Forecasting for Special Cases
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>
<thead>
<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>
</thead>
<tbody>
<tr>
<td>New-to-World</td>
<td>8-10%</td>
<td>40%</td>
<td>104 weeks</td>
<td>38-65%</td>
</tr>
<tr>
<td>New-to-Company</td>
<td>17-20%</td>
<td>47%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line Extensions</td>
<td>21-26%</td>
<td>54-62%</td>
<td>62/29* weeks</td>
<td>55-77%</td>
</tr>
<tr>
<td>Product Improvements</td>
<td>26-36%</td>
<td>65%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Re-Positioning</td>
<td>5-7%</td>
<td>54-65%</td>
<td>N/A</td>
<td>66-79%</td>
</tr>
<tr>
<td>Cost Reductions</td>
<td>10-11%</td>
<td>72%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Major revisions / Incremental improvements – about evenly split

# Product-Market Matrix

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

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

New Product Development Process
New Product Development Process

Stage 1
Discovery & Idea Generation

Stage 2
Scoping & Pre-Technical Evaluation

Stage 3
Build Business Case

Stage 4
Development

Stage 5
Test & Validate

Stage 6
Commercialize

Gate 1
Gate 2
Gate 3
Gate 4
Gate 5

100
68
47
33
28
24

Forecast Market Revenue Potential
Forecast Market Revenue Potential
Forecast Firm Sales Revenue Potential
Forecast Unit Sales
Forecast Unit Sales
Forecast Unit Sales By Location
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.)

* 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

The graph illustrates the adoption rate for different products over time. The Y-axis represents the percent of market adopters, ranging from 0% to 100%, and the X-axis represents time periods from 0 to 20. Four products are shown: Microwave, Camcorder, Cell Phone, and Color TV, each represented by a different line color.

- **Microwave**: Starts with a slow adoption rate, reaching 100% adoption by approximately period 15.
- **Camcorder**: Shows a faster adoption rate compared to the Microwave, reaching 100% around period 10.
- **Cell Phone**: Exhibits an even quicker adoption rate, nearing 100% by period 8.
- **Color TV**: Has the most rapid adoption, reaching 100% by period 7.

The graph demonstrates the typical S-curve pattern of product adoption.
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 lifecycle
Bass Diffusion Model

**Innovation Effect**

\[ n(t) = p \times [\text{Remaining Potential}] + q \times [\text{Adopters}] \times [\text{Remaining Potential}] \]

**Imitation Effect**

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

**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 = \((0.10)(750-0)+(0.25)(0)(750-0)=75k\)
- Q2 = \((0.10)(750-75)+(0.25)(75/750)(750-75)=84k\)
- 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 \( t \)
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)

Parameter values differ over time and vary by regions.

Good for estimating sales trajectories – not absolute sales

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

<table>
<thead>
<tr>
<th>Product</th>
<th>Innovation Coefficient ( p )</th>
<th>Imitation Coefficient ( q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable TV</td>
<td>.100</td>
<td>.060</td>
</tr>
<tr>
<td>Cell Phone</td>
<td>.008</td>
<td>.421</td>
</tr>
<tr>
<td>Curling Irons</td>
<td>.028</td>
<td>.993</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>.0014</td>
<td>.206</td>
</tr>
<tr>
<td>Drip Coffeemaker</td>
<td>.017</td>
<td>.993</td>
</tr>
<tr>
<td>Radio</td>
<td>.027</td>
<td>.435</td>
</tr>
<tr>
<td>Microwave</td>
<td>.002</td>
<td>.357</td>
</tr>
<tr>
<td>Non-durable product</td>
<td>.023</td>
<td>.788</td>
</tr>
<tr>
<td>Home PC</td>
<td>.121</td>
<td>.281</td>
</tr>
</tbody>
</table>

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

Estimating Diffusion Models
Estimating \( p \) & \( q \) from Recent Sales

First, transform Bass Model into linear equation:

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

Second, estimate the regression equation using past sales periods.

\[
y_i = 0 + x_{1i} + x_{2i}
\]

where:

\[
y_i = n(t) = \text{sales for period } t
\]

\[
x_{1i} = N(t - 1) = \text{cumulative sales up to period } t-1
\]

\[
x_{2i} = x_{1i}^2 = \text{square of cumulative sales}
\]

\[
p = \frac{0}{m} \quad q = \frac{2m}{m}
\]

Third, back calculate for the parameters:

\[
p = \frac{0}{m} \quad q = \frac{2m}{m}
\]

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:

<table>
<thead>
<tr>
<th>Quarter</th>
<th>n(t)</th>
<th>N(t-1)</th>
<th>(N(t-1))^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>160</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>223</td>
<td>160</td>
<td>25,600</td>
</tr>
<tr>
<td>3</td>
<td>310</td>
<td>383</td>
<td>146,689</td>
</tr>
<tr>
<td>4</td>
<td>425</td>
<td>693</td>
<td>480,249</td>
</tr>
<tr>
<td>5</td>
<td>575</td>
<td>1,118</td>
<td>1,249,924</td>
</tr>
</tbody>
</table>

- Regress using the LINEST function giving me:

<table>
<thead>
<tr>
<th>b_2</th>
<th>b_1</th>
<th>b_0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0000093</td>
<td>0.4765</td>
<td>160.18</td>
</tr>
<tr>
<td>0.0001066</td>
<td>0.1333</td>
<td>30.31</td>
</tr>
</tbody>
</table>

- 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:

$$\hat{x}_{t,t+1} = x_t + (1 - a) \hat{x}_{t-1,t} \quad 0 \leq a \leq 1$$
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:

\[
\text{Prob}(y_t = 1) = \frac{1}{n} \quad \text{Prob}(y_t = 0) = 1 - \frac{1}{n}
\]

The updating procedure becomes:

If \( x_t = 0 \) (no transaction occurs),
\[
\hat{z}_t = \hat{z}_{t-1} \quad \hat{n}_t = \hat{n}_{t-1}
\]

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
\[
\hat{x}_{t,t+1} = \frac{\hat{z}_t}{\hat{n}_t}
\]

Where:
- \( x_t \) = Demand in period t
- \( y_t \) = 1 if transaction occurs in period t, =0 otherwise
- \( z_t \) = Size (magnitude) of transaction in time t
- \( n_t \) = Number of periods since last transaction
- \( \alpha \) = Smoothing parameter for magnitude
- \( \beta \) = 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

\[
\begin{align*}
\hat{x}^{(t,t+1)} &= \frac{E7}{F7} \\
&= \text{IF}(B6>0,1,D6+1) \\
&= \text{IF}(B7>0,\alpha \cdot B7 + (1-\alpha) \cdot E6, E6) \\
&= \text{IF}(B7>0,\beta \cdot D7 + (1-\beta) \cdot F6, F6)
\end{align*}
\]
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

\[
\text{NewMSE}(z) = (x_t - \hat{z}_{t-1})^2 + (1 - w) \text{OldMSE}(z) \quad x_t > 0
\]
Forecasting Wrap Up
Demand Process – Three Key Questions

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

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

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

Demand Planning
- Product & Packaging
- Promotions
- Pricing
- Place

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

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

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 – therefore 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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