The 29th International Symposium on Forecasting, 22-24 June, 2009

A Family of Distributions for Inventory Demand Forecasting

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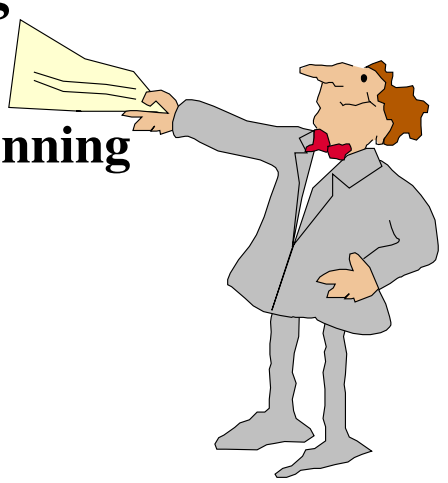
Presentation Overview

- **The Demand Forecaster's Role in the Supply Chain**
  - **Traditional perception demand forecasting for supply chains**
  - **What it has become – consumer vs. customer demand**

- **Demand Forecasting and Inventory Planning**
  - **Override adjustments to baseline forecasting**
  - **A family of distributions for lead time demand planning**



What is Demand Forecasting?

- Forecasting is all about CHANGE and CHANCE
- Revolves around predicting future quantities demanded by consumer/customer with the ability to pay
  - Exclude forecasting natural disasters (floods, earthquakes, etc.), and forecasting weather, stocks and sports
  - Not to be confused with “Planning” as a business function

Demand Forecasters Impact Many Users in the Supply Chain

Supply-Side Management

Suppliers

Figure by MIT OCW.

- Operations
- Logistics
- Supply Chain
- Merchandize Planning
- Procurement
- Finance

DM Processes

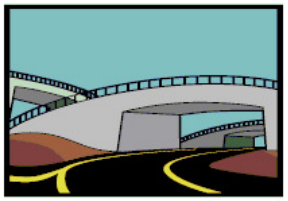


Figure by MIT OCW.

Matching supply and demand

- **Long Term**
- **Medium term**
- **Short Term**

Demand-Side Management

- Marketing
- Sales
- Merchandizing
- Customer Service

Customers

Figure by MIT OCW.

Minimize costs and inventories

Maximize revenues and margins

Maximize sustained profitability

Source: Lapide, MIT, 2006

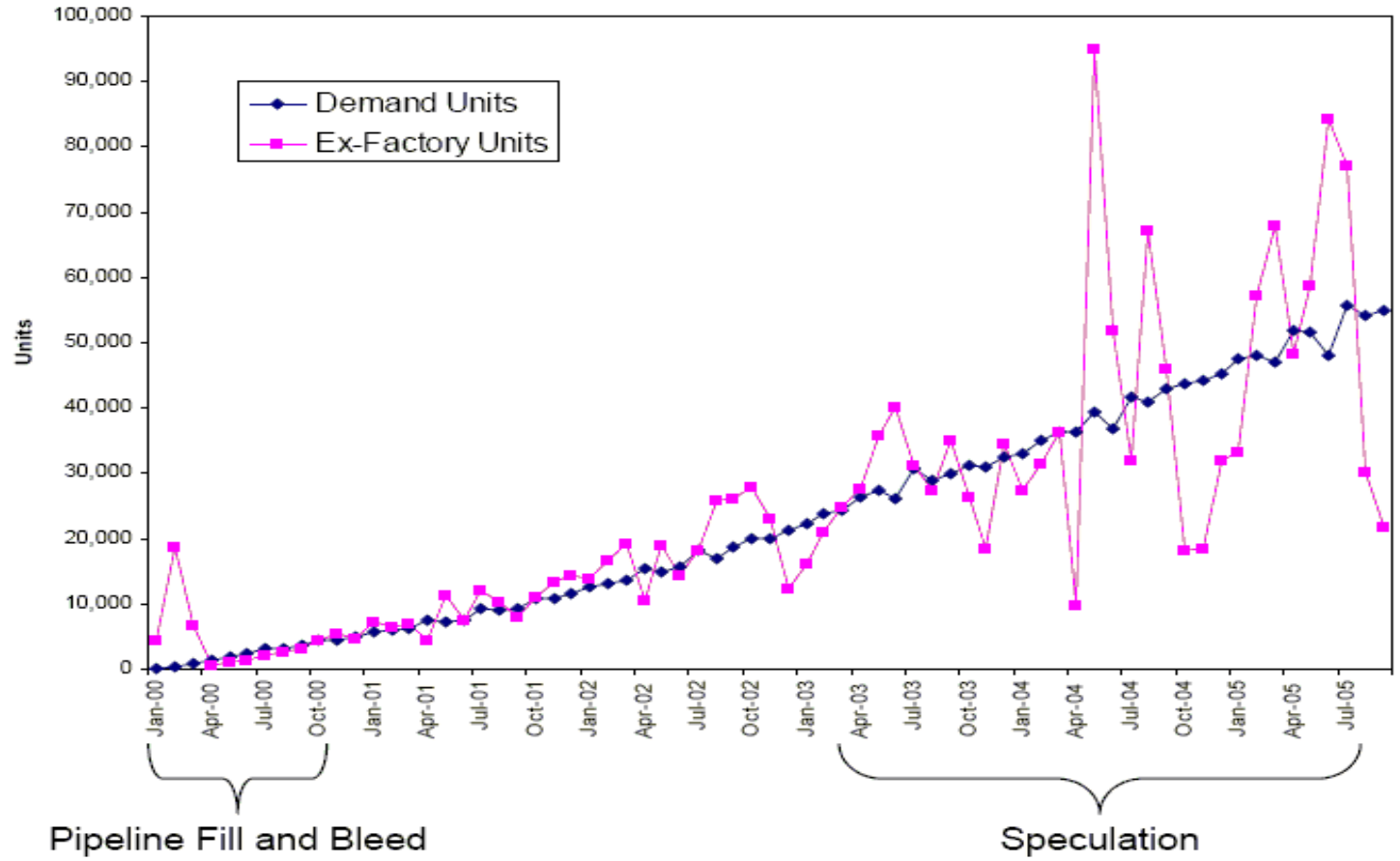
Demand Forecaster's Role

Level of Forecast	*Purposes*	
Strategic(years)	Business planning Capacity planning	
Tactical (quarterly)	Brand plans Financial planning/budgeting Sales planning Manpower planning	*Operational Forecasts*
Tactical (months/weeks)	Short-term capacity planning Master planning Inventory planning	
Operational(days/hours)	Transportation planning Production scheduling Inventory deployment	

In Particular, Demand Forecasters Can Help Answer Questions Like:

- Do I fill this customer's order now? If not, when?
- Should I fill it using available or …
  - planned inventories?
  - future production capacity?
  - future materials?
- Is this customer's order more important than a
  - customer's future order?
  - warehouse or planned replenishment order?
- If I take the order, at what price?

Consumer Versus Customer Demand



The Notion of Lead Time Demand

- **Inventory management requires forecasts over a *lead time*.**
- **The lead time is determined by the time to fulfill an order to replenish inventory.**
- **Lead time can be fixed or random.**
- **The sum of future demands over the lead time is called the *Lead Time Demand*.**

A Family of Lead Time Distributions

Exponential family (one parameter form)

$$f_{Ld}(Ld,\theta) = \exp[a(Ld)+b(\theta)+c(Ld)\ d(\theta)]$$

where a(.), b(.), and c(.) are known functions. The value θ is called the parameter of the family

- Includes Normal, Gamma, Poisson, Compound Poisson and others
- Allows zero values with non-zero probability
- Is positively skewed

Cf. Wikipedia

Determining a Safety Factor

(step 1 – reducing dimension)

1. Represent $Ld_i \leftrightarrow \{m(Ld), s(Ld), \mathbf{O_i}\}$
   $e_i \leftrightarrow \{ m(e), s(e), \mathbf{O_i}\}$

where

$$\mathbf{O_i} = \{ Ld_i - m(\underline{Ld}) \,)/\, s(\underline{Ld}) \}$$

- Since $\mathbf{O_i} = (e_i - m(\underline{e}))/s(\underline{e}))$, they are observable components of the error;
- m(.) and s(.) are location and scale statistics, respectively;

Determining a Safety Factor

(step 2 – The reduced model)

The Reduced Model:

Determine the conditional distribution of m(e) and s(e), conditional on *observed* values of $\mathbf{O_i}$:

$$m(e) = (m(Ld) - \mu)/ \sigma$$

$$s(e) = s(Ld) / \sigma$$

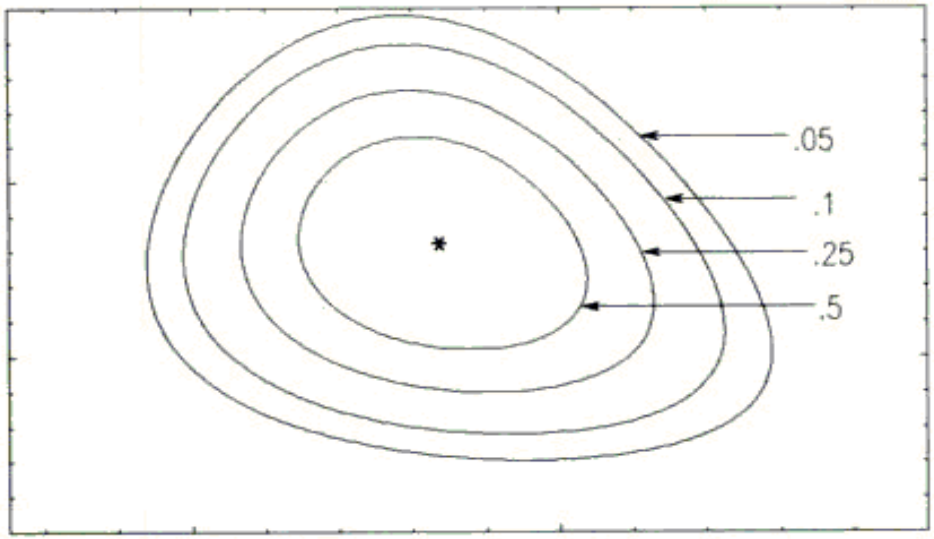
Determining a Safety Factor

(step 3 – The posterior model)

The Posterior Model:

Location component: $\mu = m(\underline{Ld}) - \sigma\, m(\underline{e})$

Scale component: $\sigma = s(\underline{Ld})/\, s(\underline{e})$



Determining a Safety Factor
(step 4)

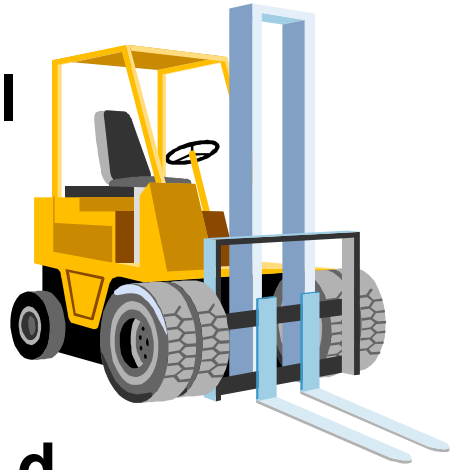
- **Define "safety factor" SF**

$$SF = \sqrt{n}\,\{\mu_{0.95} - m(\underline{Ld})\}/s(\underline{Ld})$$

where $\mu_{1-\alpha}$ = desired percentile in marginal posterior distribution for μ

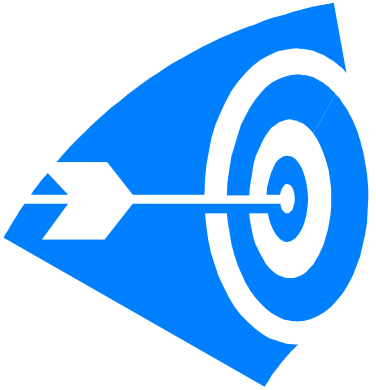
- **Then,** $m(\underline{Ld}) + SF * s(\underline{Ld})/\sqrt{n}$

Is the desired estimated percentile of the Ld distribution



Inventory Performance Measurements

Measure, measure, measure, not just forecast accuracy,



But more so

- Reduction in total inventory dollars
- Increase in inventory turns
- Percent on-time shipments
- Reduced back-order status
- Reduced cycle time

Research Opportunities

- Forecasting for inventory planning needs lead-time distributions, not just forecasts of independent demand

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- To paraphrase George Box: “All normality assumptions are wrong, but some are useful - Right tails are present in all lead-time distributions”