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CERTIFIED IN PLANNING
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MODULE 4: INTERNAL SUPPLY

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Module 4 Overview

Supply

- Section A: Functional and Operational Strategies
- Section B: Environments, Types, and Layouts
- Section C: Creating the Master Schedule
- Section D: Rough-Cut Capacity Planning and MPS Validation
- Section E: Using and Maintaining the Master Schedule
- Section F: Material Requirements Planning
- Section G: CRP, Order Promising, and Final Assembly Scheduling
- Section H: Changes and Supply Disruptions

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SECTION A:
FUNCTIONAL AND OPERATIONAL STRATEGIES

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Section A Overview

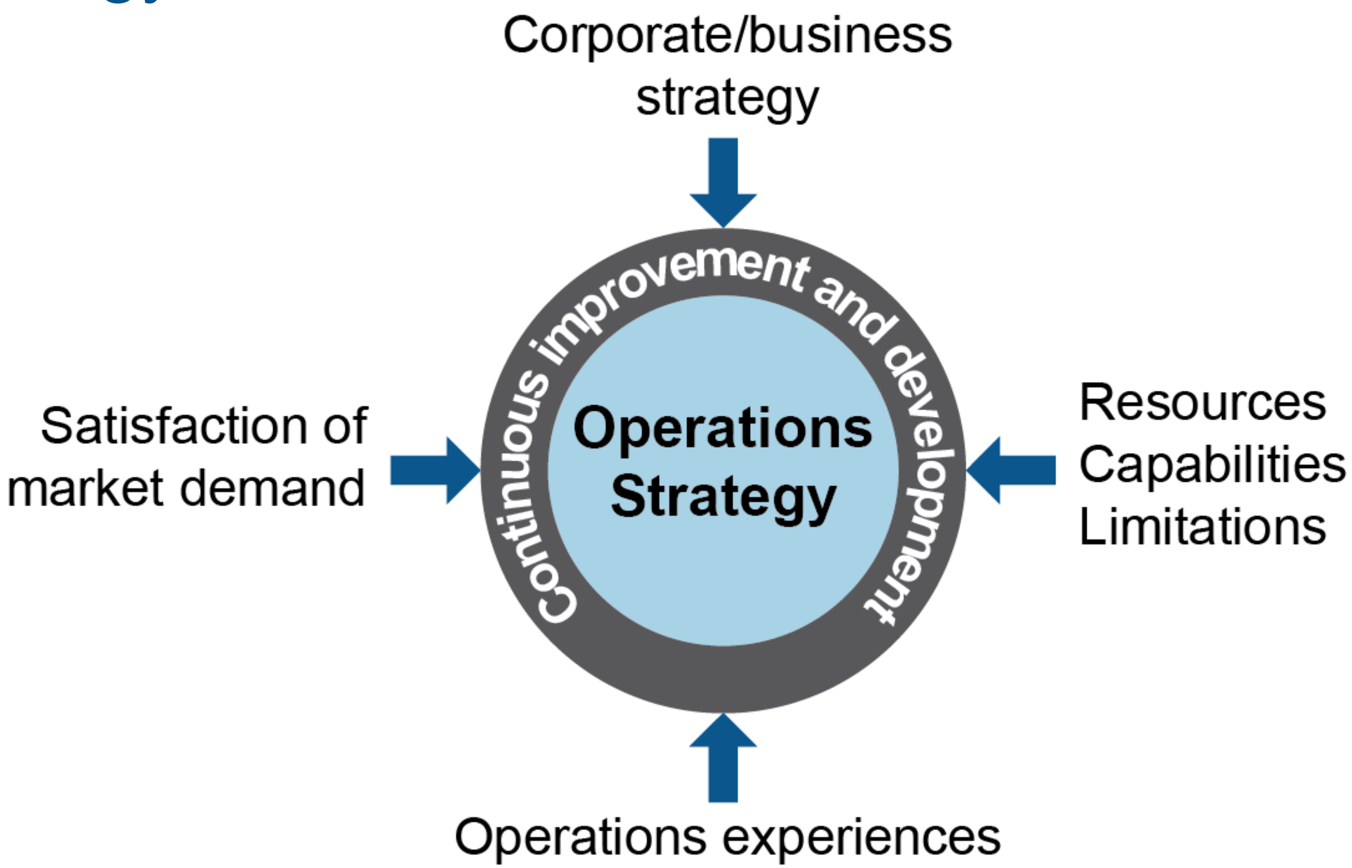
Section A Learning Objectives

- Operations strategy and the forces that shape it
- Organizational strategy
- Technology choices and cost, efficiency, and agility
- Manufacturing environments, process types, and technology

Functional and Operations Strategies

Functional strategy	Operations strategy
"A strategy that is built from the business strategy for various business functions such as finance, marketing, and production."	▪ Total pattern of decisions that shape long-term capabilities and contribution to overall strategy ▪ Should be consistent with overall strategy ▪ Distinct from operational management – Longer time frame – Broader perspective – Higher level of focus

Forces Acting on Operations Strategy



Key Areas in Operations Strategy

Process Technology and Assessments

Process technology

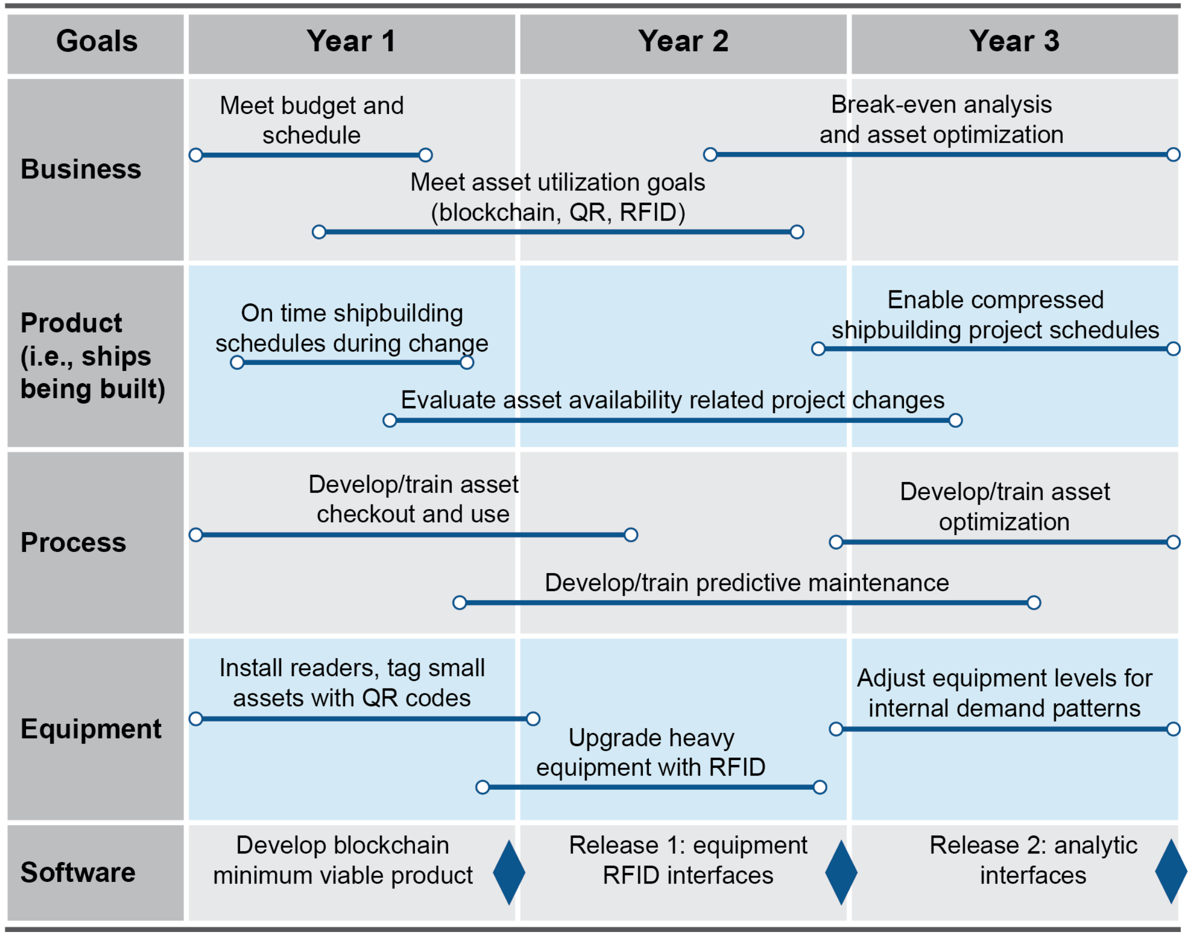
Priority	Technology Effects
Speed	Throughput and information sharing
Dependability	Coordination and feedback loops
Flexibility	Scale up/down without undue hardship; easy changeover
Quality	Standardization
Cost	Efficient/effective direct or indirect processes

Evidence-based assessments

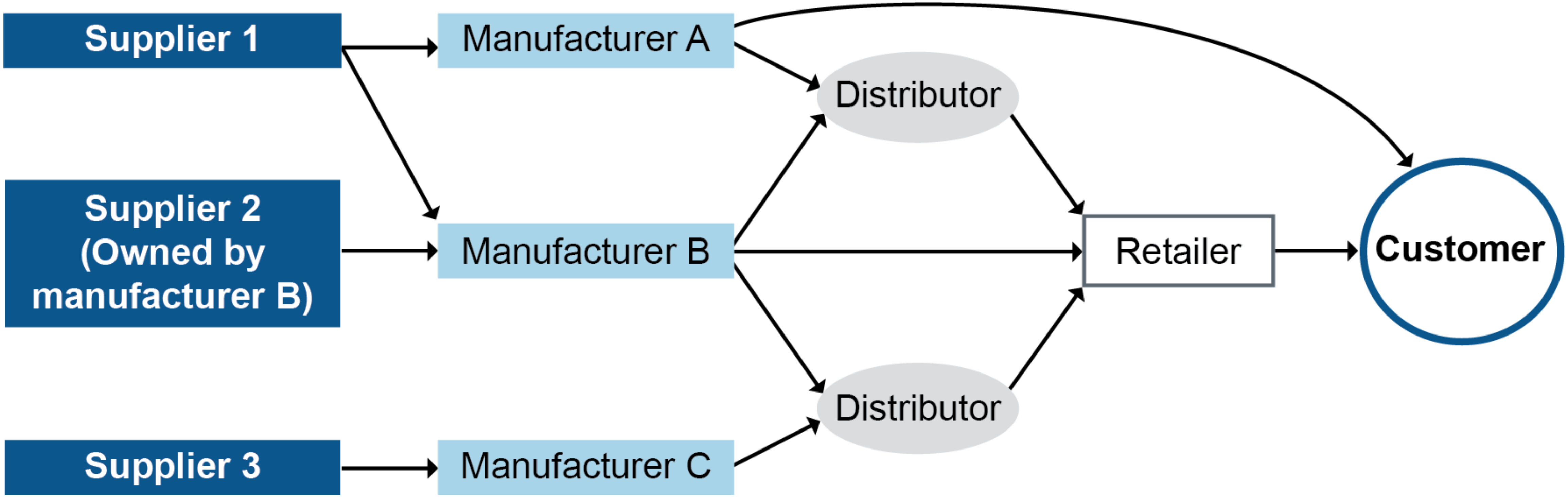
- Avoid “gut feelings” or bias toward new technologies without establishing need.
- Assess benefits and downside/risk.
- Gather data on improvements to speed, quality, etc.
- Assess financial impact (reasonable return, timing).
- Do pilot before committing.

Analysis for Functional and Operational Strategies

Technology Road Mapping (Shipbuilder Example)



Supply Chain Network Design



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SECTION B:
ENVIRONMENTS, TYPES, AND LAYOUTS

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Section B Learning Objectives

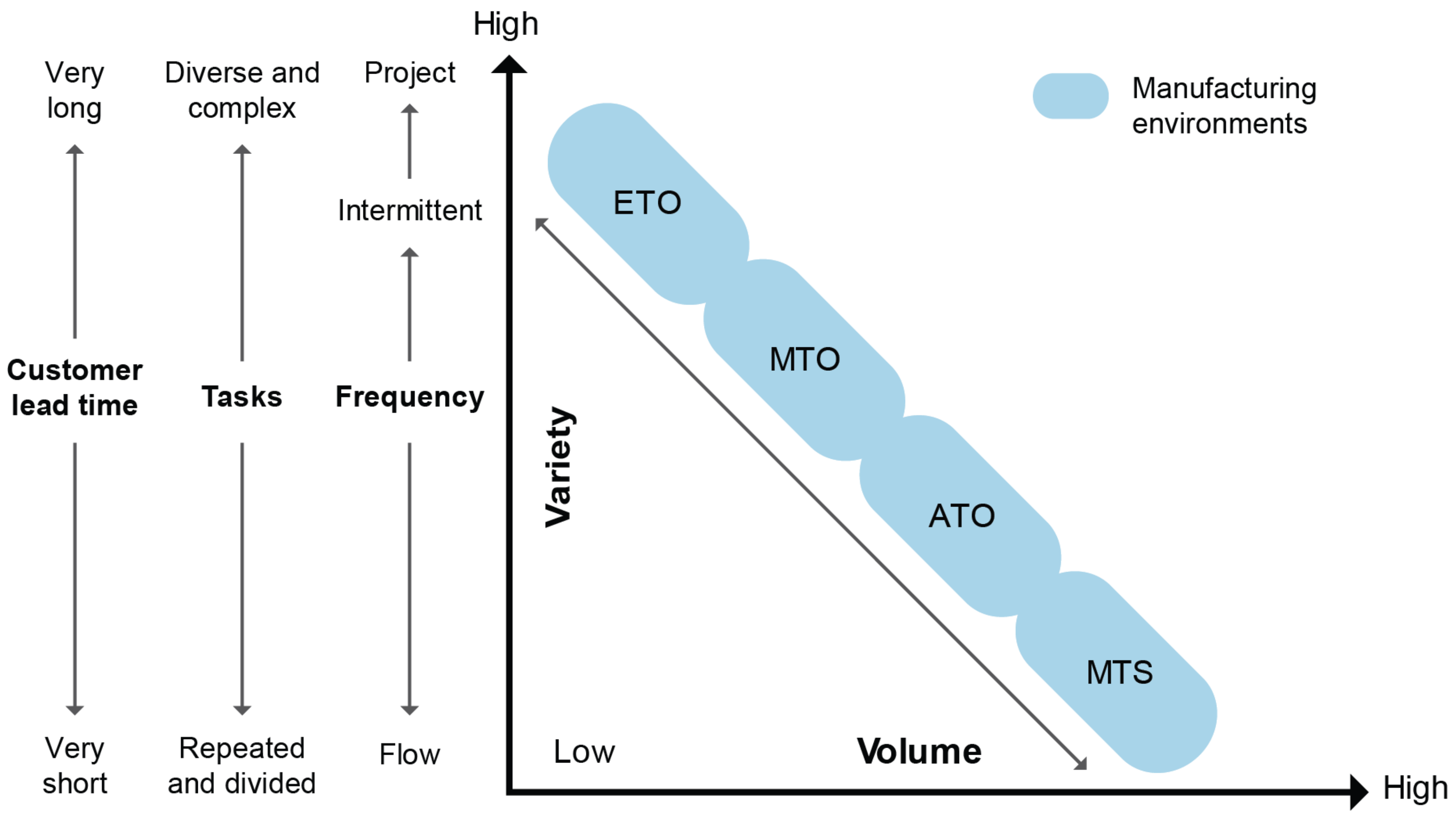
- Push-pull decoupling location and best manufacturing environment
- Forecast-driven versus demand-driven strategies
- Impact of volume and variety on technology decisions
- Tradeoffs in product-process matrix and service design matrix
- Layout choices
- Processes, layouts, and product/service life cycles

Push-Pull Operational Strategies

Forecast-driven enterprise	Demand-driven enterprise
▪ Schedules based on forecasts ▪ Unstable demand ▪ Bullwhip effect is an issue ▪ Addressing bullwhip effect – Better visibility in both directions, especially regarding promotions – Rely less on forecasting	▪ Demand-driven supply network (pull system) – Goals: reduce inventory, maintain customer satisfaction ▪ Demand-driven planning – Demand-driven materials requirements planning (DDMRP) – Dynamic strategic inventory buffers

Push-Pull Strategy and Manufacturing Environment

Product-Process Matrix and Manufacturing Environments



Manufacturing Environments

	Information	Planning	Control
ETO	Engineering design and feasibility	Detailed engineering design and project management	Adjust capacity to customer needs.
MTO	Product specifications and costing	Engineering and manufacturing capacity	Adjust configurations to customer needs.
ATO	Configuration management	Available options and lead time quotation	Meet manufacturing schedule and delivery dates.
MTS	Forecast reliability	Inventory levels	Ensure customer service levels.

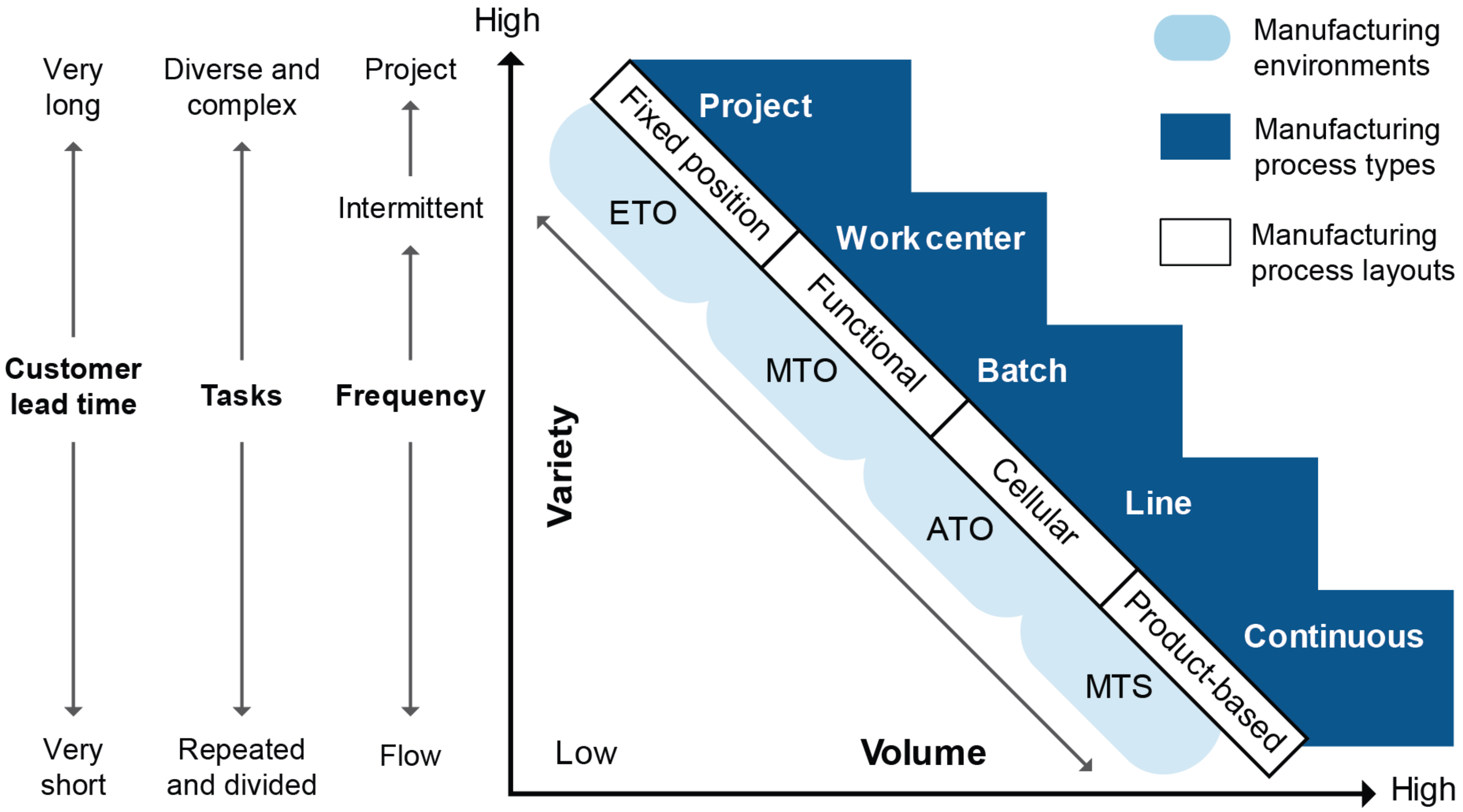
Push-Pull Strategy and Manufacturing Environment

Hybrids and Subtypes

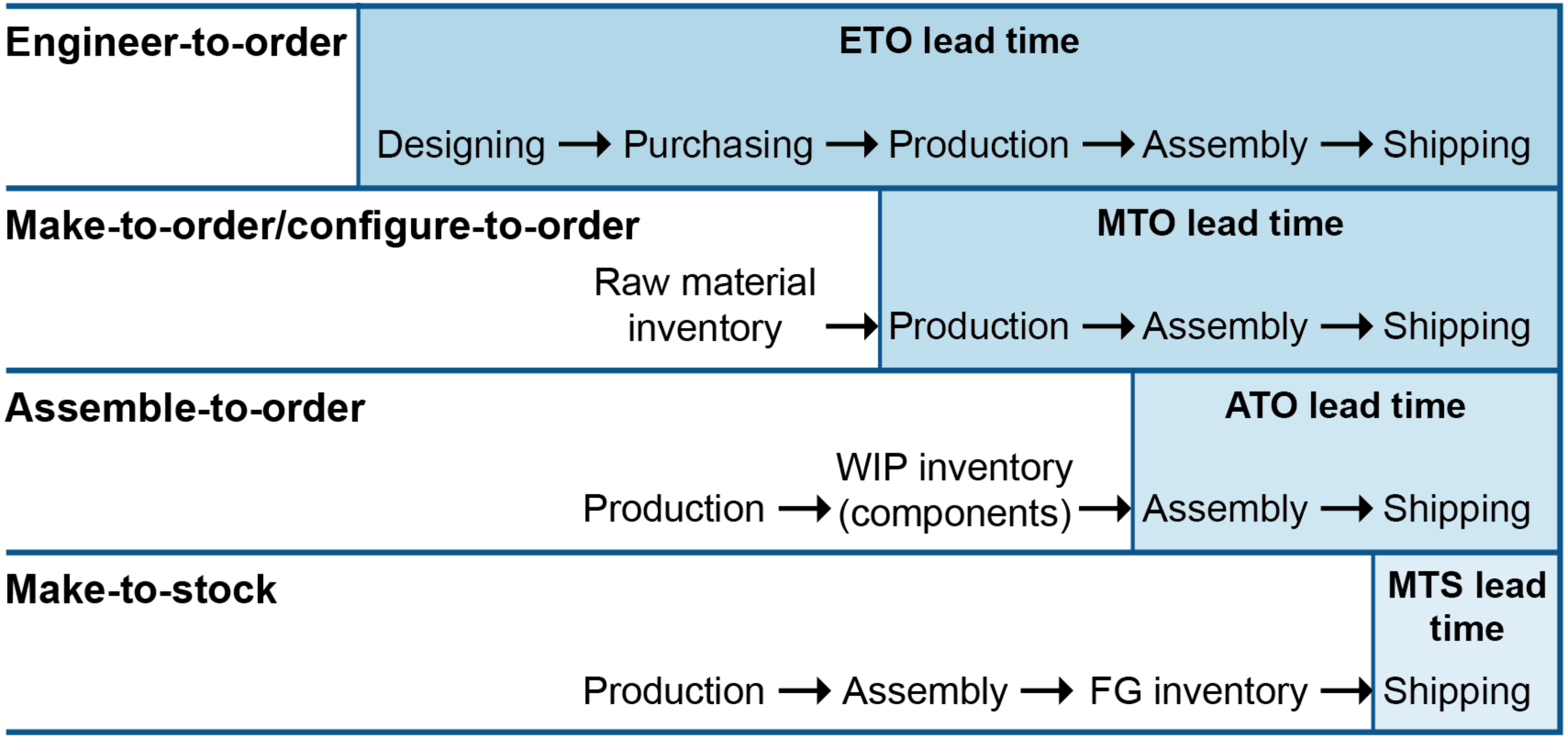
- **Configure-to-order:** Make components after order, so same lead time as MTO.
- **Mass customization:** Customize at near same cost as high-volume process.
- **Postponement:** Delay final differentiation (e.g., at distribution center) for less inventory, faster response.
- **Modular design:** Standardization into modules; more design expense but simpler assembly/maintenance; basis for ATO.
- **Package-to-order:** Bulk storage until order.
- **Remanufacturing:** Restoring product to like-new condition.

Product-Process Matrix

Environments and Process and Layout Choices



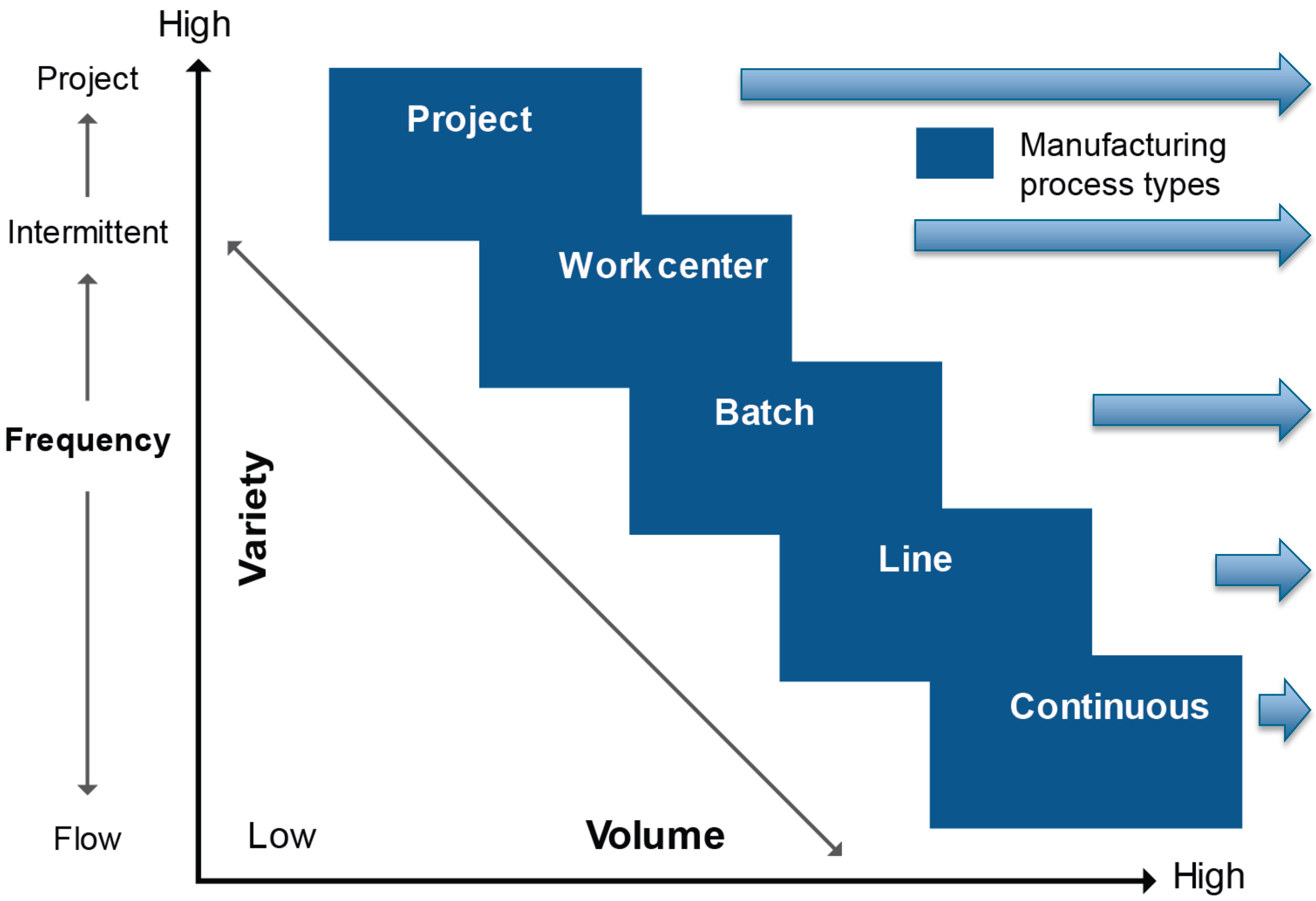
Lead Time per Manufacturing Environment



Common Manufacturing Environment Characteristics

Environment	Volume	Variety	Design	Cycle Length
ETO	Low	High	Unique	Longest
MTO	Medium-low	Medium-high	Unique configuration of standard or custom features	Long
ATO	Medium-high	Medium-low	Customized configuration of standard components	Medium
MTS	High	Low	Fixed but with many stock keeping units (SKUs)	Shortest

Manufacturing Process Type Comparison

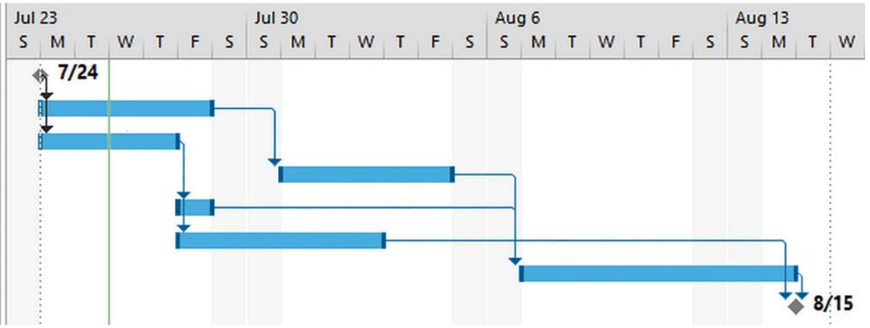


- Dedicated work centers with highly skilled workers; intermittent flow
- Work centers grouped by common function; intermittent due to custom orders and routing
- Grouped by function or cell; higher volume and longer queue; moderate skill level
- High volume; controlled rate; medium to low skill level
- Dedicated work centers, end to end; inflexible; precision required

Project Process Type

- Projects must have unique deliverables (large and complex) and a deadline.
- Control:
  - Time
  - Cost
  - Scope (what will and will not be done)

Task Name	Duration	Start	Finish	Predecessors
Start	0 days	7/24	7/24	
Task A	5 days	7/24	7/28	1
Task B	4 days	7/24	7/27	1
Task C	5 days	7/31	8/4	2
Task D	1 day	7/28	7/28	3
Task E	4 days	7/28	8/2	3
Task F	6 days	8/7	8/14	4,5
Finish	0 days	8/15	8/15	6,7



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Determining Process Type and Layout

Intermittent Process Type

- Varied routings and lots
- Unbalanced workflows
- High WIP, lead times
- Complex MPC (bottlenecks)
- Flexible equipment/labor

- Work center (job shop)
  – Smaller lots
  – Need fast setups
- Batch (batch flow or lot)
  – Longer runs, fewer setups
  – Shorten moves

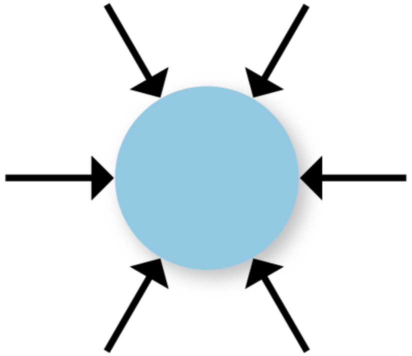
Determining Process Type and Layout

Flow Process Type

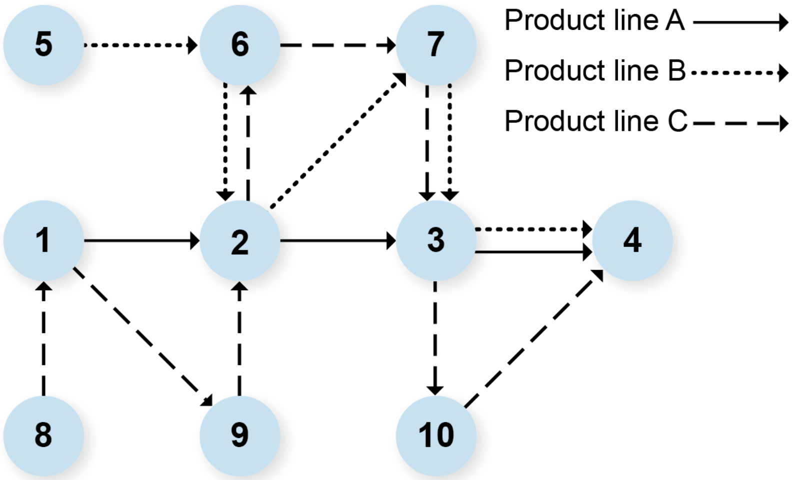
- Standardized products with devoted lines
- Nearly constant rate, so low WIP and short lead times
- Specific products only (New products need new lines.)
- Hard to change; volume must justify high capital cost
- Line process type: discrete units
- Continuous process type: liquids or bulk solids

Process Layouts

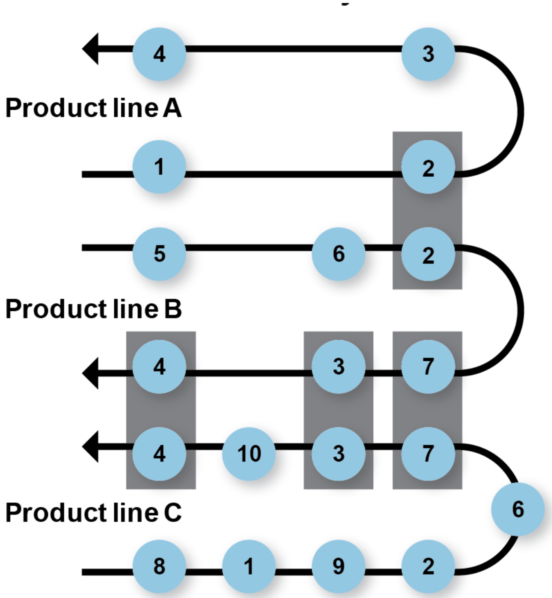
Fixed



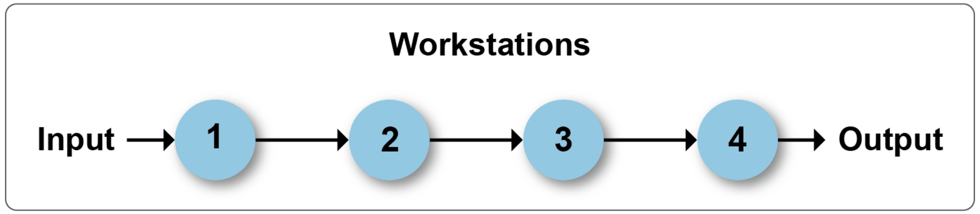
Functional



Cellular

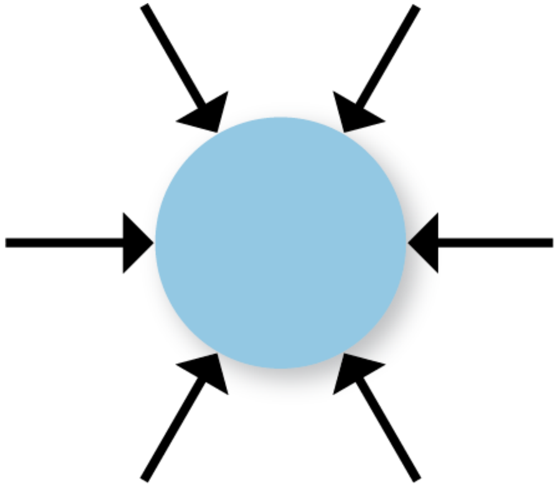


Product-based



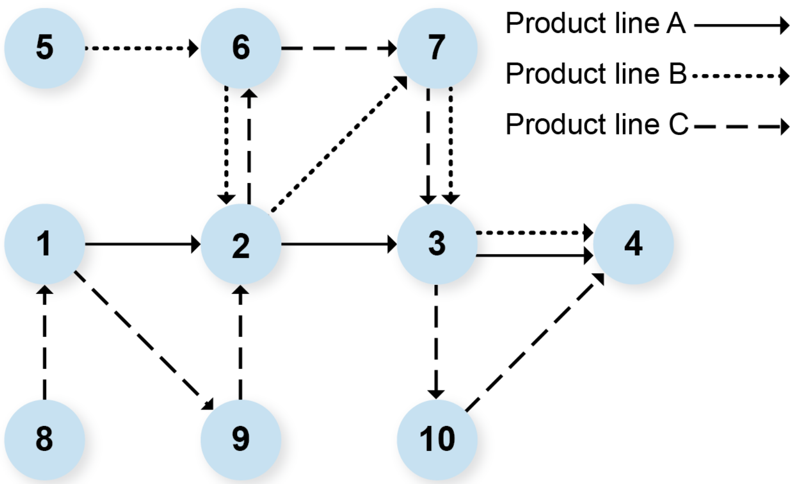
Fixed-Position Layout

Benefits	Limitations
▪ High independence of production centers. ▪ High flexibility and adaptability. ▪ Low capital investment. ▪ Low amount of material movement.	▪ High effort when moving machines to product location. ▪ Highly skilled labor is needed. ▪ Limited storage space for materials.



Functional Layout

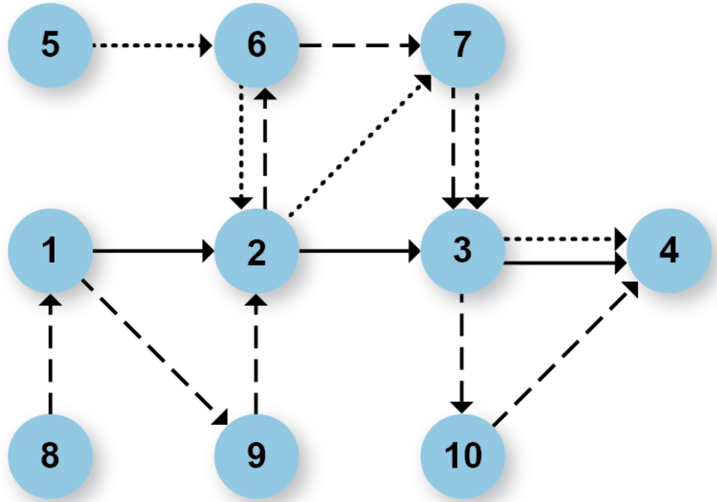
Benefits	Limitations
▪ High equipment flexibility and need for fewer machines. ▪ More specialized supervision. ▪ Ability to transfer work leads to low risk for loss of production due to machinery breakdowns.	▪ Queue time leads to higher total production time. ▪ Bottleneck potential is high. ▪ Higher handling costs due to longer product flow line.



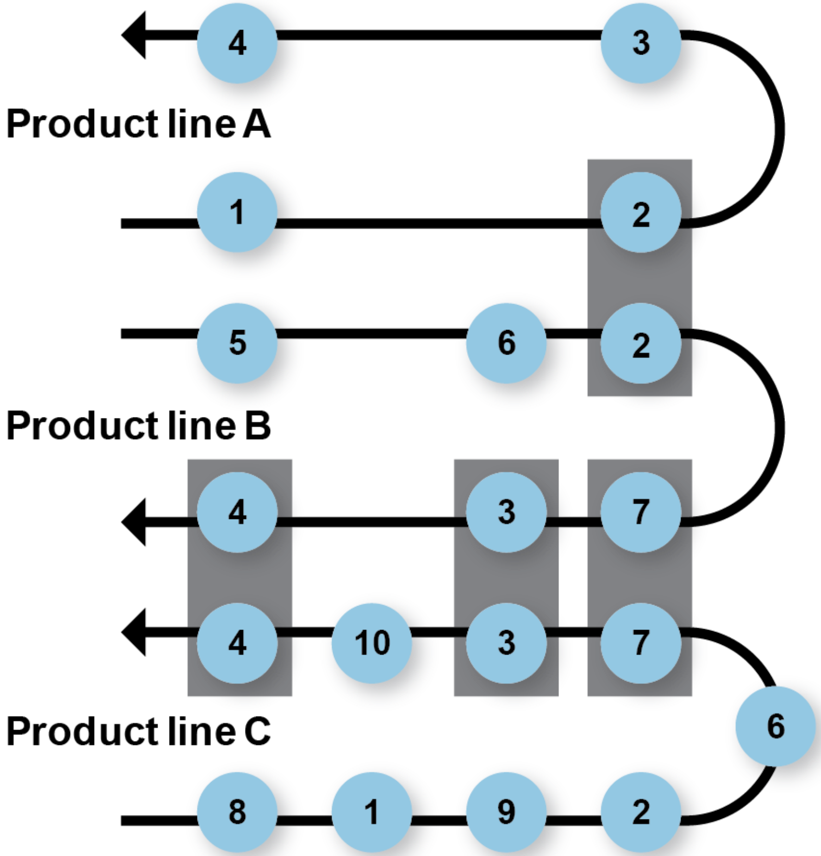
Determining Process Type and Layout

Cellular Layout

From this functional layout…



To these cellular layouts…



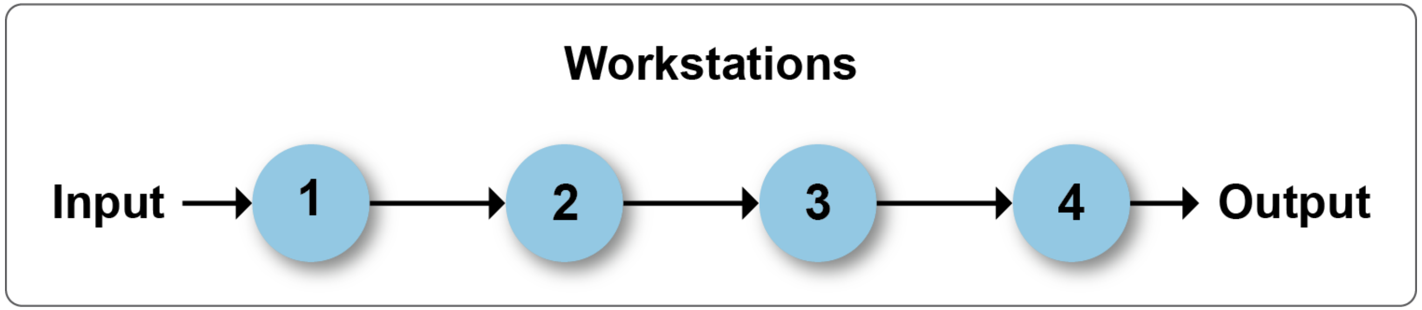
Cellular Layout (continued)

Benefits	Limitations
▪ Minimizes material-handling distances/factory floor space needs. ▪ Faster processing time. ▪ No work-in-process inventory accumulates. ▪ Lead times shrink. ▪ Reduced finished goods inventory.	▪ Works only if products can be grouped into product families. ▪ Locating work centers or cells near each other.

Determining Process Type and Layout

Product-Based Layout

Benefits	Limitations
▪ Lower total material-handling costs. ▪ Less work in process. ▪ Less floor area occupied by material in transit and storage. ▪ Simplicity of production control. ▪ Total production time is minimized. ▪ High degree of equipment and labor utilization.	▪ Limited flexibility. ▪ Manufacturing costs increase with a decrease in volume ▪ Single machine breakdown could shut down whole production line. ▪ Cannot easily respond to system changes.



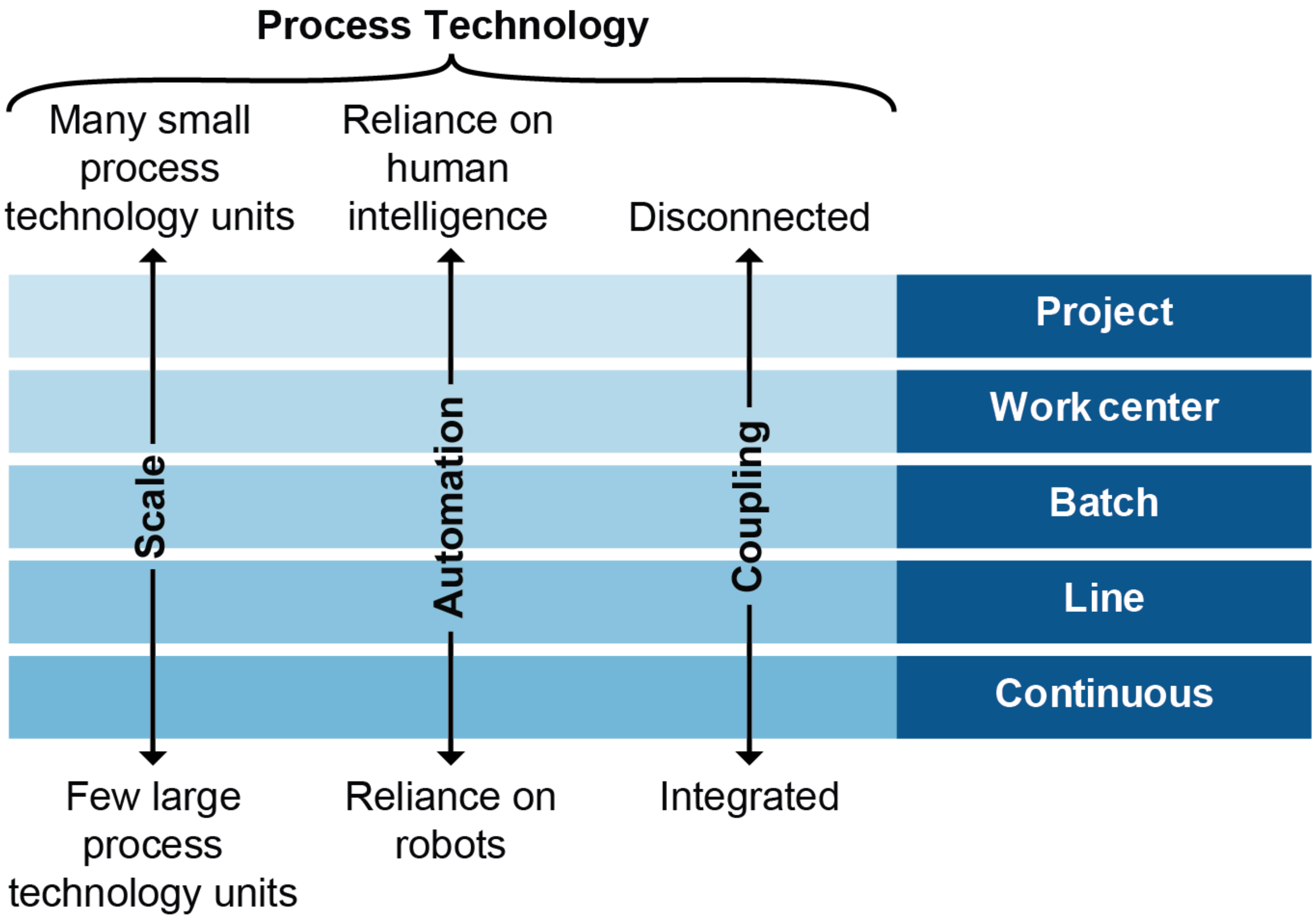
Product-Based Layout Versus Functional Layout Activity

	Product	Functional
Capital cost	↑	↓
Flexibility	↓	↑
Annual setup cost	↓	↑
Run cost	↓	↑
WIP inventory	↓	↑
Production and inventory control costs	↓	↑
Lead time	↓	↑

Process and Layout Tradeoffs

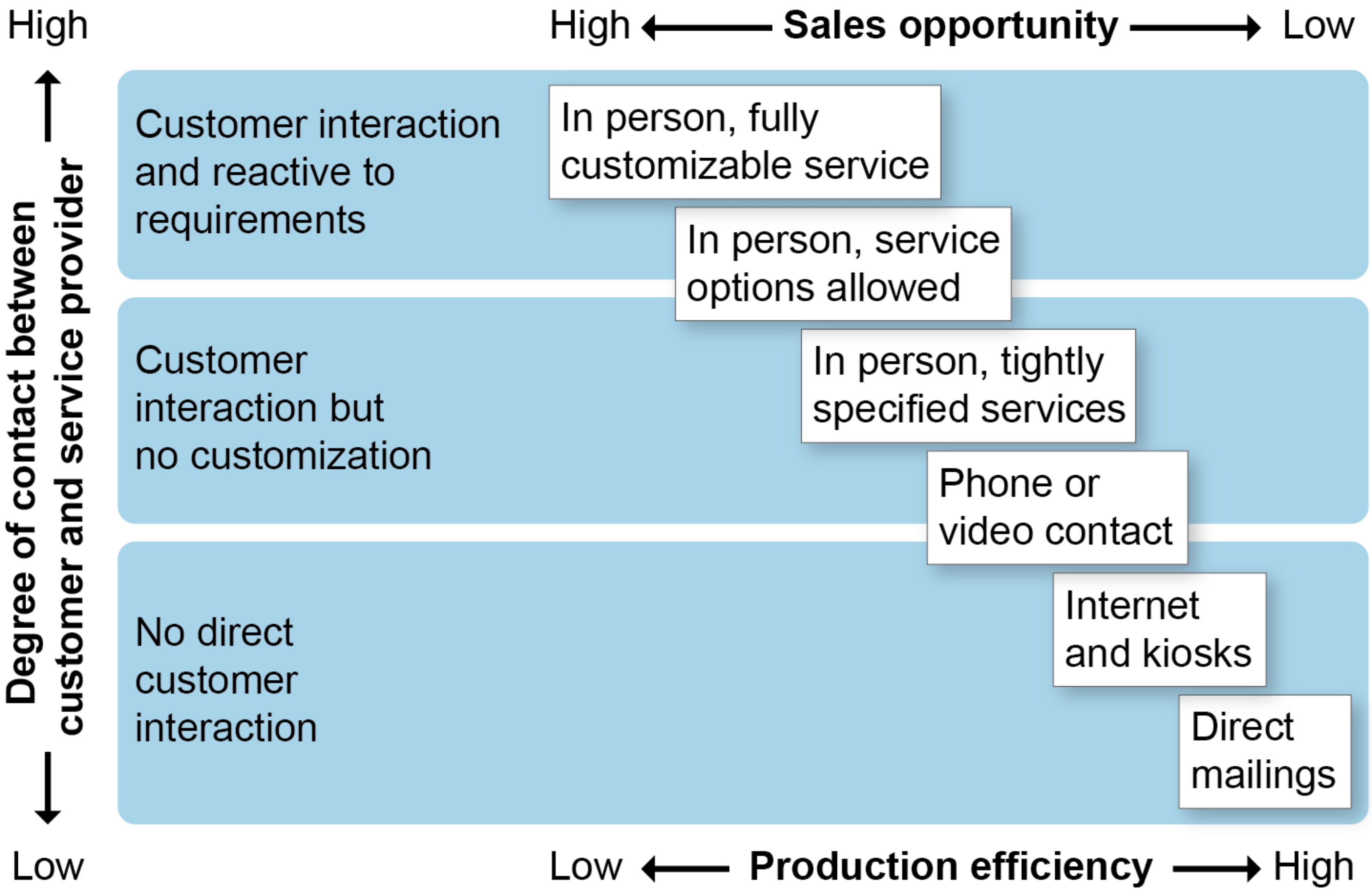
	Speed	Dependability	Flexibility	Quality	Cost
Project		Very high	Very high		
Work center		Very high	Very high		
Batch		Very high	Very high		
Line	Very high				Very high
Continuous	Very high				Very high

Process Technology and Process Types

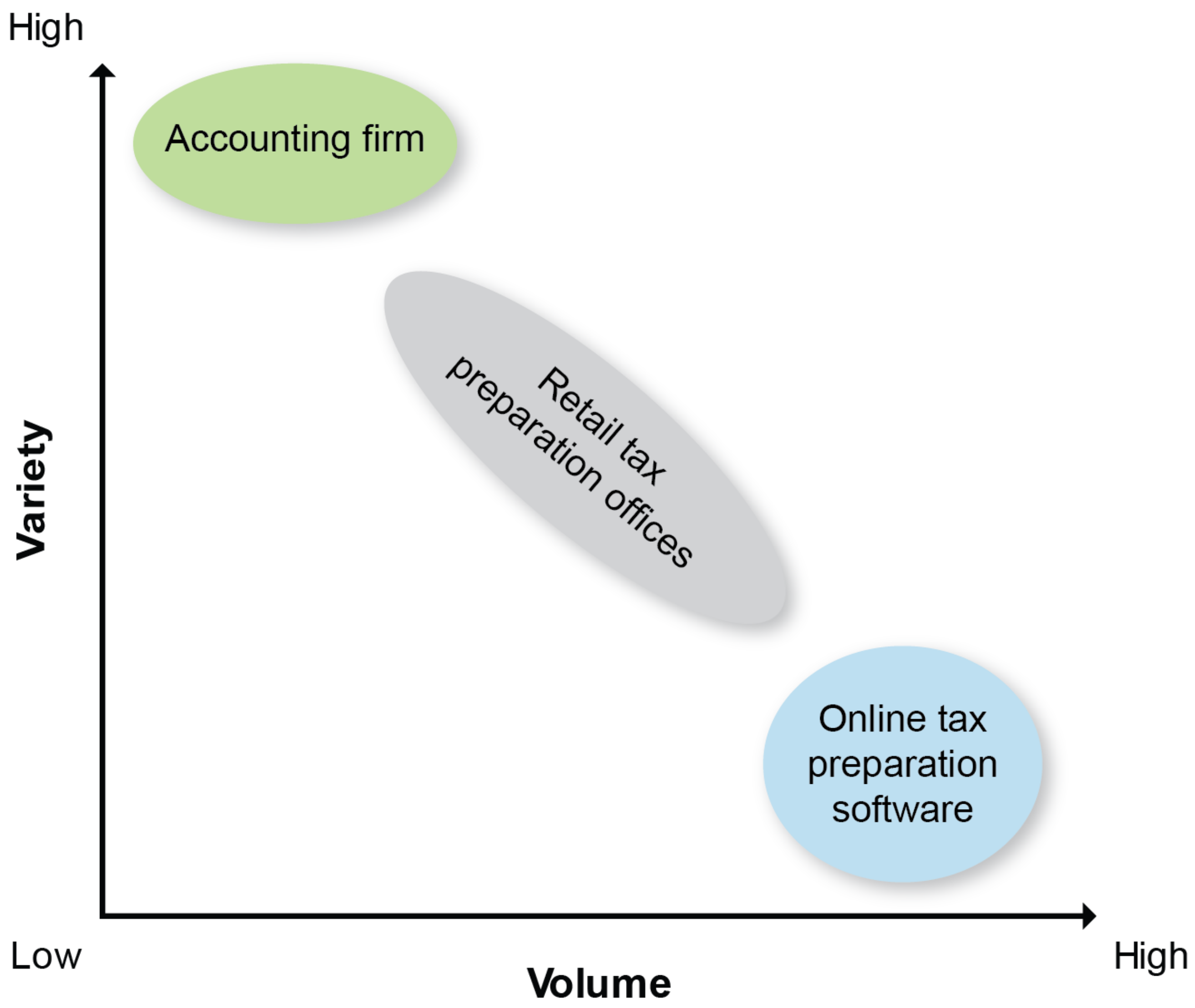


Service Design and Project Management for ETO or Improvements

Service Design Matrix



Product-Process Matrix and Service Environments



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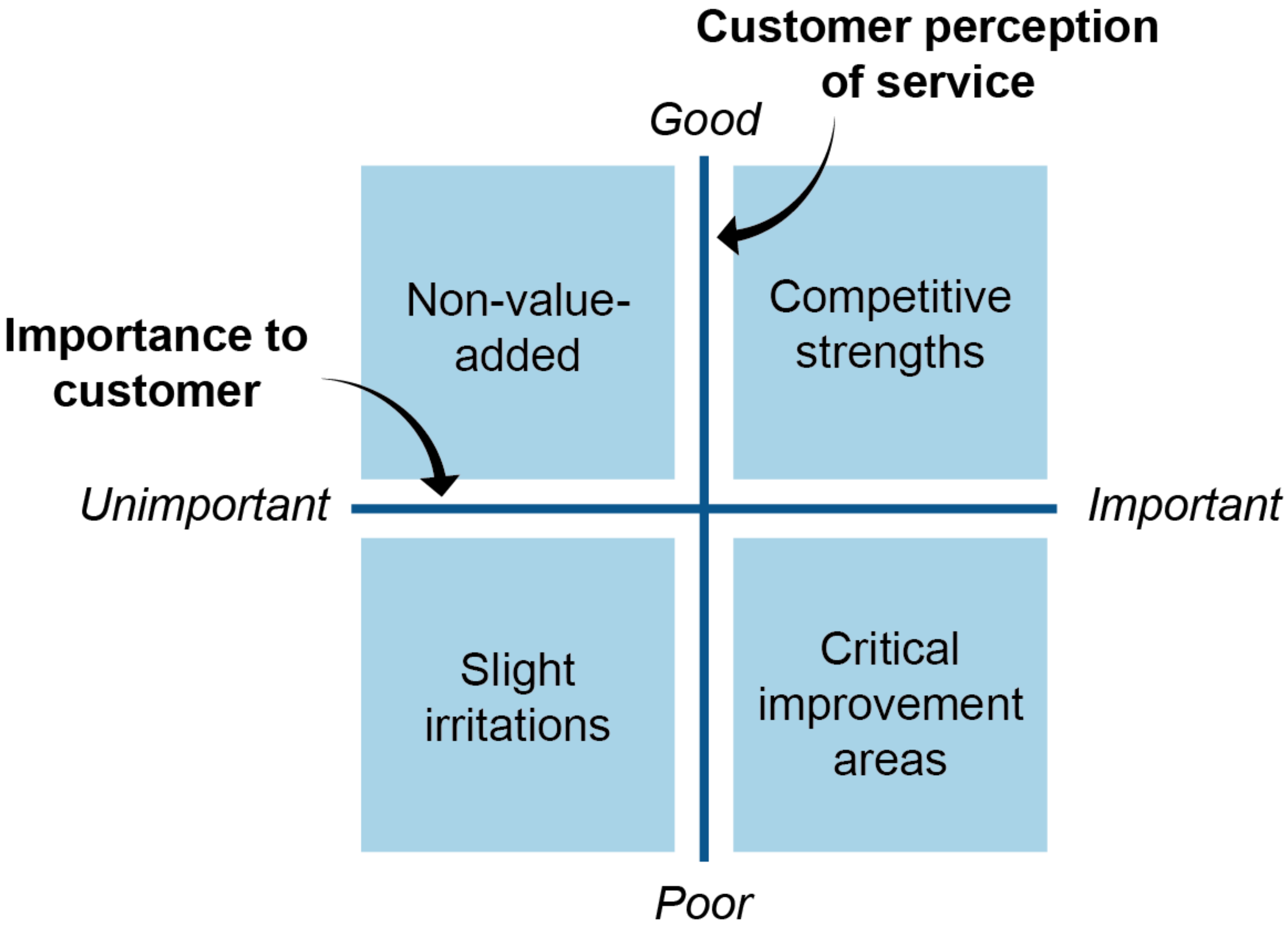
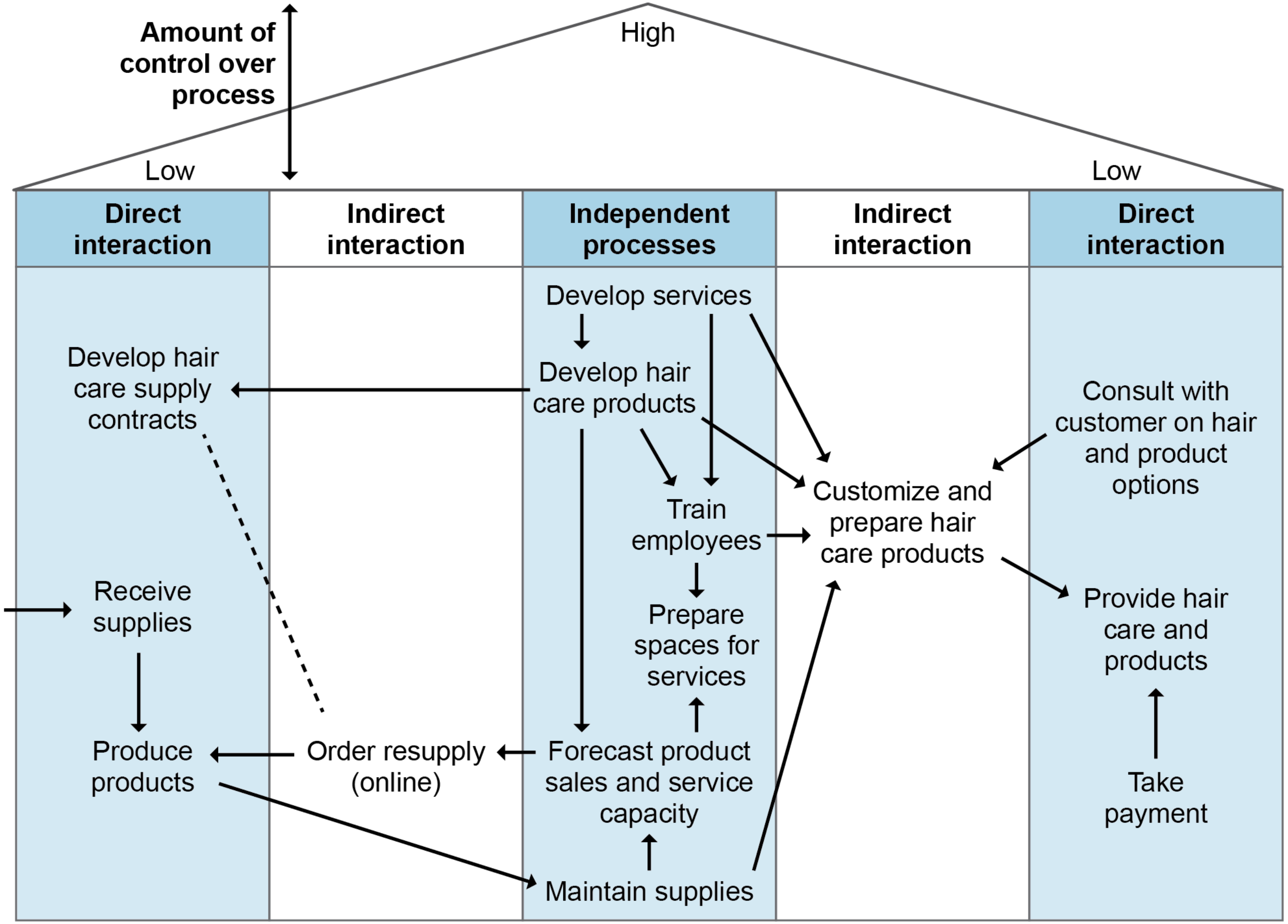
Service Gap Analysis Matrix



Service Design and Project Management for ETO or Improvements

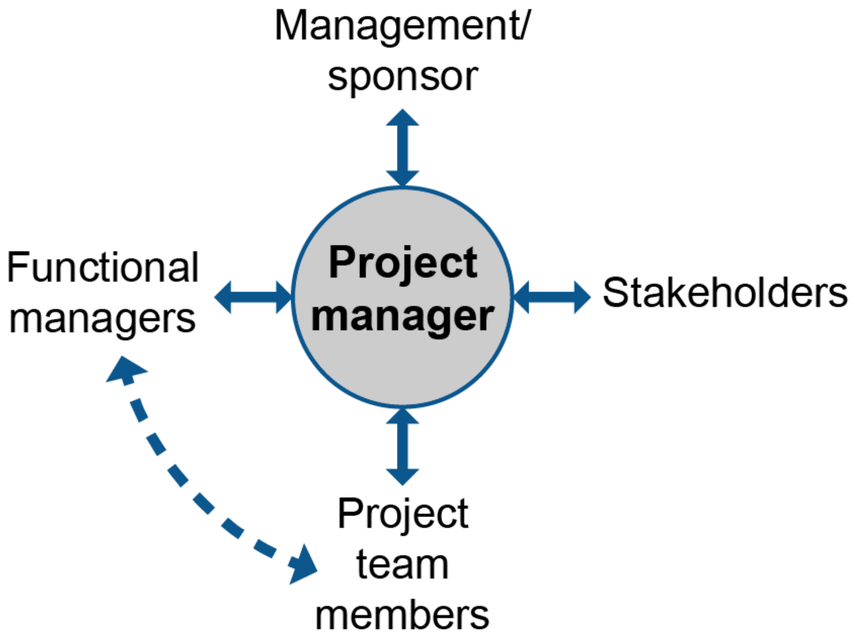
PCN Diagrams



Service Design and Project Management for ETO or Improvements

Project Management

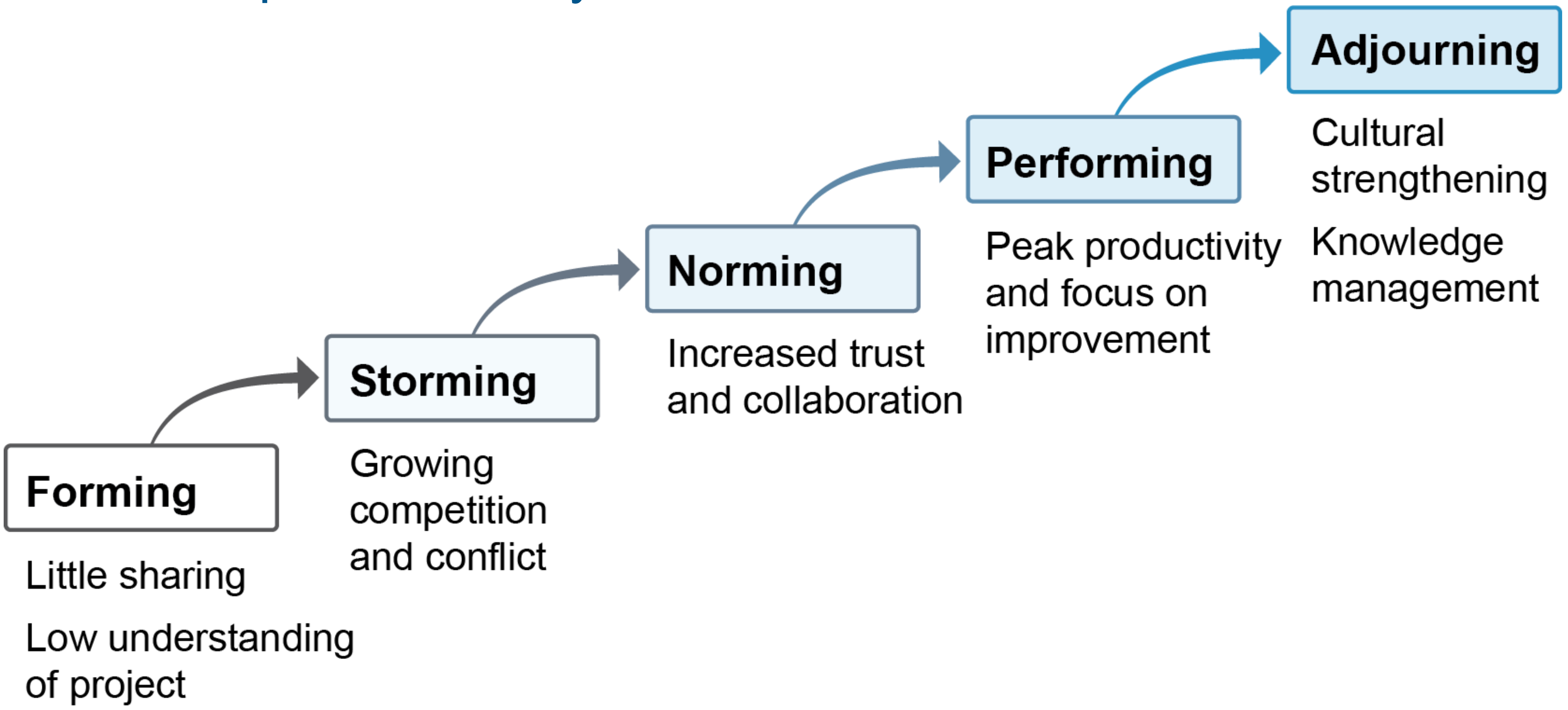
- Project charter and management support
- Project manager/leader
- Clear roles and responsibilities



Engine test	PM	Eng	Perf analytics	VP, Eng	VP, Acct
Run	I	R	I	A	I
Analyze results	I	C	R	A	I
Report	R	C	C	I	A
Follow up	R	C	I	I	A

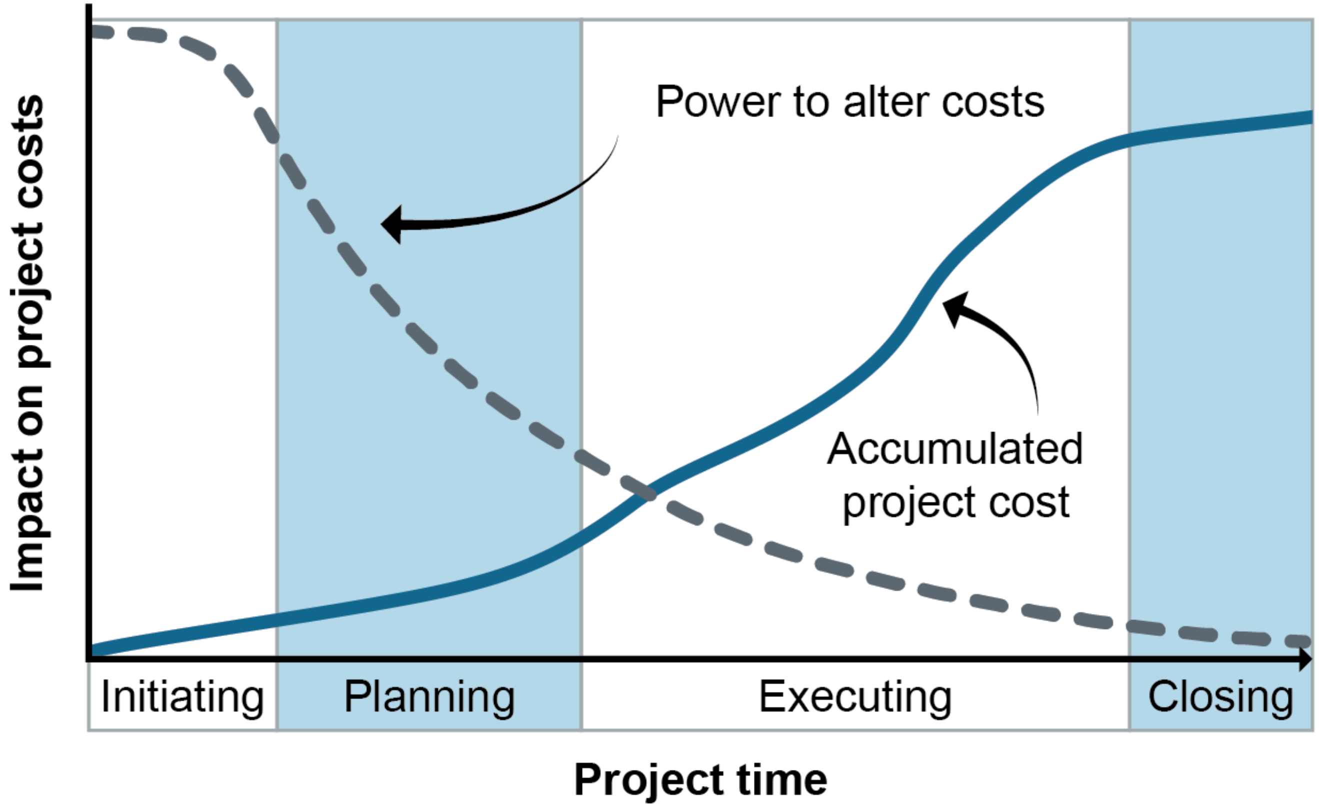
R = Responsible for task completion, **A** = Accountable for outcome,
C = Consulted (provides input on the work), **I** = Informed of progress

Team Development Theory



Traditional Project Concerns

- The project plan documents how different aspects of the project will be executed and controlled.
- Scope baseline
  - Scope statement
  - Work breakdown structure
- Project schedule
- Project budget



Agile Project Management: Scrum Example

Agile project management method for projects with high variability in requirements

- Tasks and issues can be prioritized and reprioritized to resolve bottlenecks.
- Tasks are done in sprints or iterations.
- Teams meet daily.
- Members are empowered.
- A scrum master removes obstacles.
- A product owner represents the customer.

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SECTION C:
CREATING THE MASTER SCHEDULE

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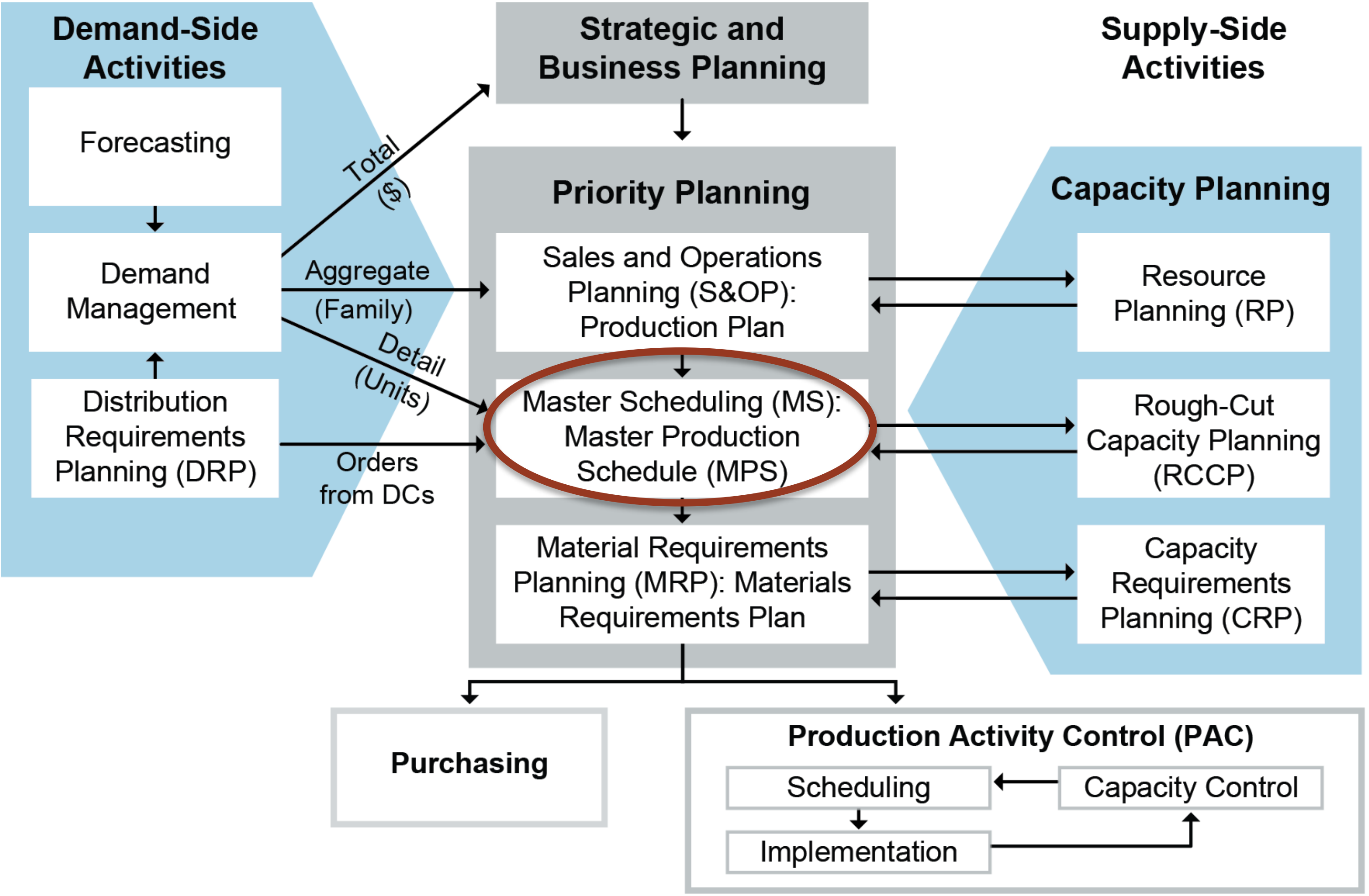
Section C Learning Objectives

- Relationships among master scheduling, capacity management, and materials management
- Elements of master scheduling grid
- Links with other processes
- How different manufacturing environments interact with master scheduling process
- Uses and types of planning bills of material (BOMs)

Master Scheduling

Maintaining the master schedule requires	Master scheduling takes into account
▪ A consistent periodic review and update cycle ▪ Timely transaction processing.	▪ Capacity limitations ▪ Production costs ▪ Resource considerations ▪ The sales and operations plan.

Master Scheduling in Manufacturing Planning and Control



Master Scheduling vs. S&OP

	Master Scheduling	S&OP
Purpose	Build schedule	S&OP production plan
Planning level	End item	Product family
Planning horizon	Longest cumulative lead time	Longest resource lead time
Planning frequency	Daily/weekly	Monthly
Planning focus	Product mix	Volume
Output	Master production schedule	S&OP production plan

How MPC Components Fit in Business Hierarchy

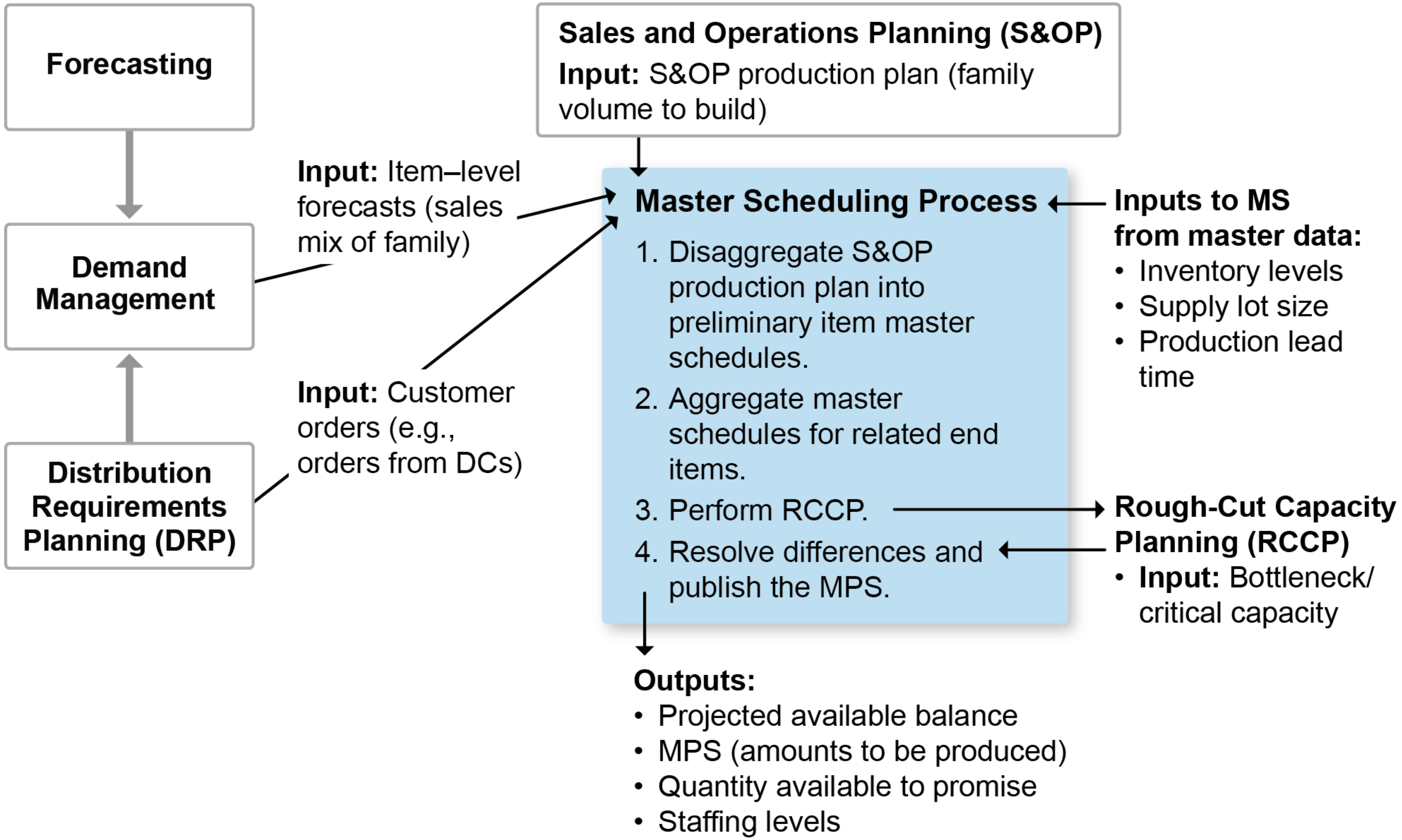
Level	Horizon	Frequency	Detail Level	Process	Validation
Strategic	>2 years	Annually	Summary	Business planning	Financing
Tactical	~18 months	Monthly	Aggregate	S&OP	Resource planning
	~3 months	Weekly	MTS = end item, ATO = subassembly, MTO = raw materials	Master scheduling	RCCP
Operational	~10 weeks	Daily	Intense	MRP	CRP
	~6 weeks	Shift	Most intense	Work orders, purchase orders	Scheduling

Master Scheduling Purpose and Objectives

- Produce what sales and operations mutually agree on; also agree on priority.
  - Make a build schedule: end items, quantities, due dates.
  - Provide resource and material information.
  - Resolve tradeoffs.
- Maintain customer service and inventories/backlogs at targeted levels.
- Make efficient and effective use of resources.
- Enable valid order promises (manage due dates).

Master Scheduling Overview

Master Production Schedule Inputs, Process, and Outputs



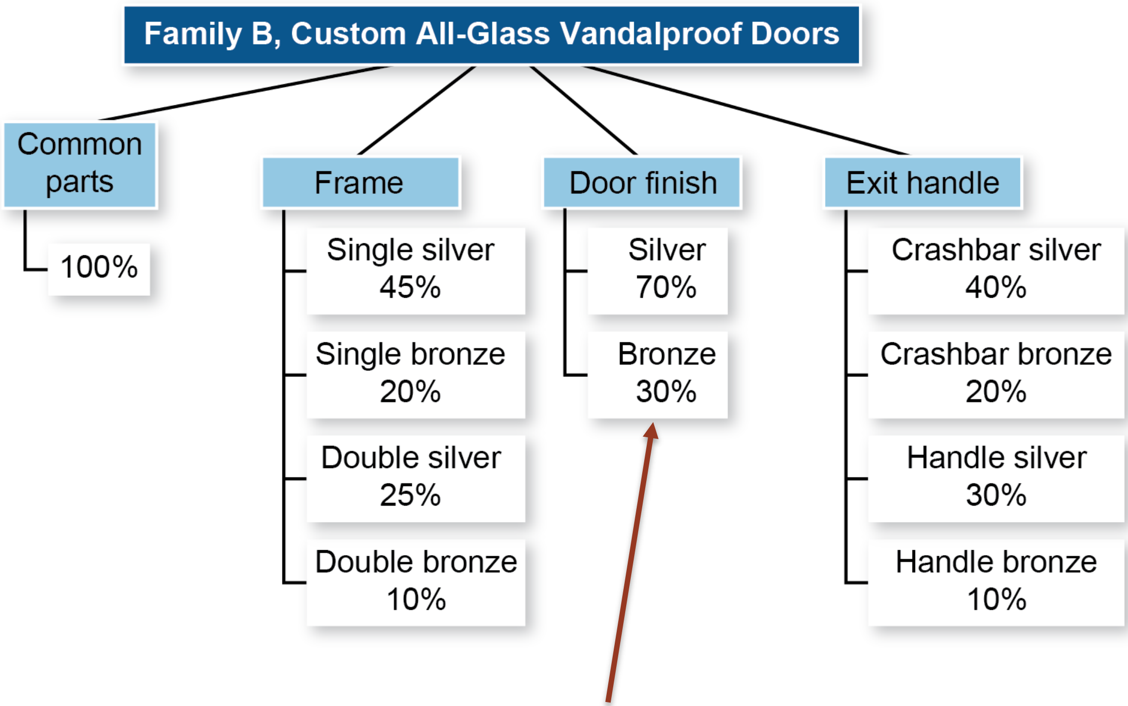
Product Structure Impact on Master Scheduling

Impact of Product Structure on Master Scheduling

Product structure

- Product structure: sequence of operations for components
- Priority of jobs
- Takes market and customer expectations and manufacturing requirements into account by prioritizing tradeoffs:
  - Customer service
  - Production efficiency
  - Inventory costs

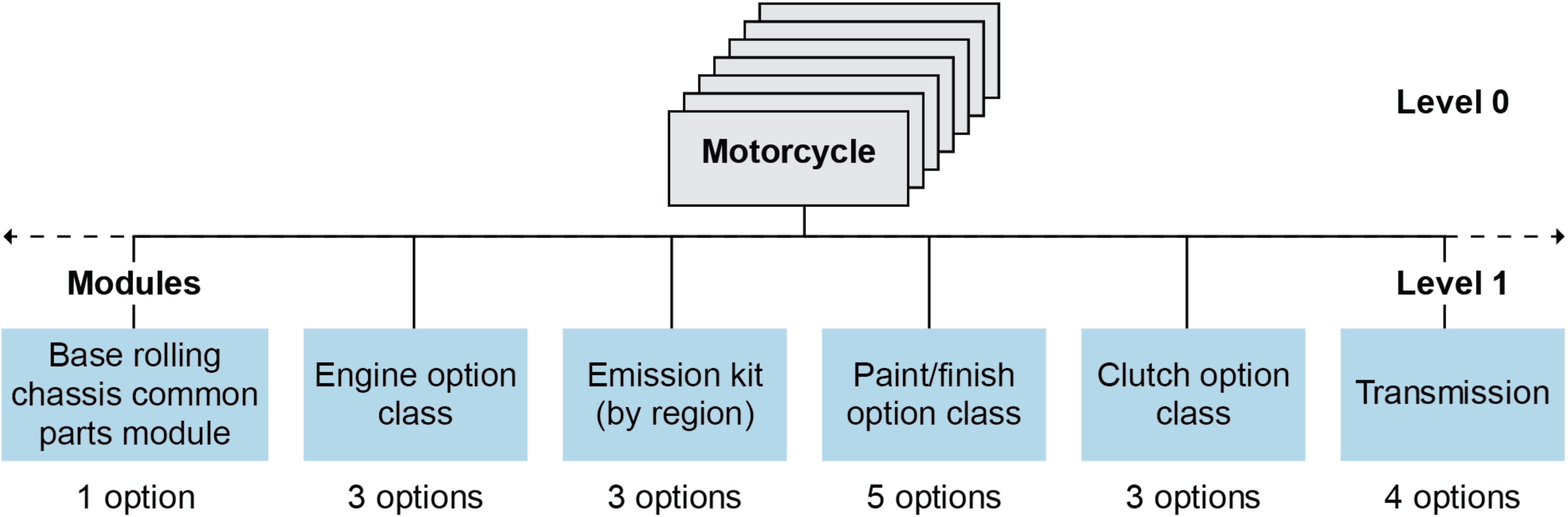
Planning BOMs (artificial grouping)



e.g., historical averages

Product Structure Impact on Master Scheduling

Modular BOMs



Creators of the Master Schedule

Master scheduler's role	Management's role
▪ Disaggregate production plan. ▪ Maintain and make changes to MPS records. ▪ Resolve tradeoffs. ▪ Monitor execution. ▪ Reconcile MPS. ▪ Launch final assembly schedule. ▪ Review and maintain change requests.	▪ Resolve most issues at pre-S&OP meeting. ▪ Consolidate executive issues: – Production and procurement change authorization – Adjustment of sales and operations plan to keep on target – Customer service performance – New product introduction – Special projects ▪ Enforce time fence policies.

Creating the Master Schedule

Techniques to create MPS

- Create time-phased master schedule grid (supply and demand over time).
- Prepare MPS per strategy (chase, level, hybrid).

Master Schedule: Make-to-stock Chase Production Example Beginning inventory = 70 Safety Stock = 0 Lot size = 100							
Week	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Constrained Demand		50	60	70	90	70	20
Customer Orders							
Projected Available Balance	70	20	60	90	0	30	10
Master Production Schedule			100	100		100	

Creating the MPS

Calculating Projected Available Balance and MPS

Ending PAB = Beginning PAB + Scheduled MPS Receipt − Demand (Orders or Forecasts)

- **Week 2 = 20 + 0 − 60 = − 40**

Master Schedule: Make-to-stock Chase Production Example							
Beginning inventory = 70 Safety Stock = 0 Lot size = 100							
Week	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Constrained Demand		50	60	70	90	70	20
Customer Orders							
Projected Available Balance	70	20	-40				
Master Production Schedule							

- Whenever PAB would go negative, schedule lot size MPS.
- Recalculate and find next negative PAB and repeat.

Constrained Demand		50	60	70	90	70	20
Customer Orders							
Projected Available Balance	70	20	60	90	0	30	10
Master Production Schedule			100	100		100	

Calculating PAB and MPS (Exercise)

Prepare a master schedule.

Opening inventory: 200 units; lot size: 1,000 units

Week		1	2	3	4	5	6
Constrained demand		100	500	250	500	100	150
Projected available balance	200	100	600	350	850	750	600
MPS			1,000		1,000		

Disaggregating from Family to Item Level

- From monthly constrained demand (3 months shown)…

Month	0	1	2	3
Sales Plan		460	450	410
Production (Leveled)		300	300	300
Ending Inventory	520	360	210	100
Average Inventory		440	285	155

- …to weekly constrained demand (13 weeks).

Individual products

Family A: Vandalproof Commercial Doors, In-Stock All-Glass									January 1 to March 31					
Weekly Forecast by Product	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**SUM**
Family A Single Door (A-SD)	50	70	70	60	70	60	60	70	40	70	50	40	30	740
Family A Double Door (A-DD)	50	40	60	40	50	60	50	40	50	30	30	40	40	580
SUM	100	110	130	100	120	120	110	110	90	100	80	80	70	1,320
Monthly SUMs (not exact)				440				460					420	1,320

- Sum of MPSs for items in family must equal production plan for that family.
- First three months in monthly constrained demand: 460 + 450 + 410 = 1,320 units.

Master Schedules for Two Items in Family A

Family A: Vandalproof Commercial Doors, In-Stock All-Glass									Batch: 100				1/1-3/31		
Master Schedules	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**SUM**
Days in Week		4	5	4	5	5	5	5	4	5	5	5	5	5	62
Weekly Leveled Production		57	72	57	72	72	72	72	57	72	72	72	72	72	889
Single Door (A-SD) Forecast		50	70	70	60	70	60	60	70	40	70	50	40	30	740
A-SD Projected Available	310	317	290	220	218	190	132	144	100	62	64	40	18	59	
A-SD MPS		57	43		58	42	2	72	26	2	72	26	18	71	489
Double Door (A-DD) Forecast		50	40	60	40	50	60	50	40	50	30	30	40	40	580
A-DD Projected Available	210	160	149	146	120	100	110	60	51	70	40	56	70	30	
A-DD MPS			29	57	14	30	70		31	69		46	54		400
Forecast SUM		100	110	130	100	120	120	110	110	90	100	80	80	70	1,320
Projected Available SUM	520	477	439	366	338	290	242	204	151	132	104	96	88	89	
Production SUM		57	72	57	72	72	72	72	57	71	72	72	72	71	889

Workable Preliminary Master Schedule Criteria

Master schedule should be realistic and achievable.

- Valid schedule
- Valid capacity
- Valid inventory or backlog
- Valid changeovers
- Valid batches and lots (honors batch and lot size policies)

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SECTION D:
ROUGH-CUT CAPACITY PLANNING AND MPS VALIDATION

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Section D Learning Objectives

- Rough-cut capacity planning and capacity planning hierarchy
- Capacity planning using overall factors (CPOF), capacity bill procedure, and resource profile approaches
- Resolving capacity imbalances
- Critical work centers
- Improving work center efficiency and utilization
- Maintenance scheduling

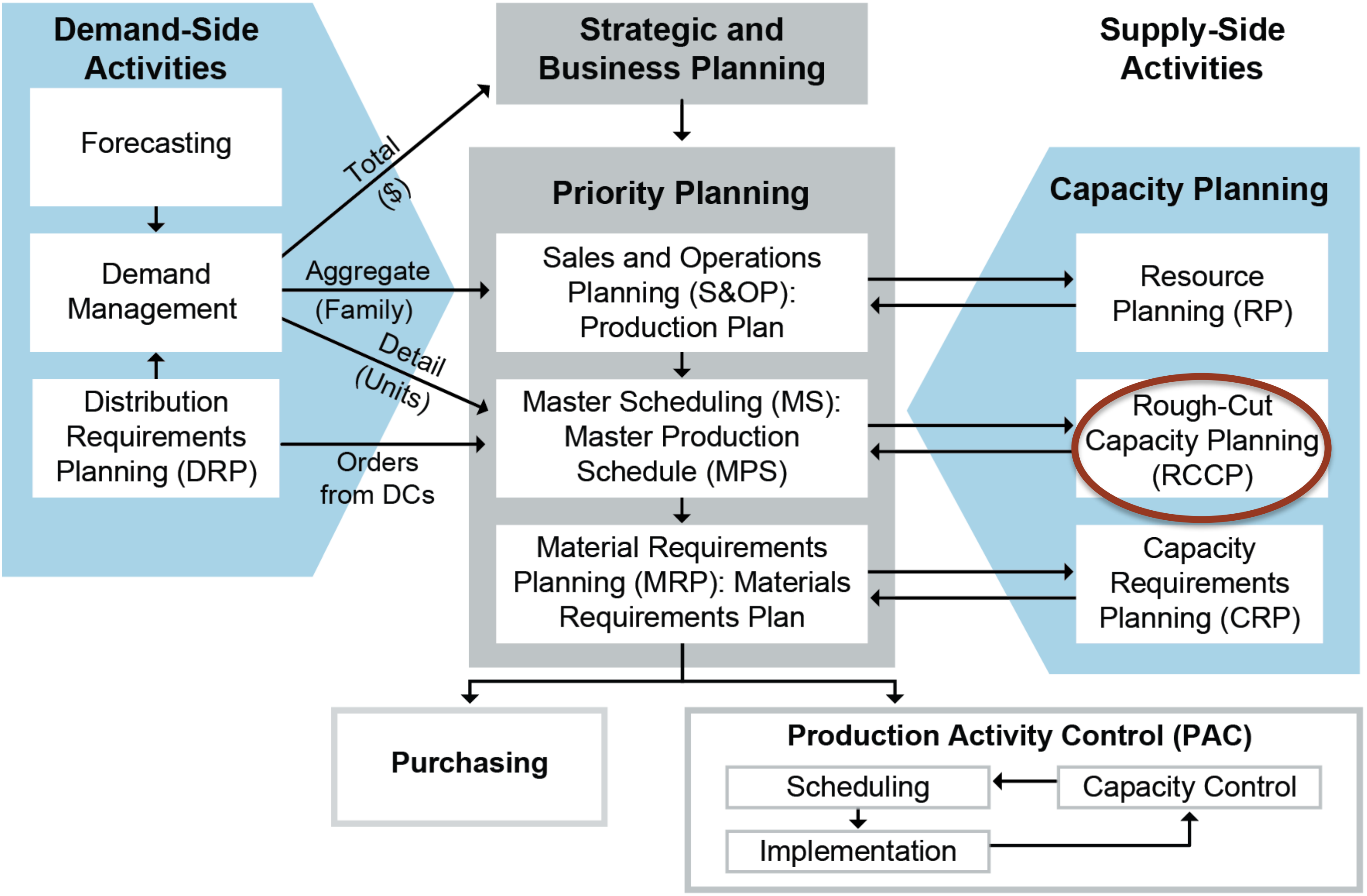
RCCP Preparation: Aggregating Master Schedules for Related Items

- Often this aggregates units back into families.
- Sums used for total load on critical resources.

Families A, B and C: Vandalproof Doors												1/1-3/31		
Master Schedules	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**SUM**
Family A (In Stock)														
A Single MPS	57	43		58	42	2	72	26	2	72	26	18	71	**489**
A Double MPS		29	57	14	30	70		31	69		46	54		**400**
Family B (Custom)														
B Single MPS		50	50	50	30	10		20	20	30	20	20	20	**320**
B Double MPS	20	20		20		30	40	20	10	20	40	20	10	**250**
Family C (Custom)														
C Single MPS		30	20	20	20	30	20	30	20	20		40	50	**300**
C Double MPS	50			10	50	30	40		50	30	40	20	20	**340**
MPS SUM	**127**	**172**	**127**	**172**	**172**	**172**	**172**	**127**	**171**	**172**	**172**	**172**	**171**	**2,099**

Rough-Cut Capacity Planning

RCCP in Manufacturing Planning and Control



RCCP Purpose and Process

- Validate critical resource availability for MPS.
- Specific models rather than average unit of family.
- Items might still have variants, so still rough-cut.

Identify critical resources and their capacity.

Develop resource profiles for each work center for items being master-scheduled.

Calculate the total load on the work centers.

Compare load to available capacity.

Balance required capacity and planned available capacity.

Master Production Schedule Validation

RCCP Approaches

CPOF	Capacity Bill Procedure	Resource Profile
▪ Least detailed ▪ MS quantities x total time per item ▪ Historical work center % applied to total hours ▪ Not sensitive to mix changes	▪ Accounts for shifts in product mix ▪ Requires a bill of materials, routing, and operation-specific direct labor-hours or machine-hours ▪ No lead time offset	▪ Considers lead-time offsets ▪ Needs data on production lead times for end units and components ▪ Lot-for-lot

Master Production Schedule Validation

Capacity Bill Procedure

		Lot Size	Operation	Work Center	Standard Setup (hours)	Standard Setup per Unit (hours)	Standard Run Time per Unit (hours)	Total per Unit (hours)
Items	**Description**							
99	A-SD	20	1 of 1	33	0.10	0.005	0.20	0.30
100	A-DD	20	1 of 1	33	0.30	0.015	0.40	0.70
101	B-SD	20	1 of 1	33	0.30	0.015	0.10	0.40
102	B-DD	20	1 of 1	33	0.55	0.0275	0.30	0.85
103	C-SD	20	1 of 1	33	0.05	0.0025	0.10	0.15
104	C-DD	20	1 of 1	33	0.10	0.005	0.30	0.40
Comp.								
202	A-Door	40	1 of 1	13	0.20	0.005	0.20	0.40
203	B-Door	40	1 of 2	13	0.20	0.005	0.15	0.35
		40	2 of 2	14	0.20	0.005	0.15	0.35
204	C-Door	40	1 of 1	13	0.10	0.0025	0.05	0.15
422	Handle/crashbar	80	1 of 1	13	0.20	0.0025	0.10	0.30
323	Lockset	80	1 of 1	13	0.20	0.0025	0.10	0.30
734	Single frame	80	1 of 1	13	0.20	0.0025	0.10	0.30
735	Double frame	80	1 of 1	13	0.20	0.0025	0.60	0.80
682	Hydraulic closer	80	1 of 1	13	0.20	0.0025	0.10	0.30
502	Kit	80	1 of 1	13	0.20	0.0025	0.10	0.30

Routing

Work Center	Total Time per Unit by Item					
	99 (A-SD)	100 (A-DD)	101 (B-SD)	102 (B-DD)	103 (C-SD)	104 (C-DD)
33	0.30	0.70	0.40	0.85	0.15	0.40
13	1.90	3.7	1.85	3.6	1.65	3.2
14	0	0	0.35	0.7	0	0
Sum (hours/unit)	**2.2**	**4.4**	**2.6**	**5.2**	**1.8**	**3.6**

Bill of Resources for Labor by End Item

Families A, B and C: Vandalproof Doors Work Center	1	2	3	4	5	6	7	8	9	10	11	12	13	Total Hours	1/1-3/31 Forecast Work Center %
33	54	75	63	71	69	96	75	59	88	66	98	82	53	**948**	14%
13	340	403	336	392	439	535	442	323	525	393	529	473	354	**5,484**	82%
14	14	32	18	32	11	25	28	21	14	25	35	21	14	**287**	4%
Total Hours	**408**	**509**	**417**	**494**	**518**	**655**	**544**	**403**	**628**	**483**	**662**	**576**	**422**	**6,719**	**100%**

Capacity Requirements for Labor Hours for 13-week period

Master Production Schedule Validation

Resource Profile Approach

Bill of resources

Families A, B and C: Vandalproof Glass Commercial Doors

Product	Polycarbonate supplier, Recycled (tons)	Labor (standard hours)	Work Center 23 (standard hours)
Family A: In-Stock All-Glass	**0.0036**	**3.3**	**0.7**
Family A Single Door (A-SD)	0.0024	2.2	0.4
Family A Double Door (A-DD)	0.0048	4.4	0.8
Family B: Custom All-Glass	**0.0038**	**3.9**	**0.7**
Family B Single Door (B-SD)	0.0025	2.6	0.5
Family B Double Door (B-DD)	0.0051	5.2	0.9
Family C: Custom w/Small Window	**0.0009**	**2.7**	**0.2**
Family C Single Door (C-SD)	0.0003	1.8	0.1
Family C Double Door (C-DD)	0.0015	3.6	0.3

Calculating load on critical resources

Families A, B & C: Vandalproof Glass Commercial Doors

Product	Week 1 MPS	Rate	Polycarbonate, Recycled (tons) Load	Rate	Labor Load (standard hours)	Rate	Week 1 Work Center 23 Load (standard hours)
Family A: In-Stock All-Glass							
Family A Single Door	57	0.0024	0.1368	2.2	125.4	0.4	22.8
Family A Double Door	0	0.0048	0	4.4	0	0.8	0
Family B: Custom All-Glass							
Family B Single Door	0	0.0025	0	2.6	0	0.5	0
Family B Double Door	20	0.0051	0.102	5.2	104.0	0.9	18
Family C: Custom Small Window							
Family C Single Door	0	0.0003	0	1.8	0	0.1	0
Family C Double Door	50	0.0015	0.075	3.6	180.0	0.3	15
SUM			**0.3138**		**409.4**		**55.8**

Resolving Capacity Imbalances

If required capacity (load) exceeds available capacity:

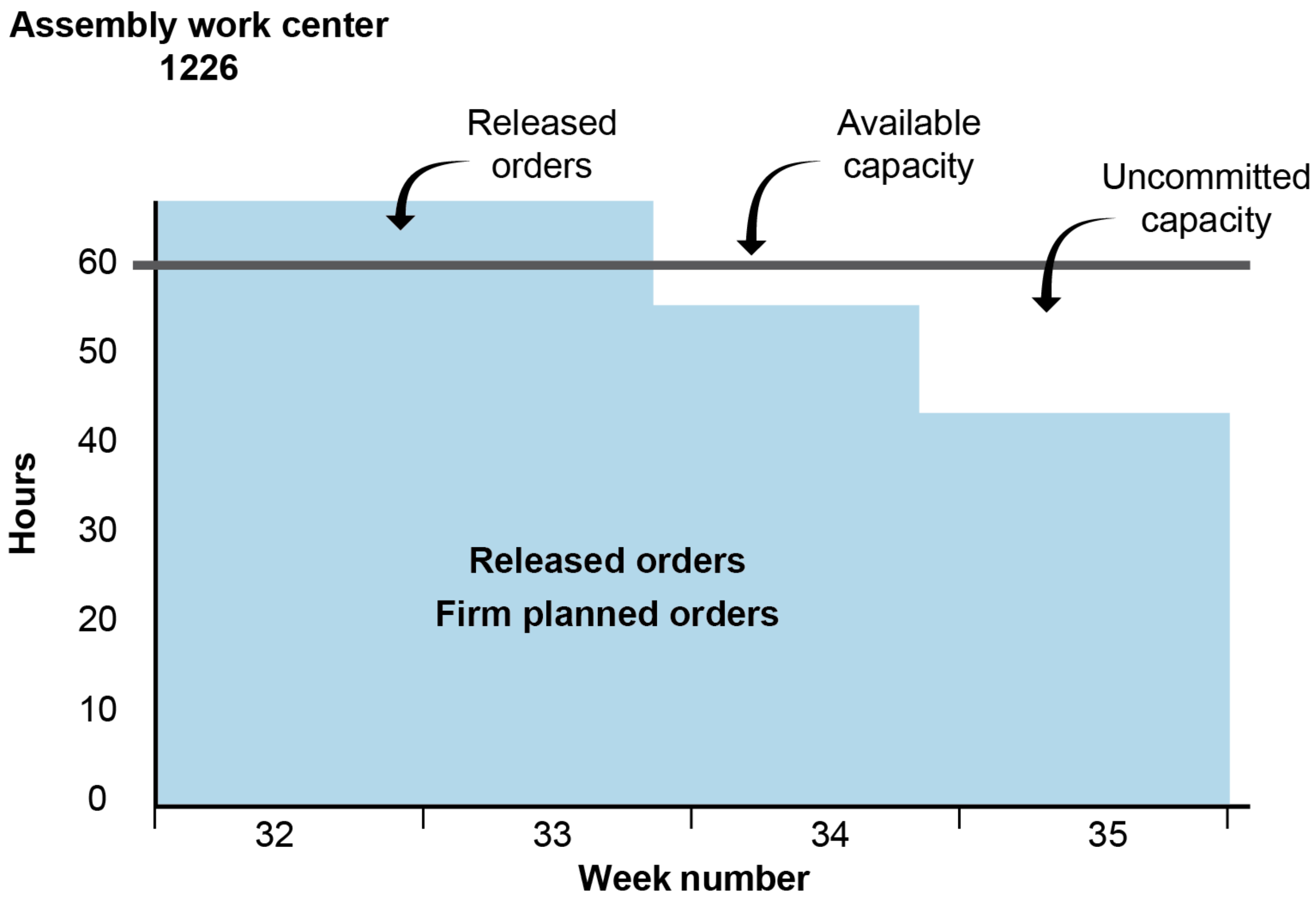
- Rebalance load to periods with available capacity.
- Increase capacity.
  - Overtime.
  - Shifting workers to other tasks.
  - Hire part-time workers or subcontract.

Workable master schedule:

- Publish for use in MRP.

APICS

Resolving Capacity Imbalances: Load Profile



- Actions focused on
  - Modification of MPS dates and quantities
  - Communication with customers on delivery flexibility
  - Changes in available capacity.

Master Production Schedule Validation

Overload and Underload Solutions

- Excerpt from bill of resources (standard hours/unit):
  - Product 1: 0.36
  - Product 2: 0.31
  - Product 3: 0.221
- Original RCCP report:
  - Capacity available per week: 58.25 hours
  - Weeks 32 and 33: 0.36 × 180 = 64.8 hours (overload)
  - Week 34: 55.8 hours
  - Week 35: 42.98 hours
- Solutions
  - 19 units of product 1 moved from weeks 32, 33 to week 34
  - 38 units of product 1 set back to week 35

RCCP report, prior to adjustment
Adjusted load and capacity: weeks 32 to 35, in hours per week

Work center 1226	32	33	34	35	Total
Standard hours	64.80	64.80	55.80	42.98	228.38
Capacity available	58.25	58.25	58.25	58.25	233.00
Over-/underload	6.55	6.55	(2.45)	(15.27)	(4.62)

MPS for weeks 32 to 35, in units

Work center 1226	32	33	34	35	Total
Product 1	180	180			360
Product 2			180	36	216
Product 3				144	144
Total	180	180	180	180	720

Revised MPS for weeks 32 to 35, in units

Work center 1226	32	33	34	35	Total
Product 1	161	161	38		360
Product 2			142	74	216
Product 3				144	144
Total	161	161	180	218	720

RCCP report, revised
Adjusted load and capacity: weeks 32 to 35, in hours per week

Work center 1226	32	33	34	35	Total
Standard hours	57.96	57.96	57.70	54.76	228.38
Capacity available	58.25	58.25	58.25	58.25	233.00
Over (under) load	(.29)	(.29)	(.55)	(3.49)	(4.62)

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SECTION E:
USING AND MAINTAINING THE MASTER SCHEDULE

APICS

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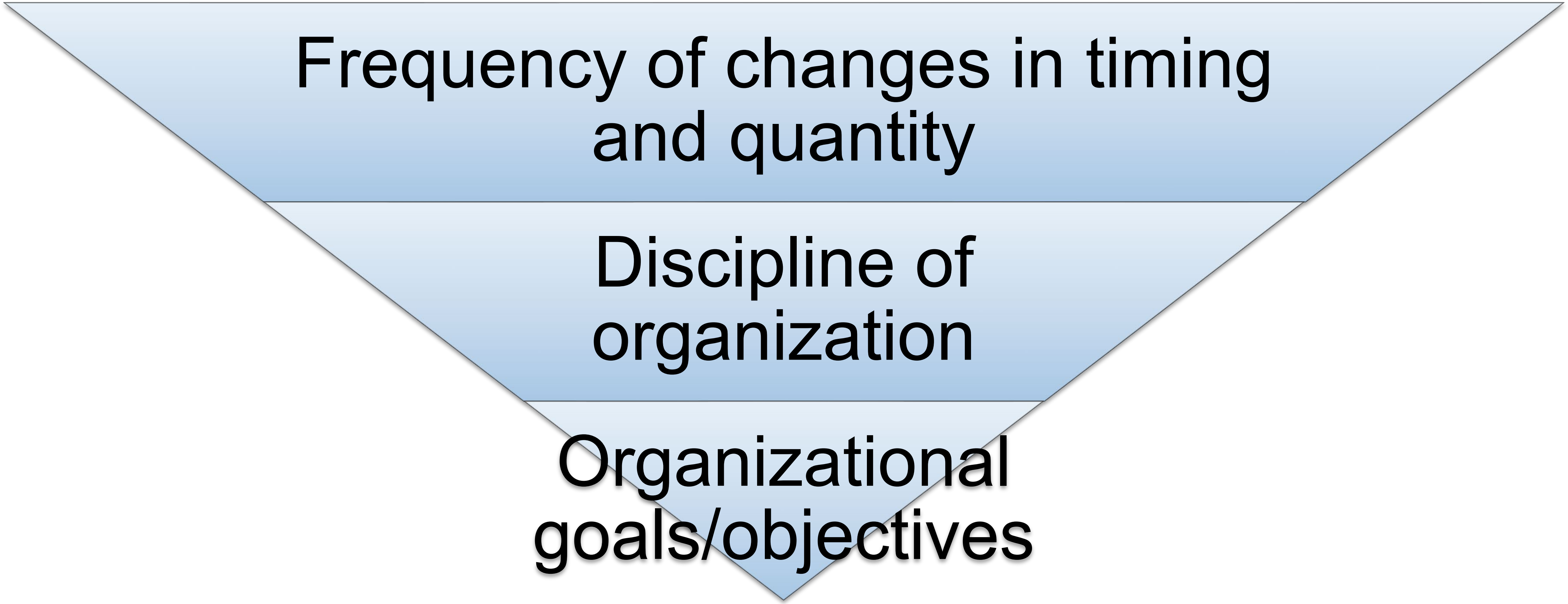
Section E Learning Objectives

- Master schedule process flow
- Time fences and zones
- Projected available balance (PAB)
- Inventory/backlog maintenance
- Engineering changes
- Consequences of not abiding by master schedule
- Master scheduling performance

Using the Master Schedule

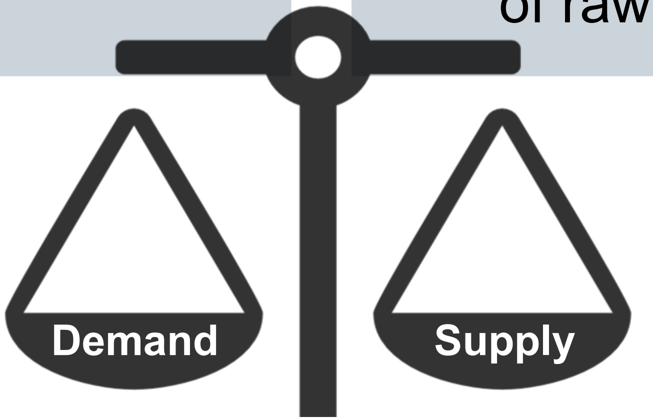
Stability of Master Schedule



Using the Master Schedule

Master Scheduling Change Drivers

Demand	Supply
▪ Competition in marketplace ▪ Variations in product transportation ▪ Supply chain partners ▪ Sales and marketing initiatives	▪ Quality issues in processes and products ▪ Reliability of supplier ▪ Supply-demand balance ▪ Manufacturing flexibility ▪ Product mix ▪ Ripple effect from untimely deliveries of raw materials



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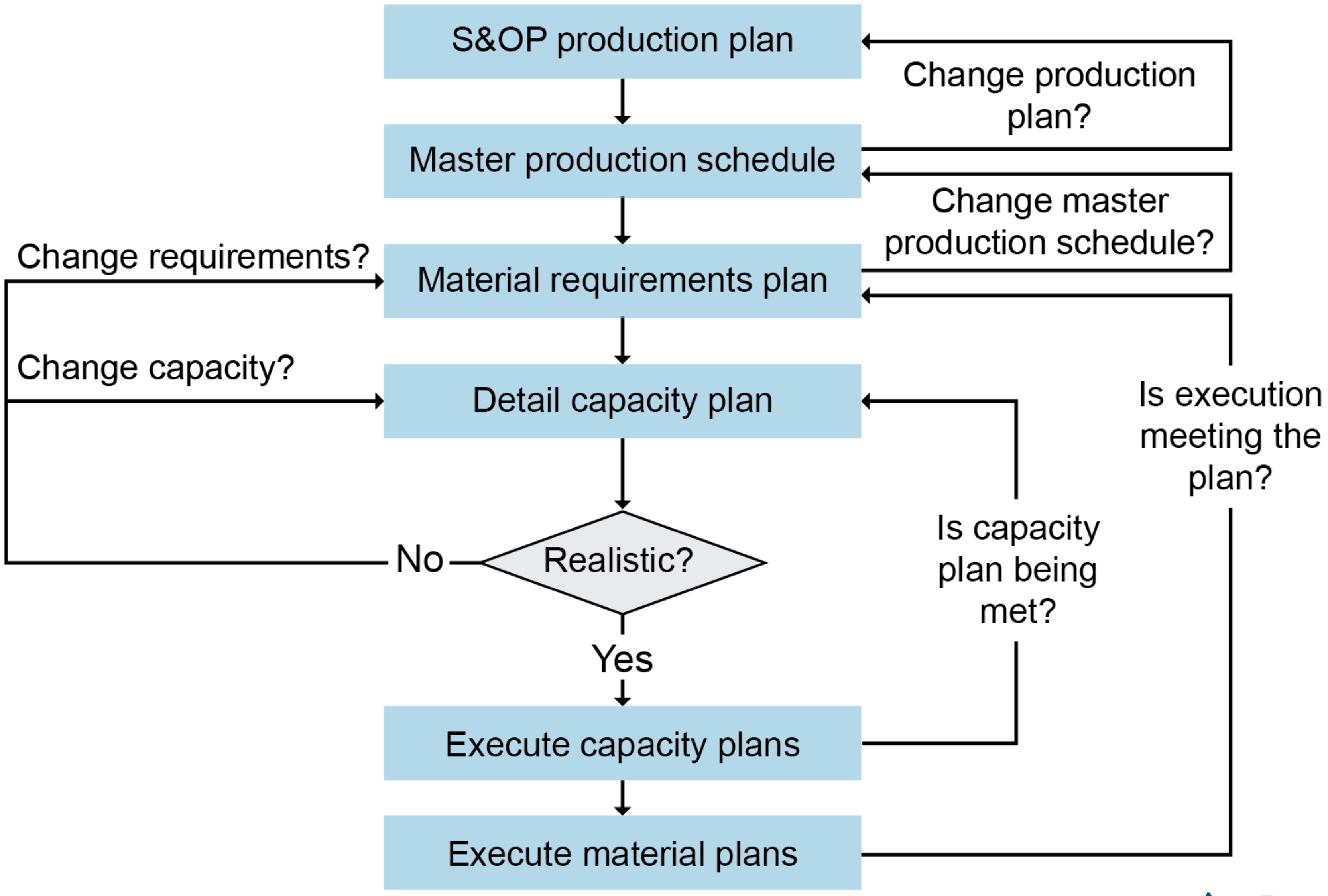
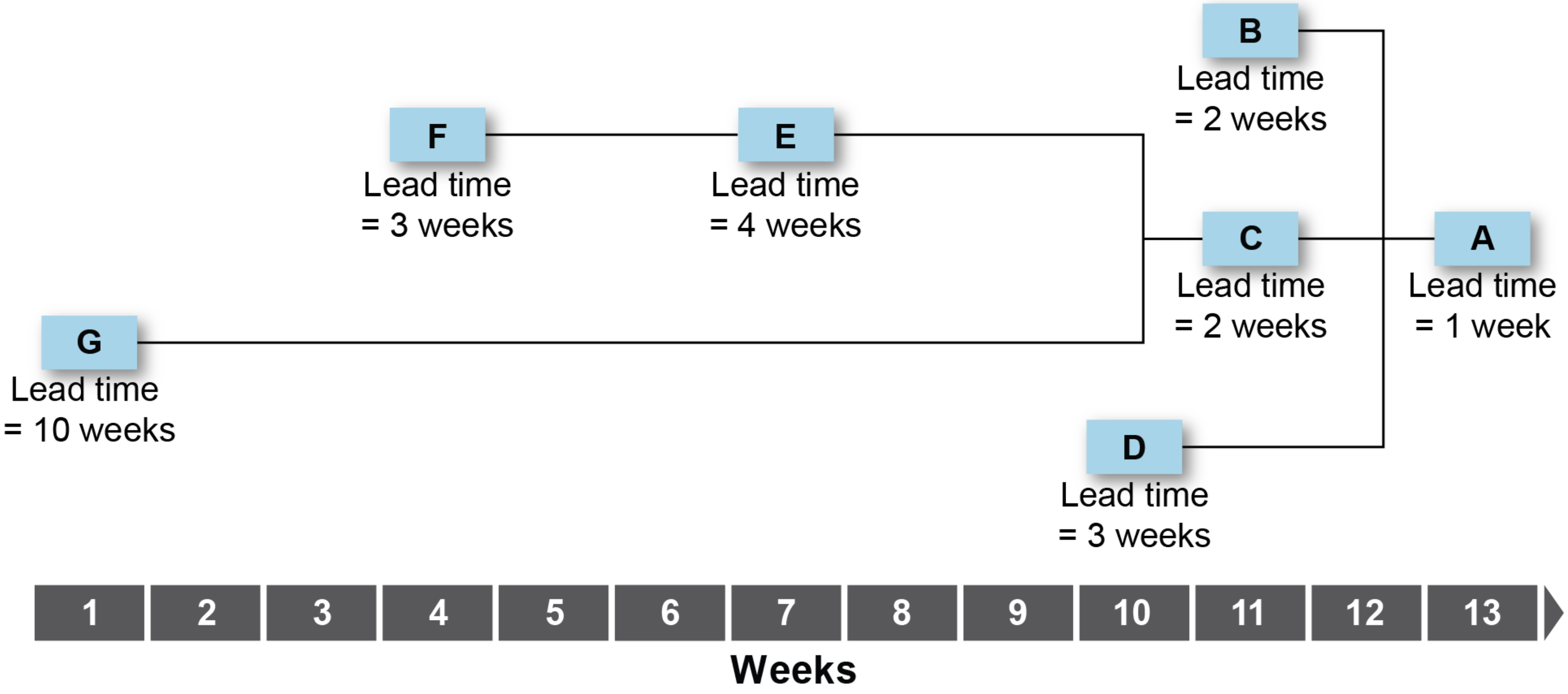
Using the Master Schedule

Master Scheduling Flowchart

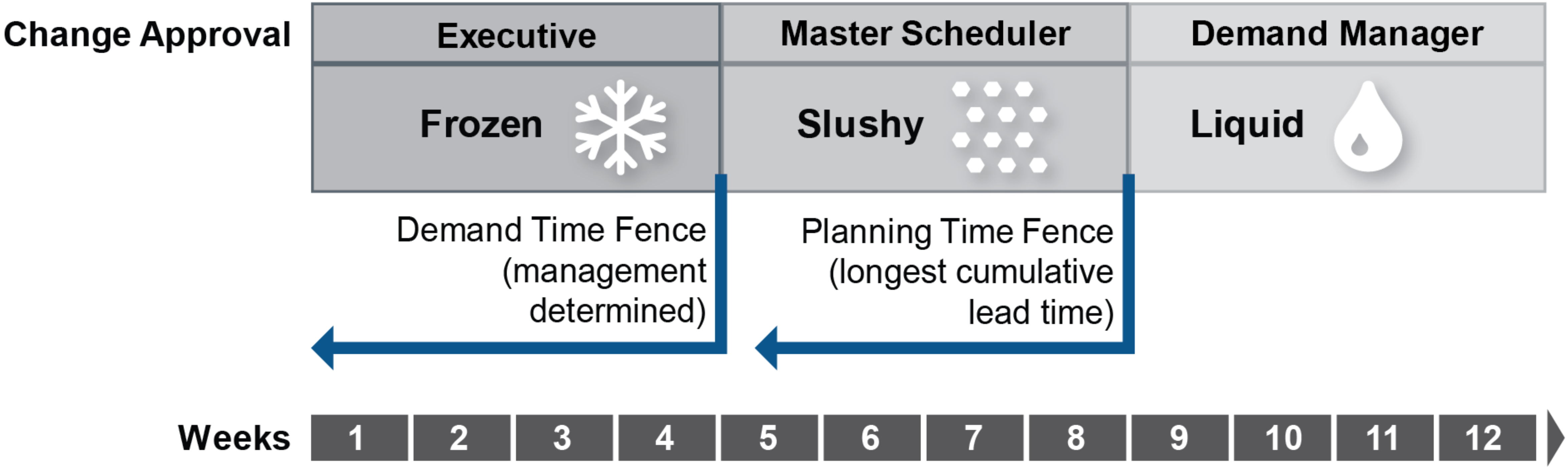


Determining Planning Horizon

Cumulative lead time plus slack time

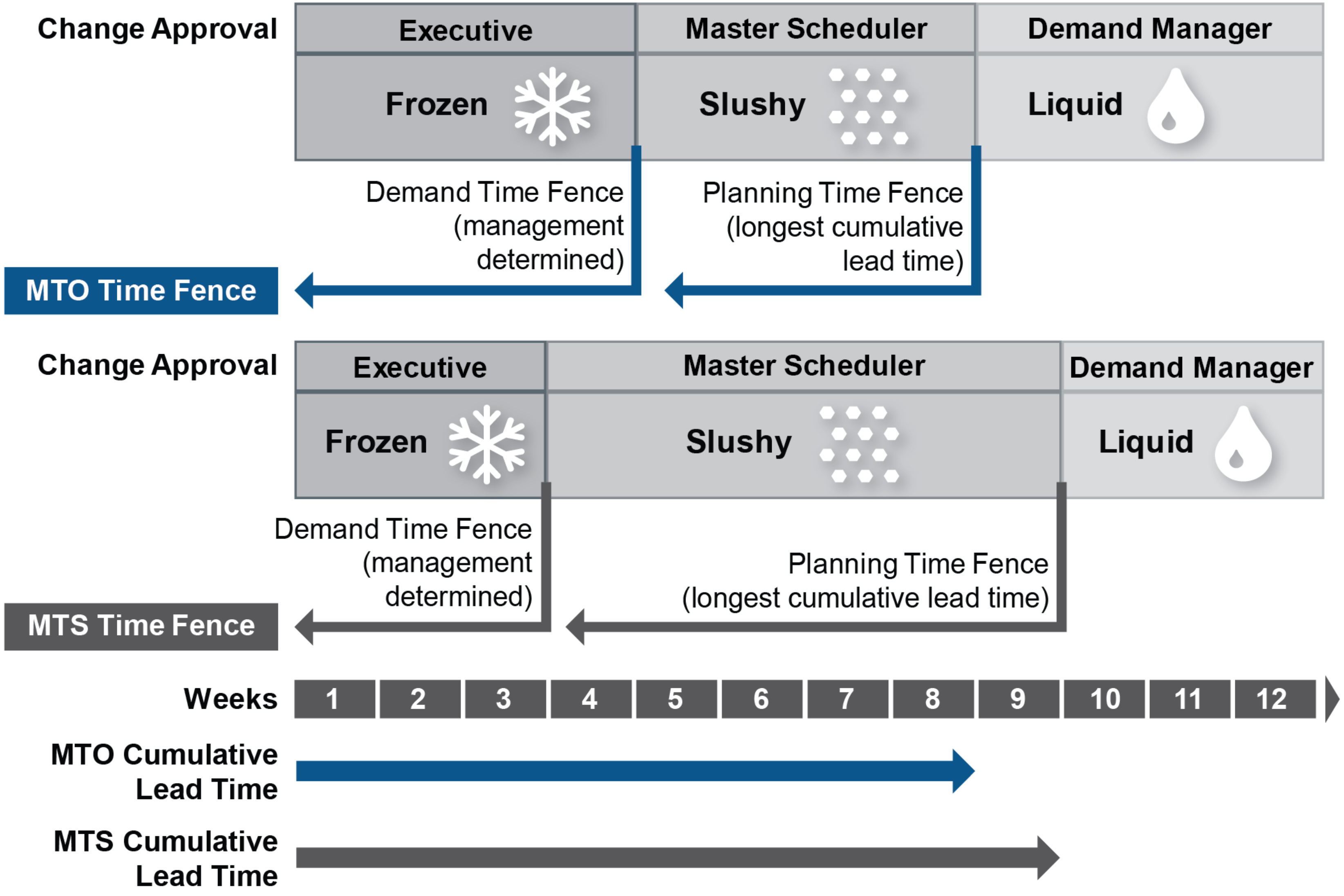


Time Fences and Zones



Using the Master Schedule

Planning and Coordinating MPS Changes



Calculating PAB When Time Fences Are Used

- Objective is to determine projected inventory levels and their sufficiency at end of each period.
- Ending PAB Before Demand Time Fence = Prior Period PAB + Scheduled MPS Receipt − Customer Orders; Week 2 = 22 + 100 − 66 = 56 Units
- Ending PAB After Demand Time Fence = Prior Period PAB + Scheduled MPS Receipt − Greater of Customer Orders or Constrained Demand; Week 5 = 9 + 100 − 70 = 39 Units

Master Schedule: Make-to-stock Chase Production Example
Beginning inventory = 70 Safety Stock = 0 Lot size = 100

Week	0	1	2	3	4	5	6 ...	12	13	14	15	16
Constrained Demand		50	60	70	90	70	20	20	20	20	20	20
Customer Orders		48	66	57	62	30	0	0	0	0	0	0
Projected Available Balance	70	22	56	99	9	39	19	99	79	59	39	19
Master Production Schedule			100	100		100		100				

Demand Time Fence (after week 3) Planning Time Fence (after week 13)

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Fine-Tuning Techniques Related to Environment

- Change inventory levels in MTS.
- Balance backlogs and capacity costs in MTO/ATO.
- Use time fences in different environments.

General Fine-Tuning Techniques

- Establish criteria for accepting an unexpected new customer order or expediting an existing customer order.
- Coordinate engineering configuration changes.
- Maintain schedule integrity.
- Understand the consequences of an unrealistic schedule.
- Respond proactively to changes in suppliers' capabilities, availability of materials or parts, timely delivery, and overall performance.

Maintaining Schedule Integrity

- Safety stock with PTF decision rule
- Hedges
  - Volume hedge
  - Product mix hedge

Action message: Reschedule MPS period 6 to period 5?

		Frozen Zone			Slushy Zone					Liquid Zone	
Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Constrained Demand		20	22	21	25	24	23	21	21	35	25
Customer Orders (Backlog)		19	17	15	11	9	5	2	1	0	0
Projected Available Balance (PAB)	50	31	14	49	24	0	27	6	35	50	25
Master Production Schedule (MPS)				50			50		50	50	

Safety stock = 5 units
Lot size = 50 units

Demand Time Fence (management determined)

Planning Time Fence (longest cumulative lead time)

Master Scheduling Performance: KPIs for Master Scheduling

- MPS aggregate performance
  - Variance of sum of MPSs from S&OP production plan by family
  - Variance of RCCP from resource plan at S&OP level
  - Variance of master schedule from financial plan or budget
- MPS stability
  - % of MPS orders that change
  - % of orders past due
- MPS lead time
  - % of planned orders violating time fence rules
  - Reduction in customer lead times over period of time
- MPS execution
  - % of perfect orders
  - Line-item fill-rate %

Master Scheduling Performance Measurement

Problem indicators	Key policies and procedures
▪ Unreliable delivery promises ▪ Persistent past-due orders ▪ Excess inventory ▪ Many schedule changes ▪ Top management intervention	▪ Clearly defined master scheduler role – Disaggregation role ▪ Senior management collaborates ▪ Time fences enforced ▪ Lot size, safety stock, lead time, etc., updated ▪ RCCP and APS

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SECTION F:
MATERIAL REQUIREMENTS PLANNING

APICS

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Section F Learning Objectives

- MRP and service parts
- MRP in different manufacturing environments
- MRP planning horizons, time buckets, inputs, and outputs
- Types of bills of material (BOMs)
- Elements of the MRP grid
- Actions in BOM explosions, low-level coding, offsetting lead time, and gross to net requirements calculation
- Metrics used to assess MRP performance

MRP Overview and Design

MRP Basics

MRP: "Set of techniques that uses BOM data, inventory data, and MPS to calculate requirements for materials."

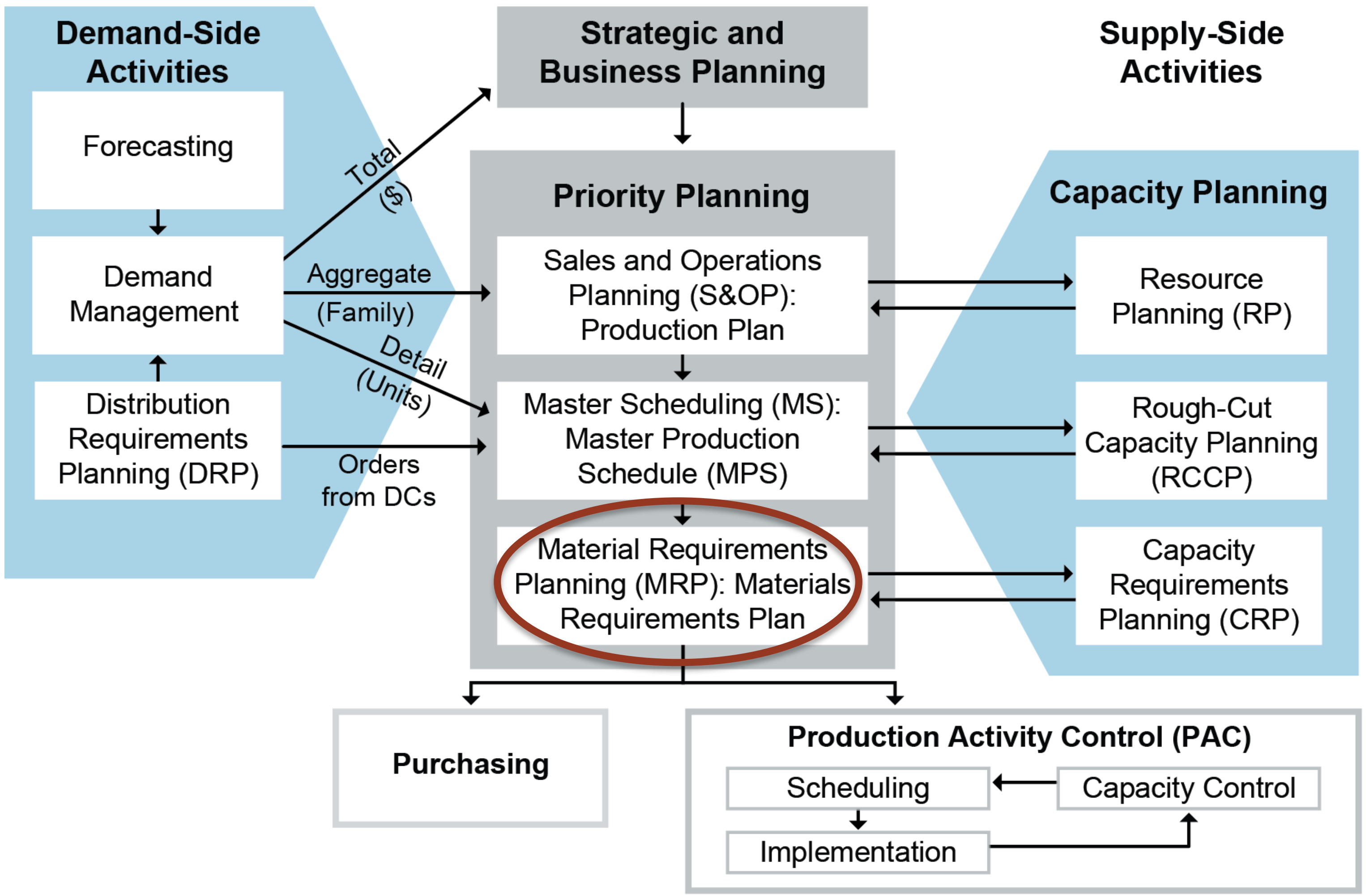
Functions of MRP

- Plan and control inventories.
- Plan and control order releases.
- Provide accurate input into capacity planning process.

Objectives of MRP

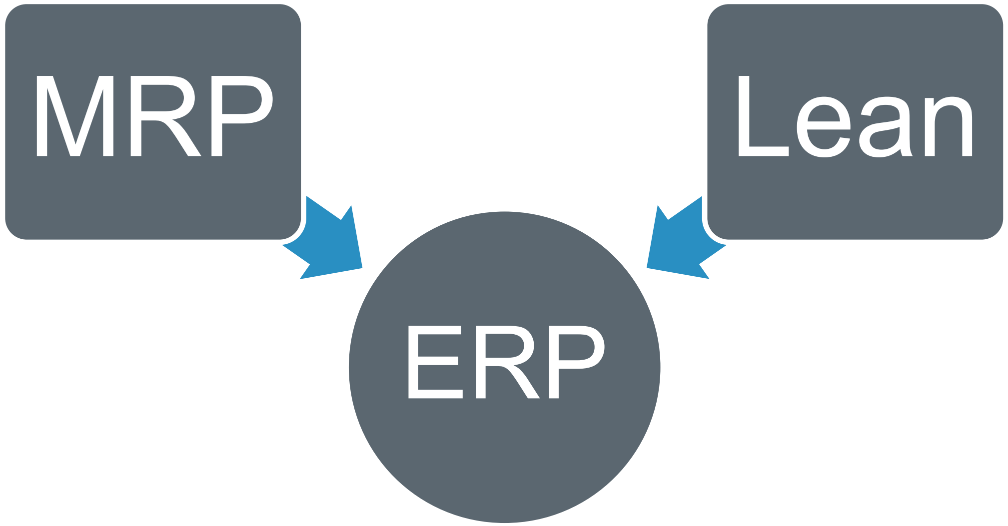
- **Planning**
  - – Precise material requirements
  - – What, how much, and when
  - – What to get from inventory
  - – What, when to order; when to schedule delivery
- **Control**
  - – Adapt to changing priorities
  - – Demand changes, supply issues, errors
  - – Update multiple details
  - – Planners able to expedite, de-expedite, add, cancel, or change planned orders

Material Requirements Planning in Context



Manufacturing Environments and Production Systems

- MRP has traditionally been used
  - In push, rather than pull, environments
  - For items with dependent, rather than independent, demand.
- ERP systems can
  - Incorporate functionality of both MRP and lean.
  - Manage parts with both dependent and independent demand (service parts).



MRP Planning Horizon Time Buckets

- Planning horizon at least as long as cumulative lead time for end item.
- Time buckets contain defined number of days of data.

Part	Lead time (weeks)	Lot size	MRP	Week 0	1	2	3	4	5	6	7	8	9
			Gross requirements						20	20		20	
			Scheduled receipts										
221			Projected available	10	10	10	10	10	0	0	0	0	0
			Net requirements						10	20		20	
			Planned order receipt						10	20		20	
	2	L4L	Planned order release				10	20		20			

Bucketless MRP Systems

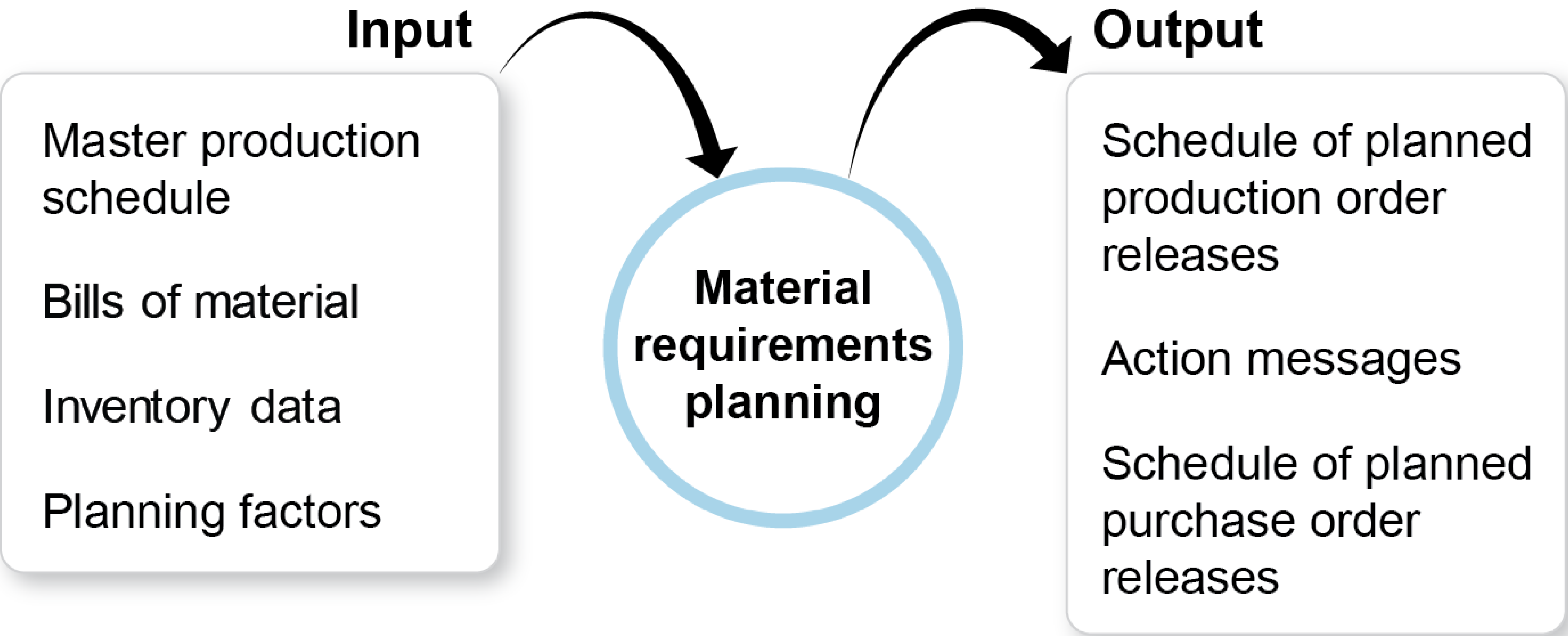
Planning bucket is one day.

Only days with events are displayed.

Fewer timing problems, better activity time phasing.

Part Number: 12345			
Lead Time (Days): 5		Safety Stock: 10	
Description: Widget		Lot Size: 50	
Date	**Transaction**	**Quantity**	**PAB**
Beginning of June			100
1-Jun	Forecast	20	80
3-Jun	MPS Receipt	50	130
4-Jun	Customer Order	100	30
5-Jun	Customer Order	25	5
5-Jun	Planned MPS Receipt	50	55

MRP Inputs and Outputs



Inputs, Process, and Outputs

Input	Description	Source
MPS	Quantities, due dates as planned and scheduled orders	Master schedule
BOMs	Quantity of each uniquely identified part to make one item	Product structure file
Planning factors	Static inventory data (lot size, lead time, yield/scrap factors, safety stock level)	Inventory records: item master
Inventory status	Dynamic inventory data for components/items (on hand, allocated, on order with due date)	Inventory records: inventory record

Process: time-phased priority plan with release/receipt plan

Outputs: Net requirements, planned order receipts, and planned order releases. Become inputs to purchasing and PAC: POs to suppliers; manufacturing orders to shop floor

MRP Inputs, Process, and Outputs

Bill of Material Concepts

Unique ID: All parts get unique part number. (If form, fit, or function changes, part gets new number.)

Single unit: All parts to make exactly one unit of Part Number 100.

Family A: In-Stock All-Glass Vandalproof Commercial Doors			
Product: Family A Double Door (A-DD)	Part Number: 100		
Description: Vandalproof glass double doors, silver trim			
Part Number	**Description**	**Quantity**	**Units**
202	Door, Family A	2	Each
422	Handle and crashbar, silver	2	Kit
323	Lockset	2	Kit
735	Door frame, double, silver	1	Each
682	Hydraulic closer, silver	2	Each
502	Hardware Kit	1	Kit

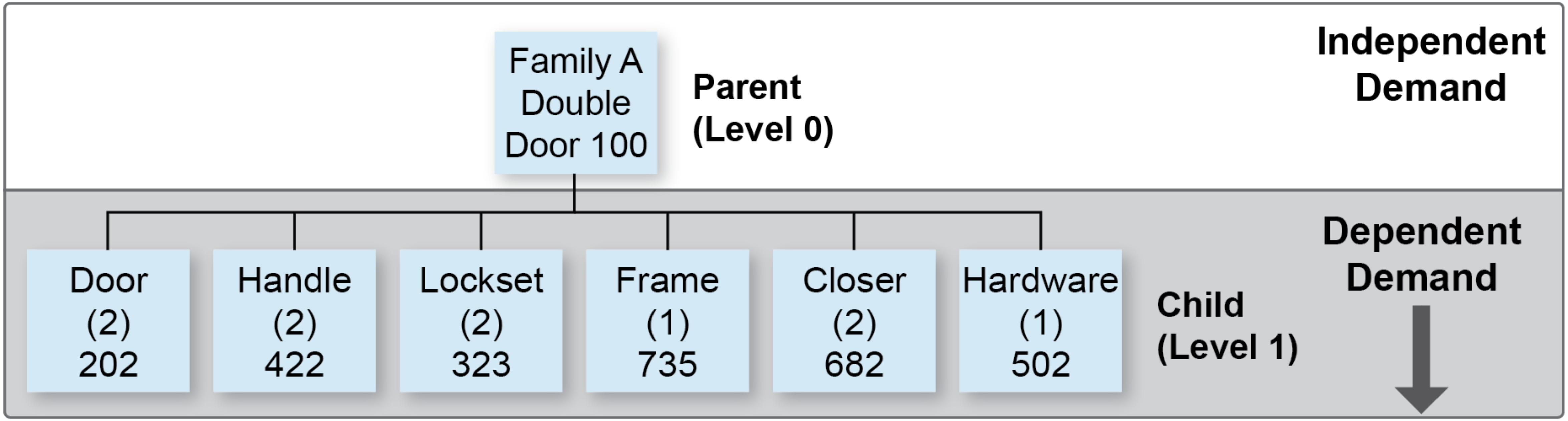
Scope: If it isn't listed, it isn't used (but some MRO supplies might be used but not listed).

Quantities

Unit of measure

Independent vs. Dependent and Parent-Child

Part 100 is available for sale and thus represents independent demand. All components used to create part 100 represent dependent demand.



How BOMs Are Used in Organizations

Engineering

- Part of specifications for new or improved products
- For example, chemical formula BOMs
- Engineering change control and start/stop dates for new BOMs or components

Customer service and service parts

- Right replacement part
- Customer options (ATO): custom BOM maybe with costs

Finance

- Direct materials costing, direct labor estimates, overhead allocation

MRP Inputs, Process, and Outputs

Single-Level BOMs

- Data in only one place, available for multiple products.
- Each part can have its own single-level BOM. (Part 202 is a child of Part 100.)

Product: Door, Family A — Part Number: 202

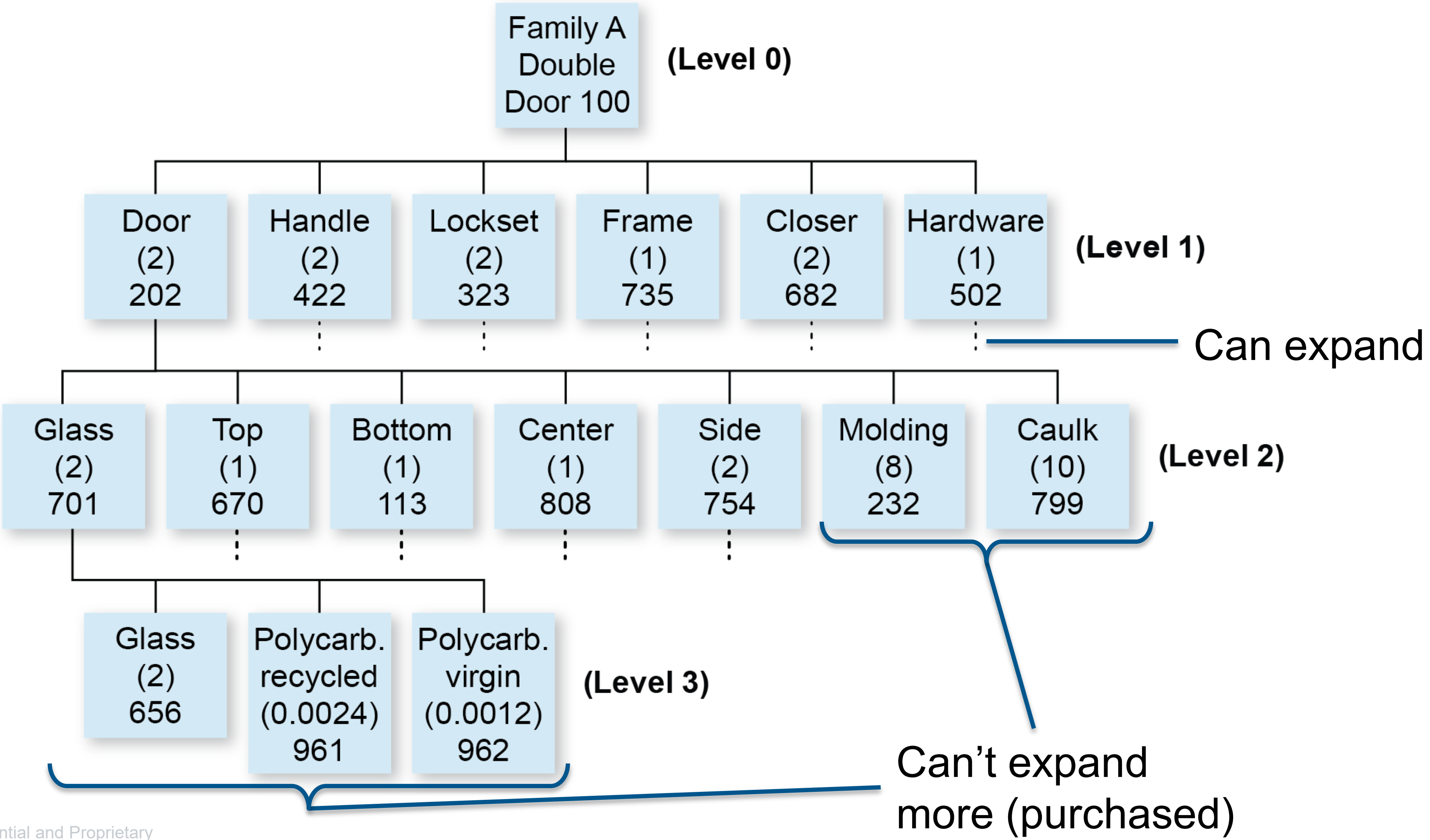
Description: Vandalproof glass door, silver trim

Part Number	Description	Quantity	Units
701	Vandalproof glass, 0.8m x 1.2m	2	Each
670	Top frame, silver	1	Each
113	Bottom frame, silver	1	Each
808	Center frame, silver	1	Each
754	Side frame, silver	2	Each
232	Molding, gray	8	Meters
799	Caulk, silicone, clear	10	Meters

Children (components) of Part 202

MRP Inputs, Process, and Outputs

Multilevel BOMs: Product Tree Format



Planning Factors

Information about ordering, policy, and use

- Lot size
- Order quantity
- Unit of measure
- Lead time
- Safety stock
- Safety lead time
- Scrap and yield

MRP Inputs, Process, and Outputs

Inventory Data

- Current inventory status
  - On-hand
  - Allocation
  - Scheduled receipts
- Inventory item record
- Historical demand and usage

Item Master Data:

Part #	Description	Unit of measure	Order policy	Order quantity	Source code	ABC code	Lead time	Standard cost
10564	gear housing	EA	FOQ	50	M	B	3	108.44

Planning factors

Safety stock	Scrap factor
0	0.10

Inventory Record:

Prime location	Drawing	Revision	Planner/ buyer	Last cycle	Last receipt	Last issue	YTD usage	MTD usage
12C3	10564B	F1	D	03/22	04/01	04/06	190	23

Status data

On hand	Allocations	Available	On order
17	7	10	22

Usage data

Transaction History:

Date	Reference	Initials	Receipts	Issues	Adjust	Stores	Location	Balance
03/13	M1056	VXS	49			S2	12C3	52
03/20	A357	MOM		15		S2	12C3	37
03/22	C87	REC			-1	S2	12C3	36
03/27	A412	MOM		22		S2	12C3	14
04/01	M1103	VXS	26			S2	12C3	40
04/06	A415	MOM		23		S2	12C3	17

MRP Inputs, Process, and Outputs

Item Numbering

System goals

- Uniformity across organization
- Free of confusion
- Few errors
- Expandable

What are some good practices in designing an item numbering system?

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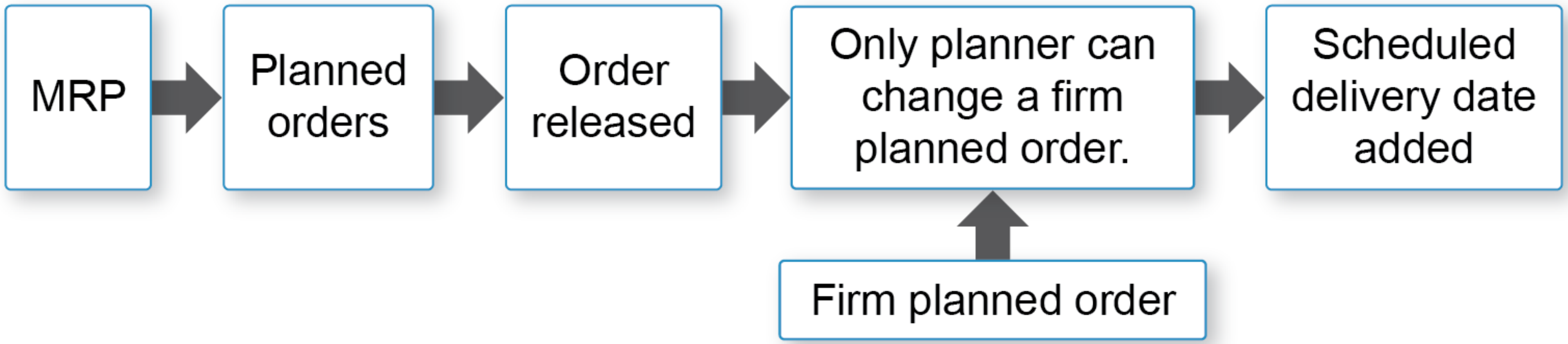
MRP Outputs

- Purchase and production orders
- Action messages and exception codes



Firm Planned Orders as an Exception Method

Example (lot size = 50 units)

Under normal MRP logic, 50 units would be released in week 3 (planned order release with 2-week lead time).

Ordered early after the scheduler was informed by the supplier of a scheduled production line shutdown on their end.

Part Number	Time		Week 0	1	2	3	4	5	6
C		Gross Requirements		40	50	60	40	50	
		Scheduled Receipts			50				
		Projected Available	40	0	0	40	0	0	0
		Net Requirements				60		50	
		Planned Order Receipt				100		50	
	2	Planned Order Release		100	50F				

Action Messages and Exception Codes

Action messages

System alerts planner of need to take action to keep system updated:

- Release order
- Reschedule in
- Reschedule out
- Cancel

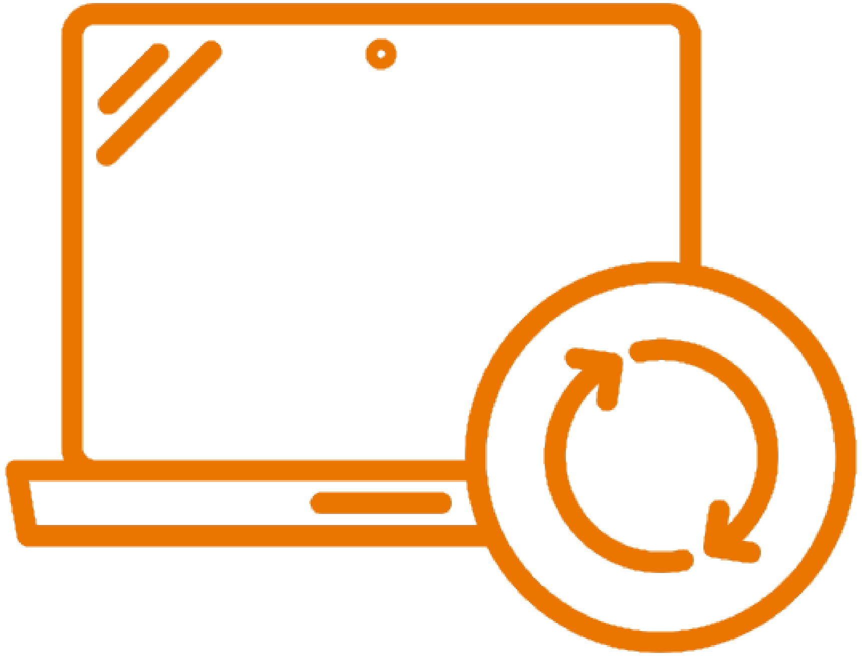
Exception codes

- Codes that draw attention to rule conflicts, mistakes, missing data

MRP Inputs, Process, and Outputs

Regenerating or Net Change MRP

- Updating the MRP records to maintain accuracy of plan
- Regeneration MRP systems
- System nervousness



MRP Grid

On item master record:

- Lead time: 2 weeks
- Lot size: 100 units

Available at beginning of period shown

Time bucket

Part Number 202 — **Week**

	MRP	**0**	**1**	**2**	**3**	**4**
From parent item planned order releases →	Gross requirements		57	101	114	86
Released orders (committed) →	Scheduled receipts		100	100		
Inventory balance into future →	Projected available	130	173	172	58	72
After inventory and receipts →	Net requirements					28
Due date (still just plans) →	Planned order receipt					100
When to order or make →	Planned order release			100		

Lead time offset

Production is scheduled only when there is demand.

MRP Planning Logic

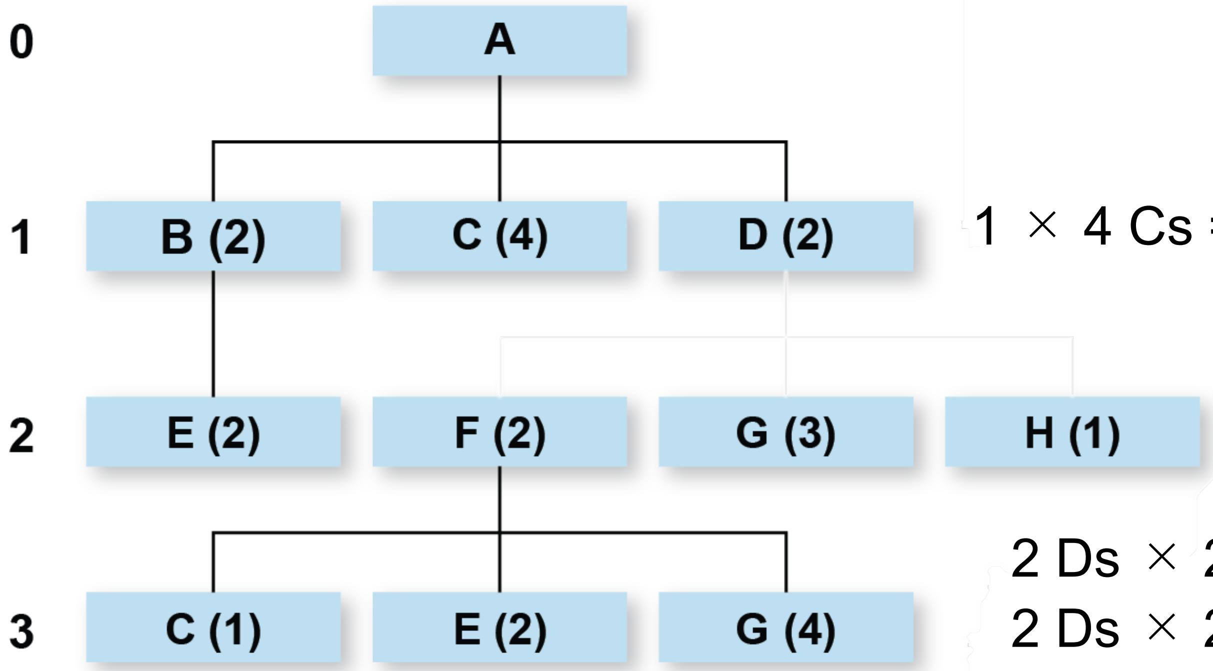
1. Calculate gross requirements at end-item level, based on MPS and service parts schedules.
2. Calculate net requirements using netting process at level 0:
   - Gross requirements
   - MINUS scheduled receipts
   - MINUS prior period projected available balance (or on-hand balance), which may be adjusted downward by allocations or have a minimum balance based on safety stock
3. If net requirement exists, create planned order release and receipt data, applying offsetting to accommodate lead time.
4. Multiply the planned order release by the quantity per in the BOM. This becomes the gross requirements for level 1 components. Repeat process through to the lowest level of the BOM.

Bill-of-Material Explosion (Exploding)

Parent	A	B	D	F
Child	B (2)	E (2)	F (2)	C (1)
Child	C (4)		G (3)	E (2)
Child	D (2)		H (1)	G (4)

Purchased components: C, E, G, H

Level



1 × 4 Cs = 4 Cs

2 Bs × 2 Es = 4 Es

2 Ds × 3 Gs = 6 Gs

2 Ds × 1 H = 2 Hs

2 Ds × 2 Fs × 1 C = 4 Cs

2 Ds × 2 Fs × 2 Es = 8 Es

2 Ds × 2 Fs × 4 Gs = 16 Gs

SUMs

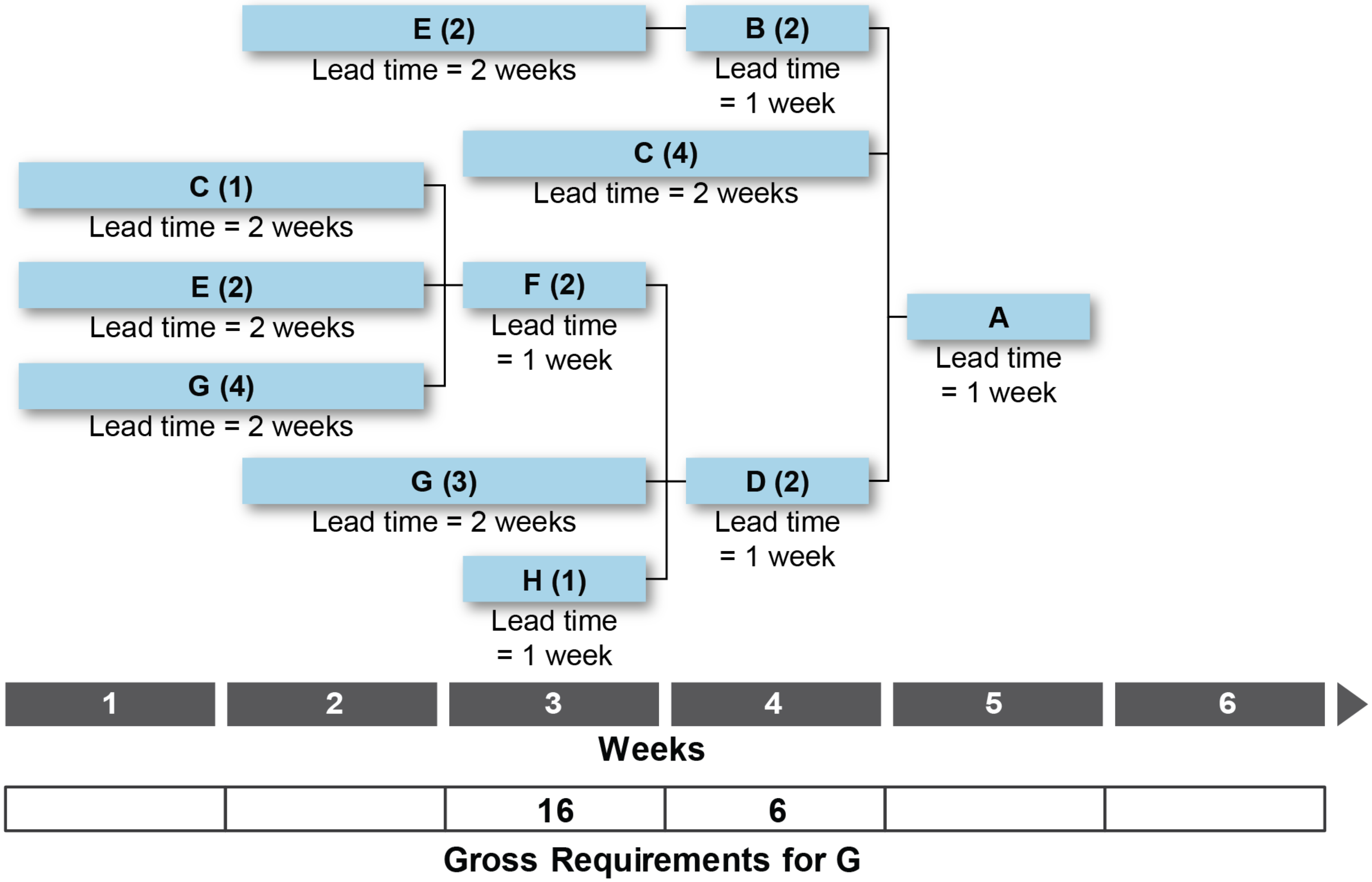
4 + 4 = 8 Cs

4 + 8 = 12 Es

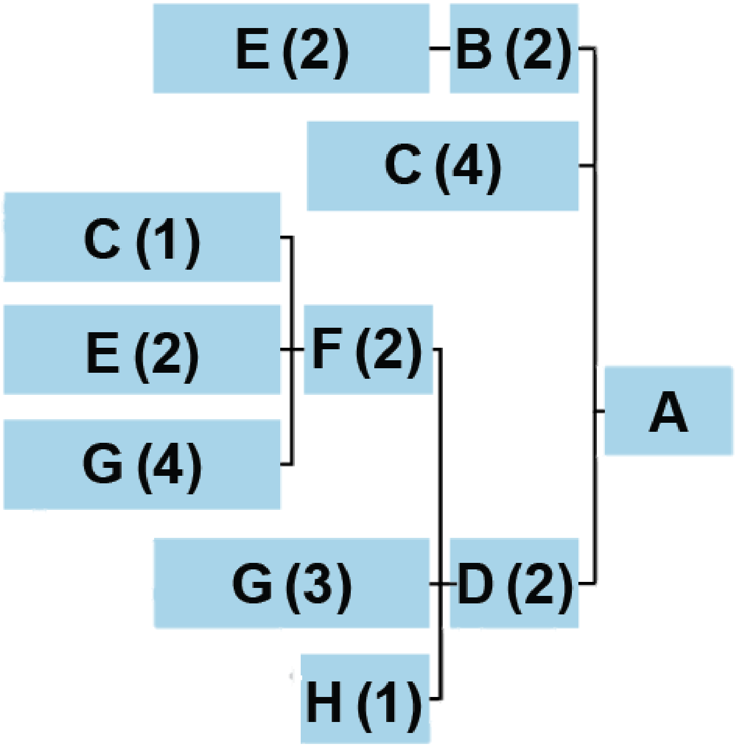
6 + 16 = 22 Gs

2 Hs

Offsetting


E (2)
Lead time = 2 weeks
B (2)
Lead time = 1 week
C (4)
Lead time = 2 weeks
C (1)
Lead time = 2 weeks
E (2)
Lead time = 2 weeks
F (2)
Lead time = 1 week
G (4)
Lead time = 2 weeks
A
Lead time = 1 week
G (3)
Lead time = 2 weeks
D (2)
Lead time = 1 week
H (1)
Lead time = 1 week
1
2
3
4
5
6
Weeks
16
6
Gross Requirements for G

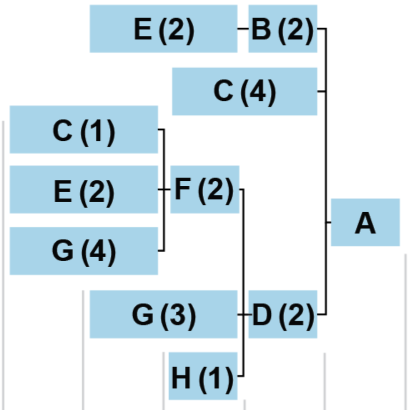
Offsetting Planned Order Releases from Receipts



Part Number	Lead Time		Week 1	2	3	4	5	6
A		Planned Order Receipt						1
	1	Planned Order Release					1	
B		Planned Order Receipt					2	
	1	Planned Order Release				2		
C		Planned Order Receipt			4		4	
	2	Planned Order Release	4		4			
D		Planned Order Receipt					2	
	1	Planned Order Release				2		
E		Planned Order Receipt			8	4		
	2	Planned Order Release	8	4				
F		Planned Order Receipt				4		
	1	Planned Order Release			4			
G		Planned Order Receipt			16	6		
	2	Planned Order Release	16	6				
H		Planned Order Receipt				2		
	1	Planned Order Release			2			

Preliminary MRP with Projected Available

Projected Available = Prior Projected Available + Scheduled Receipts + Planned Order Receipts − Gross Requirements



Part C, Week 3:
$7 + 0 + 0 - 4 = 3$

Part E, Week 2:
$4 + 5 + 0 - 0 = 9$

Part Number	Lead Time		Week 0	1	2	3	4	5	6
C		Gross Requirements				4		4	
		Scheduled Receipts			5				
		Projected Available	2	2	7	3	3	-1	-1
		Net Requirements							
		Planned Order Receipt							
	2	Planned Order Release							
E		Gross Requirements				8	4		
		Scheduled Receipts			5				
		Projected Available	4	4	9	1	-3	-3	-3
		Net Requirements							
		Planned Order Receipt							
	2	Planned Order Release							

Gross to Net Requirements

Net Requirements =

Gross Requirements − Scheduled Receipts − Prior Projected Available

Part C, Week 5:
4 − 0 − 3 = 1

Part Number	Lead Time		Week 0	1	2	3	4	5	6
C		Gross Requirements				4		4	
		Scheduled Receipts			5				
		Projected Available	2	2	7	3	3	-1	-1
		Net Requirements						1	1
		Planned Order Receipt							
	2	Planned Order Release							

Part G, Week 3:
16 − 0 − 13 = 3

Part Number	Lead Time		Week 0	1	2	3	4	5	6
G		Gross Requirements				16	6		
		Scheduled Receipts			5				
		Projected Available	8	8	13	-3	-9	-9	-9
		Net Requirements				3	9	9	9
		Planned Order Receipt							
	2	Planned Order Release							

Completed MRP

Lot size rule = 5 units

Part E, Week 4, projected available:
1 + 0 + 5 − 4 = 2

Part G, Week 4, net requirements:
6 − 0 − 2 = 4

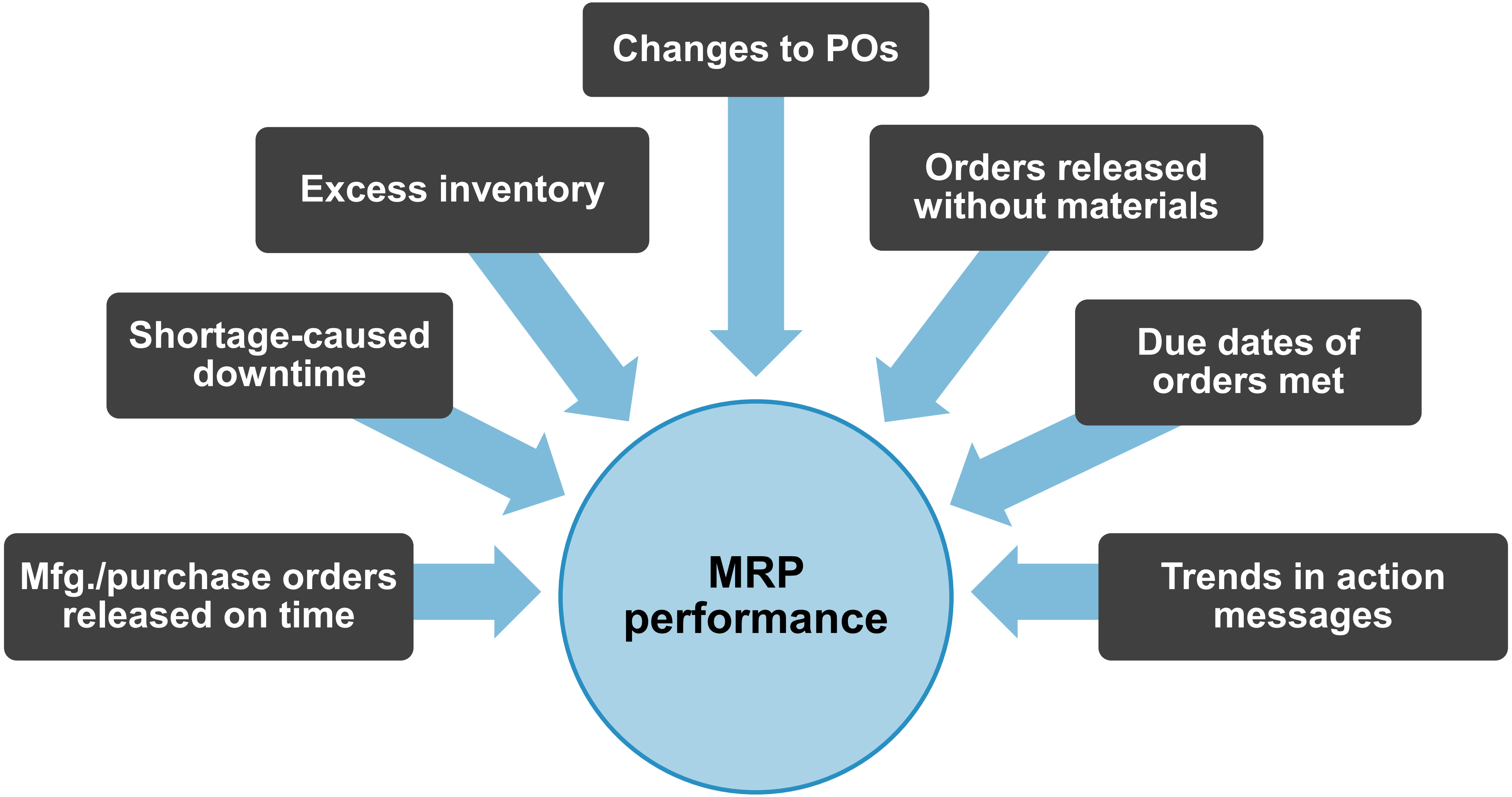
Part Number	Lead Time		0	1	2	3	4	5	6
			Week						
C		Gross Requirements				4		4	
		Scheduled Receipts			5				
		Projected Available	2	2	7	3	3	4	4
		Net Requirements						1	
		Planned Order Receipt						5	
	2	Planned Order Release				5			
E		Gross Requirements				8	4		
		Scheduled Receipts			5				
		Projected Available	4	4	9	1	2	2	2
		Net Requirements					3		
		Planned Order Receipt					5		
	2	Planned Order Release			5				
G		Gross Requirements				16	6		
		Scheduled Receipts			5				
		Projected Available	8	8	13	2	1	1	1
		Net Requirements				3	4		
		Planned Order Receipt				5	5		
	2	Planned Order Release		5	5				
H		Gross Requirements					2		
		Scheduled Receipts							
		Projected Available	1	1	1	1	4	4	4
		Net Requirements					1		
		Planned Order Receipt					5		
	1	Planned Order Release				5			

Using and Managing MRP

Planner's Role in MRP Management

- Keep materials flowing into, through, and out of operations.
- Maintaining priorities under changing conditions:
  - Changes in MPS
  - Changes to work in process
  - Actions by suppliers
- Releasing orders from action bucket
- Rescheduling open orders as needed
- Analyzing and revising planning factors
- Reconciling errors and inconsistencies
- Proactive problem solving
- Creative problem solving within the system to resolve material shortages
- Improving the process

Evaluating MRP Performance



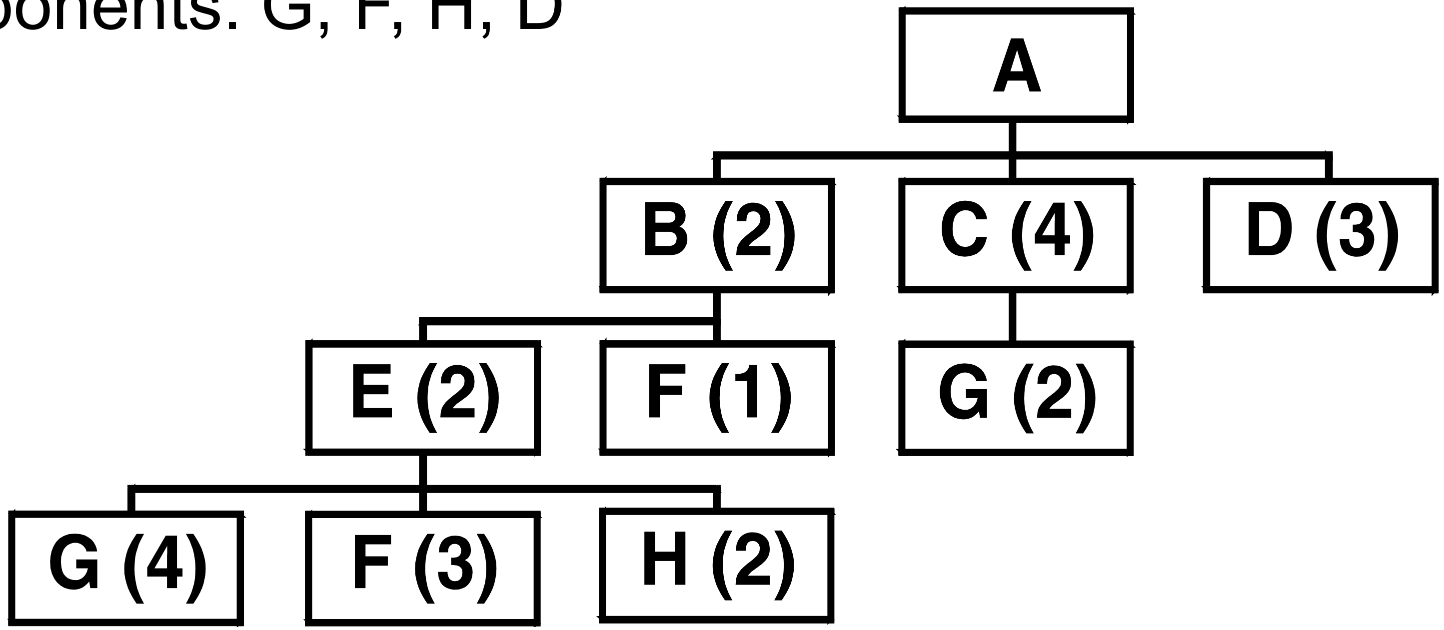
Bill of Material Product Tree Exercise

Parent	A	B	C	E
Component	B (2)	E (2)	G (2)	G (4)
	C (4)	F (1)		F (3)
	D (3)			H (2)

Given the parents and components, construct a product tree. Figures in brackets show the quantities per item.

Bill of Material Product Tree Solution

- Number of subassemblies: 3 (child)
- Number of Gs needed: 24
- Purchased components: G, F, H, D



Net Requirements and Planned Orders Exercise 1

Item F Lot size = L4L Lead time = 1	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross requirements					20	20		10
Scheduled receipts								
Projected available					0	0		0
Net requirements					20	20		10
Planned order receipts					20	20		10
Planned order releases				20	20		10	

Net Requirements and Planned Orders Exercise 2

Item D **Lot size = 160** **Allocation = 120** **Lead time = 1**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross requirements			20		220	20	20	10	
Scheduled receipts		160							
Projected available	170	210	190	190	130	110	90	80	80
Net requirements					30				
Planned order receipts					160				
Planned order releases				160					

Net Requirements and Planned Orders Exercise 3

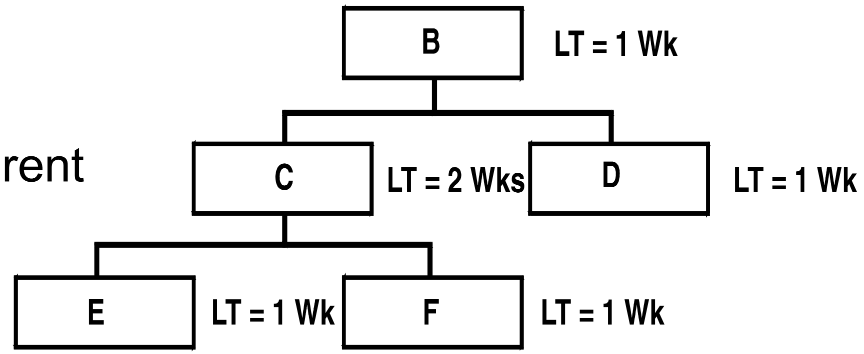
Item E Lot size = 140 Lead time = 1		1	2	3	4	5	6	7	8
Gross requirements				90	80	50	30	10	
Scheduled receipts									
Projected available	120	120	120	30	90	40	10	0	0
Net requirements					50				
Planned order receipts					140				
Planned order releases				140					

Using and Managing MRP

Planned Order Release Exercise 1

Quantity per parent in all cases = 1

Wk = week;
LT = lead time



What is the cumulative lead time for item B?

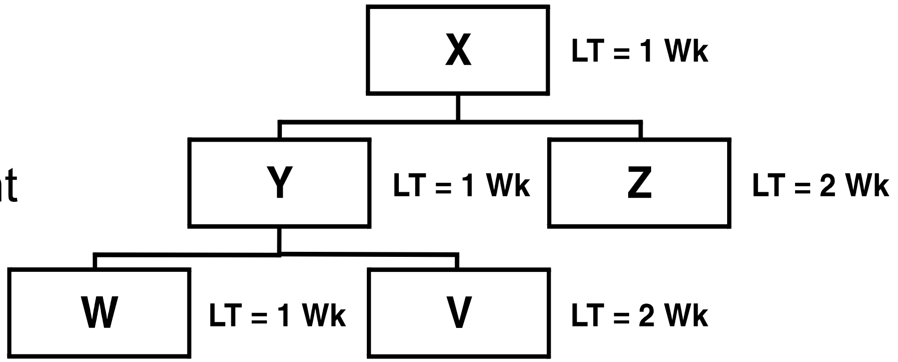
Cumulative lead time:
4 weeks

Item number	Planned order	Week 1	2	3	4	5
B	Receipt					50
	Release				50	
C	Receipt				50	
	Release		50			
D	Receipt				50	
	Release			50		
E	Receipt		50			
	Release	50				
F	Receipt		50			
	Release	50				

Planned Order Release Exercise 2

Quantity per parent in all cases = 1

Wk = week;
LT = lead time



Item number	Planned order	Week 1	2	3	4	5
X	Receipt					200
	Release				200	
Y	Receipt				200	
	Release			200		
Z	Receipt				200	
	Release		200			
W	Receipt			200		
	Release		200			
V	Receipt			200		
	Release	200				

CPIM CERTIFIED IN PLANNING AND INVENTORY MANAGEMENT

SECTION G:
CRP, ORDER PROMISING, AND FINAL ASSEMBLY SCHEDULING

APICS

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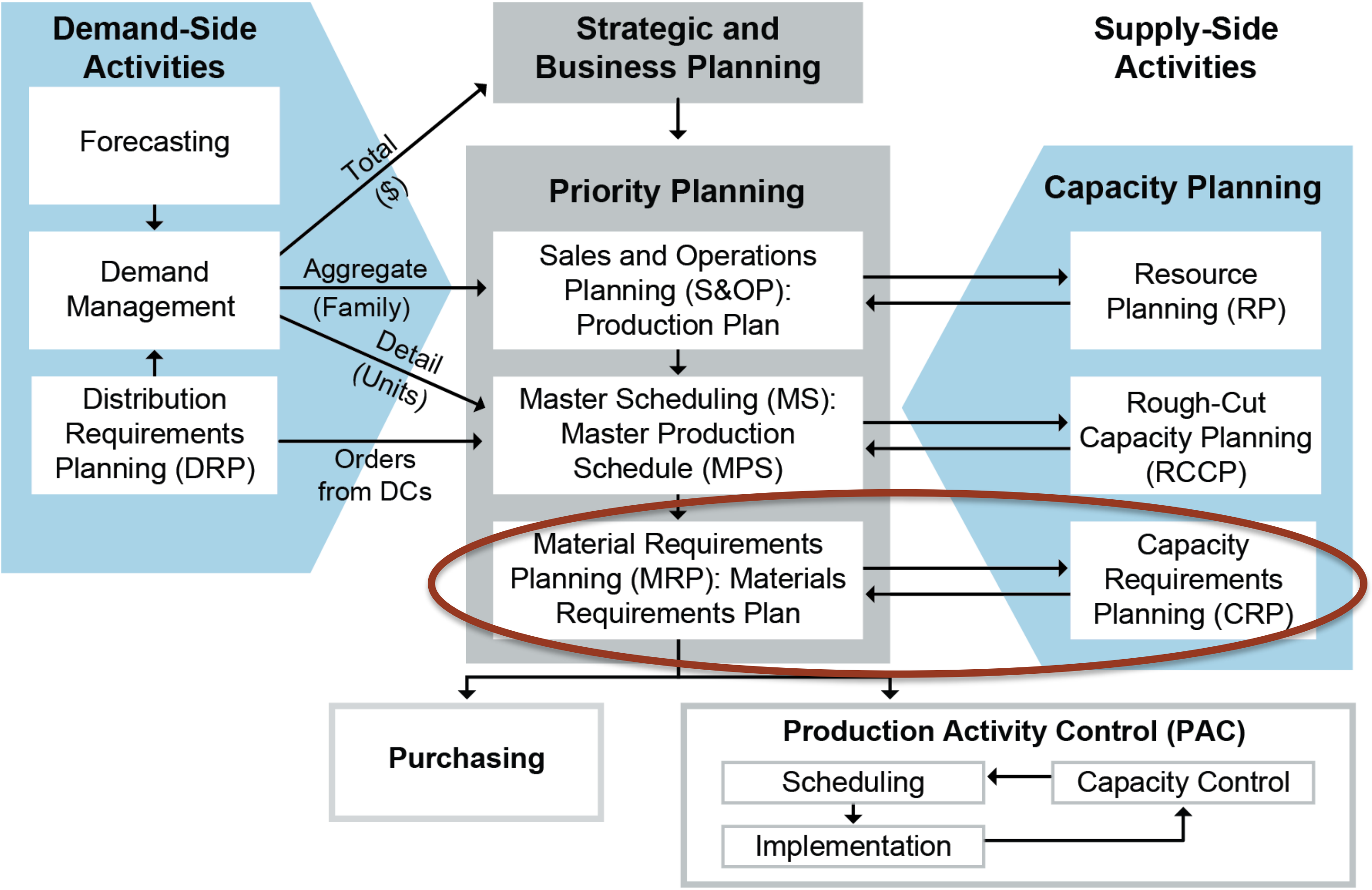
Section G Learning Objectives

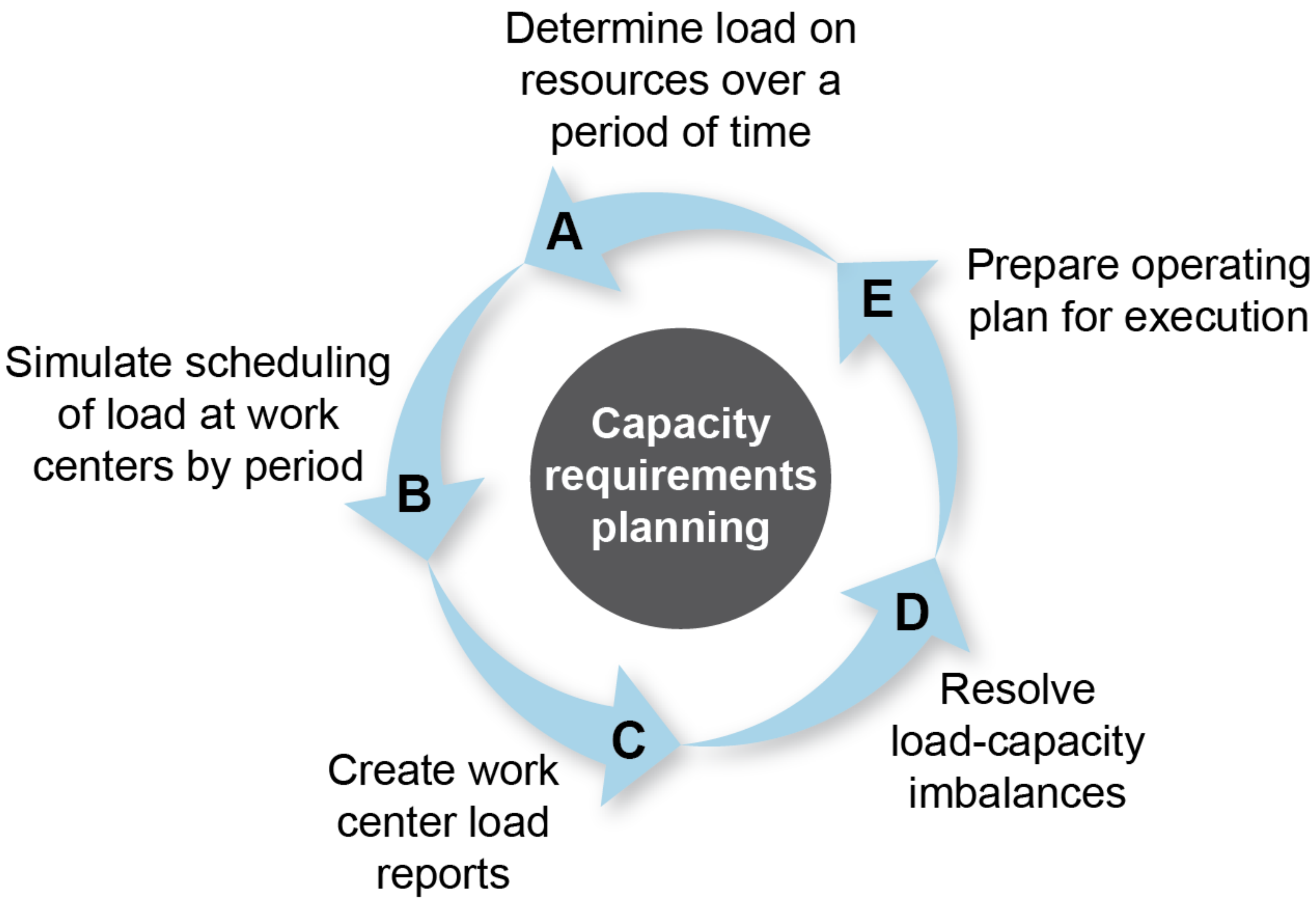
- Relation of CRP and MRP-based scheduling to planning hierarchy
- Basic process used in CRP
- Advantages and limitations of CRP
- MRP-based scheduling
- Finite and infinite capacity loading
- Authorizing production
- Available-to-promise (ATP)
- Steps in final assembly scheduling (FAS)
- Product flow (VATI)
- Sources of demand considered in FAS
- Managing consequences of unrealistic FAS
- Coordinating changes to inventory, backlog, capacity, orders, time fences, designs
- Measuring actual performance against the FAS

Capacity Requirements Planning

CRP and MRP-Based Scheduling in Planning Hierarchy



CRP Model


Determine load on resources over a period of time
A
Prepare operating plan for execution
E
Simulate scheduling of load at work centers by period
B
Capacity requirements planning
D
C
Resolve load-capacity imbalances
Create work center load reports

Advantages and Limitations of CRP

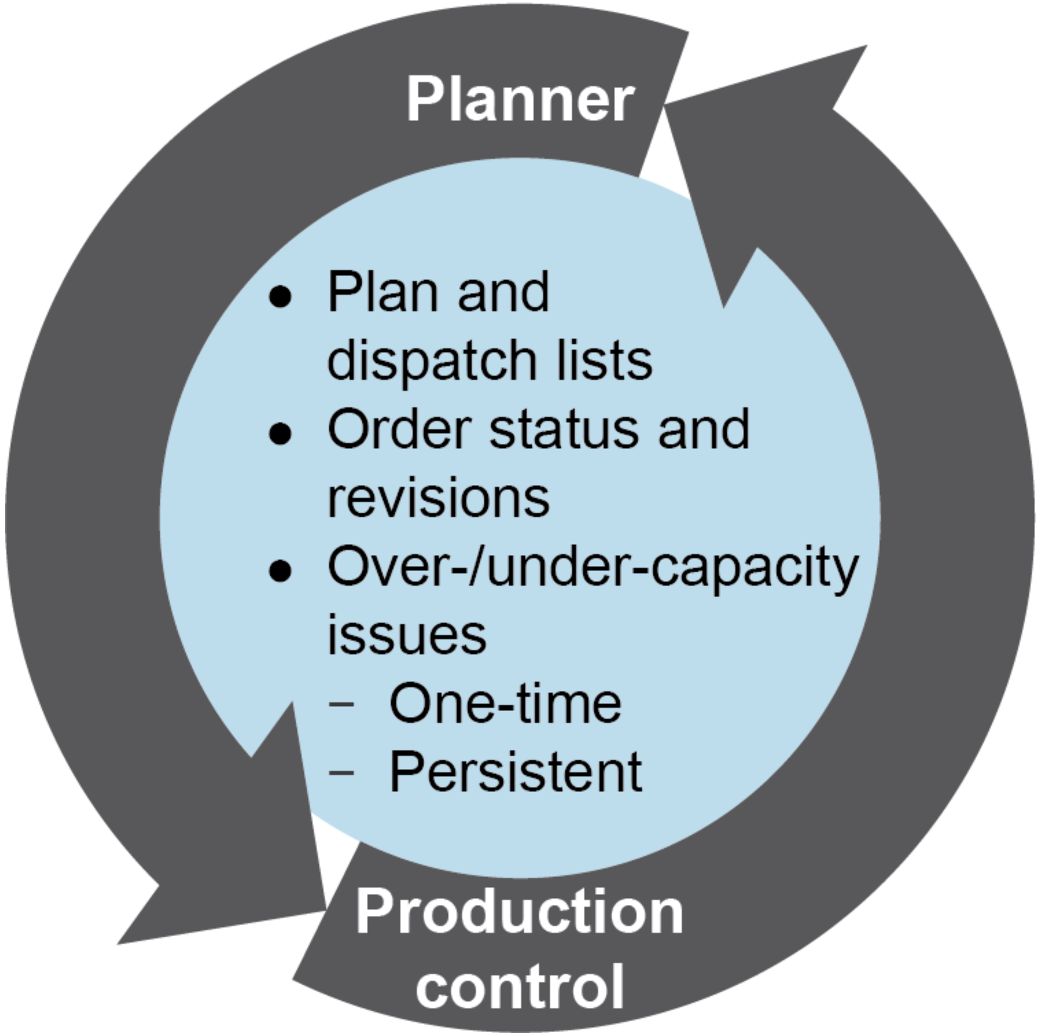
Advantages

- Reveals potential load imbalances
- Simulates effect of changes in planning factors
- Is more detailed than MRP
- Supports lead-time leveling
- Evaluate production feasibility even in DDMRP
- AI, cloud, IoT, hybrid with APS/MES

Limitations

- Not intended for daily operations
- Requires extensive data
- Provides approximations
- Is subject to changes in MPS
- Assumes infinite loading

CRP in Finite Capacity Scheduling Systems

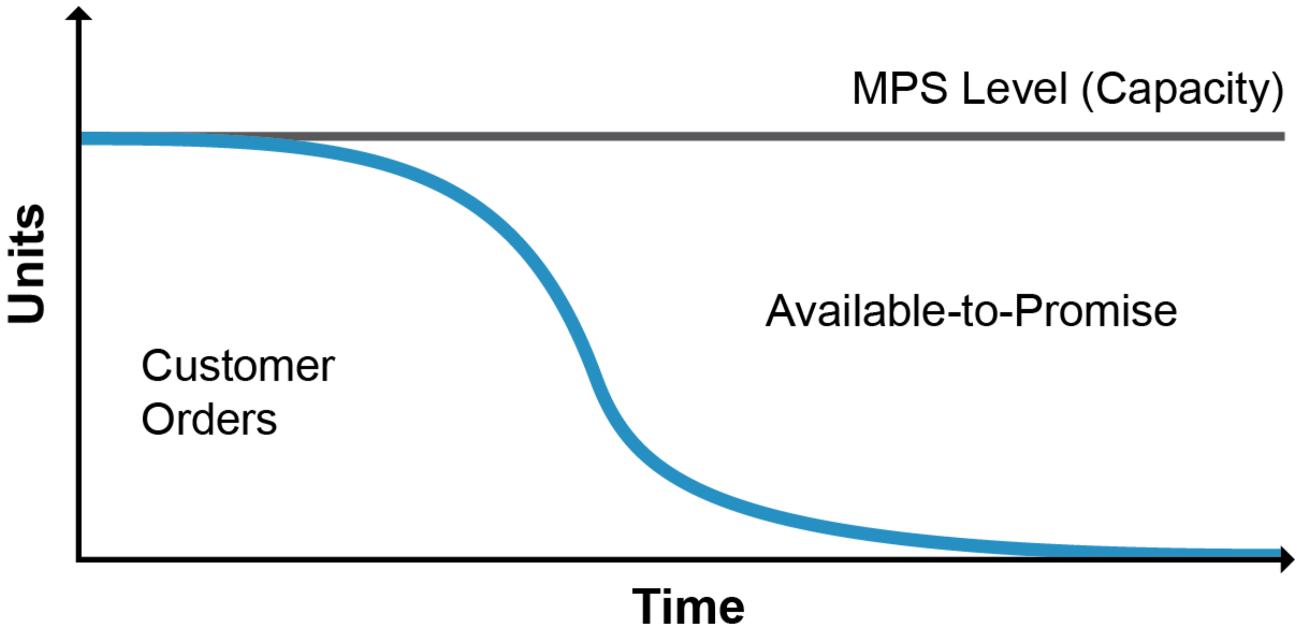


Available-to-Promise (ATP)

- Uncommitted portion of inventory and planned production maintained in the MS to support customer order promising
- Calculating ATP
  - Ignores constrained demand and focuses on customer orders only
  - Calculated for first period of master schedule grid
  - Subsequently calculated only for periods with an MPS receipt
  - Uses discrete and cumulative methods of calculation

Available-to-Promise and Order Promising

- Order entry and order promising (quantity, lead time).
- Orders that exceed available inventory (if any) look next to MPS (anticipated build schedule).
- Consensus from S&OP: realistic, achievable.



Calculating ATP: Discrete and Cumulative With/Without Look-Ahead

ATP period 1, all methods

$ATP_{Period\ 1}$ = On-Hand Quantity + MPS – ∑ Customer Orders $_{Before\ Next\ MPS}$

Discrete ATP

Discrete $ATP_{Periods\ with\ MPS}$ = MPS – ∑ Customer Orders $_{Before\ Next\ MPS}$

Cumulative ATP with look-ahead

Cumulative ATP With $Look\text{-}Ahead_{Next\ MPS\ Period}$ = Previous Cumulative ATP + MPS – ∑ Customer Orders $_{Before\ Next\ MPS}$

Cumulative ATP without look-ahead

Cumulative ATP Without $Look\text{-}Ahead_{Next\ MPS\ Period}$ = Previous Cumulative ATP + MPS – Customer Orders $_{Current\ Period\ Only}$

ATP Methods Compared

Lot size = 50 units

		Frozen Zone			Slushy Zone					Liquid Zone	
Period		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Constrained demand		20	22	21	25	24	23	21	21	25	25
Customer orders (backlog)		19	17	15	11	9	5	2	1	0	0
Projected available balance (PAB)	50	31	14	49	24	50	27	6	35	10	35
Discrete ATP		14		24		34			49		50
Cumulative ATP with look-ahead		14		38		72			121		171
Cumulative ATP without look-ahead		14		49		90			139		189
Master production schedule (MPS)				50		50			50		50

Demand Time Fence
(management determined)

Planning Time Fence
(longest cumulative lead time)

Available-to-Promise, Capable-to-Promise, and Order Promising

Calculating Discrete ATP Given Projected Negative ATP

$ATP_{Period\ 1}$ = 70 on hand + 0 units MPS − 48 units in orders = 22 units

$ATP_{Period\ 3}$ = 100 units MPS – (57 units + 62 units) = -19 units

If negative, reduce prior ATP by negative amount:
34 units − 19 units = 15 units for period 2, with period 3 now at 0 units.

Master Schedule: Make-to-stock Chase Production Example
Beginning inventory = 70 Safety Stock = 0 Lot size = 100

Week	**0**	**1**	**2**	**3**	**4**	**5**	**6 ...**	**12**	**13**	**14**	**15**	**16**
Constrained Demand		50	60	70	90	70	20	20	20	20	20	20
Customer Orders		48	66	57	62	30	0	0	0	0	0	0
Projected Available Balance	70	22	56	99	9	39	19	99	79	59	39	19
Master Production Schedule			100	100		100		100				
Available-to-Promise		22	34	-19		70		100				

Demand Time Fence | Planning Time Fence

Master Schedule: Make-to-stock Chase Production Example
Beginning inventory = 70 Safety Stock = 0 Lot size = 100

Week	**0**	**1**	**2**	**3**	**4**	**5**	**6 ...**	**12**	**13**	**14**	**15**	**16**
Constrained Demand		50	60	70	90	70	20	20	20	20	20	20
Customer Orders		48	66	57	62	30	0	0	0	0	0	0
Projected Available Balance	70	22	56	99	9	39	19	99	79	59	39	19
Master Production Schedule			100	100		100		100				
Available-to-Promise		22	15	0		70		100				

Demand Time Fence | Planning Time Fence

Cumulative ATP with Look-Ahead Exercise

Calculate cumulative ATP for periods 1 and 3.

On hand = 20; lot size = 30; safety stock (SS) = 5

Period		1	2	3	4	5
Constrained demand		5	5	8	10	15
Customer orders		5	4	7	5	0
Projected available balance	20	15	10	32	22	7
Available-to-promise (discrete)		11		18		
Available-to-promise (cumulative)		11		29		
Master production schedule				30		

$$\text{Cumulative ATP}_{\text{Period 1}} = \text{On-Hand Quantity} + \text{MPS} - \Sigma\ \text{Customer Orders}_{\text{Before Next MPS}}$$

$$\text{Cumulative ATP}_{\text{Next MPS Period}} = \text{Prev. Cumulative ATP} + \text{MPS} - \Sigma\ \text{Customer Orders}_{\text{Before Next MPS}}$$

Time Fences Exercise

Calculate the new PAB, MPS, and ATP quantities using the demand time fence.

On hand = 20; lot size = 30; safety stock (SS) = 5; demand time fence = 2

Period		1	2	3	4	5
Constrained demand		5	5	8	10	15
Customer orders		5	3	2	0	0
Projected available balance	20	15	12	34	24	9
Available-to-promise (discrete)		12		28		
Master production schedule				30		

Product Delivery: Key Component Is Order Promising.

ATP aids product delivery by

- Providing valid customer delivery dates
- Holding products before delivery
- Providing warnings on components to prevent over-promising on delivery dates
- Providing sales with up-to-date information to manage delivery expectations.

ATP can establish if

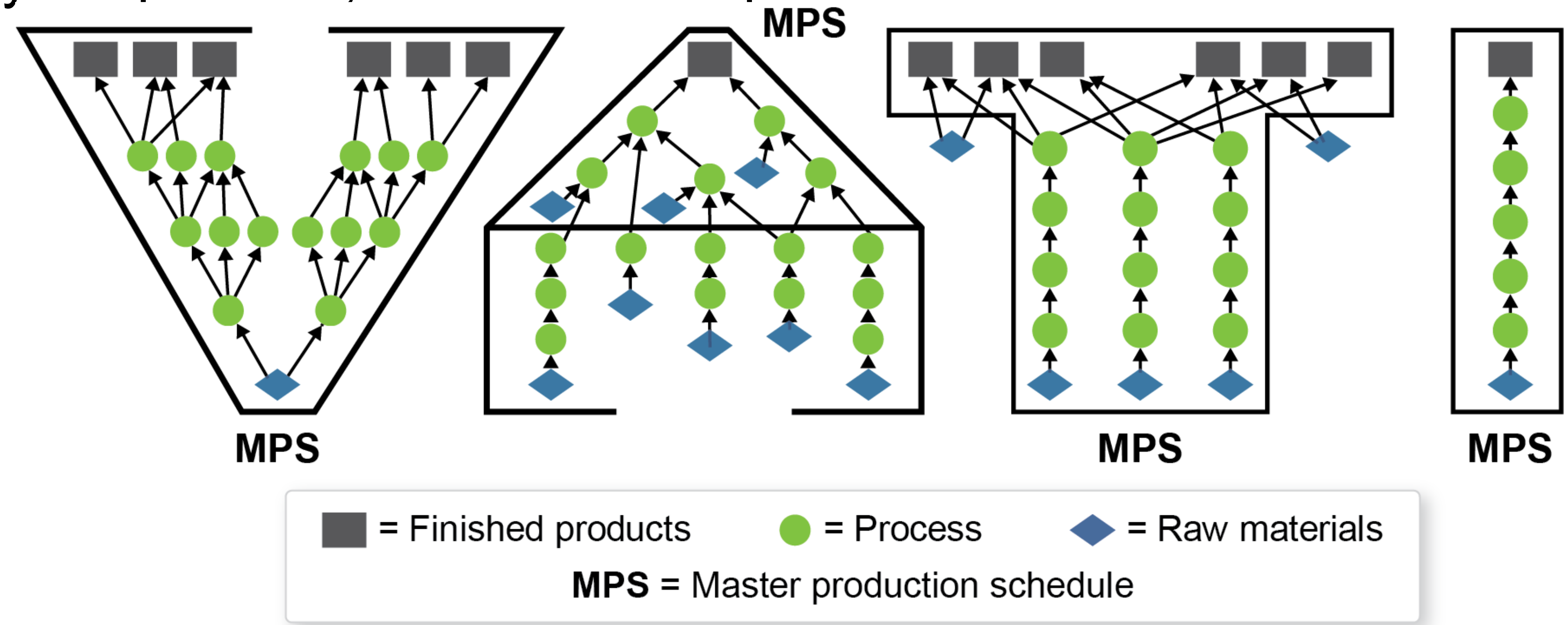
- Product is available at time of order
- Items can be shipped by customer's requested date
- Items are available for single shipment.

Final Assembly Scheduling

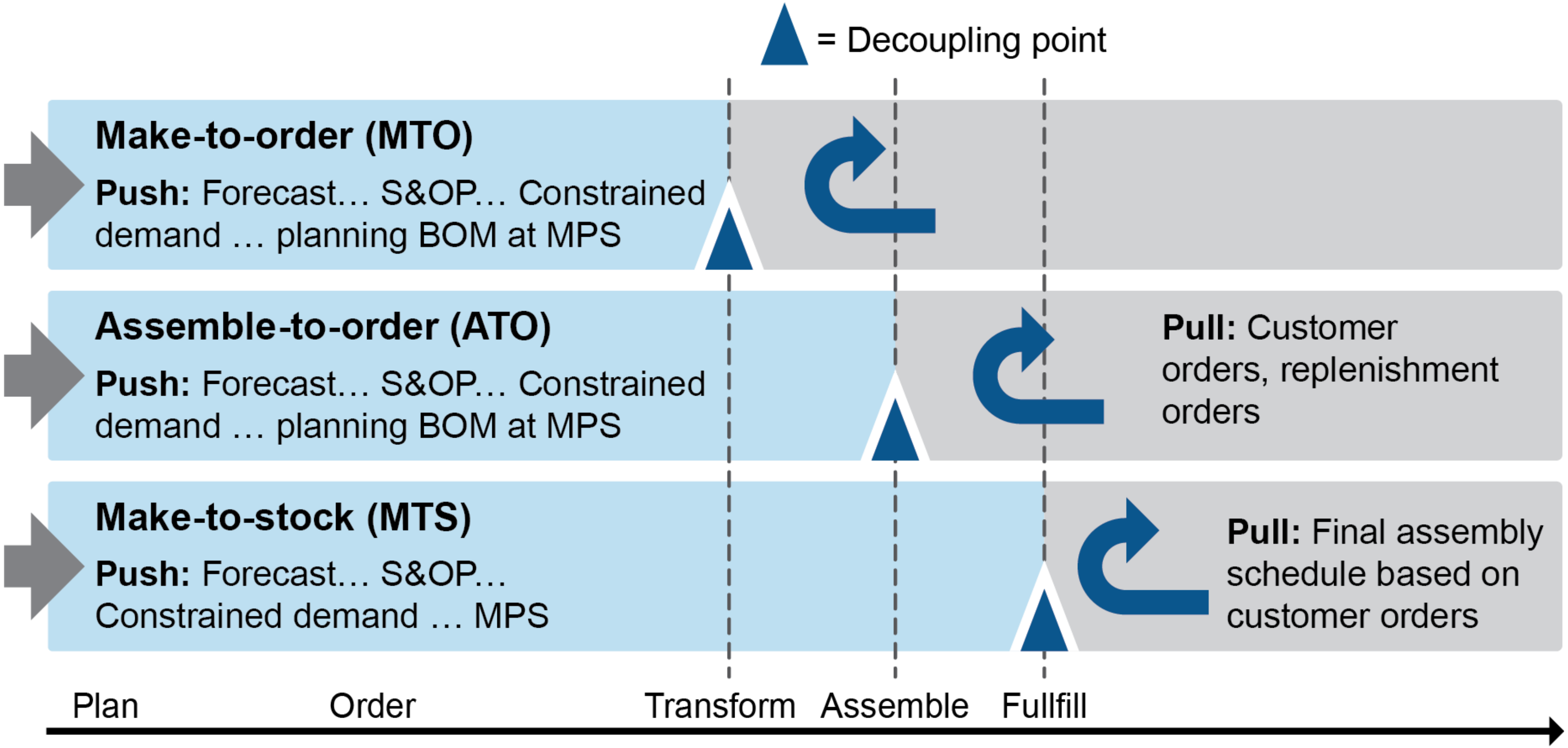
- Schedule of end-items to finish the product for specific customers' orders in a MTO or ATO.
- Prepared after receipt of customer order
- Constrained by availability of material and capacity
- Schedules operations required to complete the product from the level where it is stocked (or master scheduled) to the end-item level

Product Flow (VATI) Analysis

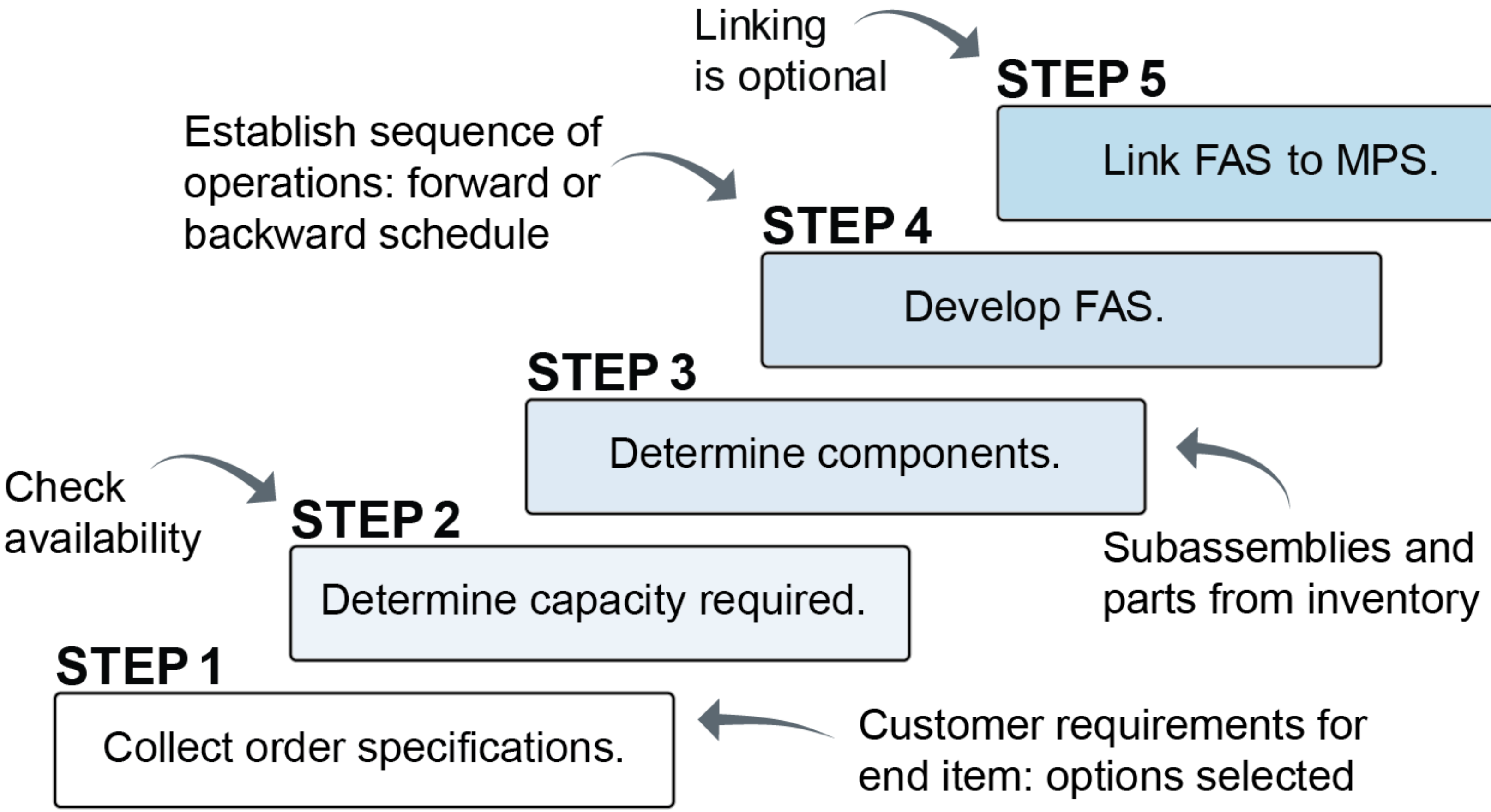
- Look at routings, BOMs, and BOM explosions.
- Study in operation; watch out for spontaneous shifts.



Order Decoupling Point By Manufacturing Environment



FAS Process


Linking
is optional
STEP 5
Link FAS to MPS.
Establish sequence of
operations: forward or
backward schedule
STEP 4
Develop FAS.
STEP 3
Determine components.
Check
availability
STEP 2
Determine capacity required.
Subassemblies and
parts from inventory
STEP 1
Collect order specifications.
Customer requirements for
end item: options selected

Options and Availability

Step 1:

Collecting Order Specifications

- Orders can come from any point of contact with the customer.
- Constraints on order specifications help ensure
  - Availability to customer
  - Organizational profitability.

Step 2:

Determining Capacity

- Uses RCCP.
- Reviews work center capacity against FAS projected load.
- Reviews external supplies to ensure availability.

Final Assembly Scheduling

Materials, Sequence, and Optional Validation

Step 3:

Determining Availability of Components

- Two-level MPS adds level of component planning for common configurations.

Step 4:

Developing the FAS

- FAS involves determining and sequencing necessary operations.

Step 5:

Linking FAS to MPS

- Linking helps validate that MPS priorities are being honored.

Final Assembly Scheduling

Planning and Coordinating Changes

- Short-term issues may lead to re-prioritizing orders.
- May require
  - Discussions with customers
  - Review and adjustment of incoming supplies.
- Longer-term issues may involve changes in
  - Inventory levels
  - Backlog sizes
  - Capacity
  - Time fences
  - Product/process designs
  - Supply factors.

Measuring FAS Performance

Assessing and potentially improving the FAS requires identifying the frequency and magnitude of variances from the schedule.

- Order accuracy
- Product quality
- Order lead time
- Order profitability
- Number of orders requiring rescheduling

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SECTION H:
CHANGES AND SUPPLY DISRUPTIONS

APICS

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Section H Learning Objectives

- Responding to supply and demand changes
- Supply and demand timing and quantity variability
- Revising planning parameters
- Using what-if analysis and simulations
- Monitoring buffer status

Replanning and Revision

Replanning Order Priorities

MRP systems can be affected by variability in

- Demand quantity
- Demand timing
- Supply quantity
- Supply timing.

Original MRP

Part	Lead time (weeks)	Lot size	MRP	Week 0	1	2	3	4	5	6	7	8	9
221	2	L4L	Gross requirements		20	20			20	20		20	
			Scheduled receipts		20	20							
			Projected available	10	10	10	10	10	0	0	0	0	0
			Net requirements						10	20		20	
			Planned order receipt						10	20		20	
			Planned order release				10	20		20			

Demand variability
Projected vs. actual

1. **Requirements** quantity shifts x units higher/lower

MRP	Week 0	1	2	3	4	5	6	7	8	9
Gross requirements		20	20			12	35		12	
Scheduled receipts		20	20							
Projected available	10	10	10	10	10	0	0	0	0	0
Net requirements						2	35		12	
Planned order receipt						2	35		12	
Planned order release				2	35		12			

2. **Requirements** timing shifts earlier/later by X periods

MRP	Week 0	1	2	3	4	5	6	7	8	9
Gross requirements		20	20		20	○	20		○	20
Scheduled receipts		20	20							
Projected available	10	10	10	10	0	0	0	0	0	0
Net requirements					10		20			20
Planned order receipt					10		20			20
Planned order release			10		20			20		

Supply variability
Planned vs. actual

3. Supplier or prior manufacturing step provides X too few/many (e.g., scrap)

MRP	Week 0	1	2	3	4	5	6	7	8	9
Gross requirements		20	20			20	20		20	
Scheduled receipts		22	16							
Projected available	10	12	8	8	8	0	0	0	0	0
Net requirements						12	20		20	
Planned order receipt						12	20		20	
Planned order release				12	20		20			

4. Supplier or production provides orders X periods late/early

MRP	Week 0	1	2	3	4	5	6	7	8	9
Gross requirements		20	20			20	20		20	
Scheduled receipts		20	○	20						
Projected available	10	10	-10	10	10	0	0	0	0	0
Net requirements			10			10	20		20	
Planned order receipt						10	20		20	
Planned order release				10	20		20			

Quantity variability | **Timing variability**

Lot-Sizing Changes

Lot-sizing models	Key points
▪ Economic order quantity (EOQ) ▪ Period order quantity (POQ) ▪ Dynamic methods – Least total cost – Part period balancing (PPB) – Silver-Meal Heuristic (least period cost) – Wagner-Whitin algorithm	▪ Minimize sum of ordering and carrying costs. ▪ Lot-for-lot can be expensive when there is low but not zero demand. ▪ Cost savings can be significant when used on all MRP items. ▪ Users need to be able to make sense of the logic.

Revising Buffers

- Safety lead time
  - Timing uncertainty
- Safety stock
  - Quantity uncertainty
- Yield factors
  - Clarify it is starting quantity.

- Buffers absorb minor variability and avoid system nervousness.
- Buffers are inherently problematic because they give the system false inputs.

Checking Feasibility and Validating Execution

What-if analysis, simulation, AI	Monitoring buffer status
▪ What-if analysis examines impact of changes to a single factor (e.g., longer lead time). ▪ Simulation includes multiple inputs within defined ranges to describe a possible scenario. ▪ AI: analytics, use with IoT, replan more frequently, fix designs, predictive maintenance…	▪ Monitor for abnormalities. ▪ Time monitoring with throughput speed. ▪ Train and communicate with system users to avoid MRP system nervousness.