Simple Bass Diffusion

Creating a Pricing Strategy that Maximizes Shareholder Value using the Provisdom Decision Platform

Original Bass Diffusion Model

- Often used for modeling diffusion processes (e.g., the rate of unit sales)
- Begins with a number of total potential unit sales
- Actual sales reduce the number of remaining potential sales
- Advertising effect – gets sales started
- Word of Mouth effect – positive feedback
- Advertising and Word of Mouth effects only apply to remaining potential sales, so eventually the sales rate decreases

A Standard Bass Diffusion Model

$$\frac{dS(t)}{dt} = R(t) * \left(A + W * \frac{(D - R(t))}{D} \right)$$

- S = Total Actual Unit Sales
- D = Total Potential Unit Sales
- R = Remaining Potential Unit Sales
- A = Advertising Factor
- W = Word of Mouth Factor

Provisdom Approach

- Fast feedback
  - First-cut usually takes less than an hour of the decision maker or analyst's time and is completed by Provisdom in less than a day
  - Efforts focus on aligning model with corporation's information
- Use all relevant information
  - Whether data or human knowledge, qualitative or quantitative, even imperfect or incomplete
- Transparent models and results
  - Problem is discretized into as many as billions of possibilities
  - Model can be queried like a database, simulated, or viewed in a decision tree
- Maximize Shareholder Value
  - Create the strategy that maximizes shareholder value
  - Compare shareholder value of optimal strategy against previous strategy to find value added

Example Application

- Corporation has option to sell VAX machines over next 7 years*
- Yearly option to set machine price such that marginal profit is $125K or $250K per unit, or to permanently stop sales
- Sales efforts, including advertising, have fixed yearly cost of $2M
- Yearly unit sales will resemble a Bass Diffusion model, but periodic and with a pricing effect
- Desire sales strategy that maximizes shareholder value

* Sample Application idea originated from Bass Diffusion Example in Business Dynamics by John D. Sterman.

Example Application: Yearly Unit Sales Model

$$\Delta S(t) = (R(t) - P) * \left[1 - \exp\left(-A - W * \frac{D(t) - R(t)}{D(t) - P}\right)\right]$$

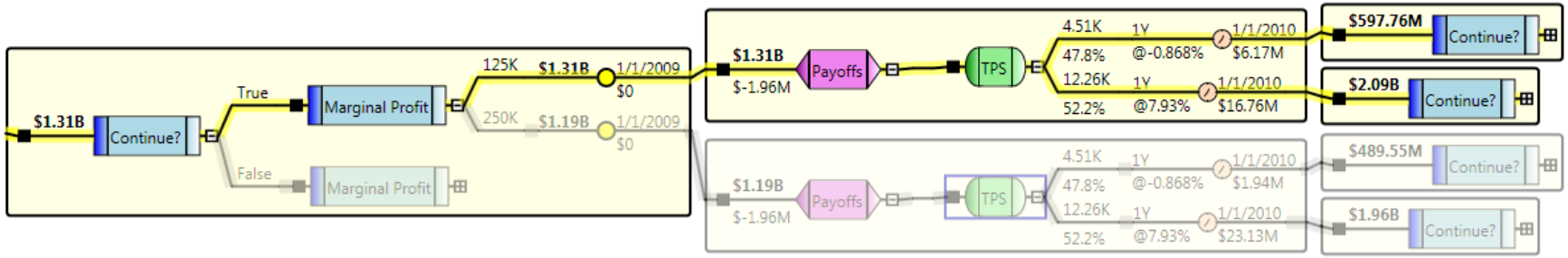
- P = Pricing Effect on Potential Unit Sales
  - P = 3800 units if marginal profit is $250K per unit
  - P = 0 if marginal profit is $125K per unit
- Total Potential Unit Sales, $D(t)$, is a function of time and is unknown until time t
- $D(0)$ = 7600 units; A = 0.011; W = 1.33
- Sales cannot be negative

Example Application: Total Potential Unit Sales

- Uncertainty resembles geometric Brownian motion with constant growth and volatility
- High uncertainty (50% volatility)
- No expected trend (0% expected growth rate)
- Positive relationship with the Market (10% correlation)

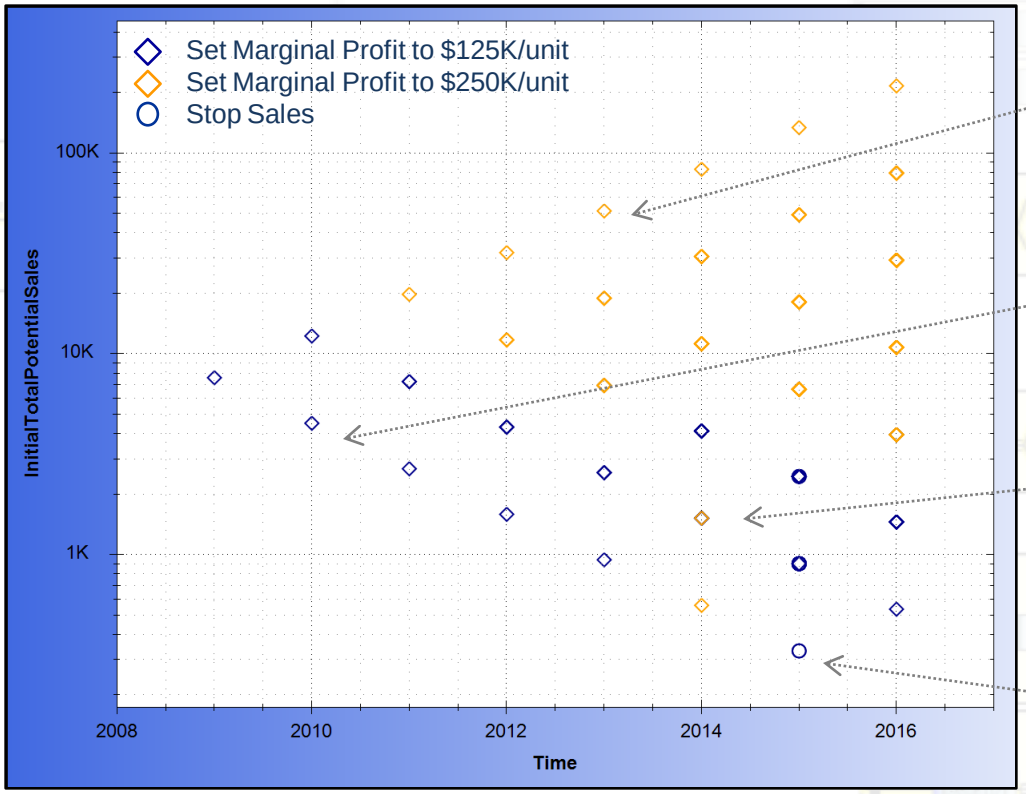
Model Feedback Sample: Screen Shot – Start of Decision Tree

- Useful for investigating model in detail
- Highlights optimal-choice paths
- In the tree below, the left-most blue rectangle represents the first decision to continue sales
- Today's optimal choice is to set the price at a marginal profit of $125K per unit, resulting in an NPV of $1.31B



Model Feedback Sample: Optimal Strategy
Total Potential Unit Sales vs. Time

- Useful for investigating full strategy
- Multiple instances on a single x, y location



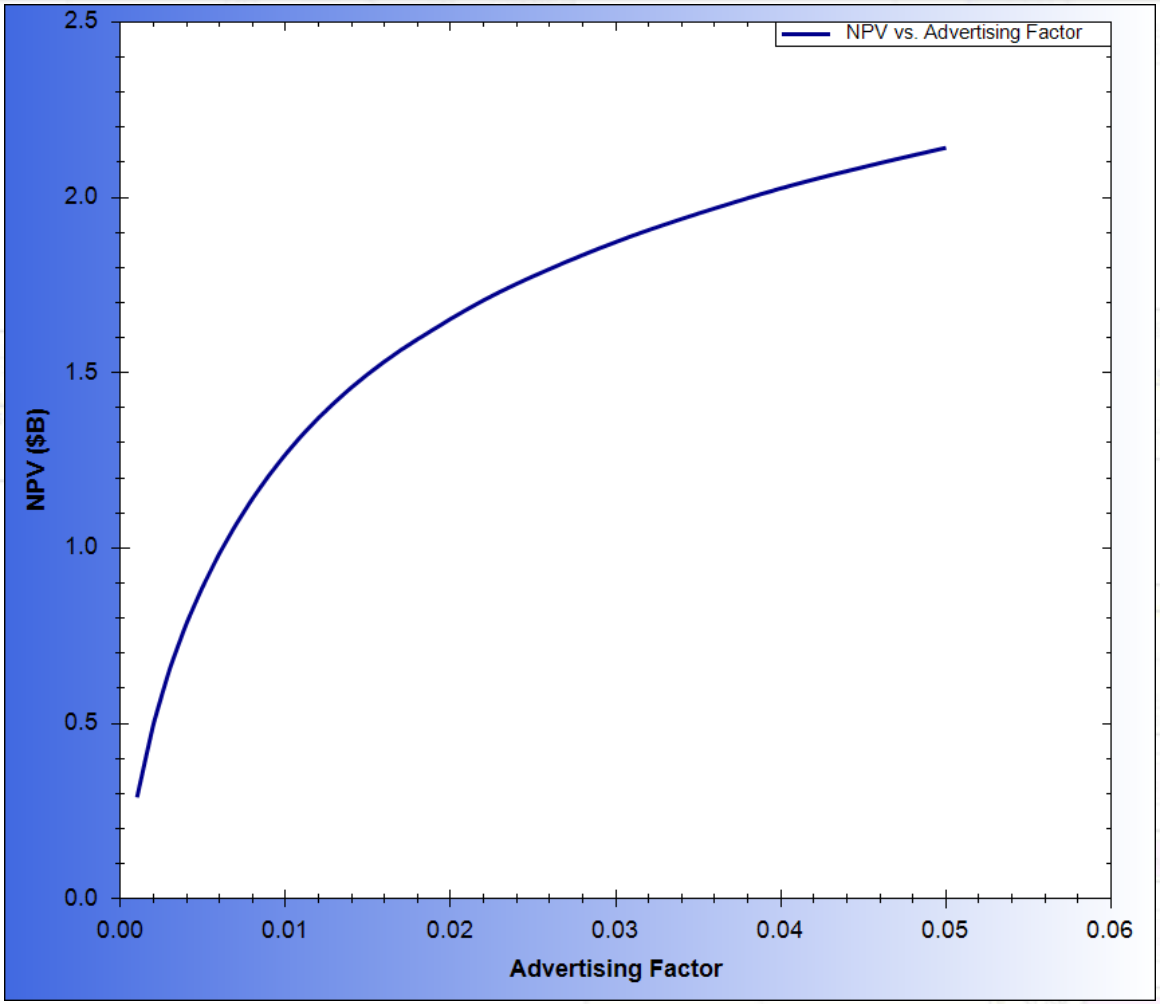
Set marginal profit at $250K per unit when Potential Sales are high, especially if later in time.

Set marginal profit at $125K per unit for at least first two or three years to increase word of mouth.

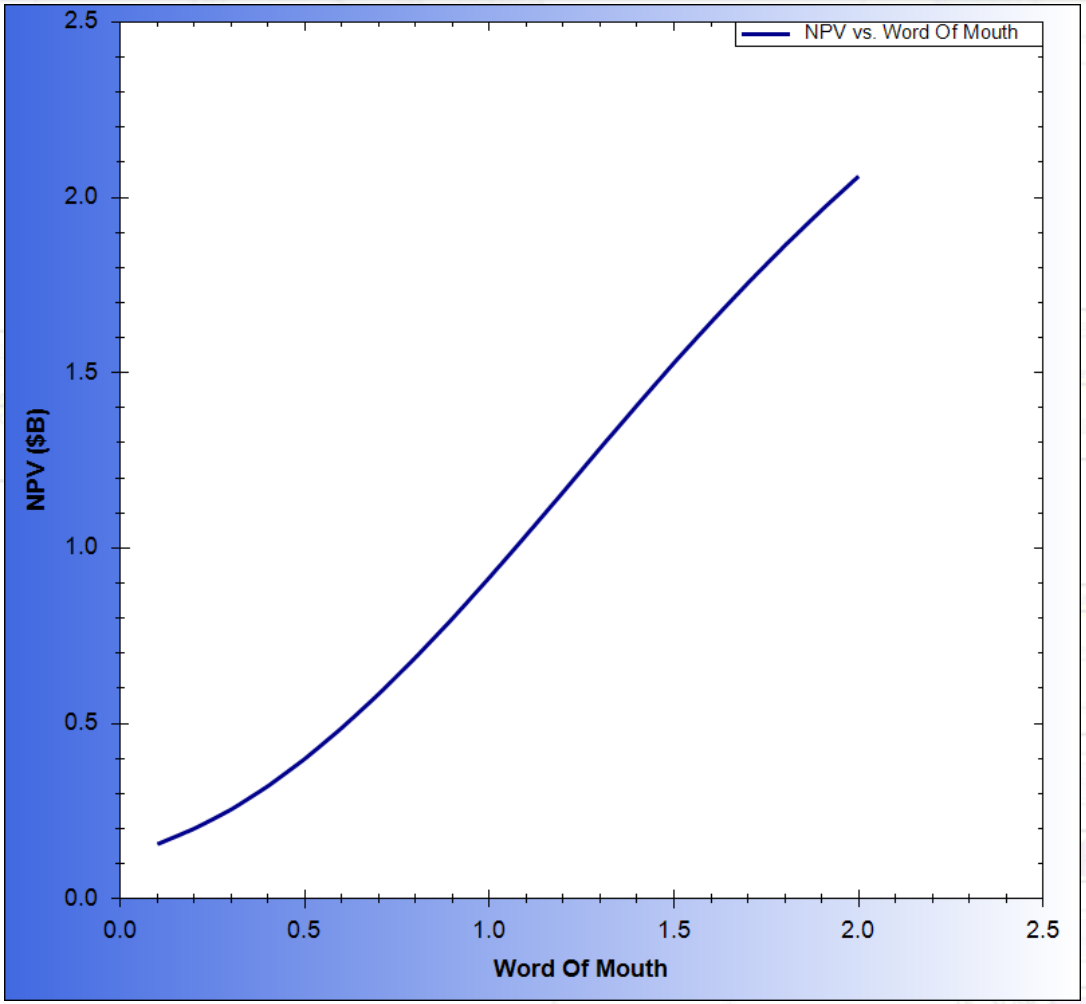
Set marginal profit at $250K per unit when nearing a sales stoppage to get most from final sales.

Stop Sales when Potential Sales are very low and towards end of 7 years.

Model Feedback Sample: Queries
NPV of Optimal Strategy vs. Advertising Factor



Model Feedback Sample: Queries
NPV of Optimal Strategy vs. Word of Mouth Factor



Model Feedback Sample: Gradient Analysis

- A sensitivity analysis that calculates a change in shareholder value with a change in a model property value
- Generally calculated with the optimal strategy and all the model properties at their original values
- Similar to a Tornado diagram but arguably more relevant
- The table below contains the gradient analysis of the three model properties that were given in terms of percentages
- Notice that volatility of Total Potential Unit Sales increases value of optimal strategy (due to corporation's option to change prices)

Model Property	d(NPV) / d(%)
Total Potential Unit Sales – Expected Growth	$72.7M
Total Potential Unit Sales – Volatility	$23.6M
Total Potential Unit Sales – Market Correlation	(-$16.0M)

Strategy that Maximizes Shareholder Value

- Today's optimal choice is to set marginal profit at $125K per unit.
- To continue to get most accurate optimal strategy over time, automatically or manually feed new state variable values into software.
- Full seven-year strategy is dynamic and complex, roughly:
  - Set marginal profit at $125K per unit for at least first two or three years to increase word of mouth.
  - Stop Sales when Potential Sales are very low and towards end of 7 years.
  - Set marginal profit to $250K per unit when Potential Sales are high, especially if later in time.
  - Set marginal profit at $250K per unit when nearing a sales stoppage to get most from final sales.

Strategy Comparisons

- Useful for calculating shareholder value added by analysis
- Table below compares optimal strategy to a strategy of setting a constant marginal profit of $250K per unit and to a strategy of setting a constant marginal profit of $125K per unit
- The comparisons are in terms of shareholder value, in both absolute and percentage terms

Strategy	NPV	$ increase to optimal	% increase to optimal
Optimal Strategy	$1,305M	$0	0%
Constant Marginal Profit of $250K	$1,059M	$246M	23.2%
Constant Marginal Profit of $125K	$837M	$468M	55.9%

Example Modifications and Extensions

- Extend model by including various advertising choices that affect the cost and sales rate.
- Replace Bass Diffusion model with nearly any other model for sales.
- Add more pricing choices.
- Modify form of relationship between Total Potential Unit Sales and Market (e.g., “if Market grows 20% over a year, then Total Potential Unit Sales is expected to grow at 5%”).

Summary of Provisdom Process

1. Gather Initial Information
2. Map Business Problem to Software (using Information Rules)
3. Run Initial Model
   - Find and execute next rule.
   - Find probabilities with a nonlinear optimization solver.
   - Discretize continuously-valued uncertainties and time.
   - Calculate proper discount rates.
4. Analyze Results
5. Refine Model
6. Automate or Update Model Periodically

```
constrain OilPrice in Money &&
    Growth = prop(Oil.Growth) &&
    Volatility = prop(Oil.Volatility) &&
    Yield = prop(Oil.Yield);
```