



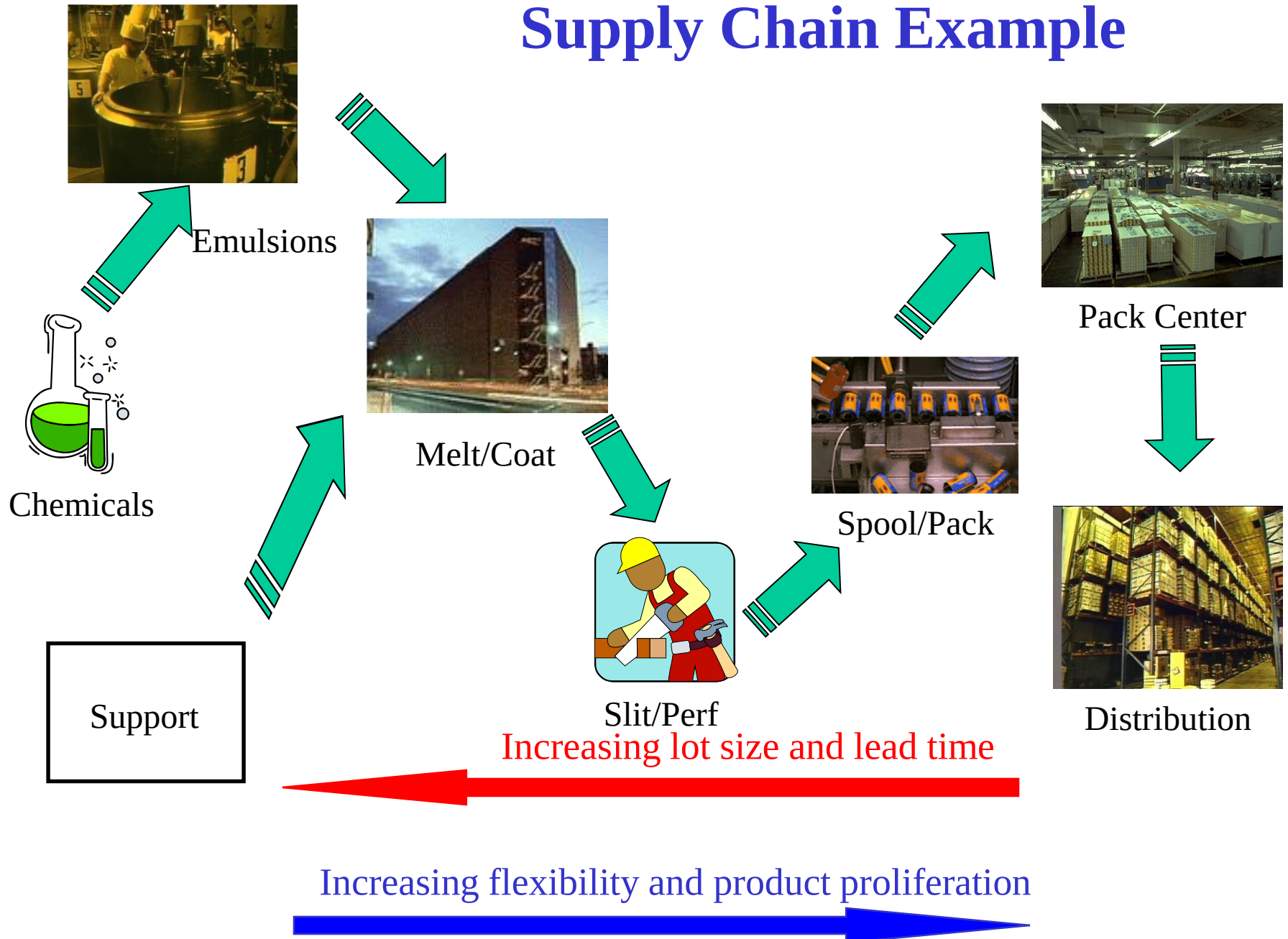
Tactical planning issues in supply chain management

Stephen C. Graves

sgraves@mit.edu

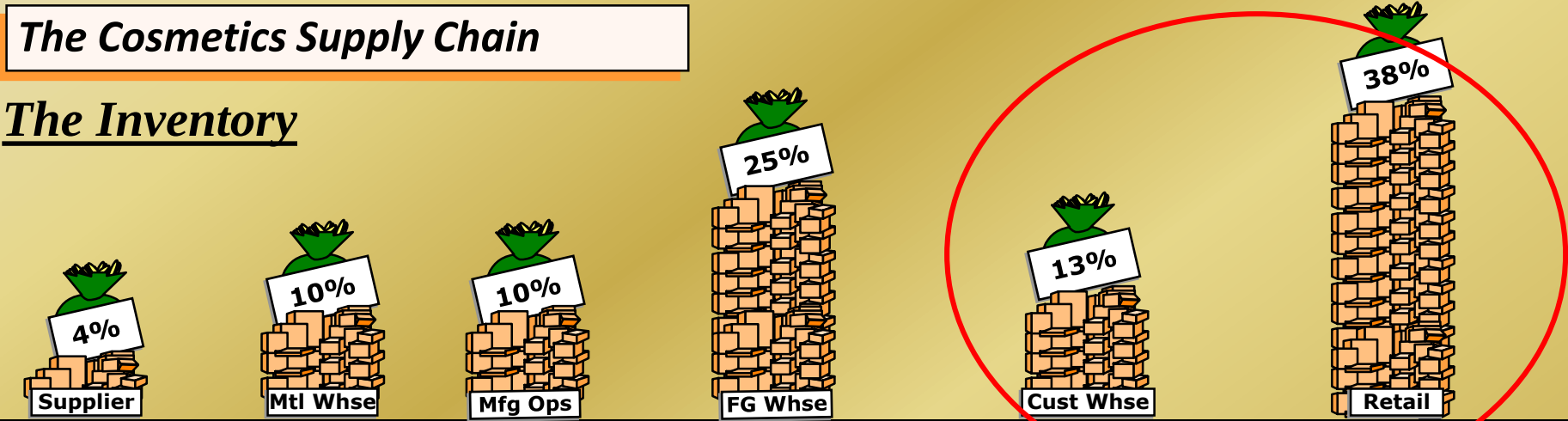
November 2019

Supply Chain Example

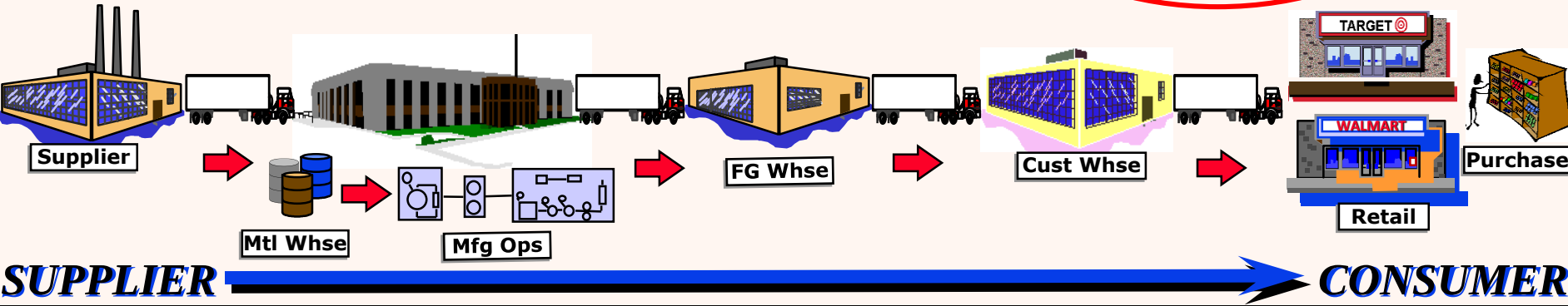


The Cosmetics Supply Chain

The Inventory

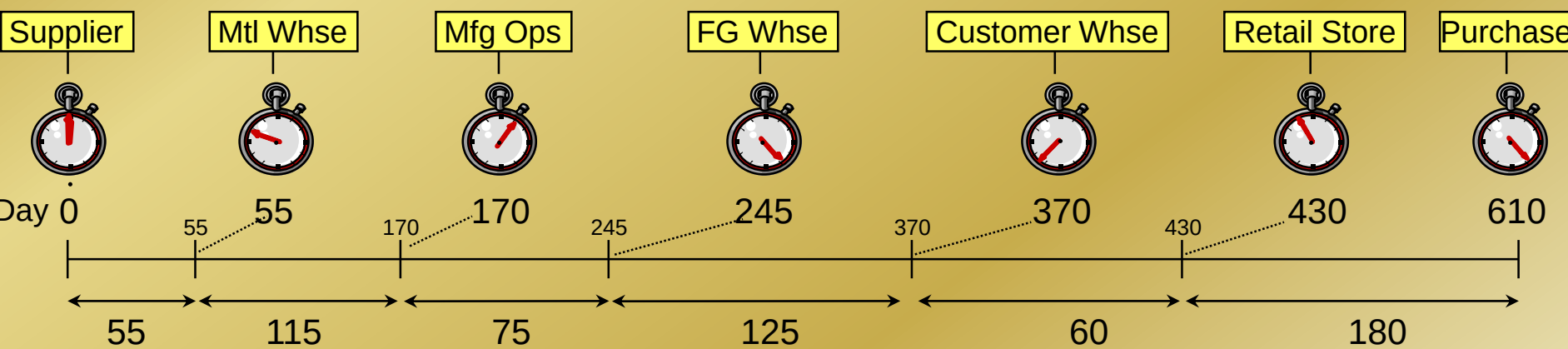


The Chain



The Time

Total = 610 days



Supply Chains and Manufacturing Systems: *Definitions*

- **Supply chain**: sequence of processes that acquire, transform and transport inputs into outputs that can serve and satisfy customer demand
- **Manufacturing system**: sequence or set of processes that transform inputs into outputs within a supply chain

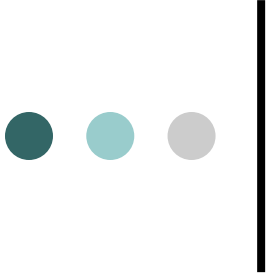
MITx Principles of Manufacturing

Supply Chains for Manufacturing I and II

- **Module I**: central theme is *inventory planning*, across a supply chain or manufacturing system: how much, what type and where, and with what effect?
- **Module II**: central theme is *capacity planning*, across a supply chain or manufacturing system: how much, what type and where, and with what effect?

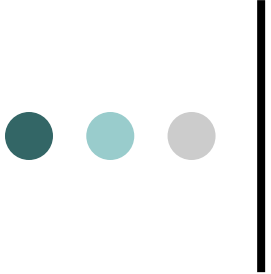
What makes planning difficult?

- Complexity of the system due to number of process steps, diversity of product flows, and time dimension
- Variability in demand and supply
- Inflexibility of process resources: constraints and/or economies of scale



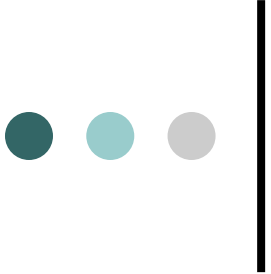
Supply Chain Management

- SCM is a set of approaches utilized to **efficiently integrate** suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the **right quantities**, to the **right locations**, and at the **right time**, in order to **minimize system-wide costs** while satisfying **service level requirements**



Types of variability

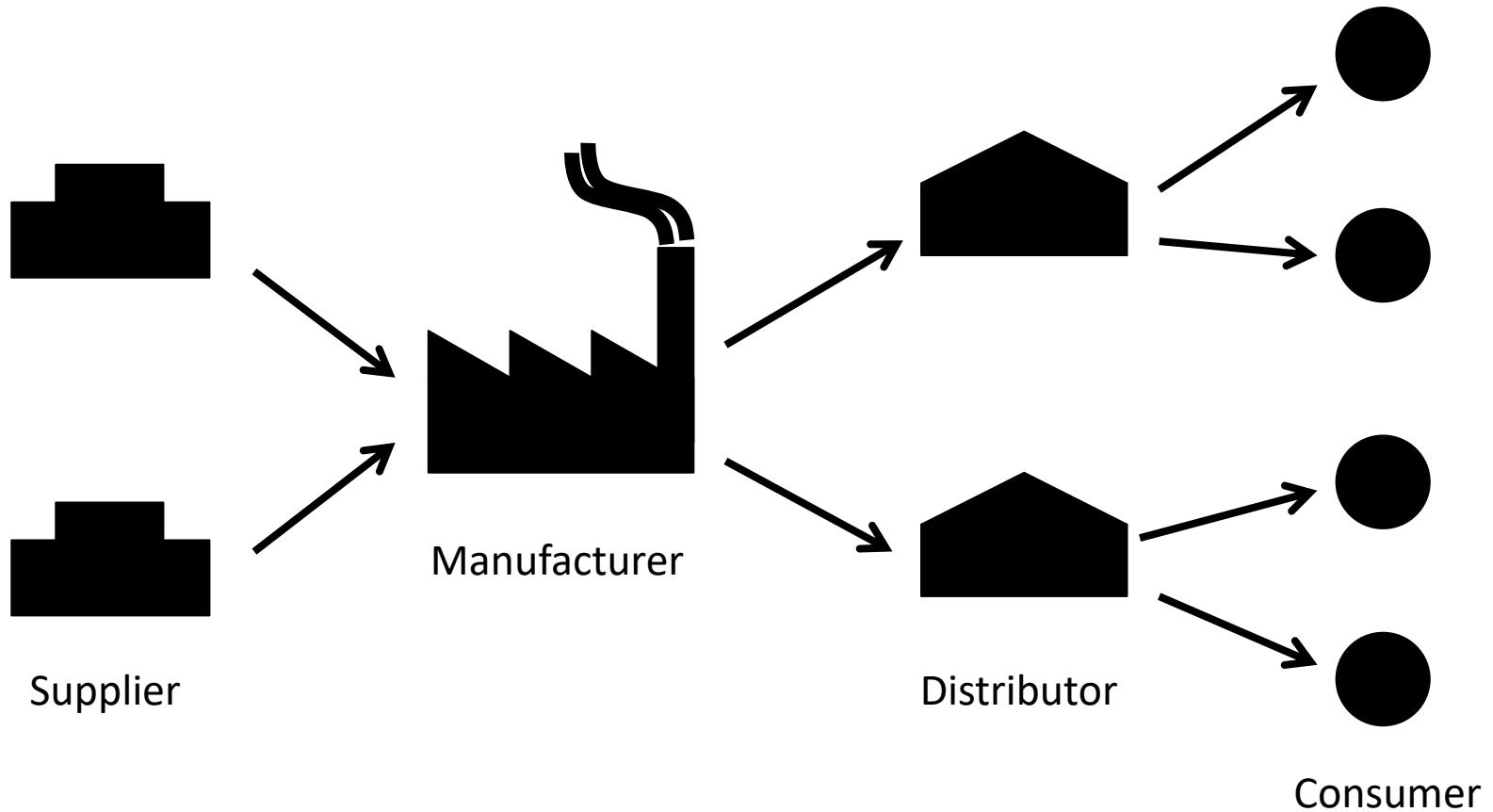
- Demand: volume, mix
- Process: yield, cycle time
- Procurement: yield, lead time, quality

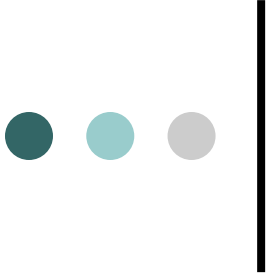


Other types of variability

- Rare and disruptive events (versus nominal variability)
- “predictable” variability, eg, cyclic patterns (versus probabilistic variability)
- Self-induced variability, eg, demand amplification, batching,... (versus exogenous)

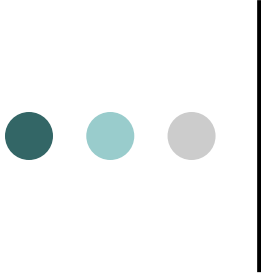
How do SCs cope with variability?





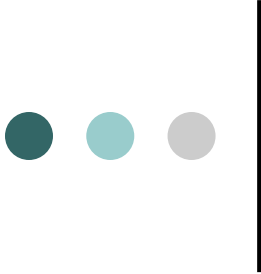
Counter measures: Buffers

- Buffers: inventory, capacity, time
- **Inventory** can be held across SC
- Reserved or underutilized **capacity** provides response option
- Increased process flow **time** or customer service **time** creates time window to balance supply and demand



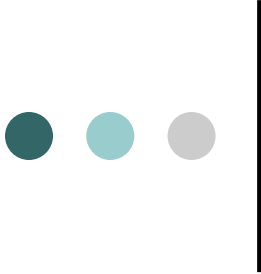
Counter measures: operational tactics

- Product/process design to permit delayed differentiation
- Smoothing to dampen variability propagation
- Dual sourcing (& expedited shipping) to provide quick response options
- Better forecasts, coordinated planning, information sharing



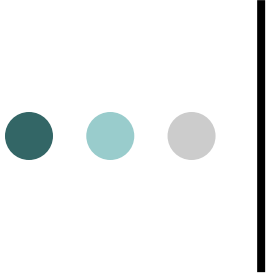
Dealing with variability: examples

- Safety stock location in a SC
- Delayed differentiation in a SC
- Dual sourcing & quick response
- Coordinated planning
- Smoothing
- Better forecast
- Inventory rationing



Dealing with variability: examples

- **Safety stock location in a SC**
- Delayed differentiation in a SC
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Safety stock location

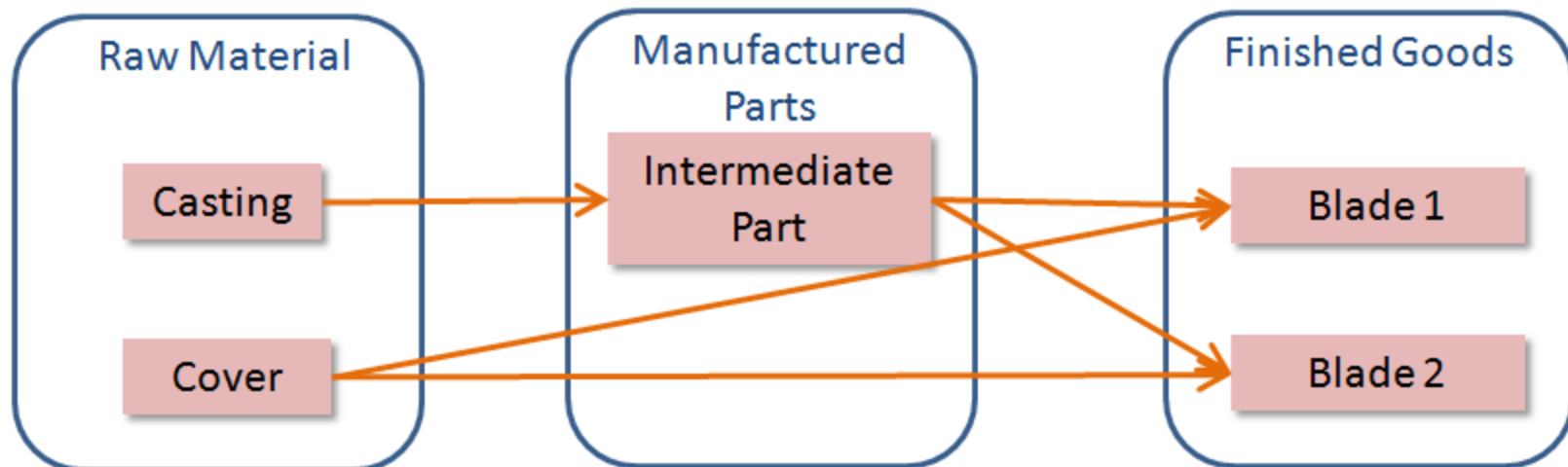
- Safety stock optimization in a supply chain
- Key concept:
 - Inventory depends on demand variability over ***total*** lead-time LT
 - Demand variability over LT proportional to $\sqrt{LT}$

Supply Chain Example

Inventory optimization in high volume aerospace supply chains

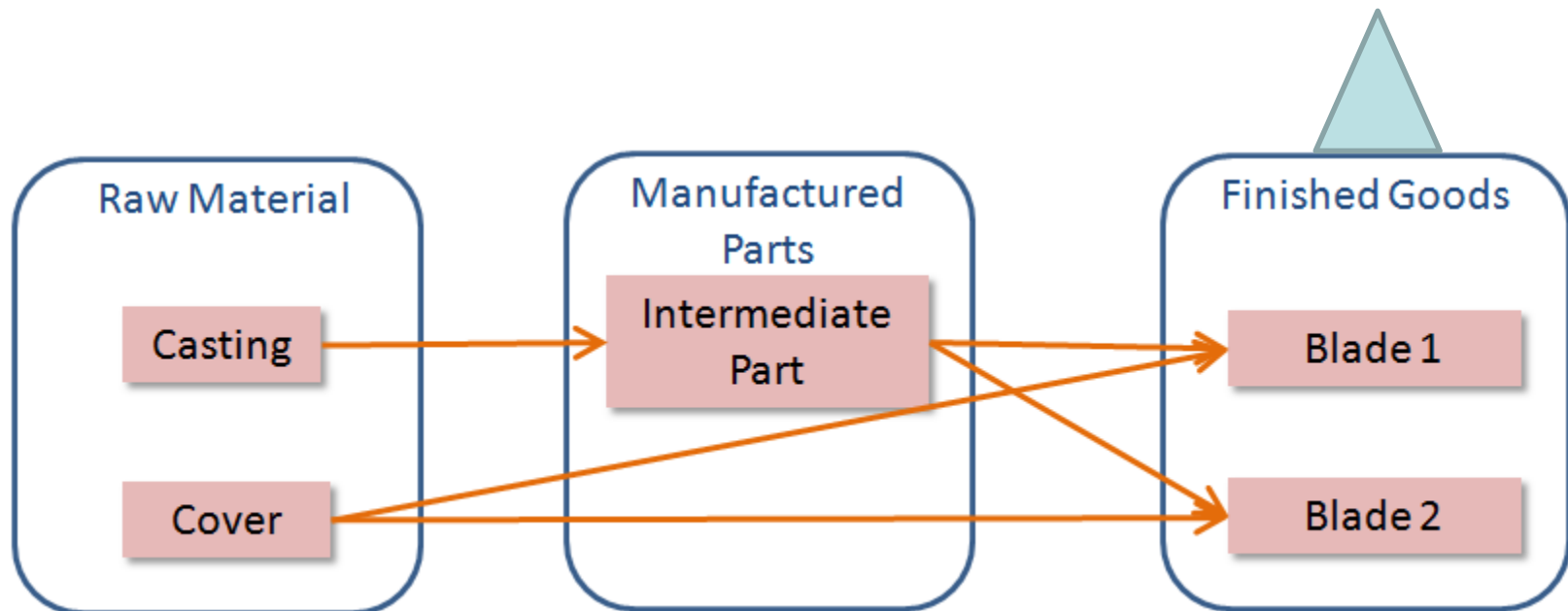
Masse, Brian, S.M, 2011

Part	Part Value	Lead Time (weeks)
Blade 1	\$400	4
Blade 2	\$425	4.5
Intermediate Part	\$250	2
Cover	\$2	1
Casting	\$75	8



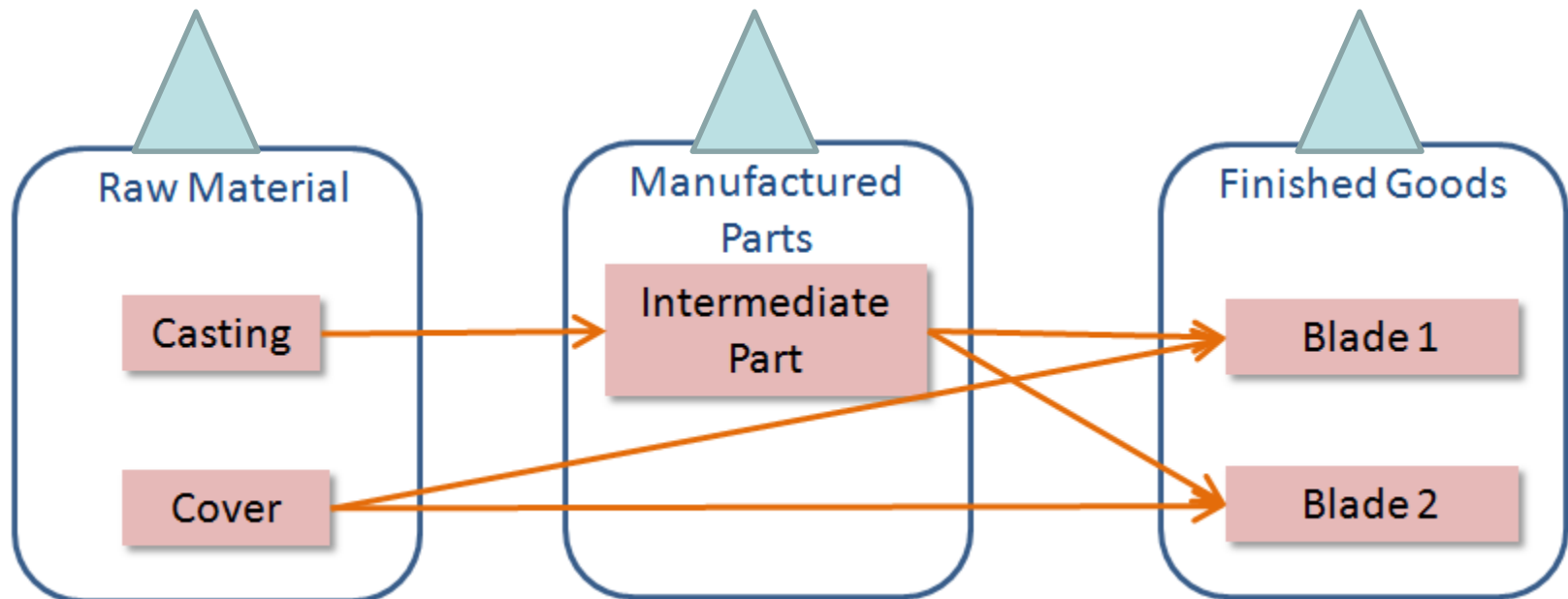
Hold only FGs; total inventory = \$189,000

Part	Part Value (\$)	Lead Time (weeks)	Service Time (weeks)	Safety Stock (units)	Safety Stock Value (\$)
Blade 1	\$400	4	0	150	60,000
Blade 2	\$425	4.5	0	305	129,000
Intermediate Part	\$250	2	10	0	0
Cover	\$2	1	1	0	0
Casting	\$75	8	8	0	0



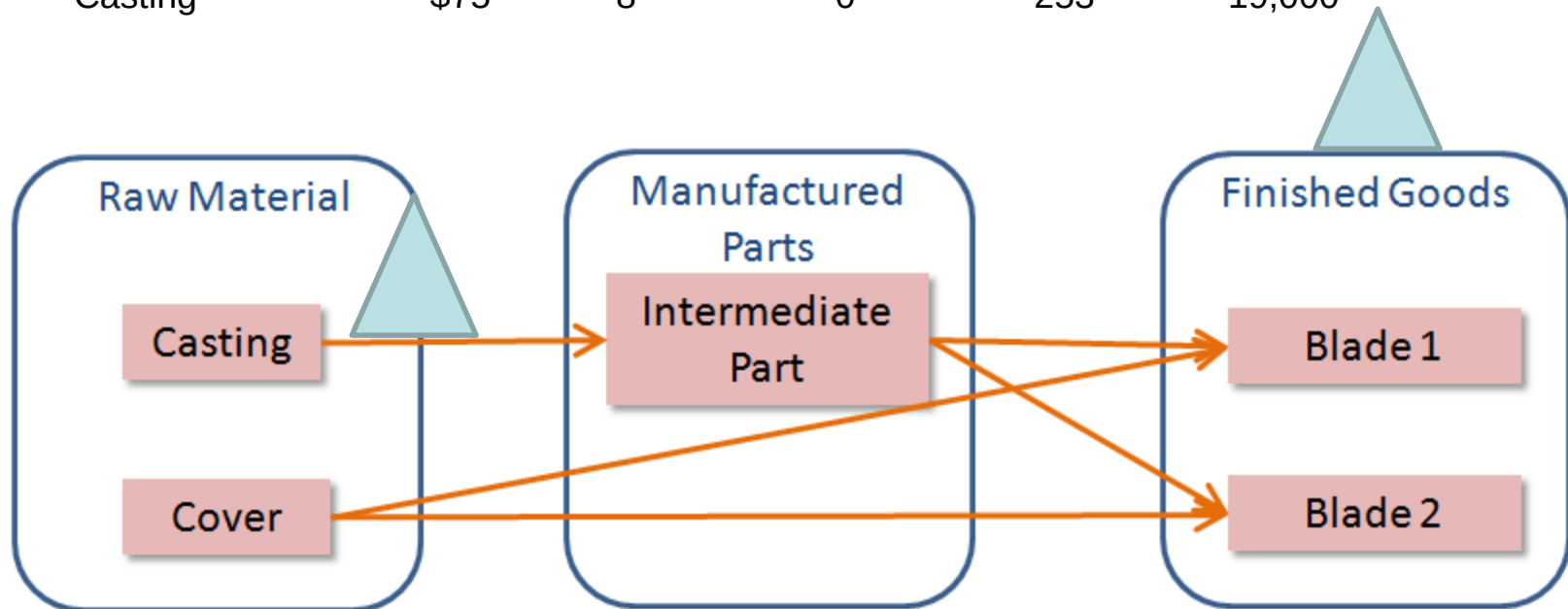
Hold SS at each stage; total inventory = \$155,000

Part	Part Value (\$)	Lead Time (weeks)	Service Time (weeks)	Safety Stock (units)	Safety Stock Value (\$)
Blade 1	\$400	4	0	80	32,000
Blade 2	\$425	4.5	0	170	72,000
Intermediate Part	\$250	2	0	126	32,000
Cover	\$2	1	0	89	200
Casting	\$75	8	0	253	19,000



Optimal SS strategy – hold castings; total inventory = \$145,000

Part	Part Value (\$)	Lead Time (weeks)	Service Time (weeks)	Safety Stock (units)	Safety Stock Value (\$)
Blade 1	\$400	4	0	98	39,000
Blade 2	\$425	4.5	0	204	87,000
Intermediate Part	\$250	2	2	0	0
Cover	\$2	1	1	0	0
Casting	\$75	8	0	253	19,000



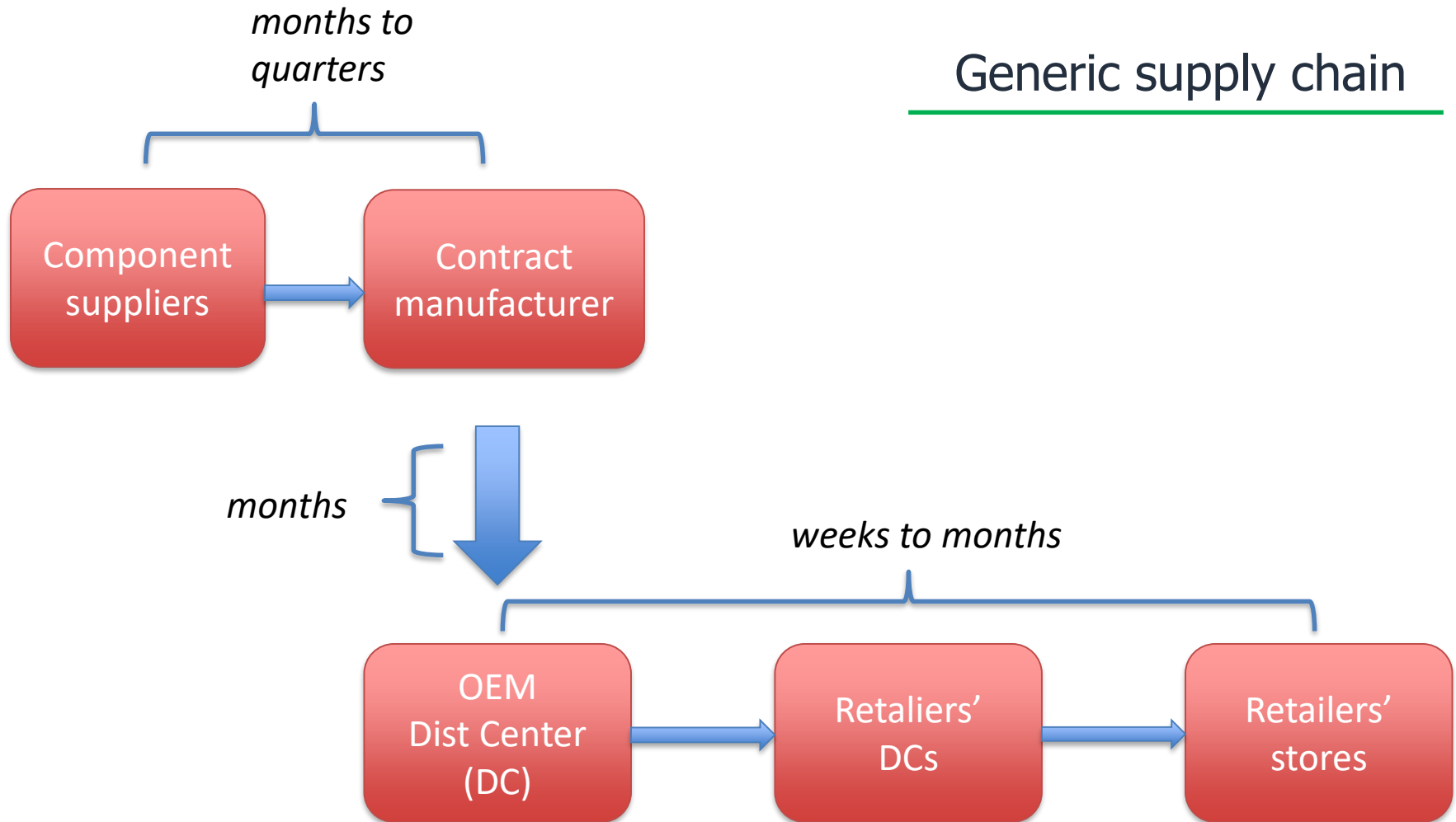
ADDITIVE MANUFACTURING FOR SUPPLY CHAINS: Quick Response

What are the key supply chain challenges?

How do supply chains cope?

How might AM help?

Generic supply chain



Additive manufacturing supply chain



Repetitive Manufacturing Example

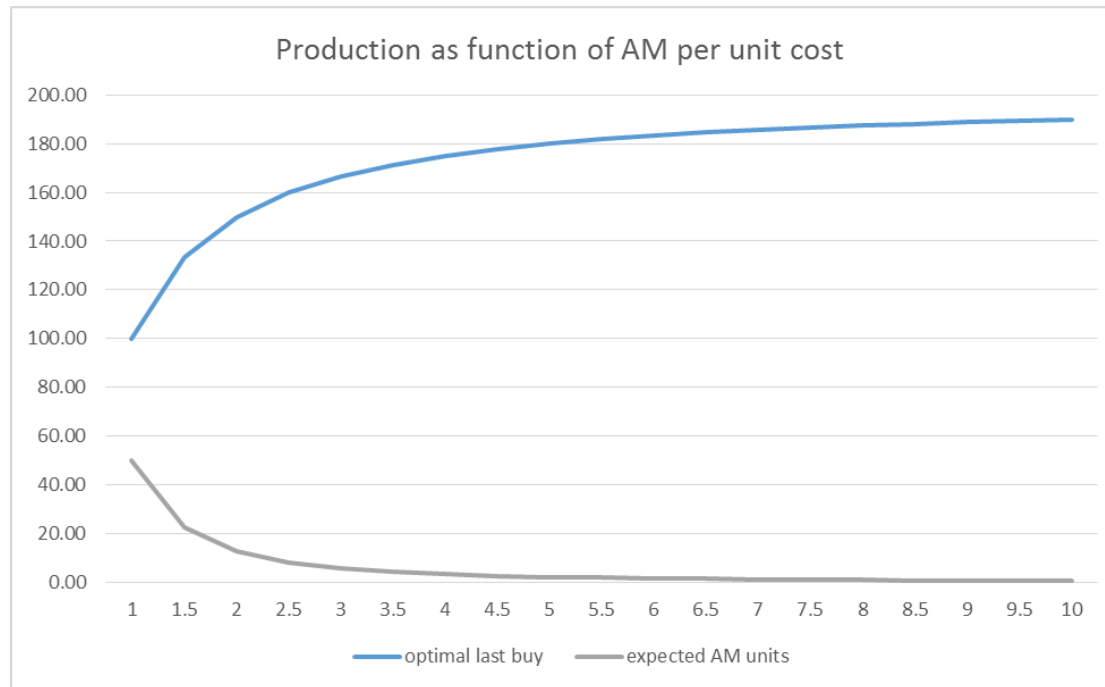
- What's the total cost for long vs. short SC?
- Variable costs:
 - RMs
 - Mfg
 - Ship
 - Taxes & Duties
- Inventory holding costs
 - Pipeline stock
 - Cycle stock
 - Safety stock

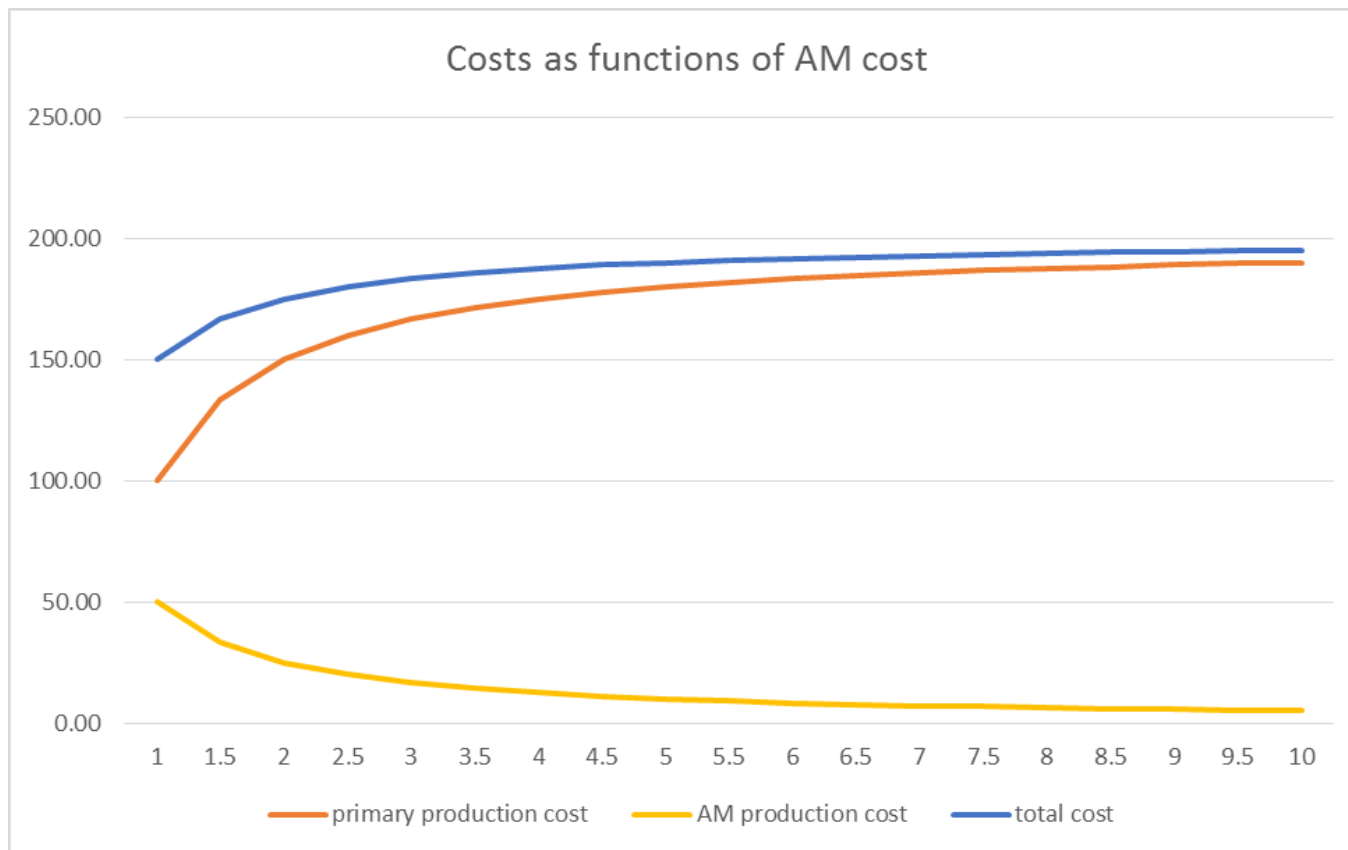
$$Inv. cost = \frac{h}{2} \times L\mu + h \times \frac{r\mu}{2} + h \times z\sigma\sqrt{L+r}$$

$$Inv. cost / unit = \frac{h}{2} \times L + h \times \frac{r}{2} + h \times z \times cv\sqrt{L+r}$$

Last Buy Example

- We can execute a last buy with primary supplier at \$1/unit;
 - Leftover units have no value
 - A shortage costs \$10/unit
 - Remaining demand is $U(100, 200)$
-
- With AM, suppose we make parts on demand at cost $c > \$1/\text{unit}$.
 - How does the Last Buy change?





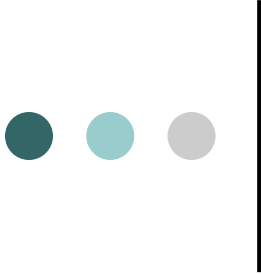
Implications from shorter supply chain

Enormous reduction in inventory and transportation

Slow mover and customized demand can be served

Increased SC responsiveness to highly variable demand

Whether it's cheaper or not will depend.....

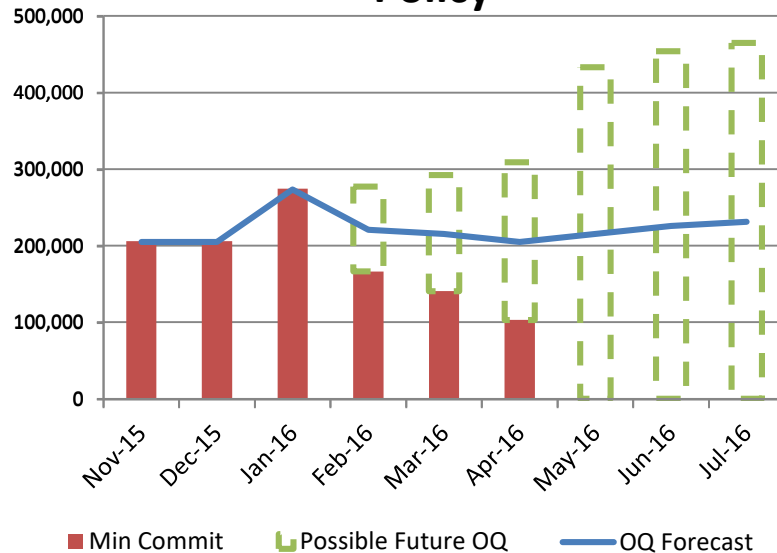


Dealing with variability: examples

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- **Coordinated planning**
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Ordering Policy – Business as usual and To-Be States

Business as Usual (BAU) Ordering Policy



*OQ (Order Quantity) Forecast =
Purchase Forecast provided to CM/OEM

Ana María Ortiz García, “Evaluating Inventory Ordering Policies: a Methodology and Application,” S.M. June 2016.

Dynamic forecast process

	demand	forecasts					
period		1	2	3	4	5	6
JAN		97	93	100	100	97	90
FEB							
MAR							
APR							

	demand	forecasts					
period		1	2	3	4	5	6
JAN		97	93	100	100	97	90
FEB	102	94	97	99	98	88	102
MAR							
APR							

	demand	forecasts					
period		1	2	3	4	5	6
JAN		97	93	100	100	97	90
FEB	102	94	97	99	98	88	102
MAR	84	105	99	94	86	97	95
APR							

	demand	forecasts					
period		1	2	3	4	5	6
JAN		97	93	100	100	97	90
FEB	102	94	97	99	98	88	102
MAR	84	105	99	94	86	97	95
APR	107	103	93	83	97	94	99

Dynamic forecast process & Frozen orders

	demand	forecasts			
period		1	2	3	4
JAN		97	93	100	100
FEB					
MAR					

	Orders			
period	1	2	3	4
JAN	97	93	100	100
FEB				
MAR				

	demand	forecasts			
period		1	2	3	4
JAN					
FEB	102	95	104	99	95
MAR					

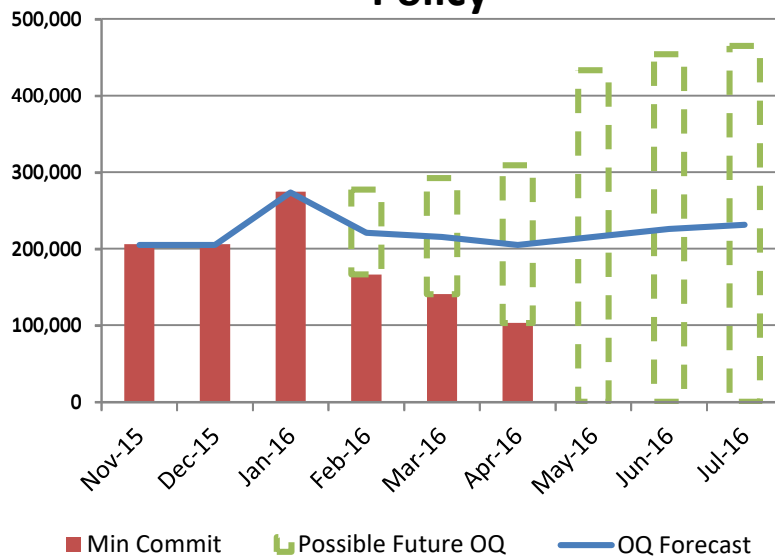
	Orders			
period	1	2	3	4
JAN				
FEB	93	100	110	95
MAR				

	demand	forecasts			
period		1	2	3	4
JAN					
FEB					
MAR	84	100	97	95	86

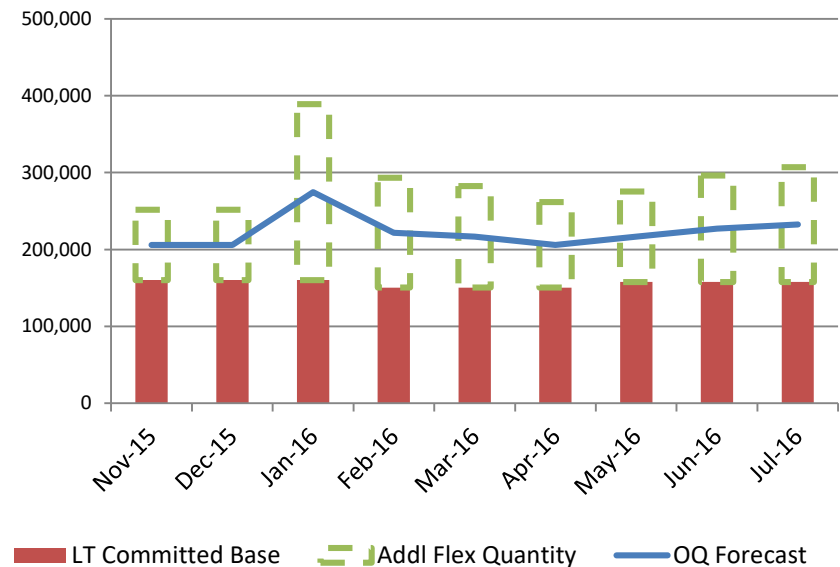
	Orders			
period	1	2	3	4
JAN				
FEB				
MAR	100	110	78	86

Ordering Policy – Business as usual and To-Be States

Business as Usual (BAU) Ordering Policy



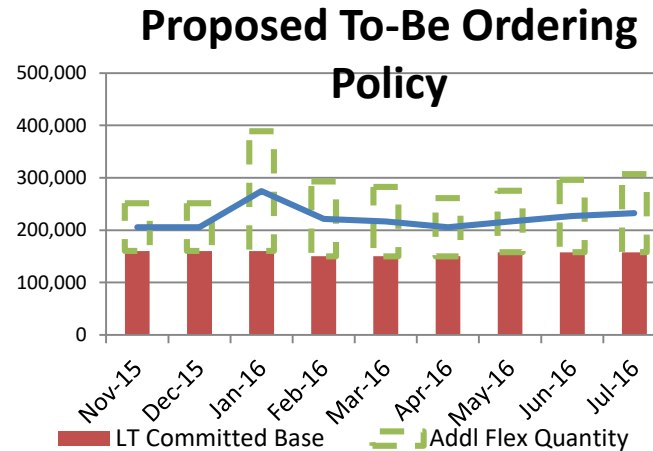
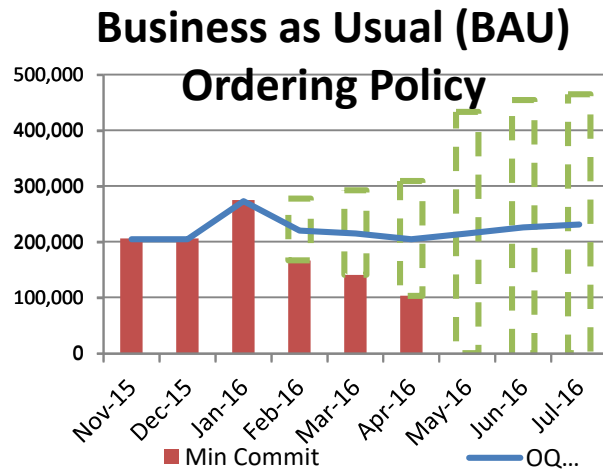
Proposed To-Be Ordering Policy



*OQ (Order Quantity) Forecast =
Purchase Forecast provided to CM/OEM

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Ordering Policy – simulated performance

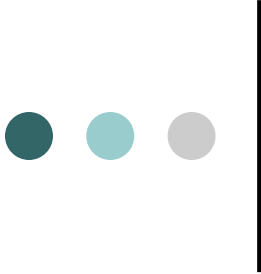


Demand: $\mu = 100$; $\sigma = 13$

3-month freeze; Vendor Orders: $\mu = 100$; $\sigma = 40$; Verizon SS = ~ 100

Committed base = 90; with flex ordering:

Vendor Orders: $\mu = 100$; $\sigma = 11$; Verizon SS = ~ 24



Wrap-Up: Dealing with variability

- **Safety stock location in a SC**
- Delayed differentiation in a SC
- **Dual sourcing & quick response**
- **Coordinated planning**
- Smoothing
- Better forecast
- Inventory rationing