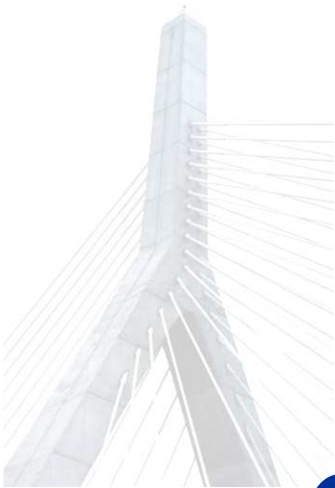

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Optimizing Inventory Management Using Demand Metrics

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Abstract

In this how-to session, we will first go through the process of evaluating demand plans, look at the pros and cons of different demand accuracy metrics, and assess the time lag for measuring accuracy.

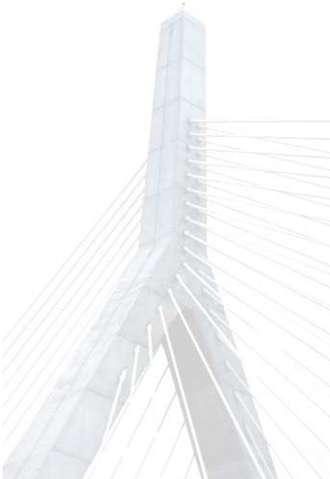
Next, we will explore how to leverage demand metrics to design scientific inventory planning parameters. Typically, organizations set safety stock in a set number of weeks or months to cover unexpected demand. This measure of weeks-forward coverage (WFC), too often dependent on the judgment of a planner, magnifies the effect of an inaccurate forecast. Here, we review some scientific methods of setting safety stock strategies that depend on the history of demand error by SKU.

You will learn:

- The pros and cons of various demand metrics
- The dangers of using weeks-forward coverage as an inventory policy parameter
- How demand metrics can be leveraged in inventory management and planning

Demand Forecast

- Demand information drives the Supply Chain
- To be effective, Demand Plans need to be
  - **Accurate**
  - **Timely**
  - **In relevant detail**
  - **Covering the appropriate time horizon**
- Long-term versus Short-term



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Forecast Error – Some Basics

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Forecast Error

- **Forecast Error is the deviation of the Actual from the forecasted quantity**
  - Error = absolute value of {(Actual – Forecast)}
  - $\varepsilon = |(A - F)|$
  - Error (%) = $|(A – F)|/A$
- **Deviation vs. Direction**
  - The first is the magnitude of the Error
  - The second implies bias, if persistent

Why divide by Actual?

Forecast Accuracy

- **Forecast Accuracy is the converse of Error**
  - Accuracy (%) = 1 – Error (%)
- **We constrain Accuracy to be between 0 and 100%.**
- **More formally**
  - Forecast Accuracy is a measure of how close the actuals are to the forecasted quantity.
  - Actuals = Forecast => 100% Accuracy
  - Error > 100% => 0% Accuracy
- **Accuracy = maximum of (1 – Error, 0)**

Quick Example

	Sku A	Sku B	Sku X	Sku Y
Forecast	**75**	**0**	**25**	**75**
Actual	**25**	**50**	**75**	**74**
Error	50	50	50	1
Error (%)	200%	100%	67%	1%
Accuracy (%)	0%	0%	33%	99%

Aggregating Errors

- **To compute one metric of accuracy across a group of products, we need to calculate an Average Error**

- **Simple Mean Absolute Percent Error**
  - Simple but Intuitive Method
    - Add the absolute errors across all items
    - Divide the above by the total of actual delivered quantity
  - MAPE is the sum of all Errors divided by the sum of all Actuals

- **MAPE is also known as Percent Mean Absolute Deviation (PMAD)**
  - Average Absolute Error divided by the Average Actual quantity.

Example of Simple MAPE

	Sku A	Sku B	Sku X	Sku Y	Total
Forecast	**75**	**0**	**25**	**75**	**175**
Actual	**25**	**50**	**75**	**74**	**224**
Error	50	50	50	1	151
Error (%)	200%	100%	67%	1%	67%
Accuracy (%)	0%	0%	33%	99%	33%

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Consideration of Alternate Demand Metrics

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Other possible Metrics

Not used as a cross-sectional Metric.

- **Mean Percent Error is an Av[illegible] Percentage Error. Very ra[illegible]sed!**
- **Mean Squared Err[illegible] the Average of the sum-squared errors. Sinc[illegible] use the root of such average, this is also known as RMSE**
  - RMSE = SQRT $[(A-F)^2 / N]$
  - RMSE is typically used to measure error on the same SKU over calendar time.
- **Weighted MAPE**
  - Weighting Deviations by Cost, Price or item-criticality such as ABC classifications.

Illustration of Error Metrics

	Forecast	Actual	Error	Abs. Error	Pct. Error
Sku A	3	1	-2	2	200%
Sku B	0	50	50	50	100%
Sku X	25	75	50	50	67%
Sku Y	75	74	-1	1	1%
Sku Z	100	75	-25	25	33%
Total	**203**	**275**	**72**	**128**	
Average	**40.6**	**55**	**14.4**	**25.6**	**80%**
				with A	w/o Sku A
Mean Percent Error =				**80%**	**50%**
Mean Absolute Percent Error =				**47%**	**46%**
Mean Absolute Deviation(MAD) =				**25.6**	
Percent Mean Absolute Deviation=				**47%**	

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Why MAPE?

- **MPE**
  - very unstable
  - will be skewed by small values
  - In the Example, Sku A drives most of the Error.
- **MAD**
  - Statistically Robust
  - Expresses a number, not a percent
  - But can be divided by Average Actual to arrive at the PMAD, which is identical to MAPE
- **MAPE is simple and elegant while robust as a computational measure!**

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Possible Abuses of simple MAPE

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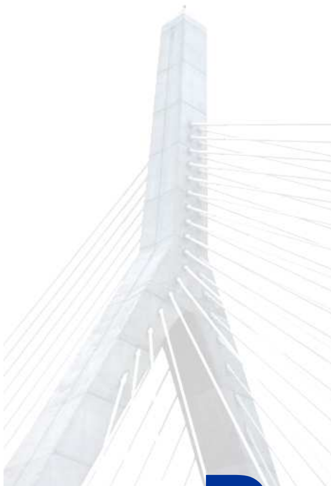
Low Value High-volume

- **Items A and B Cost $75 and $100 respectively. Item C costs $0.02 but ships in a box of 100 units.**
- **Average Volume per Month**
  - A ships 20 K units
  - B ships 30 K units
  - C ships 20 K boxes of 100 units in each box.
- **Demand Planner is measured on simple MAPE of units forecasted and shipped.**
- **What is the issue?**
  - Item C accounts for 1% of the value while weighted 98% in simple MAPE
  - Planner focuses exclusively on Item C



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Denominator Management

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What is the Denominator?

- **Another Possible Abuse**
  - Ignore the Errors
  - Focus on the Measure/Denominator
- **Divide by Actual or Forecast**
  - Depends on the tendency to bias
  - Organizational alignment

- **Divide by Forecast → Over-forecasting will improve MAPE**
- **Divide by Actual → Under-forecasting will Improve MAPE**

A simple measure of bias – Forecast Attainment

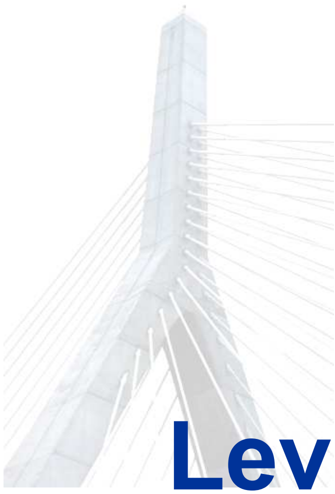
- **Forecast Attainment is the simple quotient of total Actuals over Forecast**

$$Attainment = \frac{\sum Actuals}{\sum Forecast}$$

- **This is a measure of what percent of Forecast did we actually deliver**
  - Over-deliver or under-deliver?
  - Consistently below 100% will imply an over-forecasting bias
- **Benchmark is Attainment between 95% and 105%**

Arithmetic Accuracy or Attainment

	Forecast	Actual	Error	Abs. Error	Attainment
Sku A	3	1	-2	2	33%
Sku B	0	50	50	50	9999%
Sku X	25	75	50	50	300%
Sku Y	75	74	-1	1	99%
Sku Z	100	75	-25	25	75%
Total	**203**	**275**	**72**	**128**	
Average	**40.6**	**55**	**14.4**	**25.6**	135%
	Mean Absolute Percent Error =				**47%**
	Attainment %				**135%**



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Leveraging Demand metrics to design Safety Stock Strategies

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Safety stock

- **Safety stock is defined**
  - as the component of total inventory needed to cover unanticipated fluctuation in demand or supply or both
  - As the inventory needed to defend against a forecast error
- **Hence Forecast error is a key driver of safety stock parameters.**
- **We ignore supply volatility in this discussion.**

Traditional Practice

- **Safety-stock is set in WFC**
  - Say, between four and eight weeks
  - Safety stock itself becomes a function of the forecast
  - Forecast Volatility will render the Safety stock measure meaningless
- **No distinction between minimum stock, safety stock and Target inventory level.**

Potential Process flaws

- **Service Level Goals**
  - set ambitiously too high!
- **Inventory Level Goals**
  - set ambitiously too low!
- **Multiple forecasts in the organization**
  - Results in an unidentifiable forecast error!
- So Safety stock strategies could be left to the supply planner's judgment.

Determinants of Safety Stock

- **Customer Service Levels**
  - Is product available when customer needs it?
- **Lead Time**
  - How long does it take to replenish inventory?
- **Forecast Error**
  - Can I rely on my forecast to plan my production?

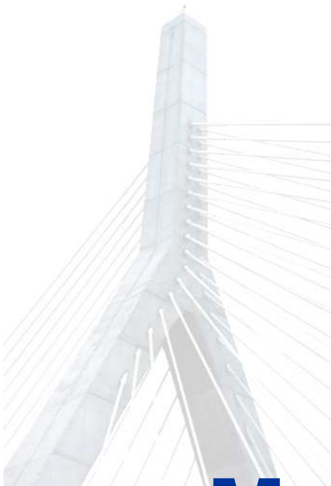
Service Levels

How expensive is 98% vs. 99.5%?

- **Customer Service Levels**
  - How often do I short an order for a specific sku?
  - Should I guarantee 100% order fill?
    - Higher the Level => Higher Safety Stock
    - Trade-off exists between Service Levels and inventory levels
  - This lets you discriminate your strategy for high-value items, high profile customers etc.

Lead Time

- **Production Lead time**
  - How long does it take to turn around a forecasted demand into real supply?
  - Longer Lead times
    - Relatively less flexibility to change production plans
    - Higher Safety stock levels
    - Forecast accuracy becomes much more important



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Mechanics of the Calculation

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Safety Stock Calculation

- **Using all three determinants of Safety stock,**

  SS = SL * Forecast Error * √Lead Time

- **SL is the number of standard deviations required for a set Customer Service Level**
  - Depending on policies – Customer Service Level may be 95, 98 or 99, 99.9.
  - SL at 98% customer service level is 2.05.
    - One-tailed test
    - Care about only over-selling the forecast

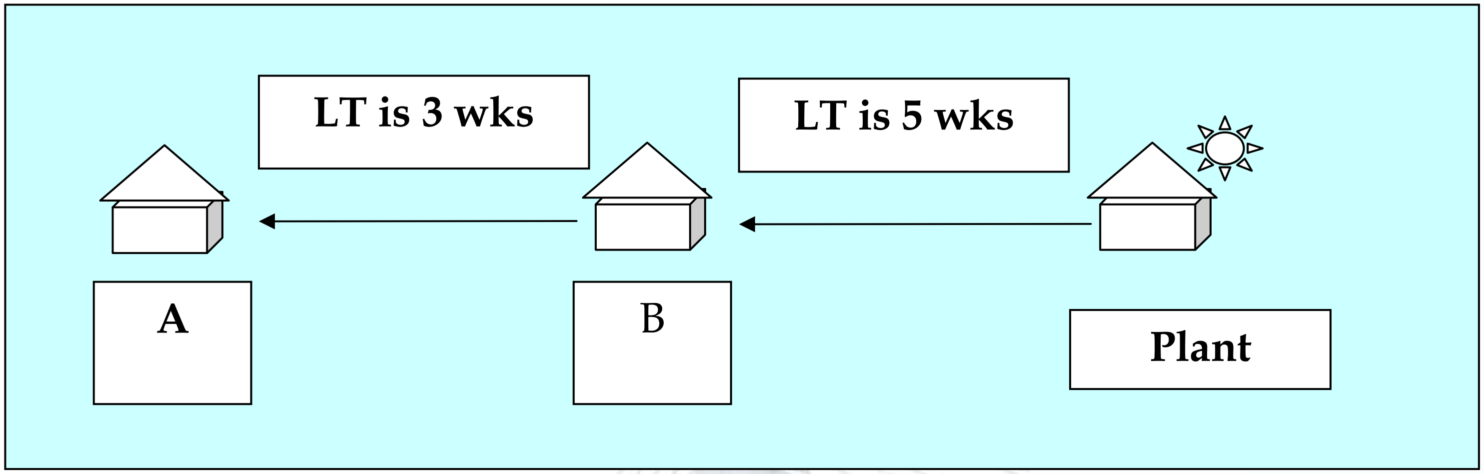
Safety Stock Calculation

- **What is the Forecast Error over my lead time?**
- **Lead time is either weeks or months, consistent with the forecast measurement period.**
  - Monthly Forecast with an eight week Lead time
  - LT = 2
- **What if my Lead time is two weeks when forecast is monthly?**
  - LT = .5 is acceptable.
  - Tricky if weekly split is uneven.
- **Finally, Forecast Error used is the Calendar Root Mean Squared Error.**

Calendar RMSE

	Forecast	Actual	Error	Error sqd	
Jan-04	100	75	-25	625	
Feb-04	90	72	-18	324	
Mar-04	80	125	45	2,025	
Apr-04	75	74	-1	1	
May-04	75	100	25	625	
Total	**420**	**446**	**26**	**3600**	
Average	**84**	**89.2**	**5.2**	**720**	
				with March	w/o March
Mean Squred Error				**720**	**393.75**
Root Mean Squred Error				**26.83**	**19.84**
RMSE relative to Actual				**30%**	**25%**

Lead Times



- **For Ware House A, SS is based on LT=3 wks**
- **For Ware House B, SS is based on**
  - Forecast Error on Demand Streams from A
  - LT=5 weeks from the Plant

Importance of Forecast Error

- **Lead times are externally determined**
- **Service Level Targets are based on policy**
  - By item
  - And hence pre-determined
  - May be by customer, introducing additional complexity.

Hence Forecast Error is the biggest driver of safety stock.

Example

		Sku X	Sku Y	Sku Z
Lead Time	Months	0.75	2	2
Service Level	98%	2.05	2.05	2.05
Forecast Error	Monthly	16	11	5
RMSE%		16%	50%	5%
Average volume		100	22	100
Safety Stock	Units	28	32	14
Safety stock in weeks		1.14	5.80	0.58

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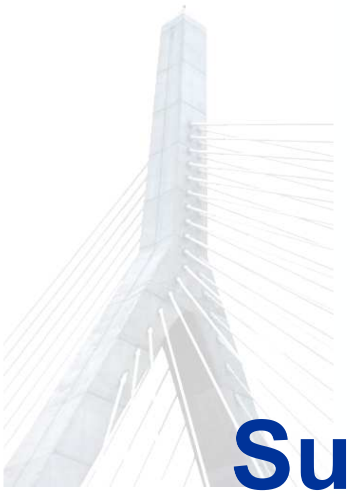

Supply Chain definitions re-examined

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Demand Volatility instead of Error

- **Some organizations use Demand Volatility instead of Forecast Error**
  - Assume either Forecast is not used in Supply Chain Planning or
  - Forecast is heavily biased and hence unusable.

- **If forecast is fairly accurate, using demand volatility will inflate required safety stock.**

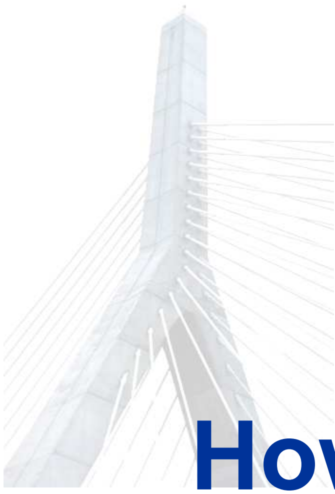
- **Demand Volatility is an acceptable measure if demand is fairly stable**
  - Implies forecasting is a waste of time
  - Use Exception Analysis to determine which items to forecast and when not to.

Demand Volatility vs Error

	Forecast	Actual	Error	Error sqd
Jan-04	45	50	5	25
Feb-04	75	70	-5	25
Mar-04	110	120	10	100
Apr-04	55	70	15	225
May-04	65	75	10	100
Total	**350**	**385**	**35**	**475**
Average	**70**	**77**	**7**	**95**
Demand Volatility (Standard deviation)				**26**
Mean Squred Error				**95**
Root Mean Squred Error				**10**
RMSE relative to Actual				**13%**

When not to use Forecast?

	Forecast	Actual	Error	Error sqd
Jan-04	70	90	20	400
Feb-04	120	95	-25	625
Mar-04	110	98	-12	144
Apr-04	98	100	2	4
May-04	130	93	-37	1,369
Total	**528**	**476**	**-52**	**2542**
Average	**105.6**	**95.2**	**-10.4**	**508.4**
Demand Volatility (Standard deviation)				**4**
Mean Squred Error				**508**
Root Mean Squred Error				**23**
RMSE relative to Actual				**24%**



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How does forecast bias affect Safety Stock Strategies?

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Any Questions?

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Thank you!

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Our specialty consulting areas include Sales forecasting, Supply Chain Analytics, and Sales and Operations Planning. Our current clients include companies on the Fortune 500 such as Teva Pharmaceuticals, FMC, Celanese AG and Abbot Labs.

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