SAP EIS: Single Stage Inventory Logic

Single-Stage Inventory Logic

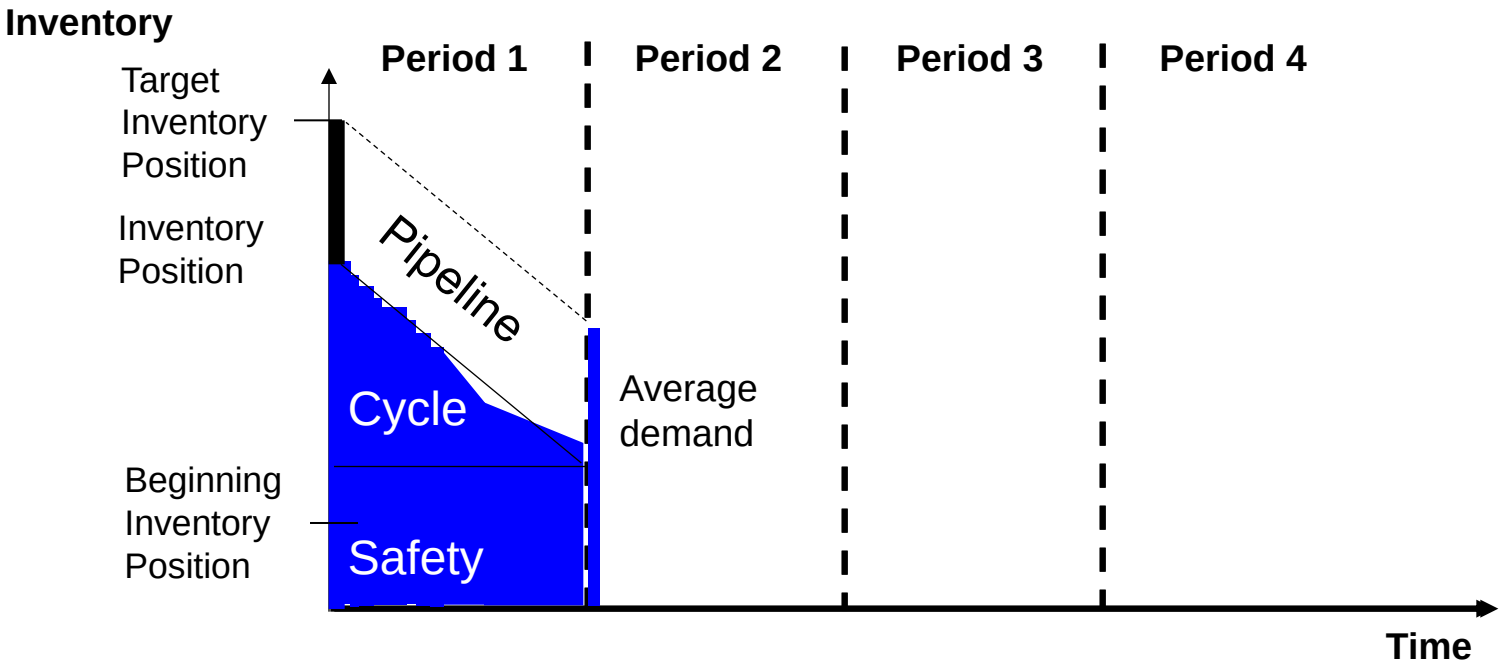
Inventory Replenishment Definitions

Impact of Key Drivers on Inventory

- Frequent versus Infrequent Review
- Instantaneous Replenishment versus Planning for Lead Time
- Known versus Uncertain Demand

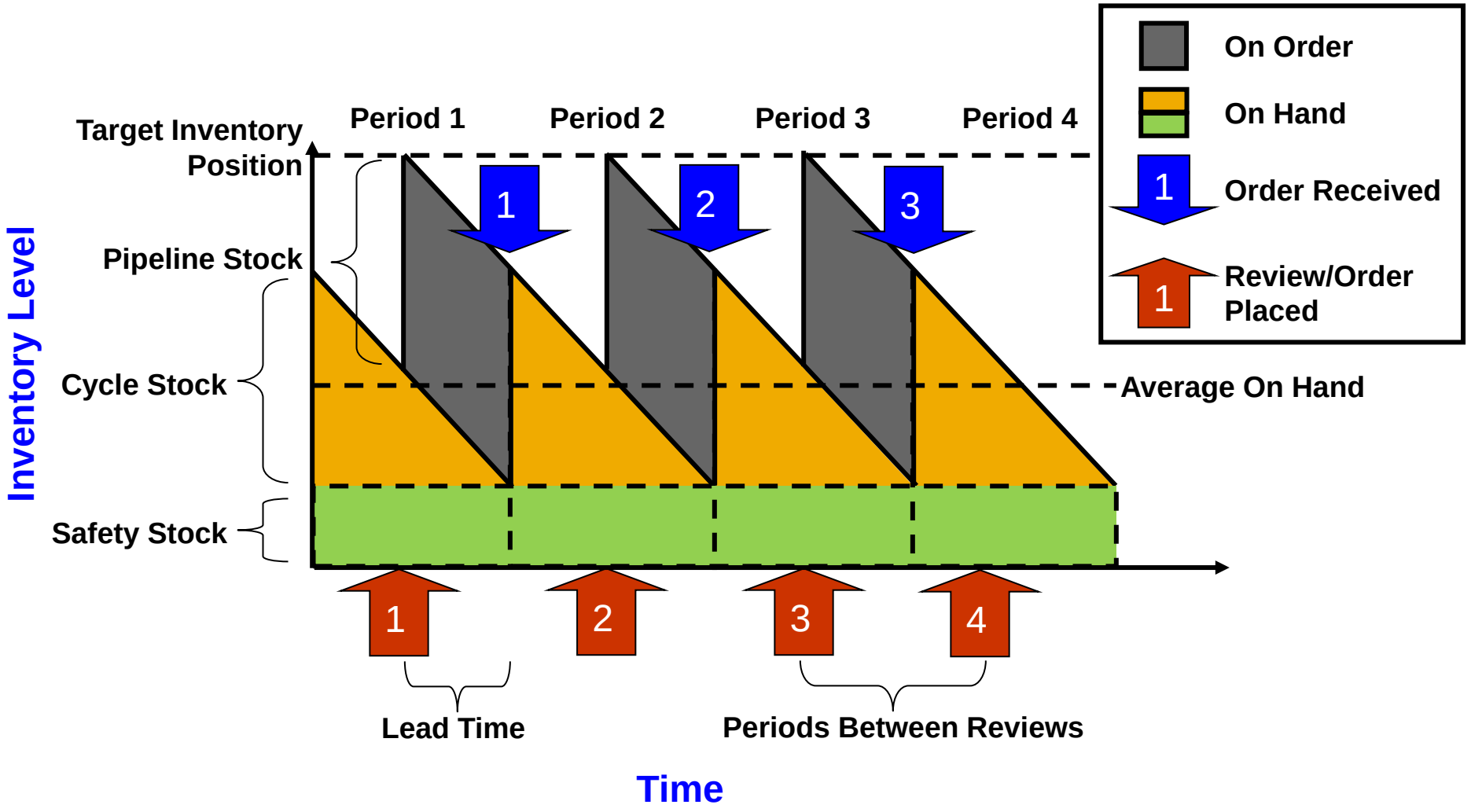
Impact of Time-Varying Demand

Inventory Review and Order Process



- The right Target Inventory Position depends on
  - Inventory needed to meet current period demand
  - Inventory needed to meet future demand until next order is received
  - Inventory needed to hedge against uncertainty
- The Target Inventory Position is set based on forecasts

Inventory replenishment and components

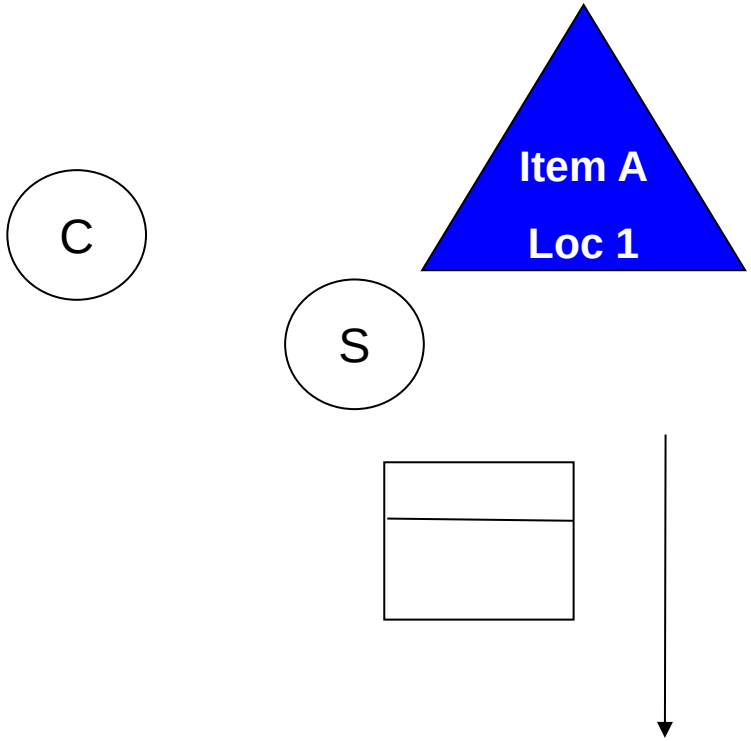


Supply Chain Inventory Building Blocks

It is the representation of the supply chain as a network of stocking points for which the inventory is planned/managed

Building blocks

- Stocking Point
  - Inventory storage of an item at a location
- Customer
  - External demand source
- Supplier
  - Provider of inventory or raw material
- Internal Demand
  - Propagated demand from downstream
- Process Point
  - Plant or other assembly point
- Path
  - Logistics connection



Forecast: In Supply Chain terms, this is not a guess

1. General acronyms for “Forecast”: Predict, Estimate, Guess. Foresee, Prognosticate, Anticipate

2. *Supply Chain* definition of Forecast:

“A formal requirement to make available to sell:
a determined quantity of specific sales units at a specified time and place.”

Forecasts by their nature are inaccurate, *but the forecast drives the business*.

Single-Stage Inventory Logic

Inventory Replenishment Definitions

Impact of Key Drivers on Inventory

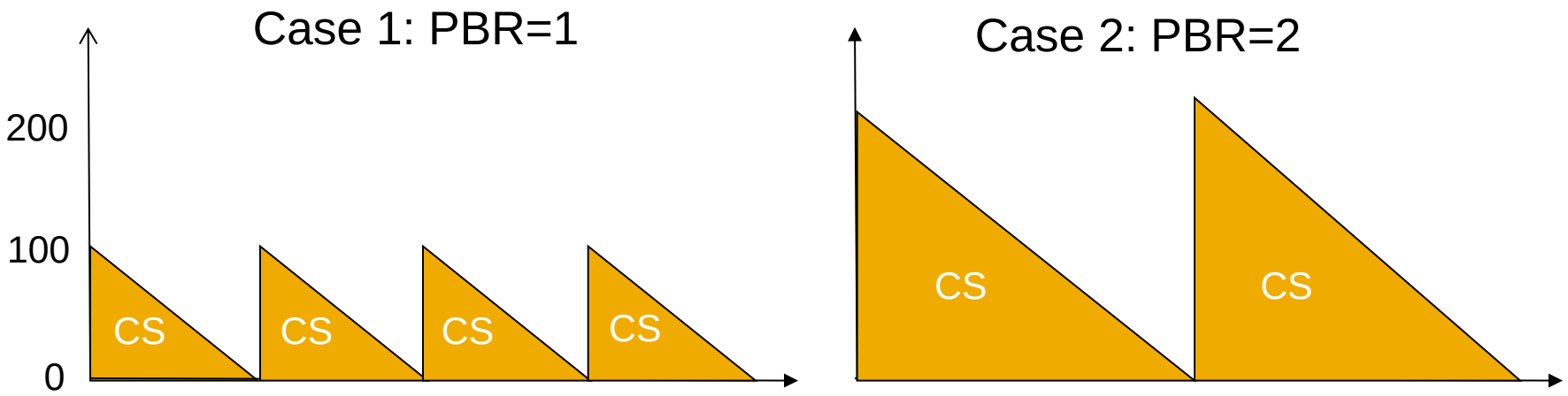
- Frequent versus Infrequent Review
- Instantaneous Replenishment versus Planning for Lead Time
- Known versus Uncertain Demand

Impact of Time-Varying Demand

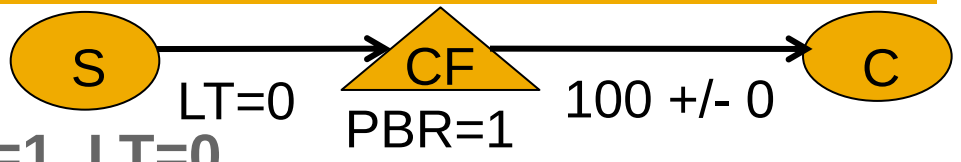
Cycle Stock is driven by Replenishment Frequency or Batch Size

Cycle Stock (CS) is based on the forecasts of all periods until the next review/order, i.e., Period Between Reviews (PBR)

- Cycle Stock Key Drivers:
  - (1) Replenishment Frequency
  - (2) Demand
  - (3) Batch Size

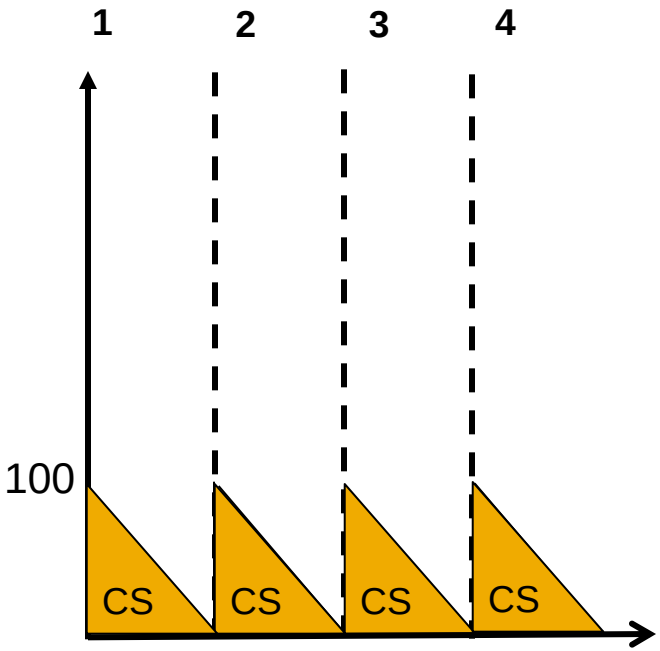


- **Insight:** Cycle stock increases with PBR



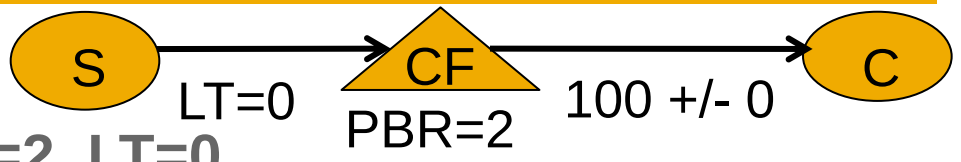
Example 1: No Variability, PBR=1, LT=0

- Demand: 100 +/- 0
- PBR: 1, Lead Time: 0



- Initial On-Hand: 0 units, Initial Pipeline: 0 units

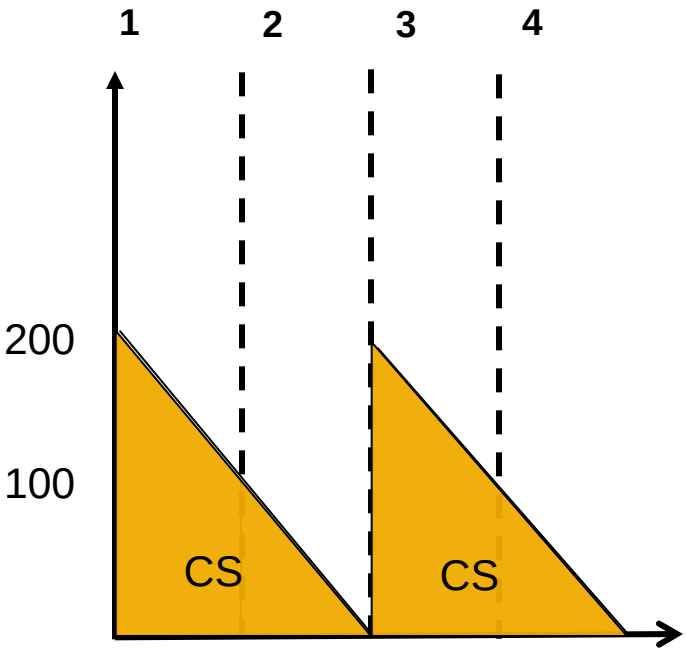
Period	1	2	3	4	Avg
Forecast (μ)	100				100
Forecast Err Sigma (σ)	0				0
Target Safety Stock	0				0
Target Inv Position	100				
On-Hand Stock		REPEAT	REPEAT	REPEAT	
- End of Prev Per	0				0
- Beg of Per After Rcpt	100				100
- End of Per	0				0
- Avg	50				50
Orders	100				100
Planned Receipts	100				100
Pipeline Stock	0				0
Cycle Stock					
- Beg of Per After Rcpt	100				100
- End of Per	0				0
- Avg	50				50



Example 2: No Variability, PBR=2, LT=0

- Demand: 100 +/- 0
- PBR: 2, Lead Time: 0

- Initial On-Hand: 0 units, Initial Pipeline: 0 units



Period	1	2	3	4	Avg
Forecast (μ)	100	100			100
Forecast Err Sigma (σ)	0	0			0
Target Safety Stock	0	-			0
Target Inv Position	200	-			
			REPEAT	REPEAT	
On-Hand Stock					
- End of Prev Per	0	100			50
- Beg of Per After Rcpt	200	100			150
- End of Per	100	0			50
- Avg	150	50			100
Orders	200	-			100
Planned Receipts	200	-			100
Pipeline Stock	0	0	1	2	0
Cycle Stock					
- Beg of Per After Rcpt	200	100			150
- End of Per	100	0			50
- Avg	150	50			100

Single-Stage Inventory Logic

Inventory Replenishment Definitions

Impact of Key Drivers on Inventory

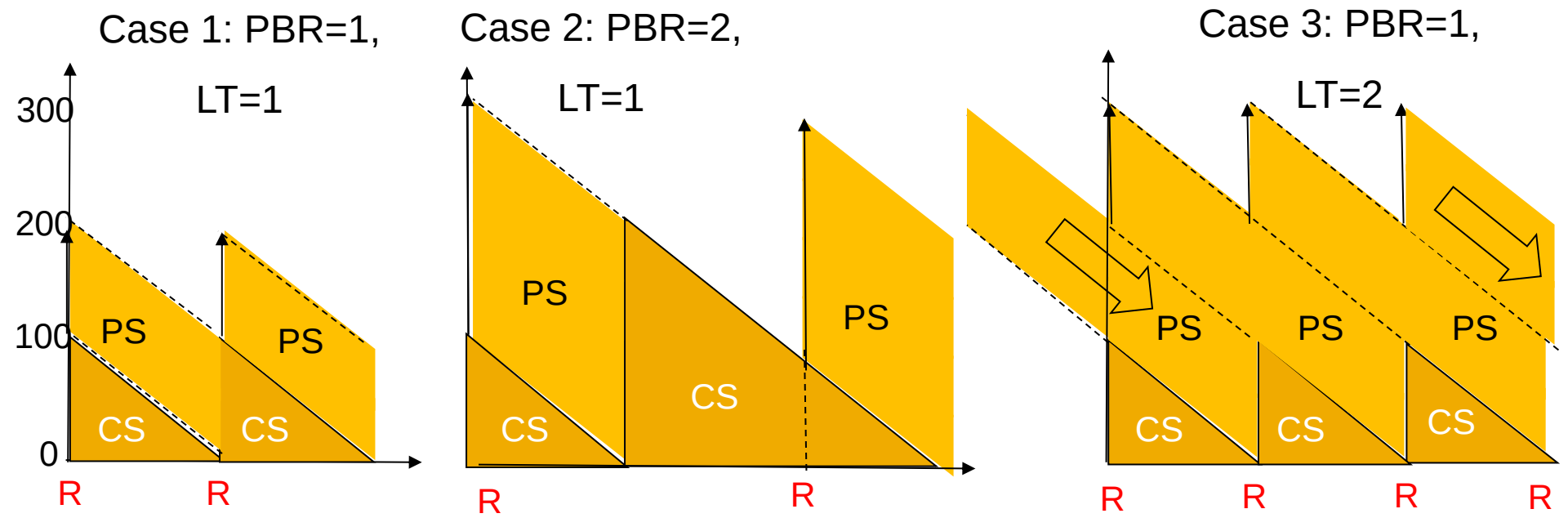
- Frequent versus Infrequent Review
- Instantaneous Replenishment versus Planning for Lead Time
- Known versus Uncertain Demand

Impact of Time-Varying Demand

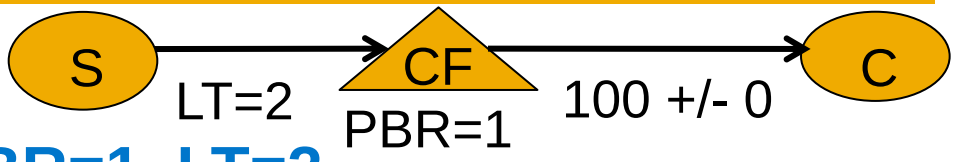
Pipeline Stock is driven by length of Lead Time

Pipeline Stock (PS) is based on the forecasts of all periods during the order processing and delivery lead time (LT)

- Pipeline Stock Key Drivers:
  - (1) Lead Times – Order Processing, Transit, Production, or Goods Receipt
  - (2) Demand

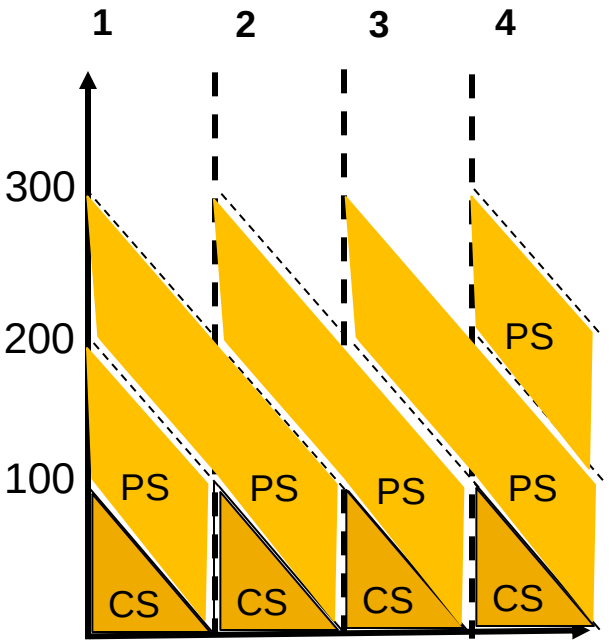


- **Insight:** Pipeline stock increases with Lead Time



Example 3: No Variability, PBR=1, LT=2

- Demand: 100 +/- 0
- PBR = 1, LT = 2
- Order-up-to replenishment policy



- Initial On-Hand: 0 units, Initial Pipeline = 200 units
- Pipeline: 100 units arriving in period 1 and period 2

Period	1	2	3	4	Avg
Forecast	100	100			100
Forecast Err Sigma	0	0			0
Target Safety Stock	0	0			0
Target Inv Position	300	300			300
On-Hand Stock			REPEAT	REPEAT	
- End of Prev Per	0	0			0
- Beg of Per After Rcpt	100	100			100
- End of Per	0	0			0
- Avg	50	50			50
Orders	100	100			100
Planned Receipts	100	100			100
Pipeline Stock	200	200			200
Cycle Stock					
- Beg of Per After Rcpt	100	100			100
- End of Per	0	0			0
- Avg	50	50			50

Single-Stage Inventory Logic

Inventory Replenishment Definitions

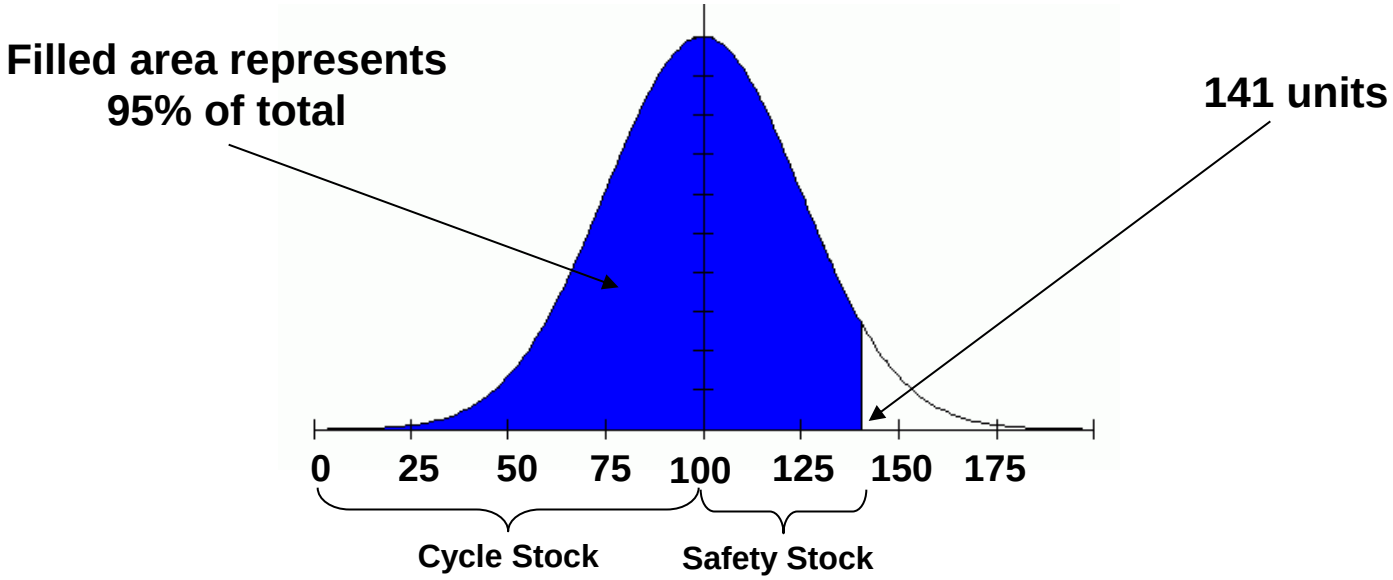
Impact of Key Drivers on Inventory

- Frequent versus Infrequent Review
- Instantaneous Replenishment versus Planning for Lead Time
- Known versus Uncertain Demand

Impact of Time-Varying Demand

Classical Formula For Computing Safety Stock

- Planning for one product/one location/one period with instantaneous lead time
- Forecast: 100 +/- 25, Forecast Error Distribution: Normal
- Service Level Target: 95% Non-stockout probability
- Classical Formula: Safety stock = z (95%) * σ = 1.64 * 25 = 41
- Target Inventory Position = 141 units, Safety Stock = 41 units



Z Factors Lookup Table

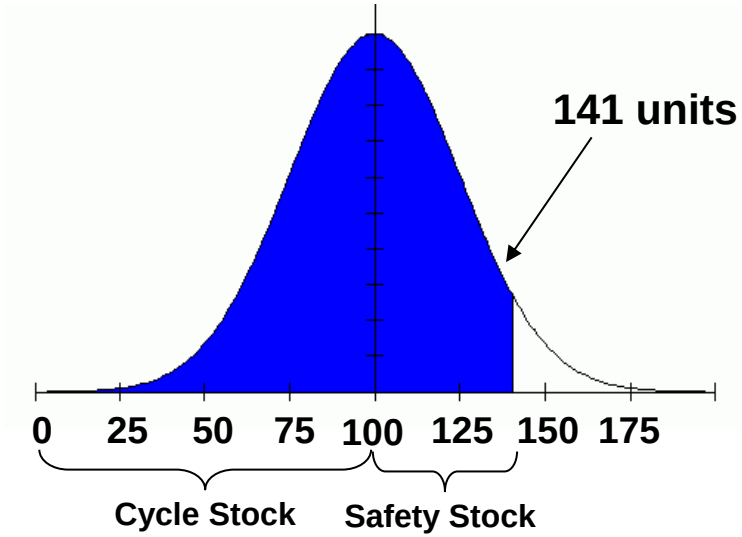
Target Service Level	z Factor
50%	0.0000
77%	0.7388
80%	0.8416
84.13%	1.0000
90%	1.2816
92%	1.4051
94%	1.5547
95%	1.6449
98%	2.0537
99%	2.3263
99.9%	3.0903
99.99%	3.7194

Forecast Standard Deviation Impacts the Width of the Distribution

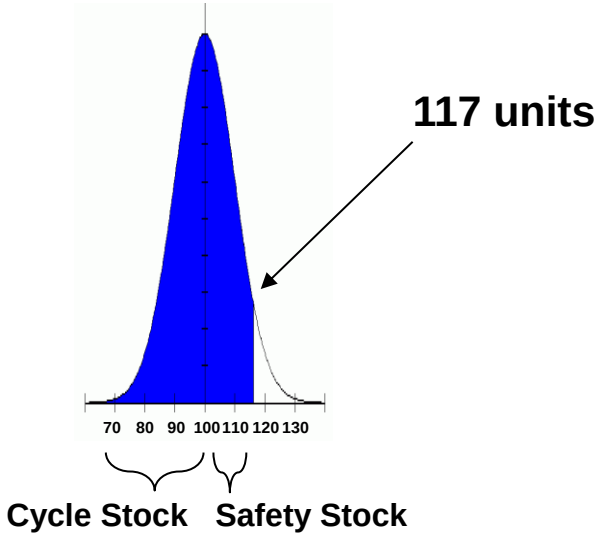
Service Level Target: 95% Non-stockout probability

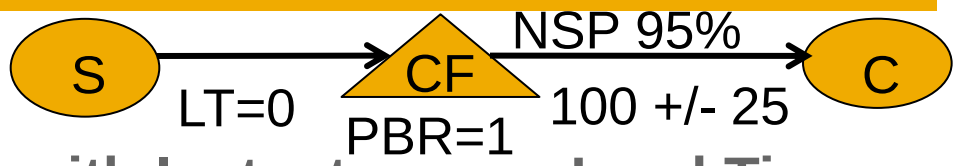
z (95%) = 1.64

Forecast: 100 +/- 25



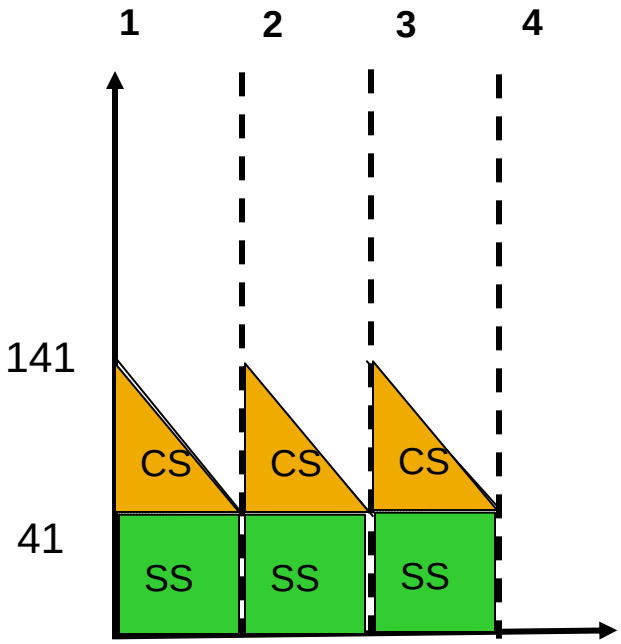
Forecast: 100 +/- **10**





Example 4: Demand Variability with Instantaneous Lead Time

- Demand: 100 +/- 25
- Service Level of 95%

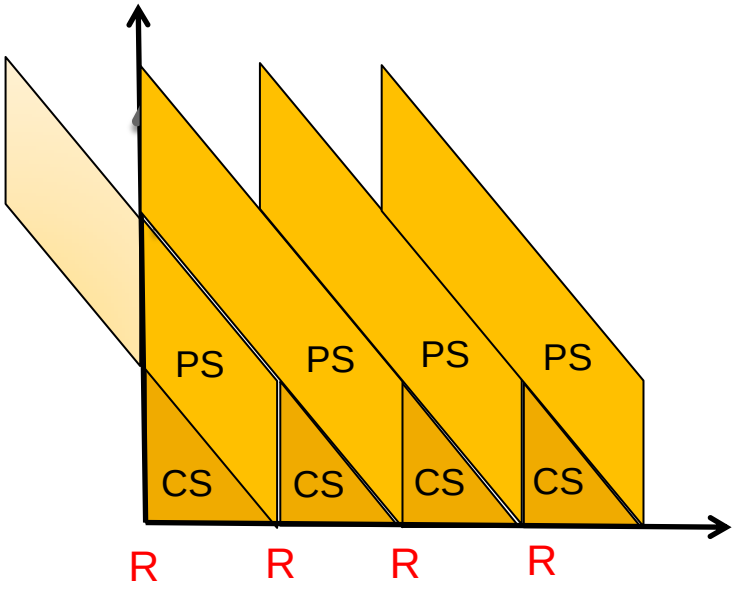


- PBR = 1, LT = 0
- Initial On-Hand = 41 units

Period	1	2	3	4	Avg
Forecast (μ)	100				100
Forecast Err Sigma (σ)	25				25
Target Safety Stock	41				41
Target Inv Position	141				141
On-Hand Stock					
- End of Prev Per	41	REPEAT	REPEAT	REPEAT	41
- Beg of Per After Rcpt	141				141
- End of Per	41				41
- Avg	91				91
Orders	100				100
Planned Receipts	100				100
Pipeline Stock	0				0
Cycle Stock					
- Beg of Per After Rcpt	100				100
- End of Per	0				0
- Avg	50				50

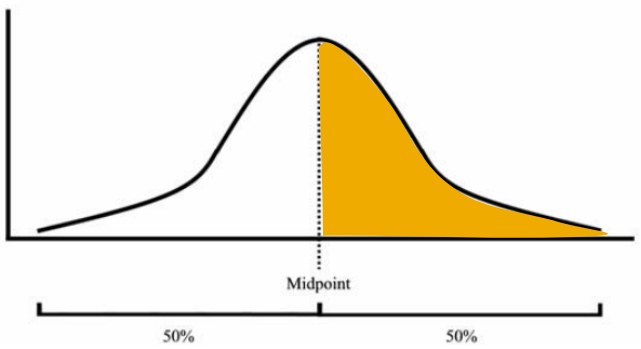
Should Lead Time Impact Target Safety Stock?

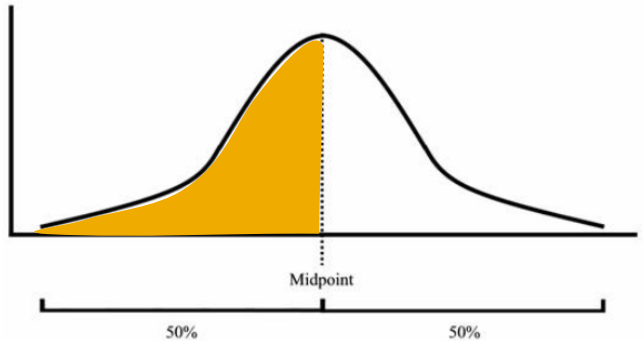
- Order placed in current period 1 arrives at start of period 3
- The next shipment doesn't arrive until the start of period 4
- Period 3 is "Most-at-Risk" of stocking out
- Exposure period = PBR + LT
- Most-at-Risk period = PBR +LT – 1 (+ corresponding review period)



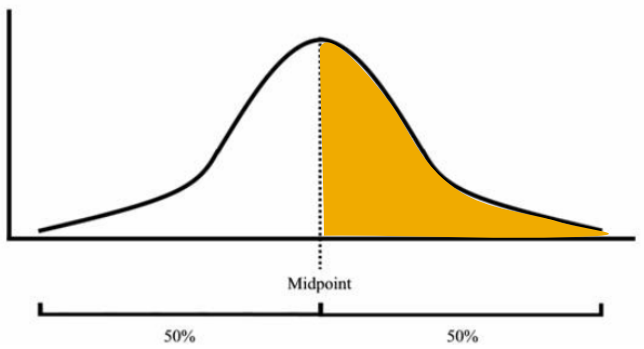
Multiple Periods Create Risk Pooling Opportunity

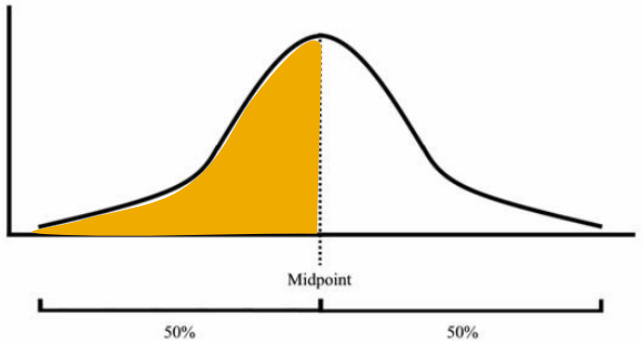
Period 1



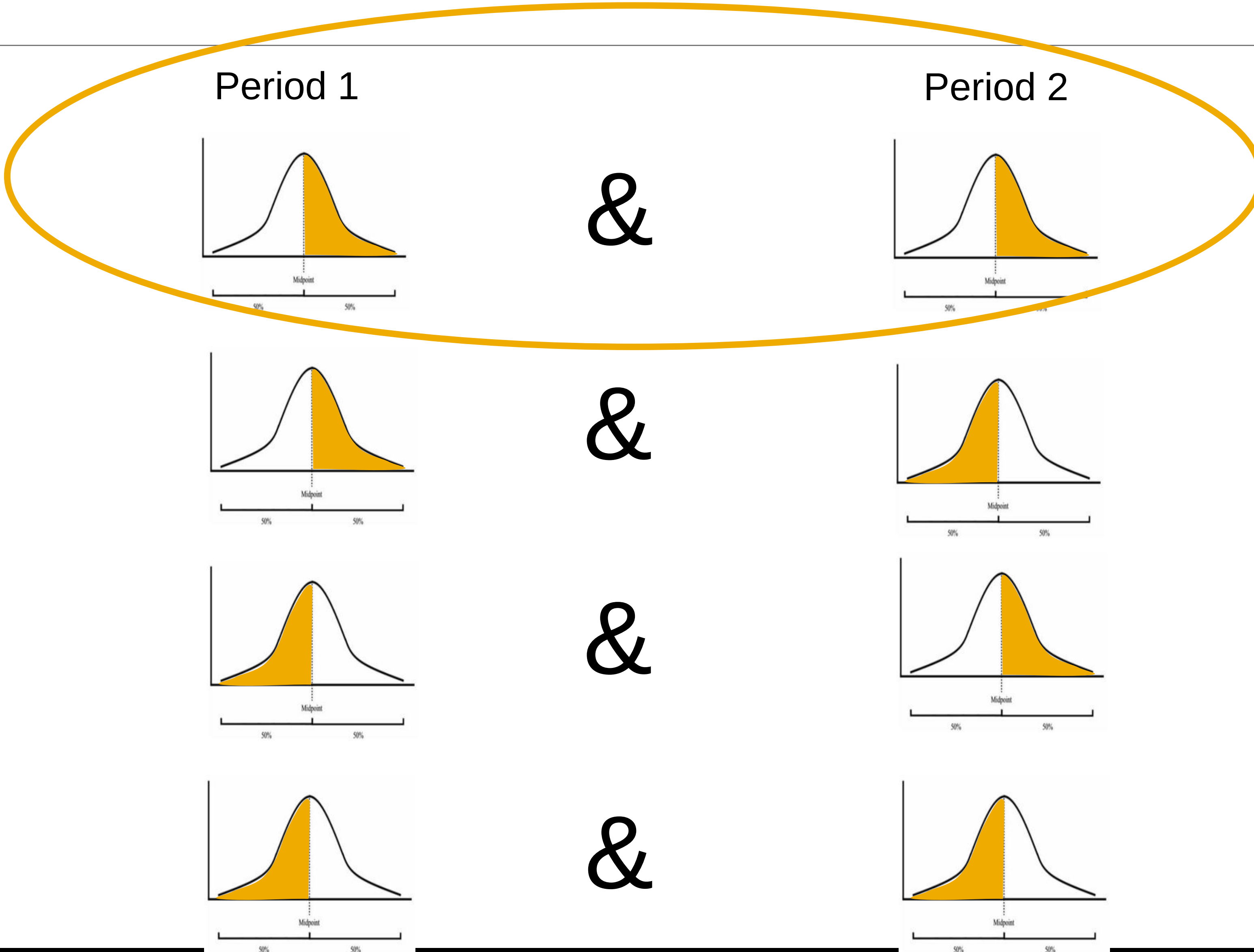


Period 2





Risk Pooling Opportunity



Impact of Exposure on Inventory Targets

Safety Stock = $z \times \sigma \times \sqrt{(LT + PBR)}$

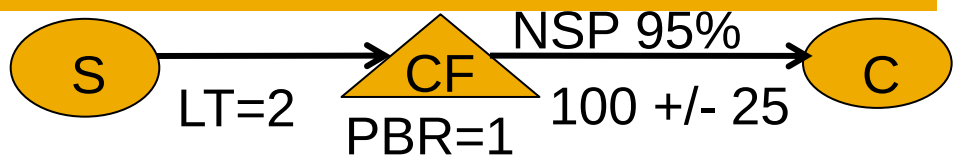
LT + PBR is referred to as the ‘Exposure Period’

z is the multiplication factor corresponding to service level target

σ is forecast error

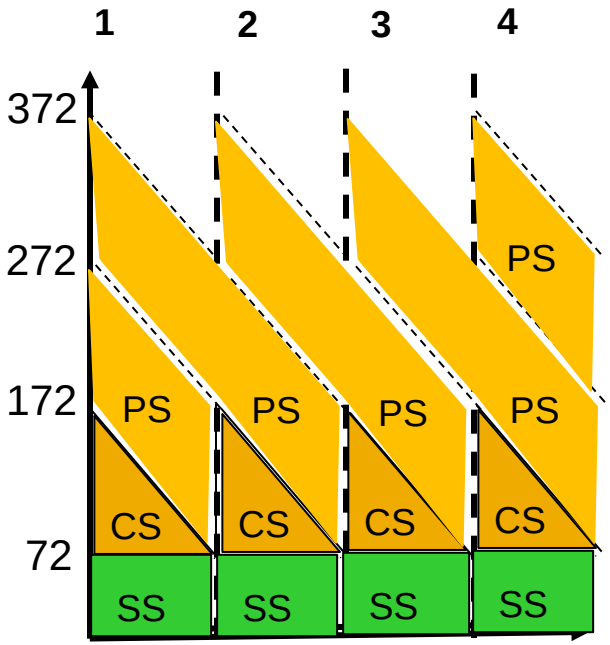
This simple formula is only valid for single-stage, normal forecast error and non-stockout probability service level metric

SAP tools do not rely on simple relationships or rules-of-thumbs but on a complex supply chain model and mathematical optimization to find the lowest-cost inventory targets that meet customer service levels.



Example 5: Demand Variability, PBR=1, LT=2

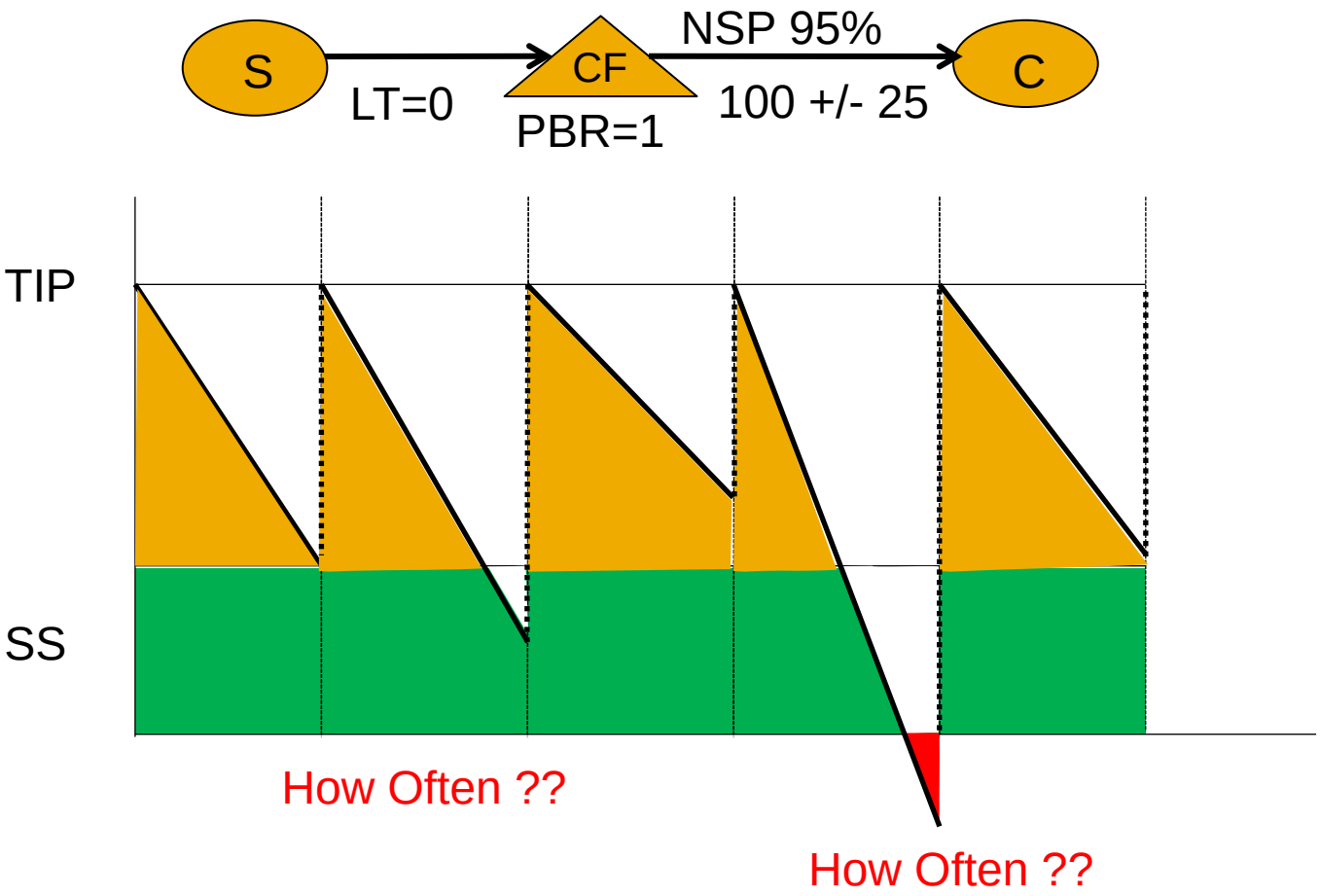
- Demand: 100 +/- 25
- PBR: 1, Lead Time: 1
- Service Level = 95%
- Order-Up-To Replenishment Policy



- Initial On-Hand = 58 units
- Initial Planned Receipts = 100 units

Period	1	2	3	4	Avg
Forecast (μ)	100				100
Forecast Err Sigma (σ)	25				25
Target Safety Stock	72				72
Target Inv Position	372				372
On-Hand Stock					
- End of Prev Per	72	REPEAT	REPEAT	REPEAT	72
- Beg of Per After Rcpt	172				172
- End of Per	72				72
- Avg	122				122
Orders	100				100
Planned Receipts	100				100
Pipeline Stock	200				200
Cycle Stock					
- Beg of Per After Rcpt	100				100
- End of Per	0				0
- Avg	50				50

Safety Stock Usage



Single-Stage Inventory Logic

Inventory Replenishment Definitions

Impact of Key Drivers on Inventory

- Frequent versus Infrequent Review
- Instantaneous Replenishment versus Planning for Lead Time
- Known versus Uncertain Demand

Impact of Time-Varying Demand

Time-Varying Inventory Targets

Safety Stock = $z\,\sigma\,\sqrt{(LT + PBR)}$

LT + PBR is referred to as the 'Exposure Period'

z is the multiplication factor corresponding to service level target

σ is forecast error

Target Inventory Position = Exposure Demand Mean + Safety Stock

= $(PBR+LT)\,\mu + z\,\sigma\,\sqrt{(LT + PBR)}$

Time-Varying Safety Stock = $z\,\sqrt{(\sigma^2_1 + \sigma^2_2 + \ldots + \sigma^2_{LT+PBR})}$

Time-Varying Target Inventory Position =

$$\underbrace{\mu_1 + \mu_2 + \ldots + \mu_{LT+PBR}}_{\text{(meet exposure forecast)}} + \underbrace{z\,\sqrt{(\sigma^2_1 + \sigma^2_2 + \ldots + \sigma^2_{LT+PBR})}}_{\text{(address exposure uncertainty)}}$$

Example 6

- **Demand: 200, 0, 100, 200, 100**
- **PBR = 2, LT = 1**
- **Initial On-Hand = 257 units**
- **95% NSP (z factor = 1.65)**

No capacity constraint

Period	R 1	2	R 3	4	5
Forecast	**200**	0	100	200	100
Forecast Err Sigma	20	0	10	20	10
Target Inv Position	337		440		
Target Safety Stock	37		40		
On Hand Stock					
- End prev per	257	57			
- Beg per after rect	257	137			
- end of per	57	137			
-Avg	157	137			
Orders	80				
Planned Receipts	0	80			
Pipeline	80				
Cycle Stock					
- beg per after rect	200	100			
- end per	0	100			
- Avg	100	100			
Safety Stock (on hand)		37			

<u>Safety Stock Target</u> (Period 1)

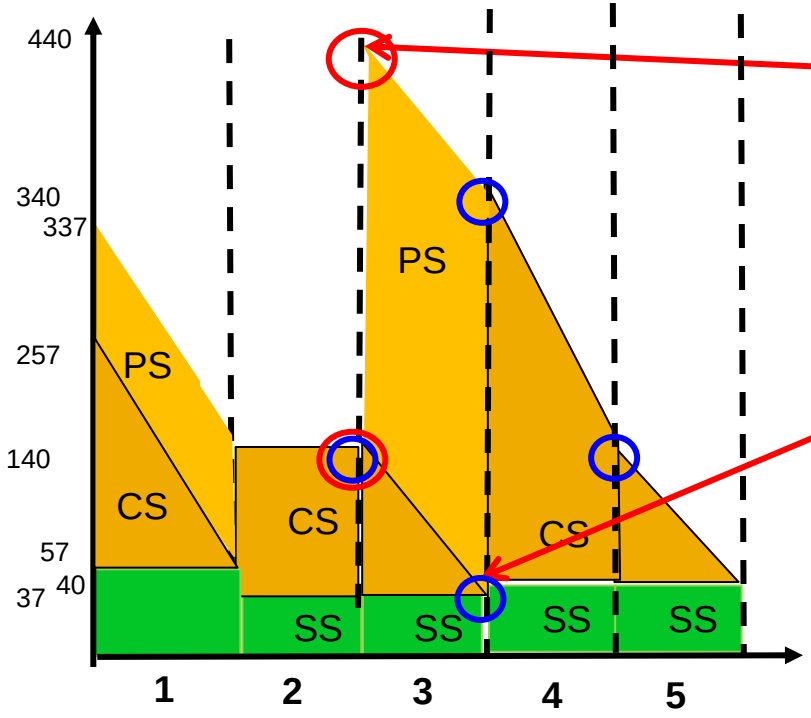
- z (95%) = 1.65
- Error = $\sqrt{(10^2 + 20^2 + 10^2)}$
  = 24.495
- SS = 1.65 * 24.495 = 40

<u>Target Inventory Position</u> (Period 1)

- TIP = (100 + 200 + 100) + 40= 440

Example 6

- **Demand: 200, 0, 100, 200, 100**
- **PBR = 2, LT = 1**
- **Initial On-Hand = 257 units**
- **95% NSP**



No capacity constraint

Period	R 1	2	R 3	4	5
Forecast	**200**	0	100	200	100
Forecast Err Sigma	20	0	10	20	10
Target Inv Position	337		440		
Target Safety Stock	37		40		
On Hand Stock					
- End prev per	257	57	137	37	140
- Beg per after rect	257	137	137	340	140
- end of per	57	137	37	140	40
-Avg	157	137	87	240	90
Orders ??	80		303		
Planned Receipts	0	80		303	
Pipeline	80		303		
Cycle Stock					
- beg per after rect	200	100	100	300	100
- end per	0	100	0	100	0
- Avg	100	100	50	200	50
Safety Stock (on hand)		37		40	

Inventory Planning Fundamentals

Cycle Stock is driven by Replenishment Frequency (PBR) or Batch Size

Pipeline Stock is driven by length of Lead Time

Safety Stock is dependent upon the uncertainty through the exposure period

Use of the Gamma Distribution allows for skewed distributions to be modeled correctly

A simple single stage inventory calculation can become fairly complex WITHOUT considering multi-stage, supply uncertainty, batch sizes, etc.…

Thank you

© 2014 SAP AG or an SAP affiliate company. All rights reserved.