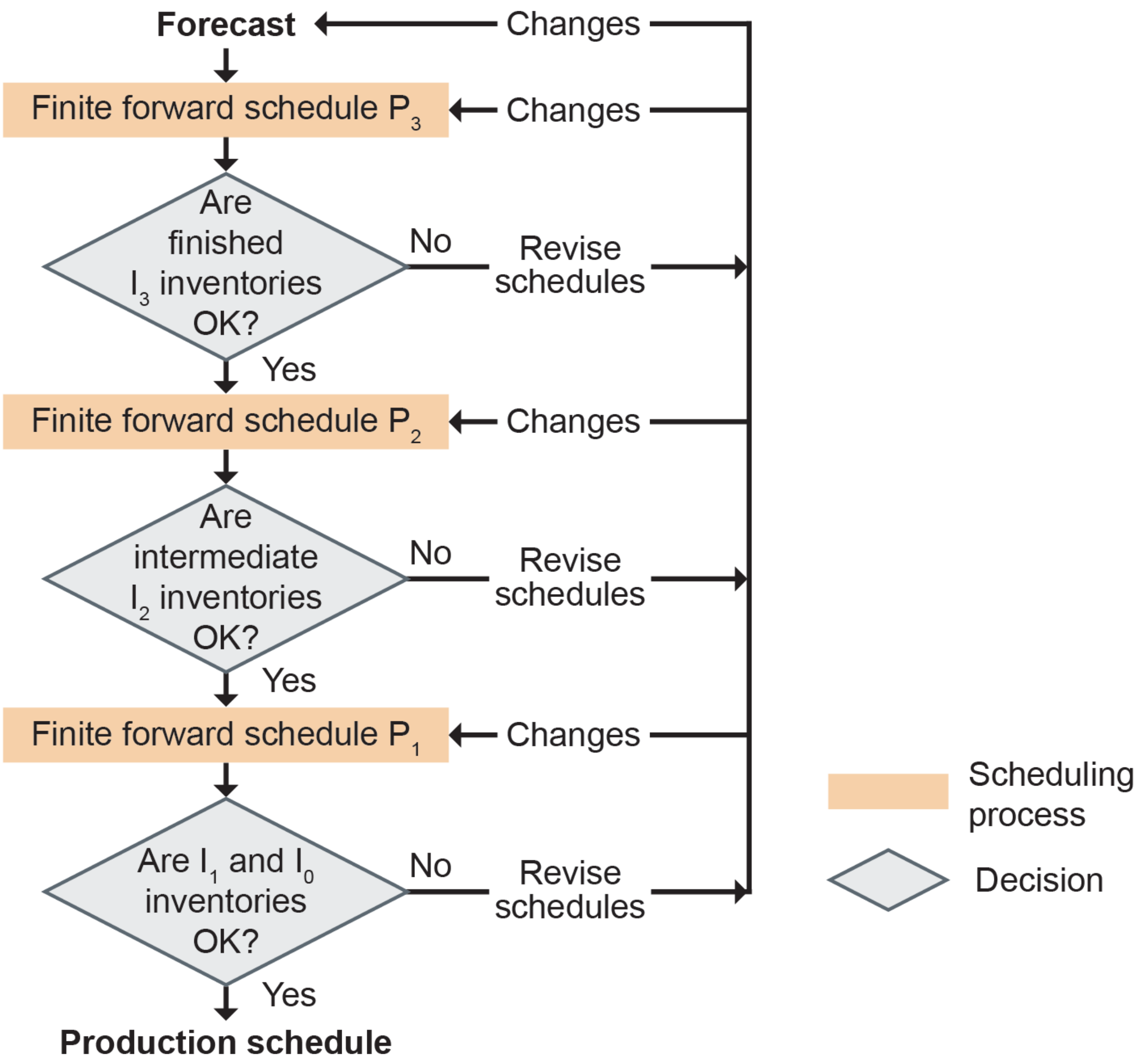
# Nonstandard Demand

## When to Use PDS or MDS

| PDS | MDS |
| --- | --- |
| ▪ Capacity is relatively expensive.<br>▪ The process unit is a bottleneck.<br>▪ Setups are expensive. | ▪ Materials are relatively expensive.<br>▪ There is excess capacity.<br>▪ Setup costs are low.<br>▪ Stage operates as job shop. |

# Nonstandard Demand

## Reverse-Flow Scheduling



CPIM

CERTIFIED IN PLANNING
AND INVENTORY MANAGEMENT

# SECTION C:
# CREATING PRODUCTION AND SERVICE SCHEDULES

APICS

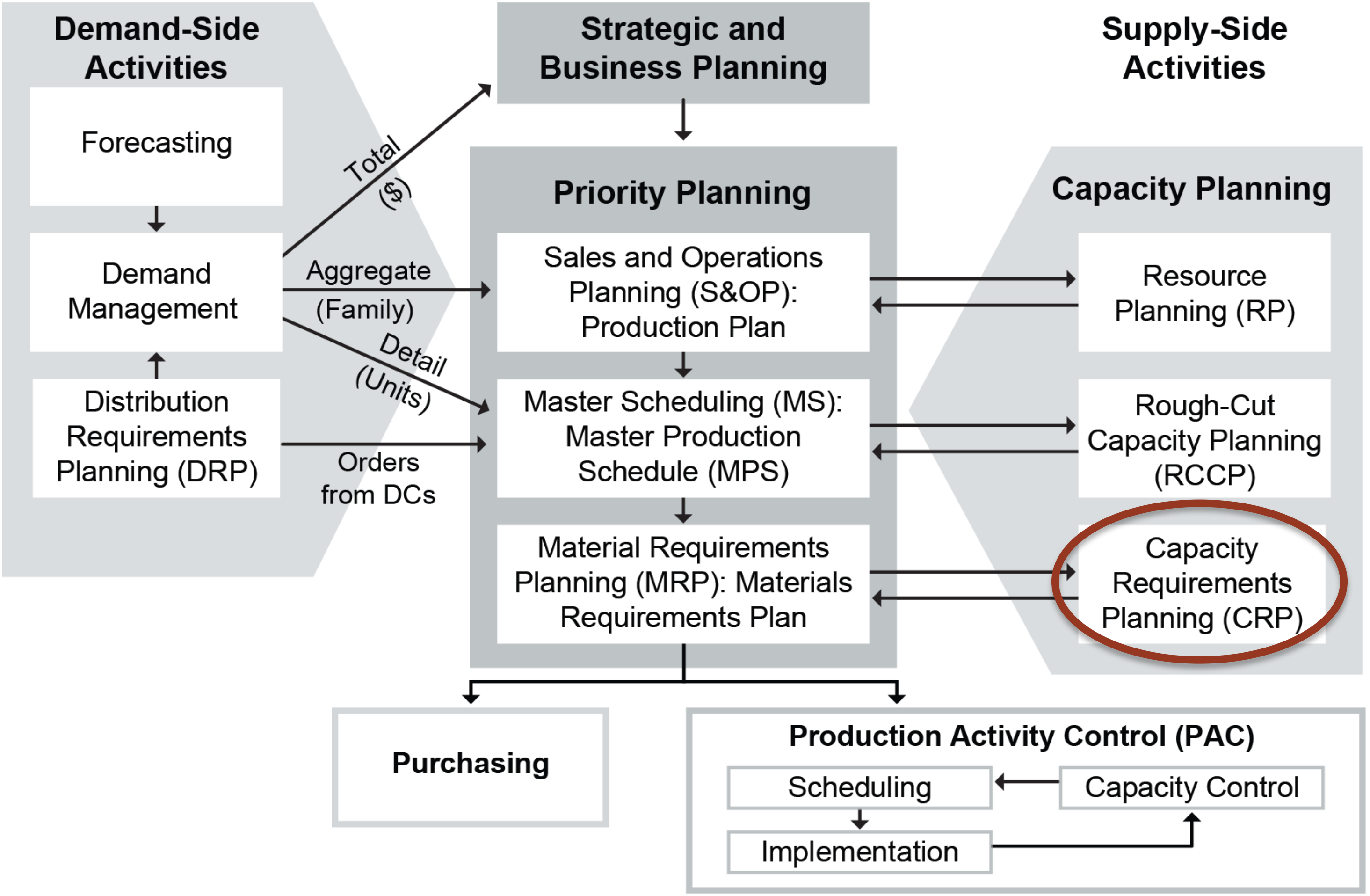
ASCM

## Section C Learning Objectives

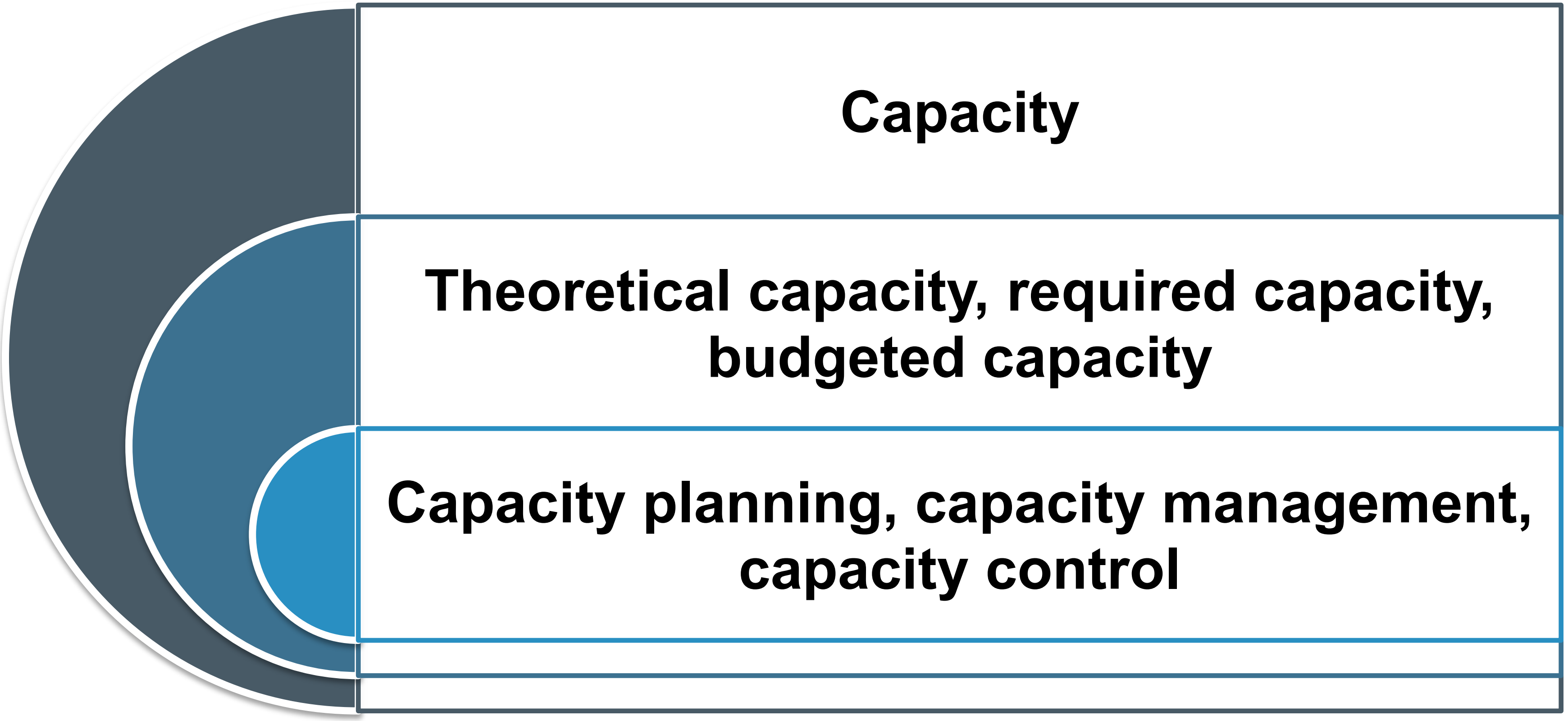
- Capacity terms and goals of capacity management
- Capacity planning in service industries
- CRP steps and inputs
- Calculating rated capacity, demonstrated capacity, efficiency, and utilization
- Safety capacity
- How load is calculated
- Capacity simulation and tactics for resolving imbalances

# Capacity Planning and Service Capacity

## Detailed Capacity Planning in MPC Process



# Key Capacity Terms

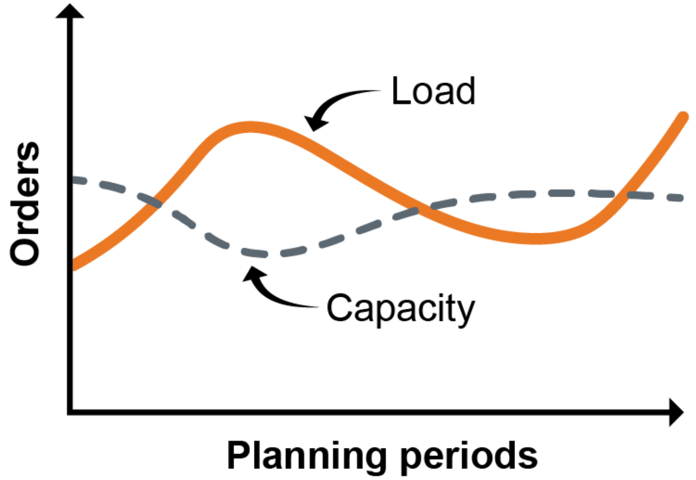


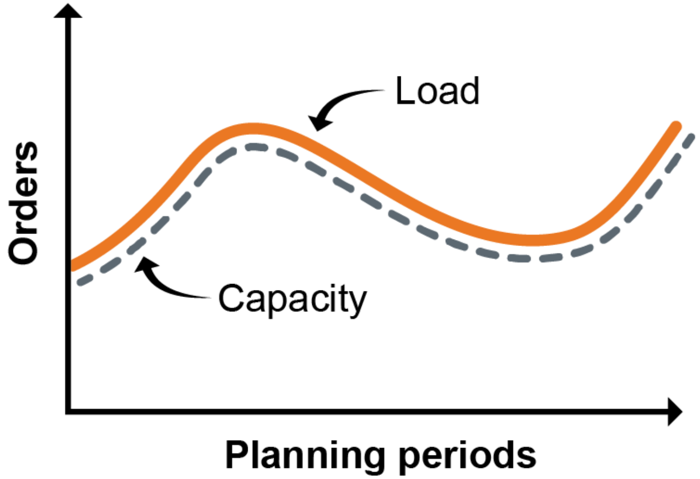

 

## Capacity Planning Goals and Challenges

**Goal: Meet operational performance objectives by**

- Increasing productive capacity
- Reducing idle capacity.



## Service Capacity

Capacity in service industries is subject to scarcity and expensive to obtain; it is a risk once obtained (increases break-even point).

Services are inherently perishable (e.g., hotel room shelf life: one day).

Tactics to adjust capacity

- Change workforce level.
- Cross-train.
- Increase customer participation.
- Use automation.
- Extend hours of operation.

# Capacity Requirements Planning (CRP)

## Steps in Iterative Capacity Planning Process

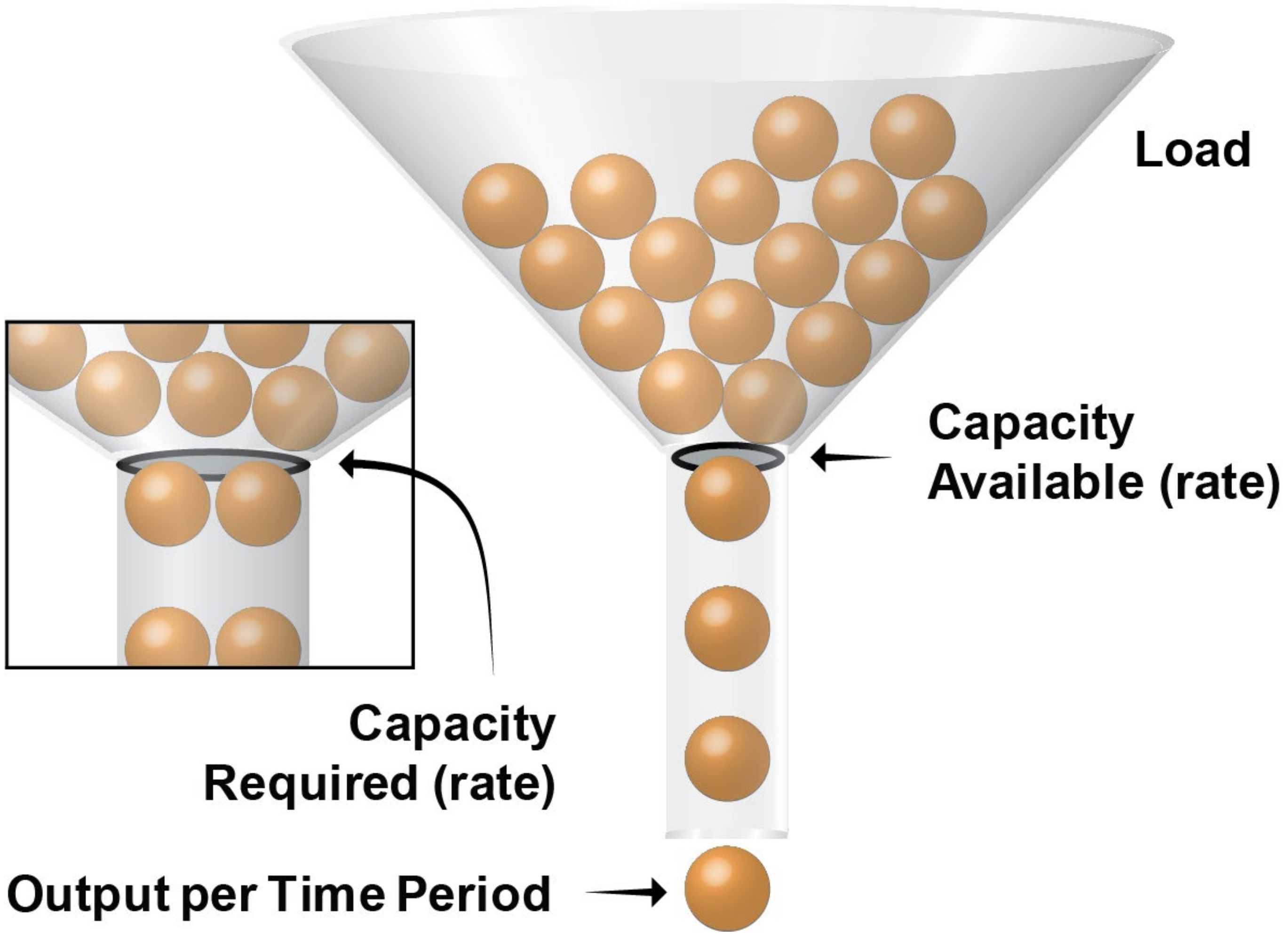
1. Calculate capacity available.
2. Calculate load per time bucket (capacity required), and determine differences between capacity available and capacity required.
3. Create work center load reports.
4. Resolve differences. Adjust available capacity first, and, if necessary, change priority plan to match capacity available.
5. Prepare plan for execution.

## Capacity Measurement Systems

- MRP priority plan in units of output.
- Capacity rarely in units of output.
  - Different work centers have different output units.
  - Some industries use aggregate measures (e.g., barrels of oil).
- Standard time (standard hours) is common unit.
  - Includes setup and run time.
  - Average worker, prescribed methods, time for rest, unavoidable delays (*ASCM Supply Chain Dictionary*).
- Extensive observation.
- Learning curve issue.

# Capacity Requirements Planning (CRP)

## Capacity Available Versus Required



# Capacity Requirements Planning (CRP)

## Inputs to CRP

**Sources of load and work center data**

- Load sources
  - Open orders (already validated) in shop order file
  - Planned order releases from MRP
  - Rework, scrap, process yield, past-due orders, prototypes, tests, etc.
- Work center data
  - Description, workdays, shifts, machines, operators, utilization, efficiency, and standard times

**Routings**
**(lead times here or in work center file)**

Part Number: 202 Description: Door, Family A
Drawing Number: D202X

| Operation No. | Work Center | Setup Time (std. hrs.) | Run Time/ Unit (std. hrs.) | Operation |
|---|---|---|---|---|
| 10 | 13 | 0.15 | 0.07 | Spot weld top, center, bottom to side 1 |
| 20 | 16 | 0.25 | 0.11 | Install glass, molding, caulk, side 2 |
| 30 | 14 | 0.15 | 0.06 | Spot weld side 2 |
| 50 | 11 | 0.05 | 0.05 | Grind |
| 60 | Stores | | | Inventory |

# Capacity Requirements Planning (CRP)

## Inputs to CRP: Manufacturing Calendar

| Week | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|---|
| 1 | | 1 | 2 / 1 | 3 / 2 | 4 / 3 | 5 | 6 |
| 2 | 7 / 4 | 8 / 5 | 9 / 6 | 10 / 7 | 11 / 8 | 12 | 13 |
| 3 | 14 | 15 / 9 | 16 / 10 | 17 / 11 | 18 / 12 | 19 | 20 |
| 4 | 21 / 13 | 22 / 14 | 23 / 15 | 24 / 16 | 25 / 17 | 26 | 27 |
| 5 | 28 / 18 | 29 / 19 | 30 / 20 | 31 / 21 | | | |

Day of the month　　Workday　　○ Non-workday

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# Capacity Requirements Planning (CRP)

## Determining Capacity Available

| May depend on | May be determined by |
|---|---|
| ▪ Product specifications<br>▪ Product mix<br>▪ Number and output rate of equipment<br>▪ Workforce rate of output. | Rated capacity<br>Demonstrated capacity |



APICS

# Efficiency Calculation Exercise

1. Engineering studies indicate that the standard time to produce one unit is 20 minutes. A work center is expected to produce 24 units of item A on a particular day (eight-hour shift). At the end of the day, 30 units were produced. What is the efficiency?

*(30 Parts x 20 Minutes)/60 Minutes per Hour = 10 Standard Hours*

$$\text{Efficiency} = \frac{\text{Standard Hours Produced}}{\text{Actual Hours Worked}} = \frac{10}{8} = 1.25$$

2. The standard cost to produce one unit is $20. From a cost accounting standpoint, was production of item A above or below standard cost?
3. If the work center maintains about the same efficiency rate, what should be done to the predetermined standard hours currently in effect?
4. What are some of the possible causes for the deviation from standard hours in this case and in general?

## Calculating Rated Capacity

Rated Capacity = Available Time × Utilization × Efficiency

Equipment or Workers × Hours in Bucket =
4 Stations × (5 Days × 8-Hour Shifts) = 160 Hours

$$\frac{\text{Actual Hours Worked}}{\text{Available Time in Hours}} = \frac{\text{130 Hours}}{\text{160 Hours}} = 0.8125 = 81.25\%$$

$$\frac{\text{Standard Hours Produced}}{\text{Hours Actually Worked}} = \frac{\text{110 Hours}}{\text{100 Hours}} = 1.1 = 110\%$$

Rated Capacity = 160 Hours × 0.8125 × 1.1 = 143 Hours

## Rated Capacity Calculation Exercise

Based on the following information, calculate the rated capacity of a work center:

- Available time = 240 hours per week
- Actual hours worked = 228
- Efficiency = 103 percent

$$\text{Utilization} = \frac{\textit{Actual Hours Worked}}{\textit{Available Time (Hours)}} = \frac{228}{240} = .95$$

$$\text{Rated Capacity} = \textit{240 Hours} \times .95 \times 1.03 = \textit{234.84 Standard Hours}$$

# Capacity Requirements Planning (CRP)

## Capacity Calculations Exercise

- Available hours = 12,000
- Actual hours worked = 10,440
- Standard hours produced = 11,480
- Utilization $= \dfrac{10{,}440}{12{,}000} \times 100\% = 87\%$
- Efficiency $= \dfrac{11{,}480}{10{,}440} \times 100\% = 110\%$
- Weekly available time $= 3 \times 16 \times 5 = 240$
- Rated weekly capacity $= 240 \times .87 \times 1.10 = 229.7$ standard hours

# Capacity Requirements Planning (CRP)

## Demonstrated Capacity

- Proven capacity: average items made times standard hours per item.
- Production records (average, not maximum).
- Already factors in utilization and efficiency.
- Scenario: Work center actually produced 100, 110, 90, and 120 standard hours over four five-day weeks.

$$\text{Demonstrated Capacity} = \frac{\text{Sum of Standard Hours per Time Bucket}}{\text{Number of Time Buckets}}$$

$$= \frac{(100 + 110 + 90 + 120)}{4}$$

$$= 105 \text{ Standard Hours}$$



APICS

## Calculating Load (Capacity Required) and Differences

1. **Calculate operation time per work order** (open or planned orders). Convert orders to standard time.

2. **Simulate order scheduling** (e.g., backward scheduling) to find start and finish dates per operation per work center.

3. **Establish load profiles.** Sum operation times for work center’s part of work orders done in time bucket.

# Capacity Requirements Planning (CRP)

## Step 1: Calculate Operation Time per Work Order

Part Number: 202 Description: Door, Family A
Drawing Number: D202X

| Operation No. | Work Center | Setup Time (std. hrs.) | Run Time/ Unit (std. hrs.) | Operati |
|---|---|---|---|---|
| 10 | 13 | 0.15 | 0.07 | Spot weld top, center, |
| 20 | 16 | 0.25 | 0.11 | Install glass, molding, |
| 30 | 14 | 0.15 | 0.06 | Spot weld side 2 |
| 50 | 11 | 0.05 | 0.05 | Grind |
| 60 | Stores | | | Inventory |

Order Number: 808

| Operation No. | Work Center | Setup (std. hrs.) | | Qty. | Run Time/Unit (std. hrs.) | | Total (std. hrs.) | 8-Hr. Days (round up) |
|---|---|---|---|---|---|---|---|---|
| 10 | 13 | 0.15 | + ( | 200 × | 0.07 ) | = | 14.2 | 2 |
| 20 | 16 | 0.25 | + ( | 200 × | 0.11 ) | = | 22.3 | 3 |
| 30 | 14 | 0.15 | + ( | 200 × | 0.06 ) | = | 12.2 | 2 |
| 50 | 11 | 0.15 | + ( | 200 × | 0.05 ) | = | 10.2 | 2 |
| 60 | Stores | | | | | | | |

Setup and run for each (planned or open) work order

Operation Time per Work Order = Setup Time + Run Time =
Setup Time + (Quantity × Standard Time per Unit)

## Step 2: Simulate Order Scheduling (Backscheduling)

- Actual scheduling done by PAC.
- Backscheduling starts with end or due date; works backward to determine start date and finish dates for each order in each work center.
- Inputs for backscheduling:
  - Quantity, due date, operation time per work order
  - Operations sequence from routing
  - Queue, wait, and move times and rated or demonstrated capacity from work center file
- Round up to nearest day for setup plus run and for queue, wait, and move.

# Capacity Requirements Planning (CRP)

## Step 2: Simulate Order Scheduling (Backscheduling)

**Work center file data**

| Work Center | Queue (days) | Wait (days) | Move (days) |
|---|---|---|---|
| 13 | 2 | 1 | 1 |
| 16 | 1 | 1 | 1 |
| 14 | 1 | 1 | 1 |
| 11 | 1 | 1 | 1 |

Order Number: 808

| Operation No. | Work Center | Start Date (a.m.) | Queue (days) | Operation (days) | Finish Date (p.m.) | Wait (days) | Move (days) |
|---|---|---|---|---|---|---|---|
| 10 | 13 | 32 | 2 | 2 | 36 | 1 | 1 |
| 20 | 16 | 38 | 1 | 3 | 42 | 1 | 1 |
| 30 | 14 | 44 | 1 | 2 | 47 | 1 | 1 |
| 50 | 11 | 49 | 1 | 2 | 52 | 1 | 1 |
| 60 | Stores | 54 | | | | | |

End here

Start here

**54 – 1 – 1 = 52**

# Capacity Requirements Planning (CRP)

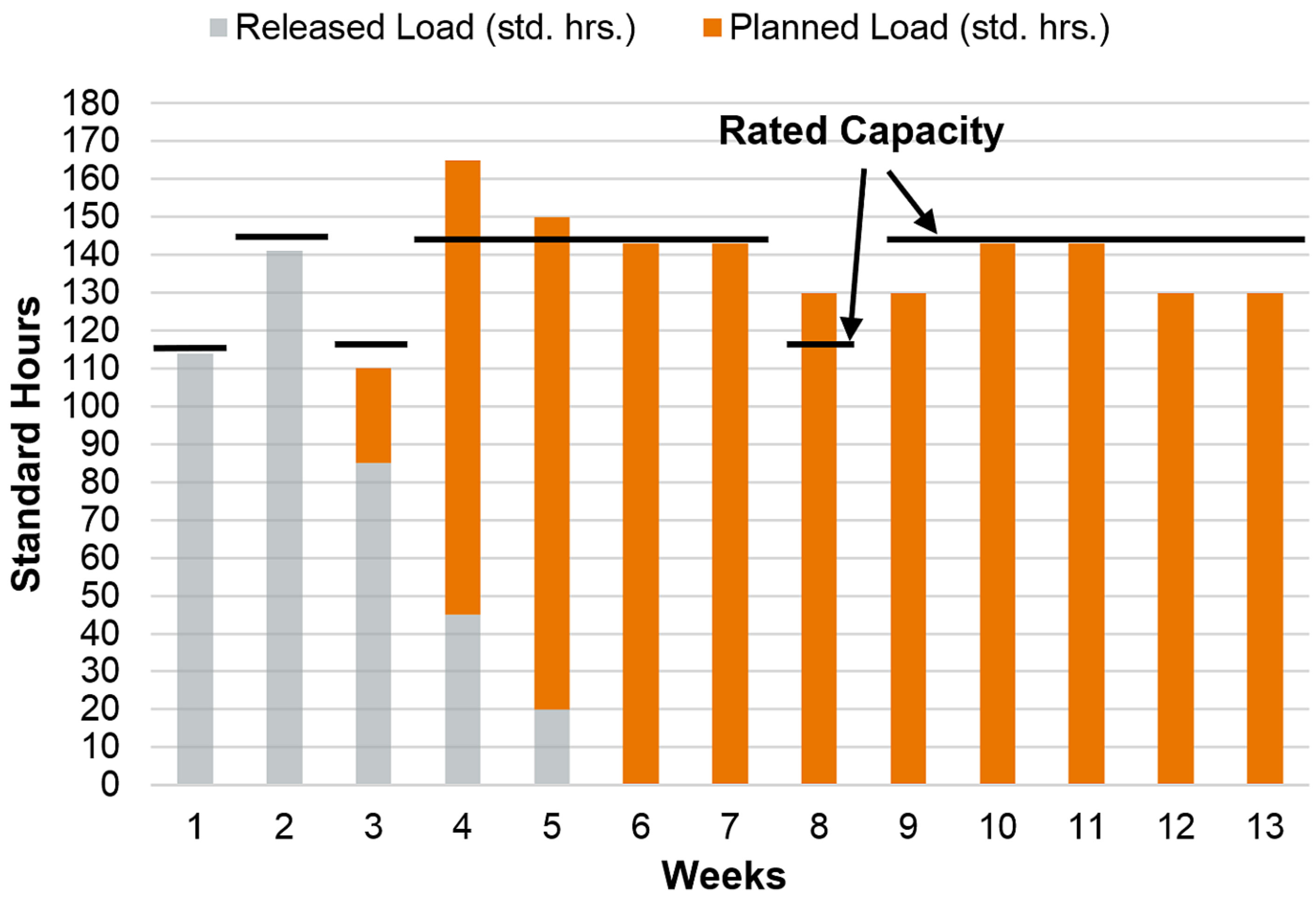
## Step 3: Establish Load Profiles

| Work Center: 13 | Load Profile | | | | |
|---|---|---|---|---|---|
| **Week** | **1** | **2** | **3** | **4** | **5** |
| **Released Load (std. hrs.)** | 114 | 145 | 85 | 45 | 20 |
| **Planned Load (std. hrs.)** | 0 | 0 | 25 | 120 | 130 |
| **Total Load** | 114 | 145 | 110 | 165 | 150 |
| **Rated Capacity** | 114 | 143 | 114 | 143 | 143 |
| **(Over)/Under Capacity** | 0 | (2) | 4 | (22) | (7) |

- Future capacity for work center based on released or planned orders for period
- 4-day weeks: 1 and 3
- 5-day weeks: 2, 4, 5

# Capacity Requirements Planning (CRP)

## Load Profile as Stacked Bar Chart



# Capacity Requirements Planning (CRP)

## Schedule Worksheet

Order quantity = 100 units

From route sheet

| Operation | Work center | Setup time (standard hours) | Run time (standard hours) | Total time (standard hours) | Days |
|---|---|---|---|---|---|
| 10 | 8 | 1.5 | 0.2 | 21.5 | 3 |
| 20 | 9 | 0.5 | 0.3 | 30.5 | 4 |

From work center files

| Work center | Queue (days) | Wait (days) | Move (days) |
|---|---|---|---|
| 8 | 2 | 1 | 1 |
| 9 | 4 | 1 | 1 |

Schedule

| Operation | Work center | Arrival date | Queue (days) | Operation (days) | Finish date | Wait and move |
|---|---|---|---|---|---|---|
| 10 | 8 | 103 | 2 | 3 | 108 | 2 |
| 20 | 9 | 110 | 4 | 4 | 118 | 2 |
| Store | Stores | 120 | | | | |

## Order Scheduling Exercise

Use the information shown in the schedule below.

Backschedule the shop order from the due date, or arrival date, at stores on day 150 to the finish dates and arrival dates of prior operations. All times are in days.

| Operation | Work center | Arrival date | Queue time | Operation time | Finish date | Wait and move |
|---|---|---|---|---|---|---|
| 10 | D2 | 127 | 3 | 2 | 132 | 2 |
| 20 | B1 | 134 | 5 | 4 | 143 | 2 |
| 30 | C4 | 145 | 2 | 1 | 148 | 2 |
| Store | Stores | 150 | | | | |

# Resolving Differences

## Change capacity first.

- Add/remove shift.
- Overtime/undertime, weekends.
- Hire/lay off over longer horizon.
- Cross-train workers.
- Alternate routing.
- Improve process.
- Know worker actual capabilities.

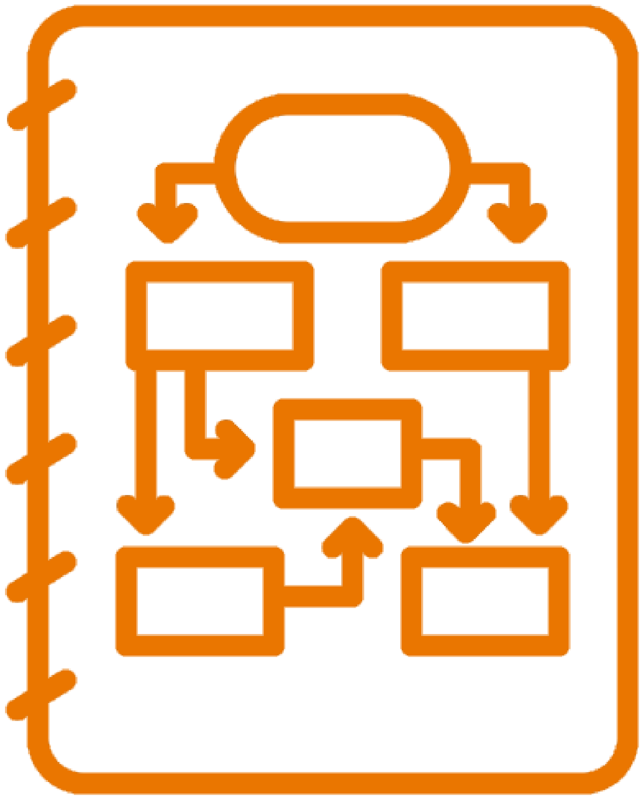
## Alter load and resimulate.

- Subcontract/outsource (reduces load) or insource.
- Late/early order release.
- Alter lot sizes or workload.
- Revise MPS (last resort).
- Resimulate schedule: New capacity issues?

# Capacity Requirements Planning (CRP)

## Redistributing Load

- Use alternate work centers.
- Use alternate routings.
- Modify operation priorities.
- Revise MPS or lot sizes.
- Run overlapping operations.
- Use lot splitting.



# CPIM

CERTIFIED IN PLANNING
AND INVENTORY MANAGEMENT

## SECTION D:
## MANAGING DETAILED SCHEDULES AND SCHEDULING MATERIALS

APICS

ascm

# Section D Overview

## Section D Learning Objectives

- Labor schedules and managing human resources
- Shop packets
- Manufacturing orders versus work orders
- Alternate routings
- Managing queue size
- Scheduling incoming materials
- Managing exceptions
- Measuring capacity planning performance

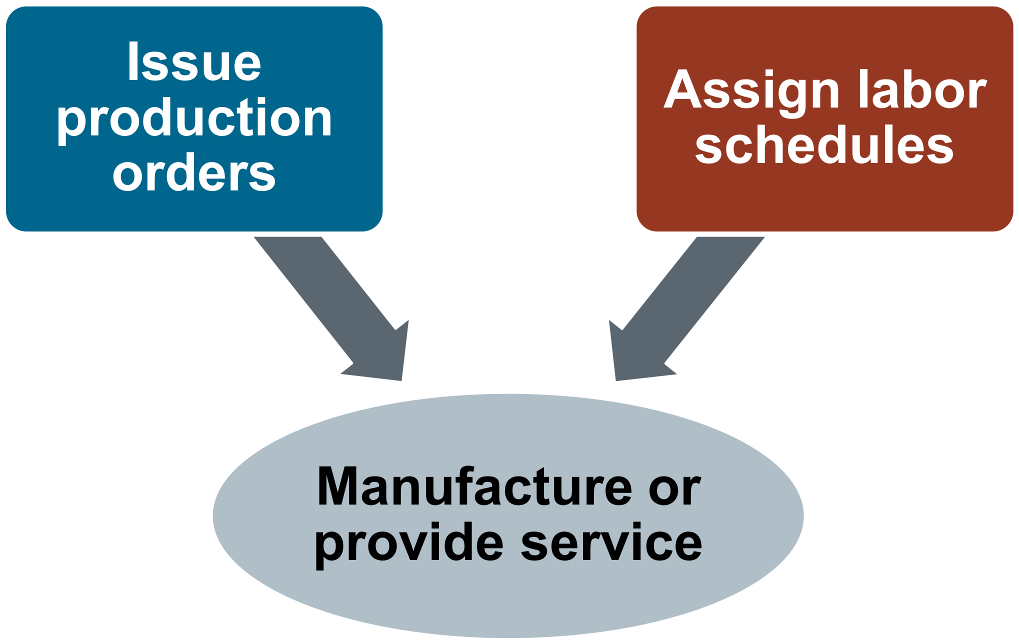
# Labor/Production Scheduling and Managing HR

## Setting Labor Schedules

- Scheduling software
  - Customizable scheduling rules
  - Templates
  - Integrating shop calendars for availability
- Labor skills matrix
  - Relative employee skill/knowledge level
  - Need for supervision
- Fixed, floating, or flexible schedules

## Issuing Production Orders and Assigning Labor

- Within constraints of supply and demand
- Needed elements
  - Start/complete dates
  - Authorization
  - Last check
  - Shop packet



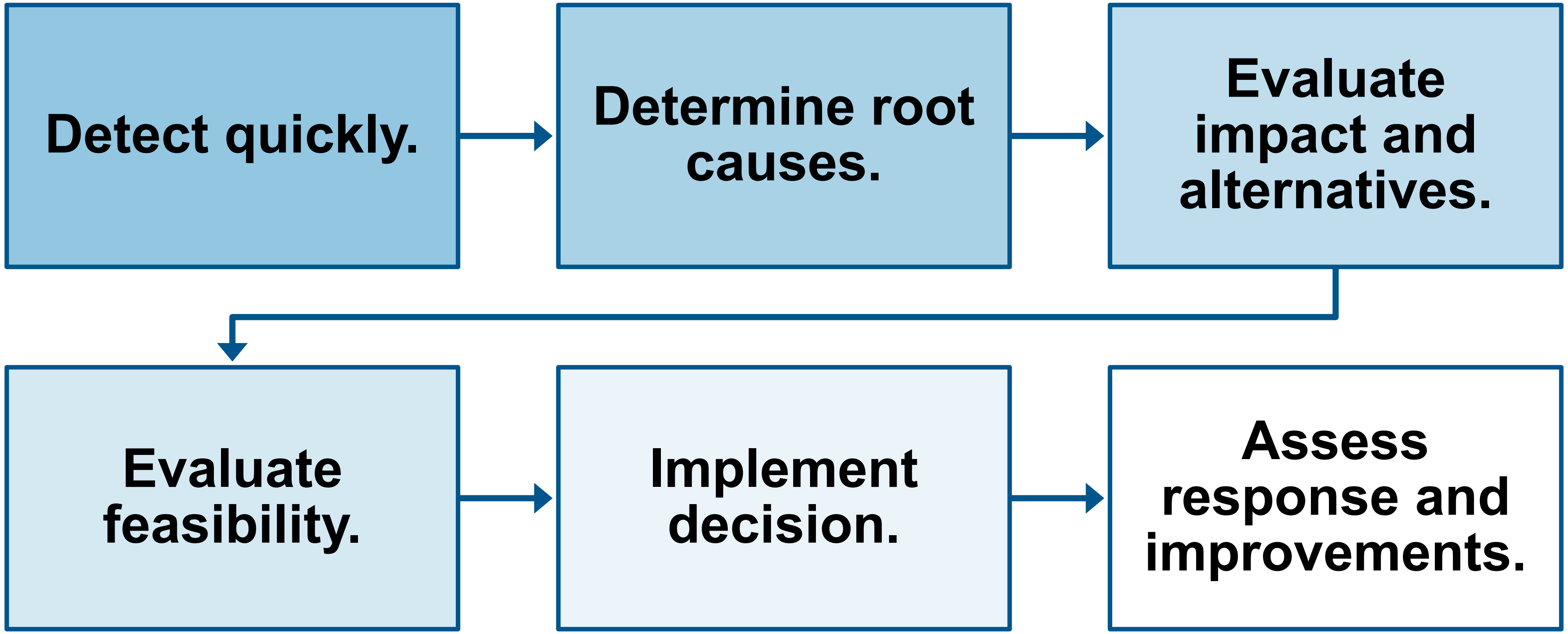
## Managing Human Resources: Implement and Help Improve

- Skilled managers are fair, communicate clearly, and see issues as problems to be solved.
- Implement effective policies and procedures to stay consistent with the organization’s values and expectations.
  - Explain in terms workers easily understand (e.g., in native language).
- Use effective work processes to manage tasks and workplace situations.
  - Evaluate level of detail (neither abstractions nor too detailed).
- Use performance management systems that incorporate feedback and rewards/recognition.
- Job enlargement, job enrichment, and job rotation

# Routings and Queue Sizes

| Managing workflows and routings | Managing queue size |
|---|---|
| ▪ Adjust process and transfer batch sizes as needed:<br>– Lot splitting<br>– Alternate routings<br>▪ Consider tradeoffs (e.g., losing workstation efficiency but gaining net efficiency). | ▪ Consider impact of queue size on queue time.<br>▪ Use I/O control, information on load from schedule, status of open orders.<br>▪ Increase capacity at affected workstations (e.g., reallocate staff, add overtime). |

## Exception Management Process



## Communications and Vendor-Managed Inventory

| Communications | VMI |
|---|---|
| ▪ Robust and timely communication can<br>– Reduce lead times and overhead costs<br>– Preserve good relations with suppliers.<br>▪ Changes can be limited by supplier capacity and contracts. | ▪ Given uncertain demand, vendor-managed inventory (VMI) can reduce<br>– Risk<br>– Inventory level<br>– Cost. |

## Capacity Planning Performance Indicators

- Performance to schedule
- Customer service ratings
- Unbudgeted increases in costs
- Orders declined due to lack of capacity
- Quality problems
- Stockouts
- Inventory metrics
- Excessive utilization levels

APICS