Forecasting for Special Cases

MIT Center for Transportation & Logistics

Agenda

- New Products
- Intermittent Demand
- Forecasting Wrap-Up

New-to-World

first of their kind, creates new market, radically different

New-to-Company

new market/category for the company, but not to the marketplace

Line Extensions

incremental innovations added to complement existing product lines and targeted to the current market

Product Improvements

new, improved versions of existing offering, targeted to the current market – replaces existing products

Product Repositioning

taking existing products/services to new markets or applying them to a new purpose

Cost Reductions

reduced price versions of the product for the existing market

Why does it matter?

New Product Categories

<table>
<tr><th>Type of New Product</th><th>Percent of Introductions</th><th>Forecast Accuracy (1-MAPE)</th><th>Launch Cycle Length</th><th>Success Rate</th></tr>
<tr><td>New-to-World</td><td>8-10%</td><td>40%</td><td rowspan="2">104 weeks</td><td rowspan="2">38-65%</td></tr>
<tr><td>New-to-Company</td><td>17-20%</td><td>47%</td></tr>
<tr><td>Line Extensions</td><td>21-26%</td><td>54-62%</td><td rowspan="2">62/29* weeks</td><td rowspan="2">55-77%</td></tr>
<tr><td>Product Improvements</td><td>26-36%</td><td>65%</td></tr>
<tr><td>Product Re-Positioning</td><td>5-7%</td><td>54-65%</td><td rowspan="2">N/A</td><td rowspan="2">66-79%</td></tr>
<tr><td>Cost Reductions</td><td>10-11%</td><td>72%</td></tr>
</table>

* Major revisions / Incremental improvements – about evenly split

Adapted from Cooper, Robert (2001) Winning at New Products, Kahn, Kenneth (2006) New Product forecasting, and PDMA (2004) New Product Development Report.

Product-Market Matrix

		Product Technology	
		Current	New
Market	Current	**Market Penetration** **Forecasting Approach**: Quantitative analysis of similar situations with item: time series, regression, etc. Cost Reductions & Product Improvements	**Product Development** **Forecasting Approach**: Analysis of similar items: “looks-like” analysis or analogous forecasting Line Extensions
	New	**Market Development** **Forecasting Approach**: Customer and market analysis to understand market dynamics and drivers Product Repositionings	**Diversification** **Forecasting Approach**: Scenario planning & analysis to understand key uncertainties & factors New-to-Company & New-to-World

Adapted from Kahn, Kenneth (2006) New Product Forecasting.

Why do firms launch new products?

- Companies earn significant revenue & profit from new products:
  - Revenue - 21% to 48%
  - Profit – 21% to 49%

- By Selected Industries (revenue/profit):

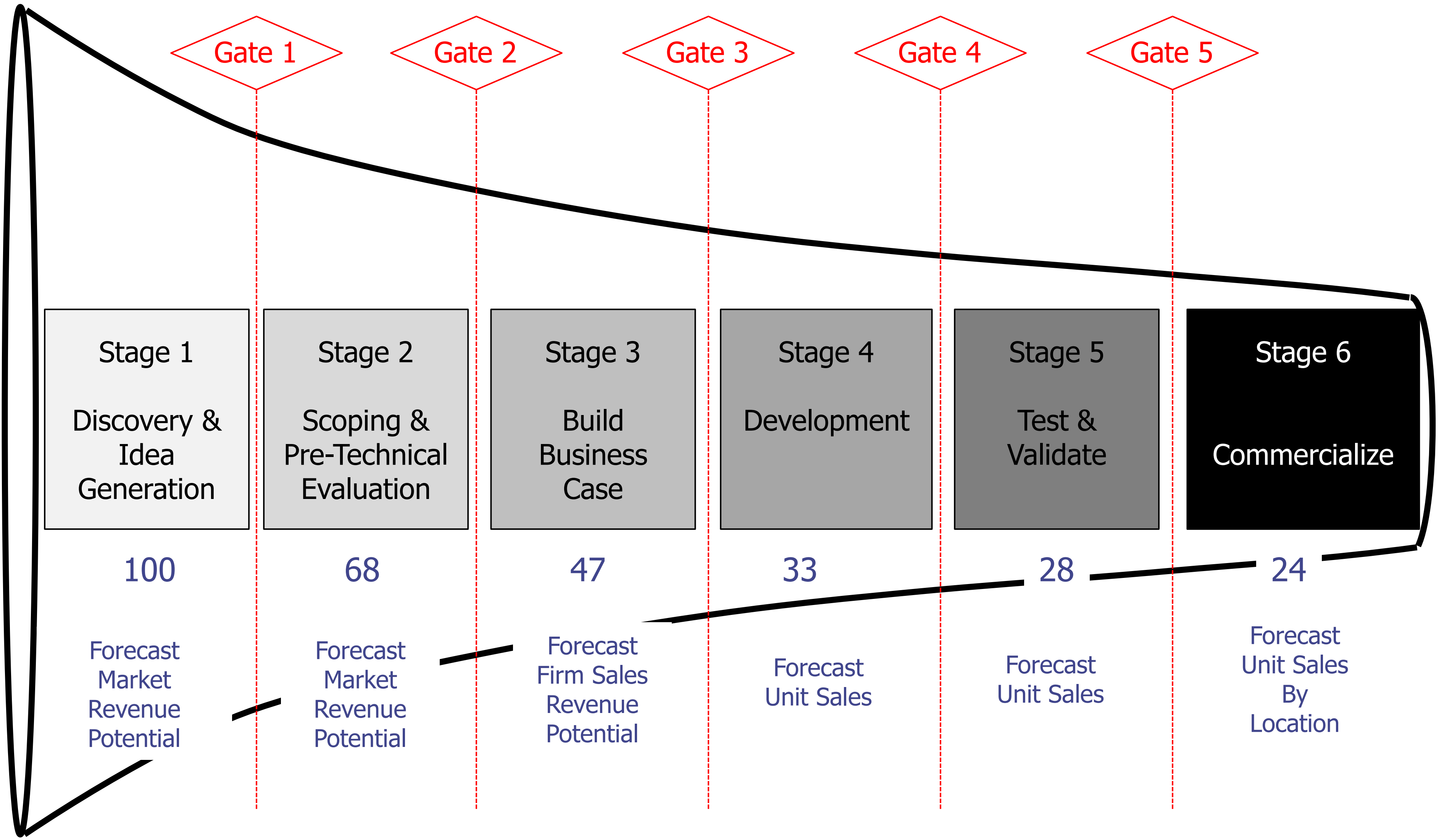
Fast Moving Consumer Goods	24%	24%
Consumer Services	25%	24%
Chemicals	18%	22%
Healthcare	31%	33%
Technology	47%	44%

- Product lifecycle is shortening and/or ability to maintain pricing is eroding faster

Adapted from Cooper, Robert (2001) Winning at New Products, Kahn, Kenneth (2006) New Product forecasting, and PDMA (2004) New Product Development Report.

New Product Development Process

New Product Development Process



New Product Forecasting Methods

Customer/market research	57%
Jury of executive opinion	44%
Sales force composite	39%
Looks-like analysis	30%
Trend line analysis	19%
Moving average	15%
Scenario analysis	14%
Exponential smoothing	10%
Experience curves	10%
Delphi method	8%
Linear Regression	7%
Decision trees	5%
Simulation	4%
Others:	9%

- Methods differ by stage and by new product type.
- On an average, companies use 3 different methods to forecast new products.
- Business-to-Business (B2B) firms tend to use qualitative forecasts more than the Business-to-Consumer (B2C) firms.
- B2B firms have a longer forecasting horizon (34 months) compared to the B2C firms (18 months.)

Adapted from Kahn, Kenneth (2006) New Product Forecasting.

* Based on a survey of 168 companies.

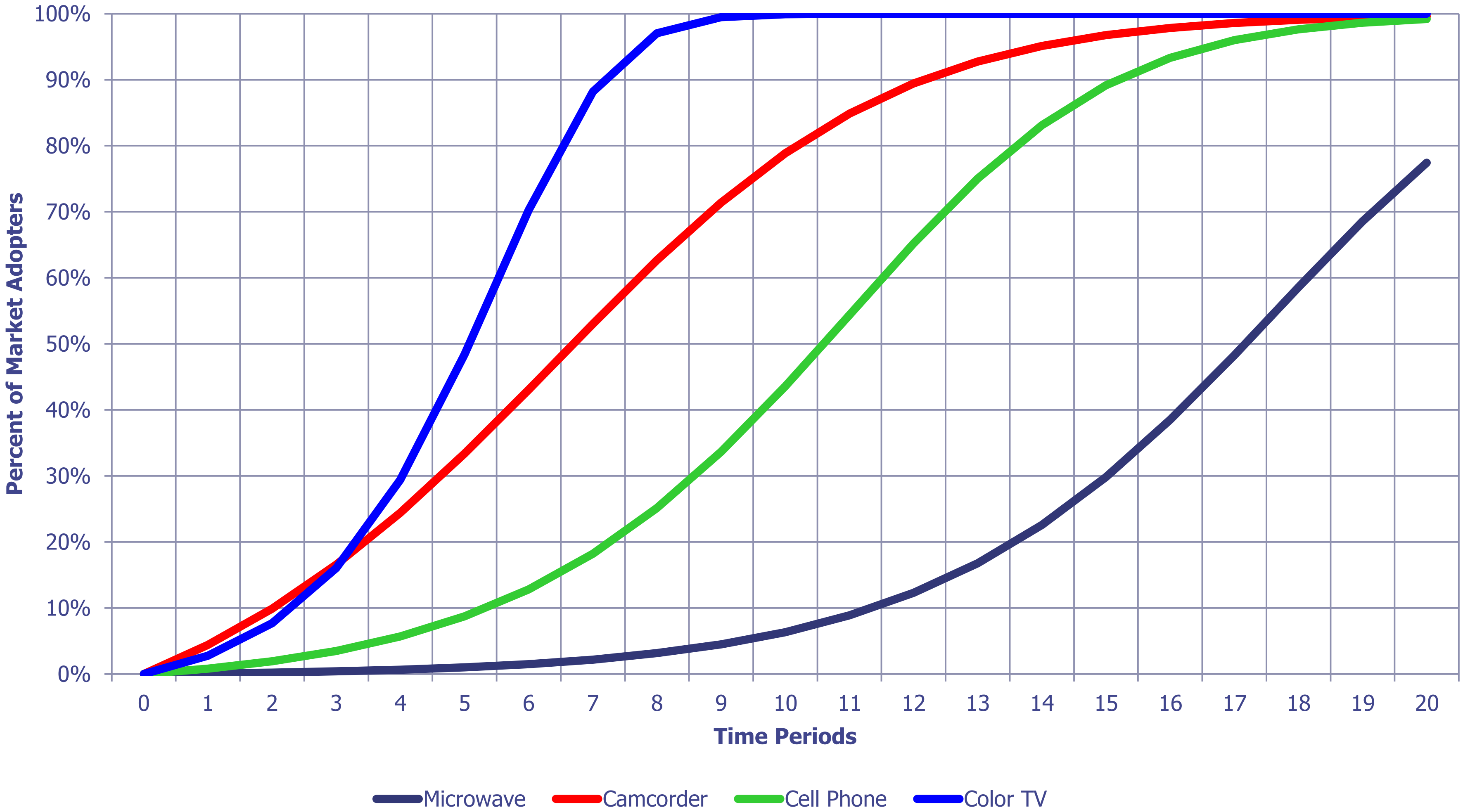
“Looks-Like” or Analogous Forecasting

- How to do it
  - Look for comparable product launches
  - Create month by month (week by week) sales record
  - Use the percent of total sales as guide to trajectory
  - Similar to using “comps” in real estate
- Structured Analogy
  - Create database of past launches (sales over time)
  - Characterize each launch by
    - Product type
    - Season of introduction
    - Price
    - Target market demographics
    - Physical characteristics
  - Use characteristics of new product to query old launches
  - Avoid only including successful launches!

Adapted from Gilliland, Michael (2010) Business Forecasting Deal.

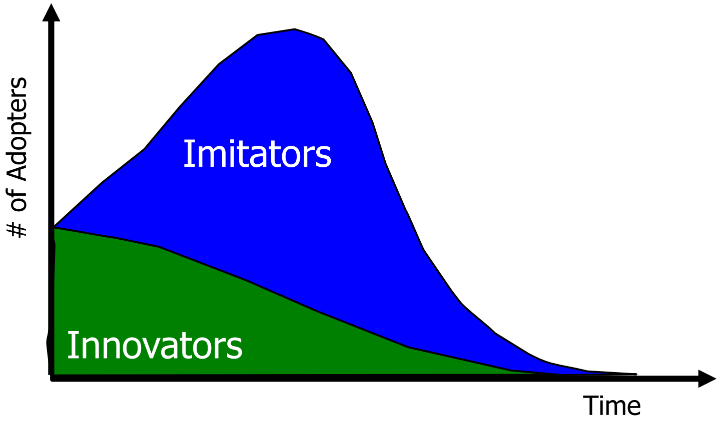
Diffusion Models

S-Curve for Adoption Rate

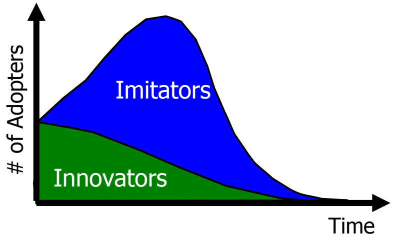


Bass Diffusion Model

- Two effects driving product adoption:
  - Innovation Effect (p)
    - Innovators are early adopters – high intrinsic tendency to adopt
    - They are drawn to the technology regardless of who else is using it
    - Innovator demand peaks early in the lifecycle
  - Imitation Effect (q)
    - Imitators hear about the product by word of mouth
    - They are influenced by behavior of their peers & social contagion
    - Imitator demand peaks later in the lifecyle



Bass Diffusion Model



Innovation Effect / Imitation Effect

n(t) = p x [Remaining Potential] + q x [Adopters] x [Remaining Potential]

$$n(t) = p\,[m-N(t-1)] + q[N(t-1)/m][m-N(t-1)]$$

Example: iWidget Sales

Management estimates the iWidget has a 4 year product life with total sales of 750,000 units. They estimate that p=0.10 and q=0.25 for this product. Project sales by quarter:

Q1 = (.10)(750-0)+(.25)(0)(750-0)=75k
Q2 = (.10)(750-75)+(.25)(75/750)(750-75)=84k
Q3 . . . .

Where:
- **p** = Coefficient of innovation
- **q** = Coefficient of imitation
- **m** = Total number of customers who will adopt
- **n(t)** = Number of customers adopting at time t
- **N(t-1)** = Cumulative number of customers by time t

Quarter	Innovation Effect	Imitation Effect	Cum. N(t-1)	n(t)
1	75	-	-	75
2	68	17	75	84
3	59	31	159	90
4	50	42	250	92
5	41	47	341	87
6	32	46	429	78
7	24	41	507	65
8	18	34	572	52
9	13	26	624	39
10	9	19	663	28
11	6	14	691	20
12	4	9	710	13
13	3	6	724	9
14	2	4	733	6
15	1	3	739	4
16	1	2	743	3

Bass Diffusion Model Parameters

- So where do these p & q values come from?
  - Look for previous studies
  - Identify "like" products in terms of
    - Environmental context (e.g., socioeconomic and regulatory environments)
    - Market structure (e.g., barriers to entry, number of competitors)
    - Buyer behavior (e.g., consumer, business)
    - Marketing mix strategies (e.g., promotion, pricing)
    - Characteristics of the innovation (e.g., complexity, relative advantage)

Typical values:
- $p \sim 0.03$ and often <0.01
- $q \sim 0.38$ and $0.3 \leq q \leq 0.5$

Parameter values differ over time and vary by regions.

Good for estimating sales trajectories – not absolute sales

Provides estimate of time of peak sales: $t^*=\ln(q/p)/(p+q)$

Product	Innovation Coefficient p	Imitation Coefficient q
Cable TV	.100	.060
Cell Phone	.008	.421
Curling Irons	.028	.993
Dishwasher	.0014	.206
Drip Coffeemaker	.017	.993
Radio	.027	.435
Microwave	.002	.357
Non-durable product	.023	.788
Home PC	.121	.281

Sources from Lilien G. and A. Rangasamy Marketing engineering, Revised 2nd Edition (2006), Kahn (2006), Bass, F (1969) "A New Product Growth Model," and Van den Bulte, C (2002) "Diffusion Speed Across countries & Products".

Estimating Diffusion Models

Estimating p & q from Recent Sales

First, transform Bass Model into linear equation:

$$n(t) = p\left[m - N(t-1)\right] + q\left[\frac{N(t-1)}{m}\right]\left[m - N(t-1)\right]$$

$$n(t) = pm - pN(t-1) + qN(t-1) - \left(\frac{q}{m}\right)\left[N(t-1)\right]^2$$

$$n(t) = pm + (q-p)N(t-1) - \left(\frac{q}{m}\right)\left[N(t-1)\right]^2$$

Second, estimate the regression equation using past sales periods.

$$y_i = b_0 + b_1 x_{1i} + b_2 x_{2i}$$

where:

$y_i = n(t) =$ sales for period t

$x_{1i} = N(t-1) =$ cumulative sales up to period t-1

$x_{2i} = x_{1i}^2 =$ square of cumulative sales

$$b_0 = pm \qquad b_1 = q - p \qquad b_2 = \frac{-q}{m}$$

Third, back calculate for the parameters:

$$p = \frac{b_0}{m} \qquad q = -b_2 m$$

$$b_1 = q - p = -b_2 m - \frac{b_0}{m}$$

$$0 = -b_2 m^2 - b_1 m - b_0$$

$$m = \frac{b_1 \pm \sqrt{b_1^2 - 4 b_2 b_0}}{-2 b_2}$$

Recall Quadratic Eqation:

$ax^2 + bx + c = 0$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Example: Diffusion Model

- Suppose I have the following sales information for the first 5 quarters of a product launch:

Quarter	n(t)	N(t-1)	N(t-1)^2
1	160	0	0
2	223	160	25,600
3	310	383	146,689
4	425	693	480,249
5	575	1,118	1,249,924

- Regress using the LINEST function giving me:

(0.000093)	0.4765	160.18
0.0001066	0.1333	30.31
0.98	35.32	#N/A
48.17	2	#N/A
120,203.73	2,495.47	#N/A

b_2	b_1	b_0
s_{b2}	s_{b1}	s_{b0}
R^2	s_e	
F	d_f	
SSR	SSE	

- Back solving for p, q, m:

m= 5430
p= 0.030
q= 0.506

- My regression equation becomes:

$$n_t = 160.18 + (0.4765)N_{t-1} - (0.000093)(N_{t-1})^2$$

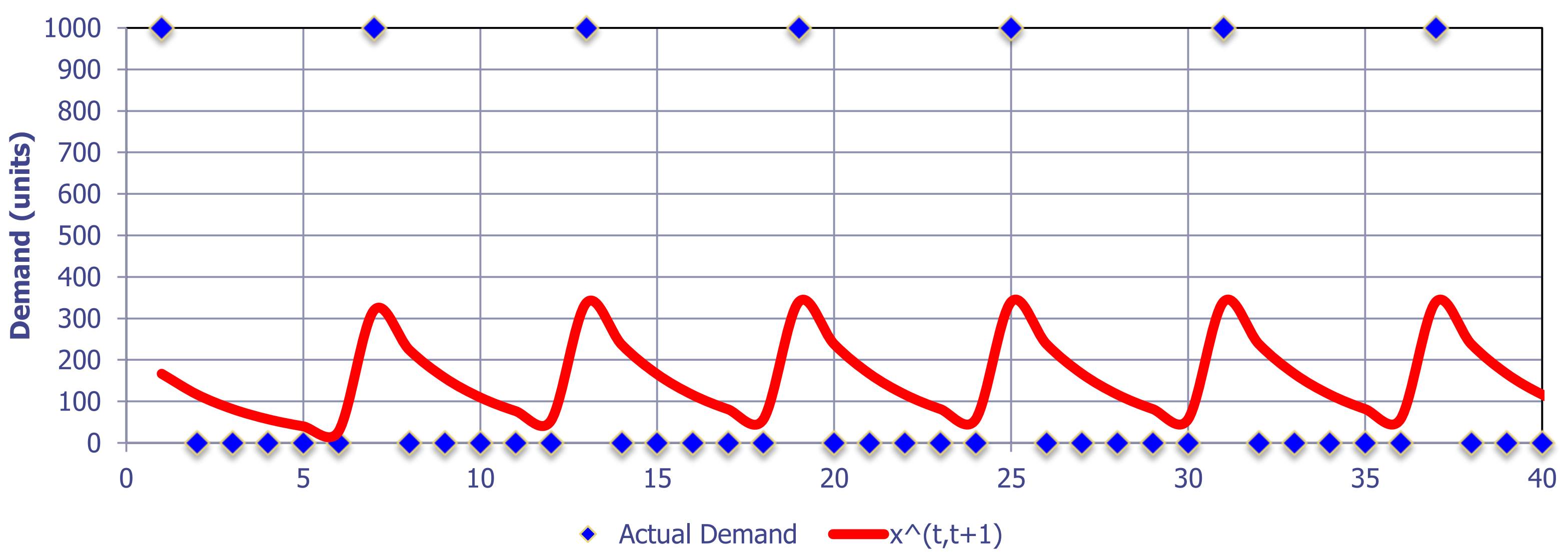
- Use these parameters to estimate future sales or compare to similar past product launches

Forecasting Products with Intermittent Demand

Problems with Intermittent Demand

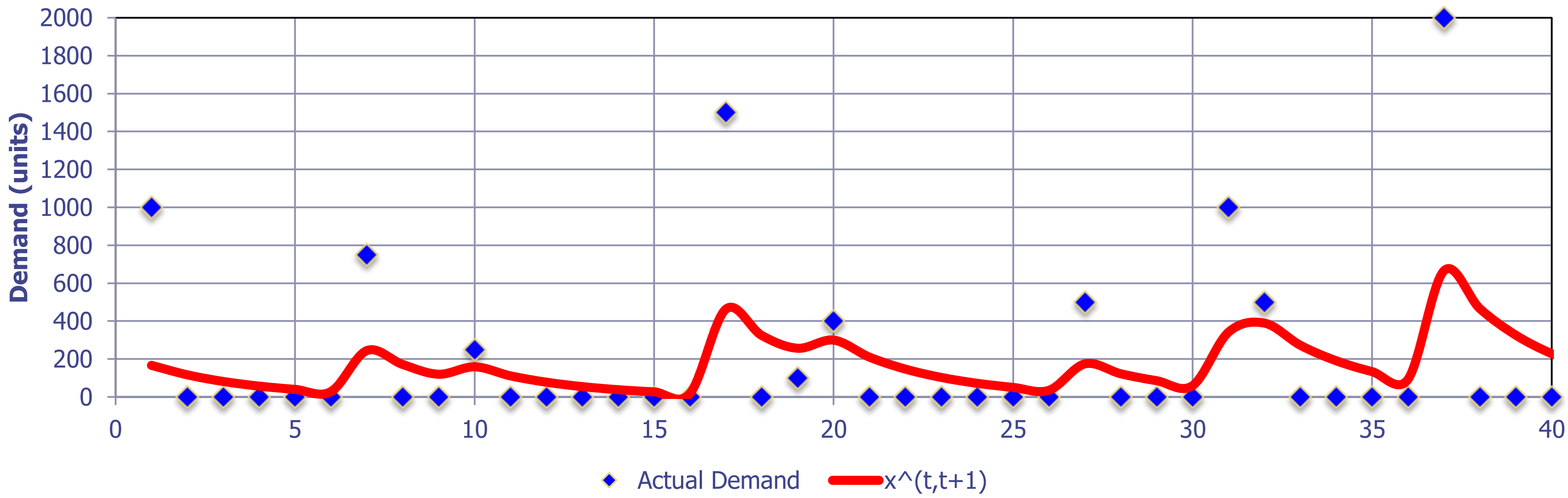
- Suppose I had an item that is ordered every 6 months for 1,000 units. Average monthly demand = 2000/12 = 167 units.
- What happens if I forecast demand using simple exponential smoothing:

$$\hat{x}_{t,t+1} = \alpha x_t + (1-\alpha)\hat{x}_{t-1,t} \qquad 0 \le \alpha \le 1$$



Problems with Intermittent Demand

- Or more realistically, my demand for product is infrequent, of different size, and irregularly ordered.
- Forecasting demand using simple exponential smoothing results in additional noise.
- Separate components of demand and model separately:
  - Time between transactions
  - Magnitude of individual transactions



Croston's Method

Demand process: $x_t = y_t z_t$

If demand is independent between time periods, then the probability that a transaction occurs is 1/n, that is:

$$\text{Prob}\left(y_t = 1\right) = \frac{1}{n} \qquad \text{Prob}\left(y_t = 0\right) = 1 - \frac{1}{n}$$

The updating procedure becomes:

If $x_t=0$ (no transaction occurs),

$\hat{z}_t = \hat{z}_{t-1}$

$\hat{n}_t = \hat{n}_{t-1}$

If $x_t>0$ (transaction occurs),

$\hat{z}_t = \alpha x_t + (1-\alpha)\,\hat{z}_{t-1}$

$\hat{n}_t = \beta n_t + (1-\beta)\,\hat{n}_{t-1}$

Forecast

$\hat{x}_{t,t+1} = \hat{z}_t / \hat{n}_t$

Where:

- $\mathbf{x_t}$ = Demand in period t
- $\mathbf{y_t}$ = 1 if transaction occurs in period t, =0 otherwise
- $\mathbf{z_t}$ = Size (magnitude) of transaction in time t
- $\mathbf{n_t}$ = Number of periods since last transaction
- α= Smoothing parameter for magnitude
- β = Smoothing parameter for transaction frequency

Approach adapted from Silver, Pyke, & Peterson (1998), Inventory Management and Production Planning and Scheduling

Croston's Method – An Example

- Using same data:
  - Average demand per year ~2,000 units
  - Irregular transaction size and time between orders
- Create a forecast for demand going forward using Croston's method

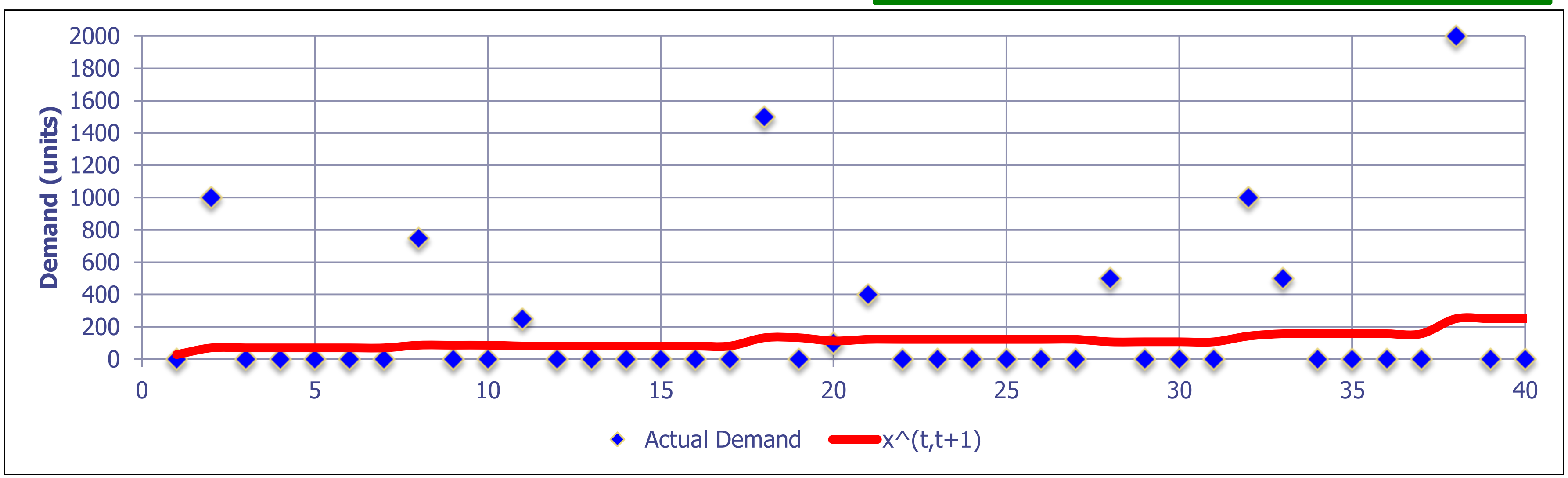
	A	B	C	D	E	F
1		Alpha =	0.30			
2		Beta =	0.20			
3						
4	t	Actual Demand	x^(t,t+1)	n(t)	z^(t)	n^(t)
5	1	0	28	5	167	6.00
6	2	1000	69	6	417	6.00
7	3	0	69	1	417	6.00
8	4	0	69	2	417	6.00

=E7/F7

=IF(B6>0,1,D6+1)

=IF(B7>0,C1*B7+(1-C1)*E6,E6)

=IF(B7>0,C2*D7+(1-C2)*F6,F6)



Croston's Method

- Essentially shifts the updating to only after an order occurs.
  - Smooths out the forecast for replenishment purposes – average usage per period
  - Unbiased and has lower variance than simple smoothing.
- Cautions
  - Infrequent updating introduces a lag to responding to magnitude changes
  - Recommended use of smoothing for MSE of non-zero transaction periods

$$\text{NewMSE}(z) = w\left(x_t - \hat{z}_{t-1}\right)^2 + (1-w)\text{OldMSE}(z) \qquad x_t > 0$$

Forecasting Wrap Up

Demand Process – Three Key Questions

What should we do to shape and create demand for our product?

Demand Planning

- Product & Packaging
- Promotions
- Pricing
- Place

What should we expect demand to be given the demand plan in place?

Demand Forecasting

- Strategic, Tactical, Operational
- Considers internal & external factors
- Baseline, unbiased, & unconstrained

How do we prepare for and act on demand when it materializes?

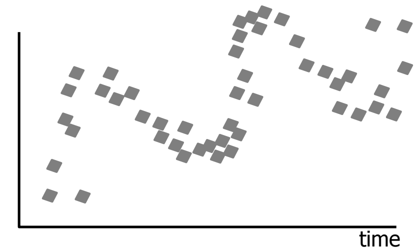
Demand Management

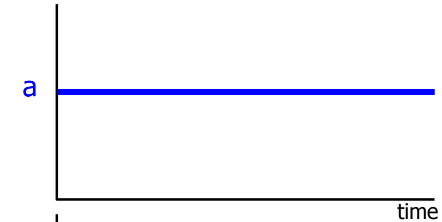
- Balances demand & supply
- Sales & Operations Planning (S&OP)
- Bridges both sides of a firm

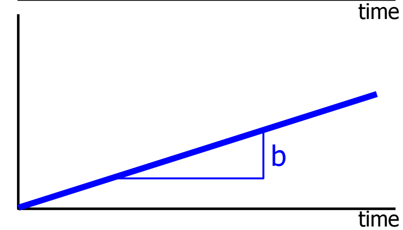
Material adapted from Lapide, L. (2006) Course Notes, ESD.260 Logistics Systems.

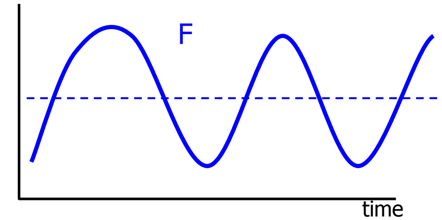
Many Forecast Methods & Approaches

- Subjective Approaches
  - Judgmental – someone somewhere knows
  - Experimental – sample local and extrapolate
- Objective Approaches
  - Time Series – pattern matching
    - Simple models (Moving Average, Cumulative, Naïve)
    - Exponential smoothing - balancing new & old information
    - Smoothing constants determine "nervousness" & response
    - Lots of bookkeeping, updating & tricky initialization
  - Causal Analysis – underlying drivers
    - Ordinary Least Squares (OLS) Regression
    - A single dependent variable (y) and one or more independent variables (x1, x2, …)
    - Testing the model and individual coefficients
    - Watch-Outs: Correlation ≠ Causation & Avoid over-fitting
- Most firms use a portfolio of different techniques & methods









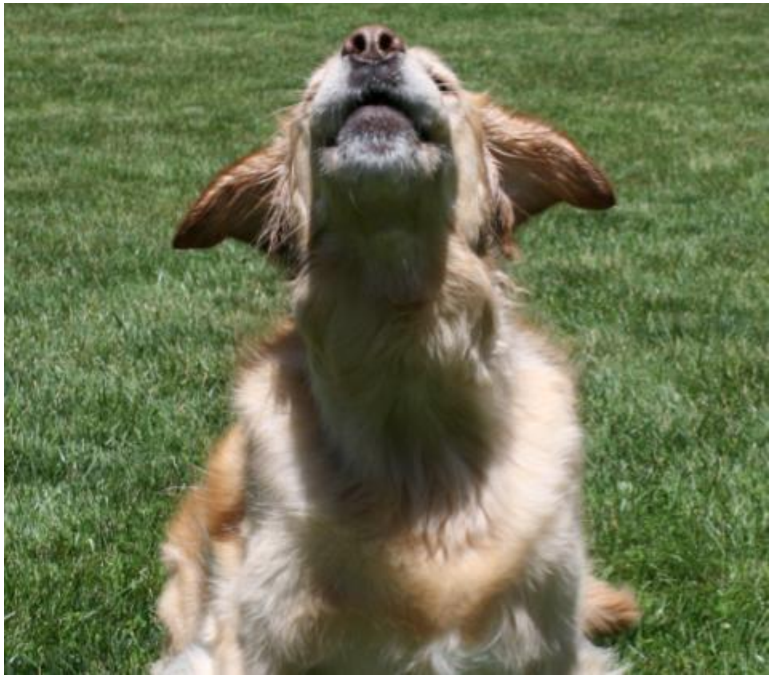
Special Cases for Forecasting

- New Products
  - No history – there fore needed new methods
    - "Looks Like" Forecasting
    - Diffusion Models (innovator and imitator)
  - Different types of new products – Different methods
    - New-to-World
    - New-to-Company
    - Line Extensions
    - Product Improvements
    - Product Re-Positioning
    - Cost Reductions
  - New product development process (stages & gates)
- Intermittent Demand
  - Croston's Method – smooths out sporadic and irregular transactions

Final Forecasting Comments

- Data Issues Dominate
  - Sales data is not demand data
  - Transactions can aggregate and skew actual demand
  - Historical data might not exist
- Practical Things to Look For
  - Forecasting vs. Inventory Management (avoid bias)
  - Statistical Validity vs. Use and Cost of Model
  - Demand is not always exogenous
  - Error trending over time – is it creeping?
- Hidden Costs of Complexity – the more complex the system:
  - the less frequently the parameters are checked and updated
  - the less likely anyone who uses the system understands it
  - the less likely operational teams will trust the output

Questions, Comments, Suggestions? Use the Discussion!



"Dutchess"
Photo courtesy Yankee Golden Retriever Rescue (www.ygrr.org)

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