Perfume Engineering
Pure Ambition

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Overview

1. Objective
2. Background
4. Marketing
5. Happiness Function
6. Results
7. Economic Analysis

Objective

The objective of our project is to engineer a new scent of perfume over a 10 year life span. In addition to this, marketing of the product and economic analysis must also be taken into account.

Background

Functions of a Perfume

Functions	Examples
Provide a pleasant odor	Air fresheners
Cover base smell of product	Soaps or lotions
Give product identity	Banana Boat sunscreen
Signify product change	New and Improved!

Perfume Construction

Making a scent – Attributes

- Scent – Ingredients
- Color – Aesthetics
- Oiliness of fluid – Concentration of Essential Oils
- Initial strength of fragrance - Concentration
- Endurance - Time

These attributes' role in the happiness function will be discussed in later slides.

Parts of a Perfume

There are three main parts of a perfume:

- **Basics**
  - the basics are the materials in the essential oil that are present at higher percentages
- **Diluent**
  - ingredients in the perfume that dilutes the mixture
- **Solvent**

Emulsion

- Due to the solubility of the essential oils in water, perfume is an emulsion
  - Range from < 1 ppm to 20,000 ppm
  - Not a significant amount
- Oil and aqueous phase
  - Continuous phase
  - Dispersed phase
- A stable emulsion is necessary

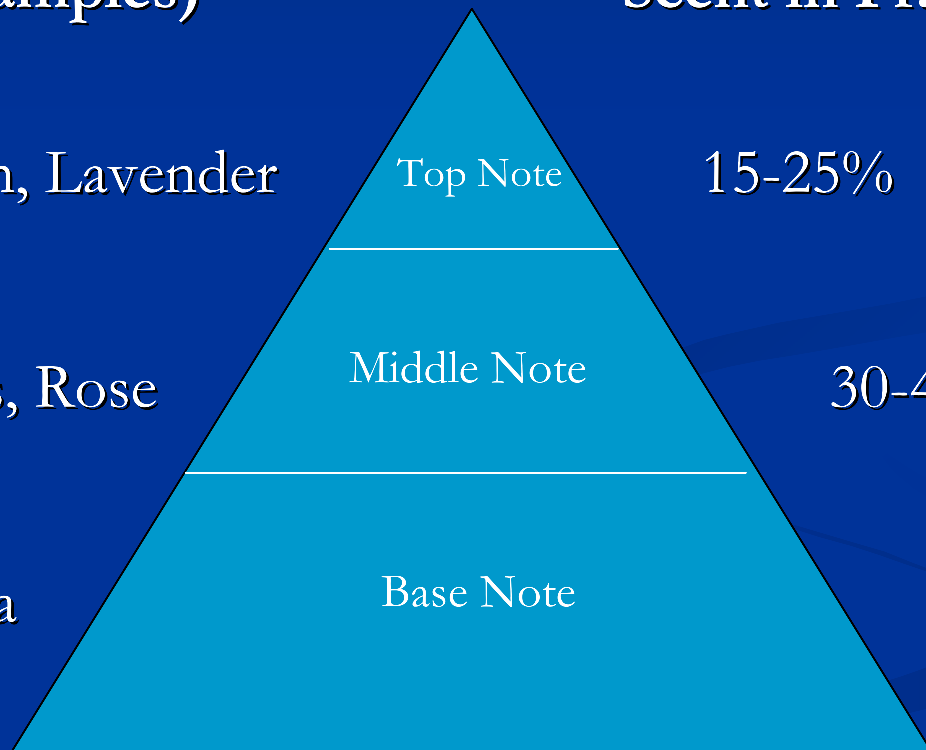
http://www.lesestein.de/bildarchiv-vorschau/wissenschaft.htm

Vocabulary

- **Top note** – component of a fragrance with high evaporation rate
- **Middle note** – component of a fragrance with medium evaporation rate
- **Base note** – component of a fragrance with low evaporation rate
- **Odor threshold** – minimum concentration in air at which an odor is detectable by the human nose
- **Odor value** – the concentration in air of an odor

Scent Pyramid Example

Type of scent (Examples)	Typical Percentage of Scent in Fragrance
Lemon, Lavender	15-25%
Hibiscus, Rose	30-40%
Musk, Vanilla	45-55%



Mata, Vera G., Paula B. Gomes, and Alfrio E. Rodrigues. "Engineering Perfumes." AIChE Journal 51 (2005): 2834-2852.

Types of Perfumes

Types	Total (vol %)	Remainder (vol %)	
	Oil	Alcohol	Water
Parfum	15 to 30	90 to 95	5 to 10
Eau de Parfum	8 to 15	80 to 90	10 to 20
Eau de Toilette	4 to 8	80 to 90	10 to 20

We chose to use Eau de Parfum to reach the "average" market

Plan of Action

- Determine the components of a perfume that maximize the ROI and the Happiness
- To do this:
  - First calculate the market and the demand
  - Next determine the initial composition of perfume
  - Relate attributes of perfume to economics using the scent concentrations as manipulated variables
  - Use Solver in Excel to optimize ROI by varying scent concentrations

Marketing

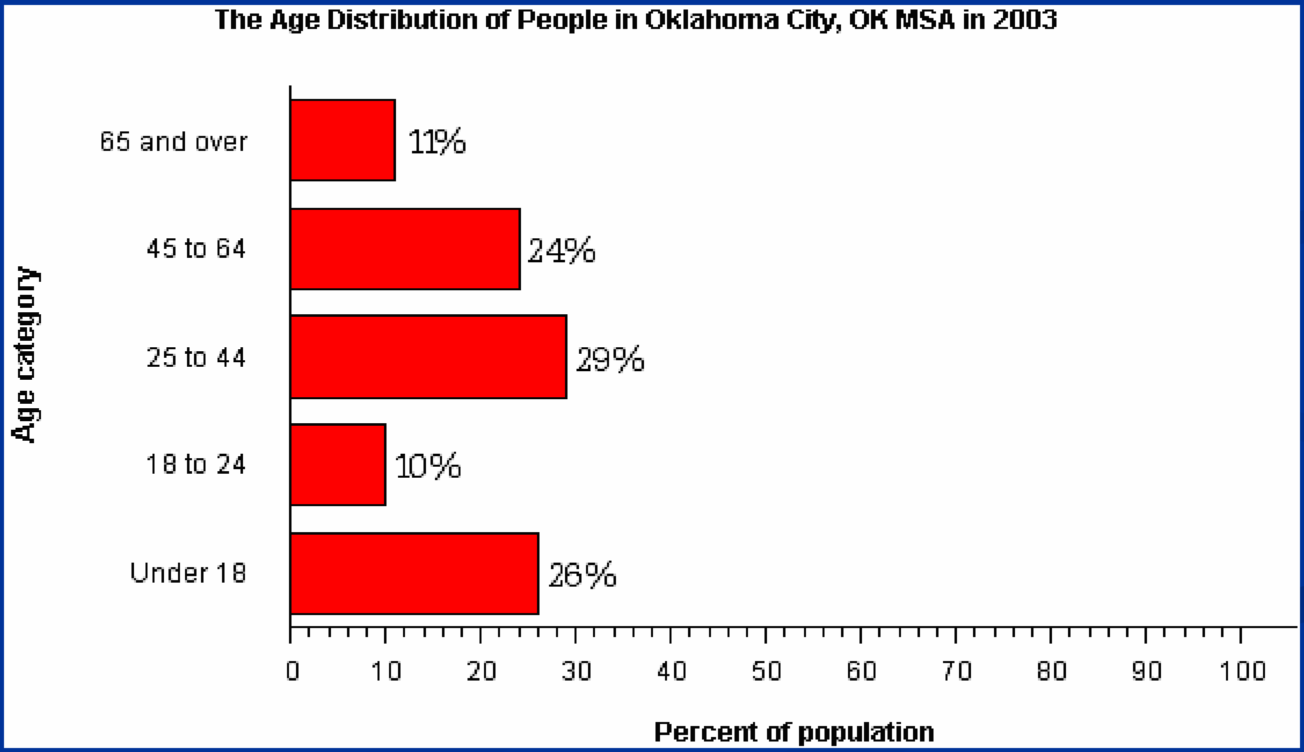
Target Market

- Female

- Age 25-40
- We chose this market because this group is more likely to have a stable job/income.

Introduction Location

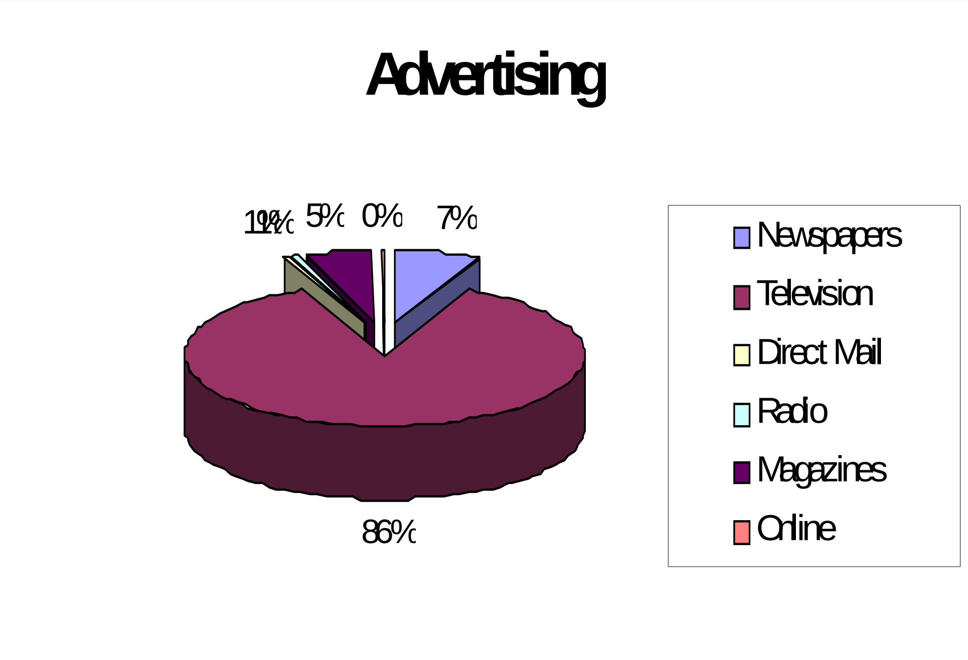
- Due to investment opportunities, Oklahoma City Metropolitan Statistical Area (MSA) is our choice introduction location



Advertising

The intended course of action is to advertise to the target market in the MSA. Therefore we have chosen to advertise in the following areas:

Advertising	
Type	Cost / Week ($)
Newspapers	1300
Television	16500
Direct Mail	125
Radio	100
Magazines	1000
Online	50



Pricing Model

- **Budget Model**

$$p_1 d_1 + p_2 d_2 = Y$$

$$p_1 d_1 = \frac{\alpha}{\beta} p_2 d_2 \frac{d^{\alpha}{}_1}{d^{\beta}{}_2}$$

- Where
  - p_1 and p_2 are ours and our competitor's product prices ($/bottle)
  - d_1 and d_2 are our and our competitor's demand (# of bottles sold)
  - Y is total amount of sales for product ($)

Pricing Model

- **Fixed Demand Model**

$$d_1 + d_2 = D$$

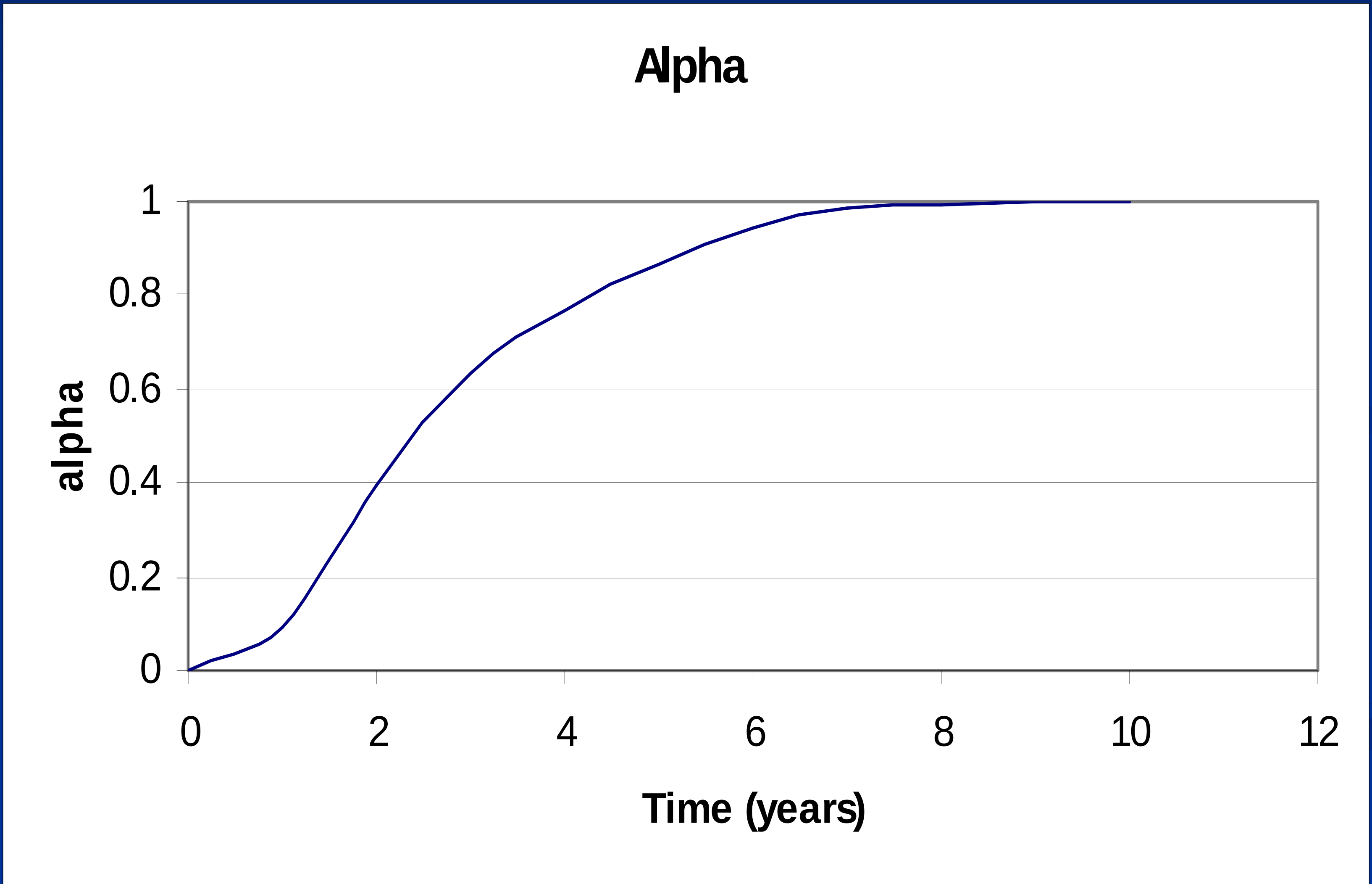
$$d_1 = \left(\frac{\alpha}{\beta}\right)^{\frac{1}{1-\alpha}} \left(D - d_1\right)^{\frac{1-\beta}{1-\alpha}}$$

- For our product, the budget model is most appropriate. Although this may be the case, due to demand constraints, the fixed demand model will be implemented accordingly.

Determination of α

- α determined through several logical assumptions
- Assume that competition is completely recognized, horizontal fit
- Assume linear recognition fit, then plateau for our recognition
- All of the α's are averaged over time

Graph of α Determination



Happiness Function

Perfume Survey

- A survey was used to determine the qualities of a fragrance desired by the target market
- Given to a sample group of target market; females between the ages of 25 and 40
- Asked to rate several perfumes over a period of eight hours
- Asked to define characteristics of ideal perfume
- These values were used to model the "perfect" fragrance

Components

What are consumers looking for in a perfume?

Scent (60%)

Endurance (35%)

Color (3%)

Initial strength of fragrance (1%)

Oiliness of fluid (1%)

$$H(\text{perfume}) = (0.6)y_{\text{scent}} + (0.35)y_{\text{endurance}} + (0.03)y_{\text{color}} + (0.01)y_{\text{viscosity}} + (0.01)y_{\text{init.strength}}$$

Additional Variables

- There were other determinants to consider in a consumer's initial purchase of a perfume that were not considered directly in the happiness function. These include:
  - Skin reaction – Set as a concentration constraint (Each EO cannot exceed 5 vol% of total perfume volume)
  - Price – Determined with pricing model

Initial Scent

- How pleasing or displeasing the scent of the perfume on immediate application is to the consumer

$$y_{scent-0hr} = z_{citrus}\left(\frac{x_{have}}{x_{want}}\right)_{citrus} + z_{natural}\left(\frac{x_{have}}{x_{want}}\right)_{natural} + z_{floral}\left(\frac{x_{have}}{x_{want}}\right)_{floral} + z_{musk}\left(\frac{x_{have}}{x_{want}}\right)_{musk} + z_{oriental}\left(\frac{x_{have}}{x_{want}}\right)_{oriental}$$

- Where z = weight each scent carries
- Where x = mole fraction for each scent

Scent After Four Hours

- The smell of the perfume after four hours
  - How pleasing or displeasing to the consumer the scent of the perfume is four hours after application

$$y_{scent-4hr} = z_{natural}\left(\frac{x_{have}}{x_{want}}\right)_{natural} + z_{floral}\left(\frac{x_{have}}{x_{want}}\right)_{floral} + z_{musk}\left(\frac{x_{have}}{x_{want}}\right)_{musk} + z_{oriental}\left(\frac{x_{have}}{x_{want}}\right)_{oriental}$$

  - Top note is no longer detectable

Scent After Eight Hours

- The smell of the perfume after eight hours
  - How pleasing or displeasing to the consumer the scent of the perfume is eight hours after application

$$y_{scent-8hr} = z_{natural}\left(\frac{x_{have}}{x_{want}}\right)_{natural} + z_{musk}\left(\frac{x_{have}}{x_{want}}\right)_{musk} + z_{oriental}\left(\frac{x_{have}}{x_{want}}\right)_{oriental}$$

  - Top note and middle note are no longer detectable

Color

- The color of the packaging
  - How appealing the color of the perfume packaging is to the consumer

$$y_{color} w_{color} = K * (0.03)$$

- For our fragrance, the happiness due to color is assigned the number 1
  - The color red was chosen based on the results of the survey which maximizes happiness for color

Oiliness

- The oiliness of the perfume was determined using the concentration of the essential oils in the perfume

$$y_{oiliness} w_{oiliness} = \left\{ \begin{matrix} 1 & low < c_{oil} < high \\ 0 & if\ not\ met \end{matrix} \right\} \times (0.01)$$

- The range is determined by the concentration constraints set by the volume percentage of oil allowed in an eau de parfum
- Volume Percent Range: 8% – 15% of total

Initial Strength

- Any unhappiness caused by the initial scent of the fragrance being either too strong or too weak on initial contact

$$y_{init.strength} w_{init.strength} = \left\{ 1 - \left(\frac{|C_A - C_W|}{C_W} \right) \right\} * (0.01)$$

- Where C_A is the actual initial concentration in air, and C_W is the wanted concentration in air determined by survey data and comparison to competition

Endurance

- How long the smell will still be noticeable to others after it is applied
  - The amount of time that the perfume can still be detected by others in a ten centimeter radius from the person wearing the perfume

$$y_{endurance1} w_{endurance} = \left(OV_i \Big|_t^z - Thrs_i \Big|_t^z \right) \times (0.17)$$

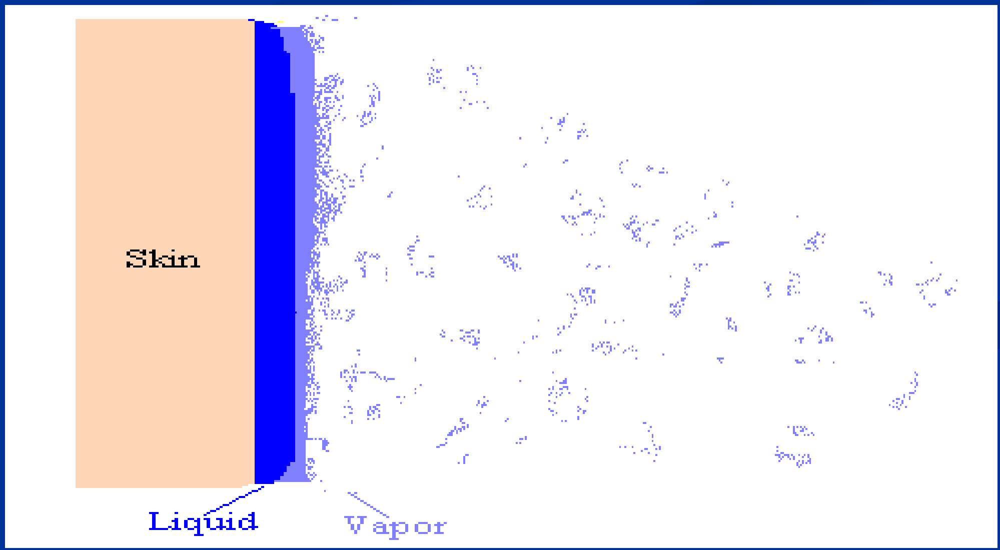
Thrs = odor threshold OV = odor value

- With: f = 0; if $\left(OV_i \Big|_t^z - Thrs_i \Big|_t^z \right)$ <= 0

  f = 1; if $\left(OV_i \Big|_t^z - Thrs_i \Big|_t^z \right)$ > 0

Diffusion Model

- The endurance parameter in the function has two variables: time, distance
- A diffusion model was used to approximate the change in concentration of the fragrance over time and distance



$\ln \gamma_i = \ln \gamma_i^C + \ln \gamma_i^R$

Activity Coefficients

- Activity coefficients were obtained using the UNIFAC method from The Properties of Liquids and Gases by Reid, Poling, and Prausnitz[1]
- This method was used because it determined activity coefficients due to interactions between structural groups instead of utilizing experimental data

[1] Reid, Prausnitz, Poling. The Properties of Gases and Liquids. 4th Edition. New York City, NY. McGraw-Hill, Inc. 1987

$\ln\gamma_i = \ln\gamma_i^c + \ln\gamma_i^R$

Activity Coefficients

$$\ln\gamma_i = \ln\gamma_i^c + \ln\gamma_i^R$$

- Combinatorial – due to differences in sizes and shapes of the molecules in the mixture
- Residual – due to energy interactions between the different groups

Analysis in Excel

Using Excel, we iterated the change in concentration over time up to a distance of 1 ft and a time of 8 hours

- Most data was known with the exception of the concentration change over distance
- This was calculated using a derivation of Fick's Second Law

Common name	Major component	Initial composition (x_{io})	P_{sat} (psi)	P (psi)	γ_i	MW (mol weight)
Sandalwood	Linalool	0.348653202	0.05599552	101325	380.6092428	154.244
		5				
		n_{tot} (mol)	x_i	y_i	$c_i\|_t$ (mol/m^3)	dc_i/dz at z=0
		0.095850271	0.348653202	7.33E-05	0.002999163	-0.376729966
		0.091594211	0.364723549	[illegible]	0.003137402	-0.205729462
		[illegible]	0.369262757	7.77E-05	0.003176449	-0.201951969
		0.089051678	0.374991776	7.89E-05	0.00322573	-0.158598722
		0.088388074	0.377750294	7.95E-05	0.00324946	-0.156313636
		0.087571784	0.381214884	8.02E-05	0.003279262	-0.134408181
		0.087107758	0.383196732	8.06E-05	0.003296311	-0.132818753
		0.08653846	0.385668976	8.11E-05	0.003317577	-0.119024219
		0.086182602	0.387217685	8.14E-05	0.003330899	-0.117828832
		0.085748172	0.389135916	8.18E-05	0.0033474	-0.108118051
50	0.033364268	0.08545973	0.390409233	8.21E-05	0.003358354	-0.107173042
55	0.033360871	0.0851096	0.391975421	8.24E-05	0.003371826	-0.099857953
60	0.033357707	0.084867028	0.393058502	8.27E-05	0.003381143	-0.099084443
65	0.033354567	0.084574284	0.394381901	8.3E-05	0.003392527	-0.093316598
70	0.03335161	0.084364873	0.39532579	8.32E-05	0.003400646	-0.092666966

Fick's Second Law

$$\frac{\partial c_i}{\partial t} = D \frac{\partial^2 c_i}{\partial z^2}$$

- Small amount of liquid on surface with concentration changing over time
- Derivation for numerical analysis
- Required assumptions due to lack of experimental data
    - Liquid and gas phases are in equilibrium
    - Unidirectional diffusion
    - Ideal gas law holds
    - Each component diffuses separately

Diffusion Model

- A diffusion model was used to define endurance in the perfume
- Optimum endurance of the scent was defined by using the concentration of the fastest depleting base note at time equal to eight hours
- This concentration must be equal or greater than the threshold of the scent to be considered as "enduring"

Numerical Analysis

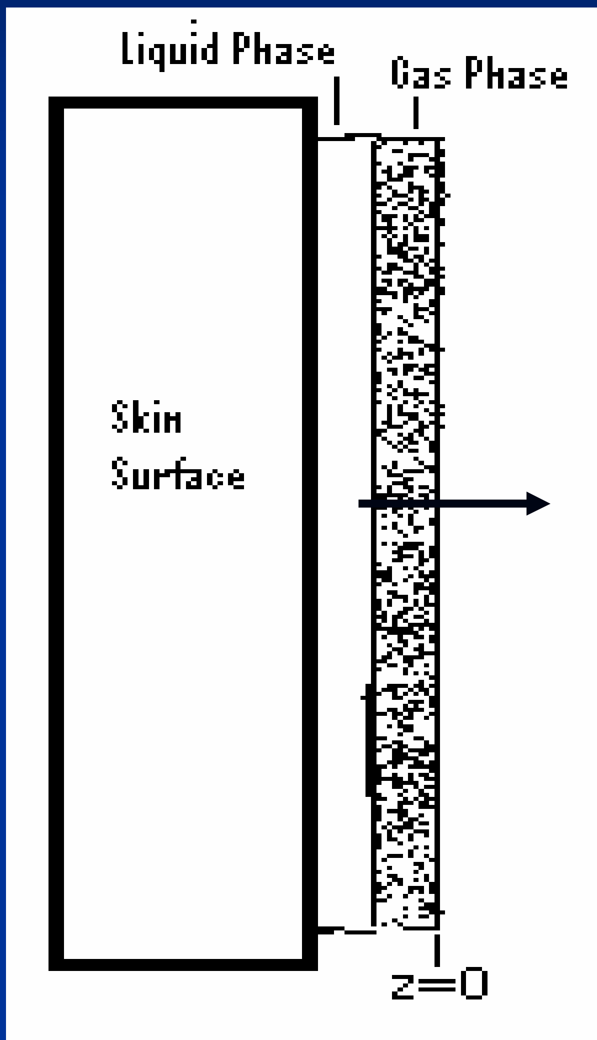
Derivation of Fick's 2nd Law

$$\frac{(c_{z,t} - c_{z,t-\Delta t})}{\Delta t} = D\frac{\left[c_{z+\Delta z,t-\Delta t} - 2c_{z,t-\Delta t} + c_{z-\Delta z,t-\Delta t}\right]}{\Delta z^2}$$

Boundary Conditions:

- $t = 0$, $C_A(z, 0) = C_{Ao}$ for all z
- $z = 0$, $C_A(0, t) = C_{As}$ for $t > 0$
- $z = \infty$, $C_A(\infty, t) = C_{Ao}$ for all t

Diffusion Model (cont.)



From Fick's 2nd Law

$$\frac{\left(c_z^t - c_z^{t-\Delta t}\right)}{\Delta t} = D\,\frac{\left[\left(\dfrac{c_{z+\Delta z}^{t-\Delta t} - c_z^{t-\Delta t}}{\Delta z}\right) - \left(\dfrac{c_z^{t-\Delta t} - c_{z-\Delta z}^{t-\Delta t}}{\Delta z}\right)\right]}{\Delta z}$$

Expanding we get

$$c_z^t = c_z^{t-\Delta t} + \frac{D\Delta t}{\Delta z^2}\left[c_{z+\Delta z}^{t-\Delta t} - 2c_z^{t-\Delta t} + c_{z-\Delta z}^{t-\Delta t}\right]$$

Simplifying we get

$$c_z^t = \frac{1}{2}\left[c_{z+\Delta z}^{t-\Delta t} + c_{z-\Delta z}^{t-\Delta t}\right]$$ with $\Delta z = \sqrt{2D\Delta t}$

Analysis in Excel Cont'd

$\Delta c / \Delta z$

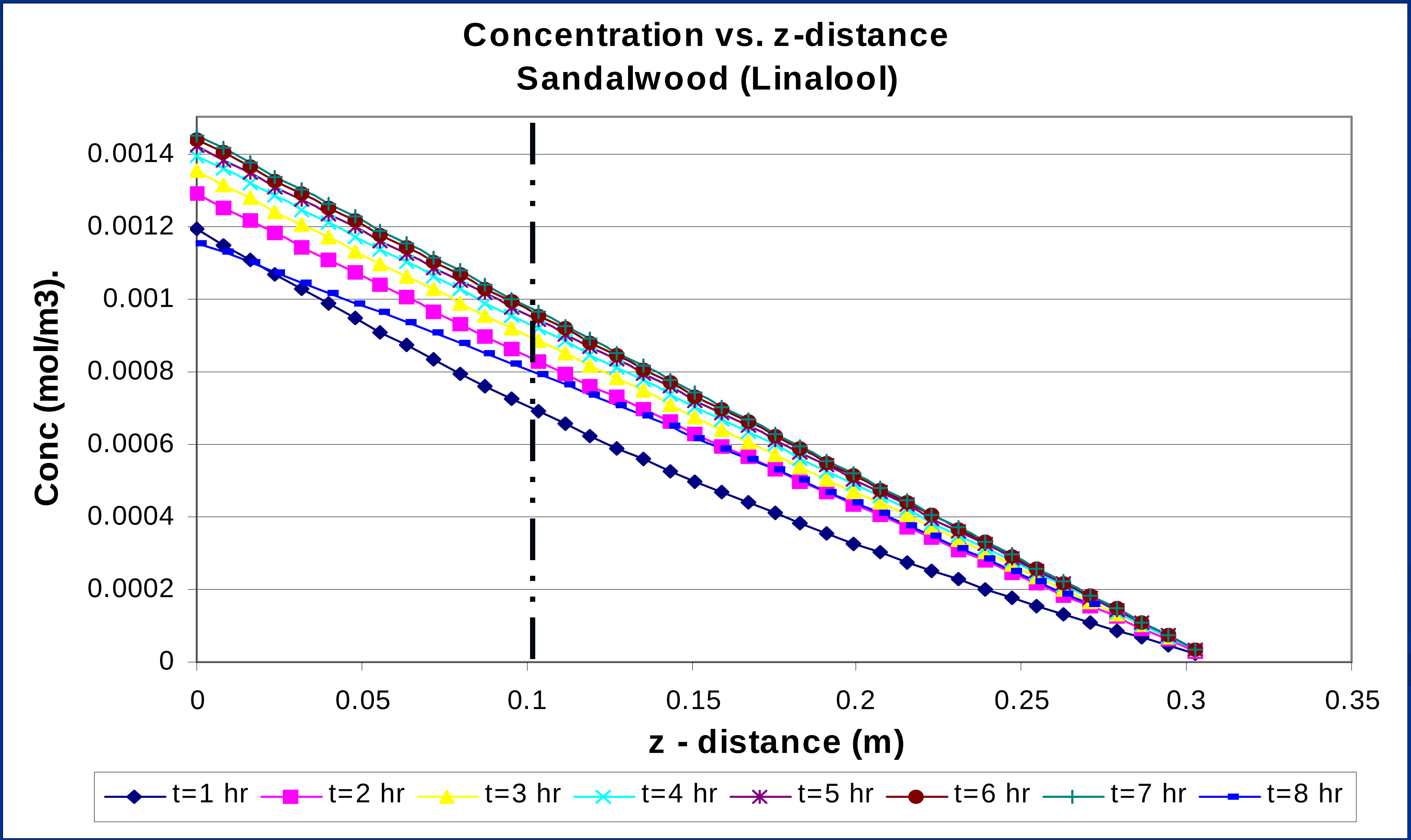
With these values, we can find the concentration at any time and at any position

$c \big|_{z}^{t}$

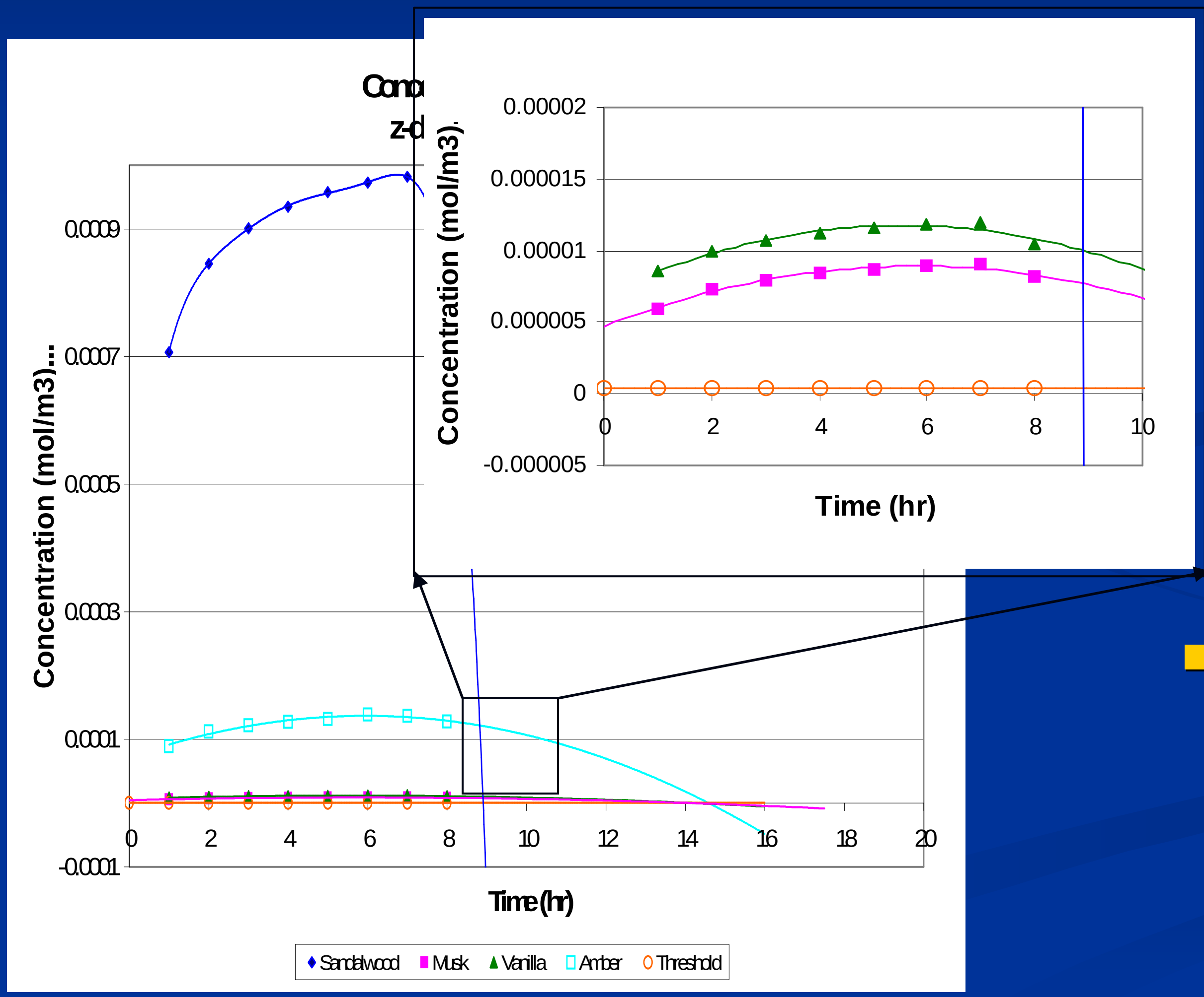
Sandalwood	Δz	0.008				
	z	z+dz	z+2*dz			
	0	0.007961	0.015922	0.023883	0.031844	0.039805
Conc (c_i |t (mol/m3))						
0.000702338	0	0	0	0	0	0
0.000737787	0.000351	0	0	0	0	0
0.000751718	0.000369	0.000176	0	0	0	0
0.000767066	0.000464	0.000184	8.78E-05	0	0	0
0.00077665	0.000476	0.000276	9.22E-05	4.39E-05	0	0
0.000787086	0.000526	0.000284	0.00016	4.61E-05	2.19E-05	0
0.000794557	0.000536	0.000343	0.000165	9.09E-05	2.31E-05	1.1E-05
0.00080264	0.000569	0.00035	0.000217	9.41E-05	5.09E-05	1.15E-05
0.000808835	0.000576	0.000393	0.000222	0.000134	5.28E-05	2.82E-05
0.000815507	0.000601	0.000399	0.000263	0.000137	8.11E-05	2.93E-05
0.00082084	0.000607	0.000432	0.000268	0.000172	8.34E-05	4.83E-05
0.000826563	0.000626	0.000438	0.000302	0.000176	0.00011	4.97E-05
0.00083127	0.000632	0.000464	0.000307	0.000206	0.000113	6.93E-05

Concentration Profiles

Concentration profiles were developed by plotting concentration versus time at distance z



Concentration vs. Time

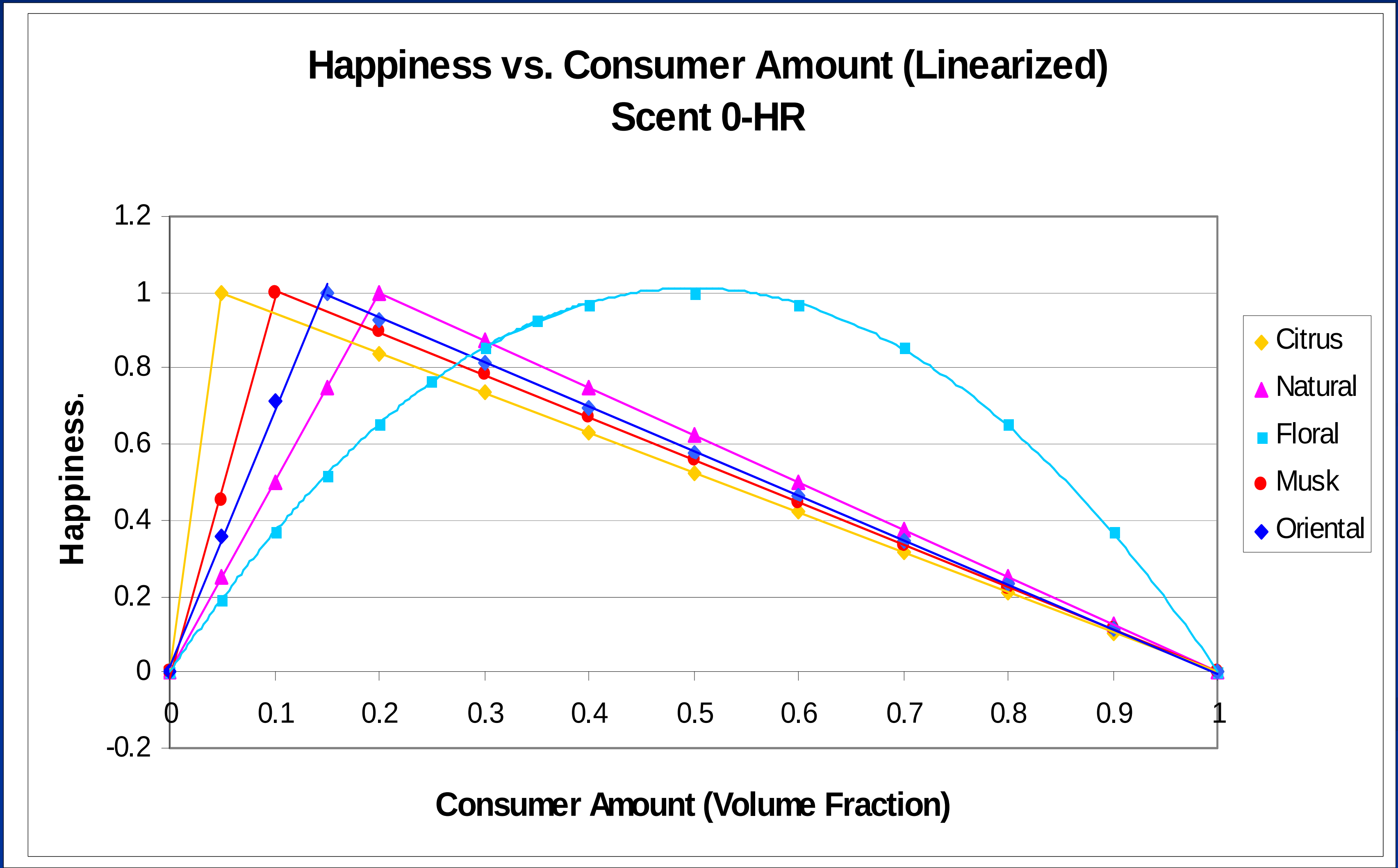


- The fastest depleting component was determined to be Sandalwood, with a threshold in air of 6.4 x 10^{-5} g/m^3, and an endurance time of 9 hours
- Based on these values, the endurance of the perfume was determined

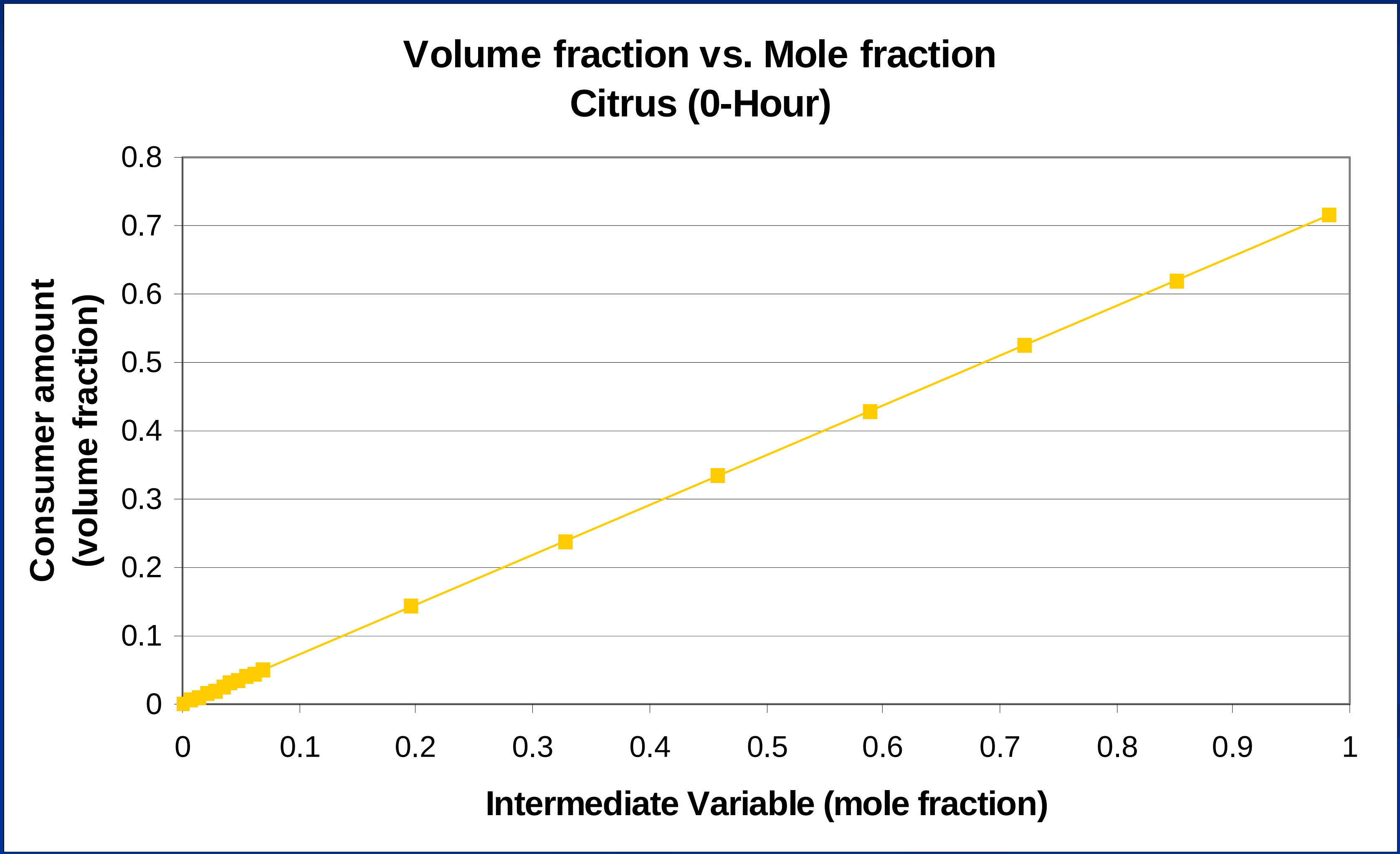
Happiness Function

- To determine the engineered variables with respect to the consumer variables from the survey, graphs of happiness versus each consumer variable were developed
- These were then related to intermediate variables which could be manipulated to form the fragrance

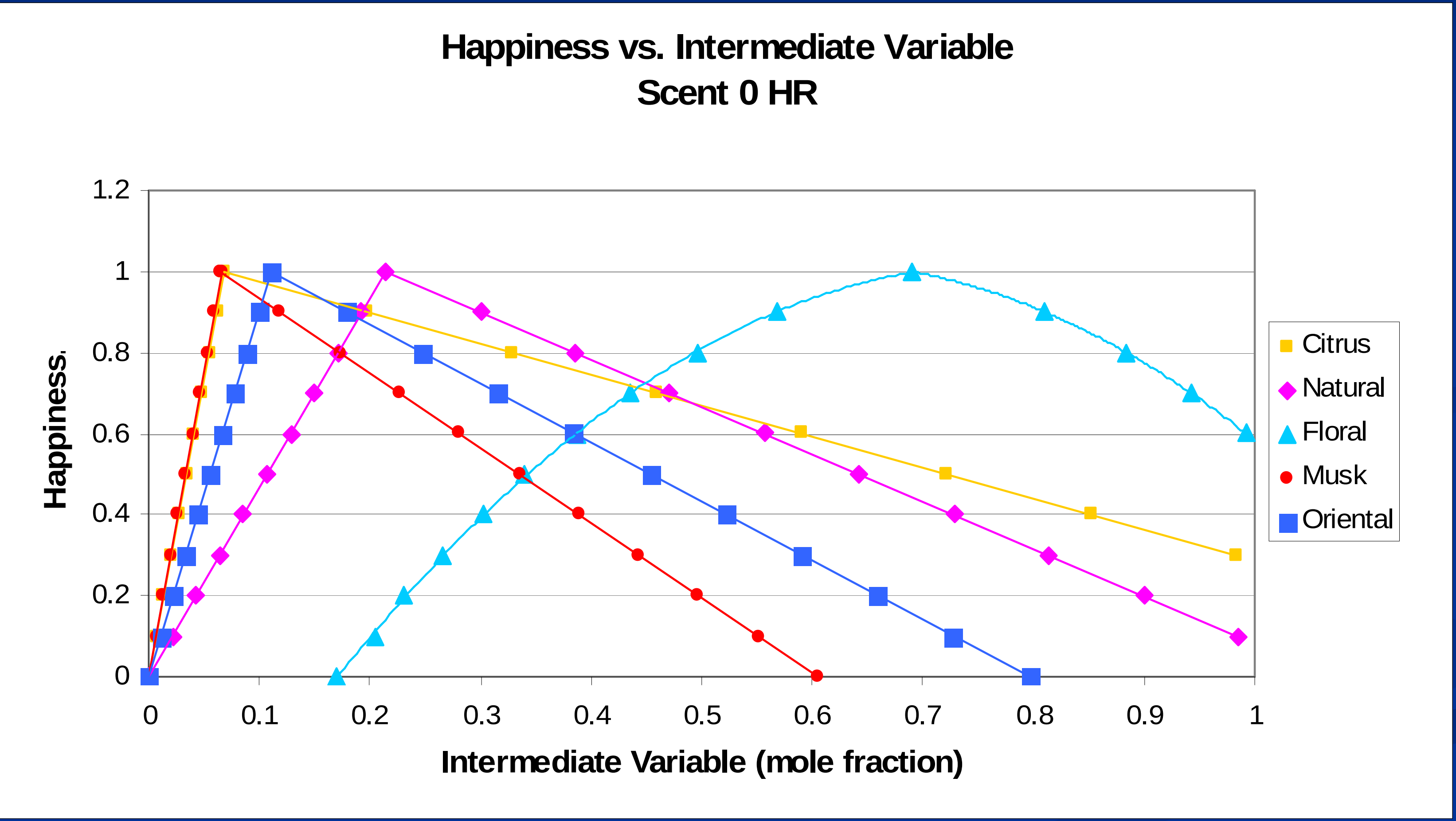
Scent Graphs



Scent Graphs



Scent Graph With Intermediate Variable



Determination of β

Happiness Comparison		
Categories	**Pure Ambition**	**Competition**
Scent	19.9	23.2
Endurance	8.0	8.0
Init. Strength	9.9	6.7
Color	10.0	8.5
Oiliness	0.50	6.5

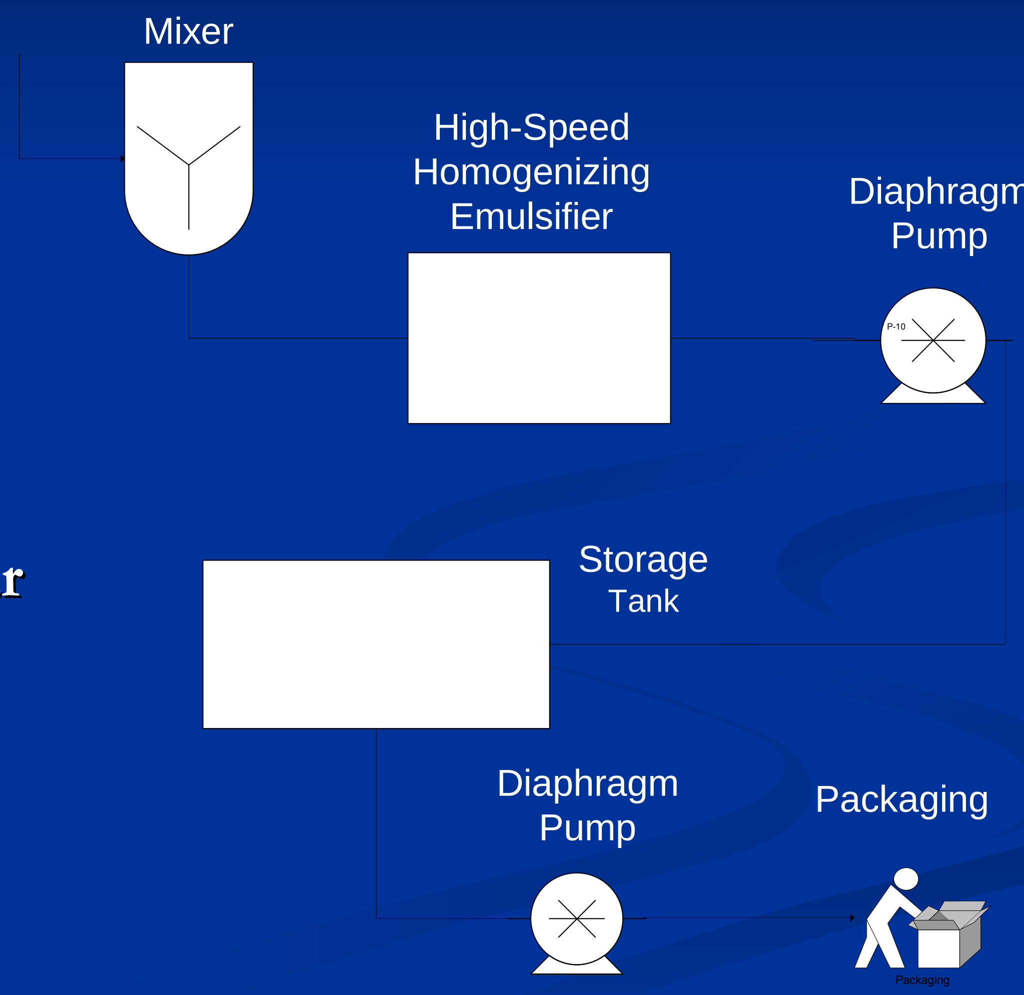
Overall Score	6.90	7.6
Overall Happiness	**0.718**	**0.756**

β = Happiness of Competition / Happiness of Pure Ambition

Economic Analysis

Process Flow Diagram

- Based on demand model
- Production
  - 13300 bottles/year
  - 1.7 oz/bottle
  - 665 liters/year



Capital Investment

Component	Basis for Estimate	Cost ($)
DIRECT COSTS		
Onsite		
Purchased equipment:		
Mixer	w/ motor (Fig 12-46) SS Rotary double-cone blender	17,500
Homogenizer / Emulsifier	Fong Hwang Enterprise Co. Ltd.	5,200
Storage Tank	0.1 cubic meter (Fig 12-52)	2,700
Pump	2 pumps (Fig 12-21)	2,800
Filler/Bottling Machine	Turbofil Packaging Machines, LLC	20,000
Total Purchased Equipment		48,200
Installation	47% Purchased equipment cost	22,654
Instrumentation and controls	36% Purchased equipment cost	17,352
Piping	68% Purchased equipment cost	32,776
Electrical	11% Purchased equipment cost	5,302
Offsite		
Building	18% Purchased equipment cost	8,676
Yard Improvement	10% Purchased equipment cost	4,820
Service Facilities	70% Purchased equipment cost	33,740
Total Direct Cost		173,520
INDIRECT COST		
Engineering	33% Purchased equipment cost	15,906
Construction	41% Purchased equipment cost	19,762
Legal expenses	4% Purchased equipment cost	1,928
Contractor's fee	22% Purchased equipment cost	10,604
Contingency	44% Purchased equipment cost	21,208
Total Indirect Plant Cost		69,408
Fixed Capital Investment	Direct cost + Indirect cost	242,928
Working Capital	15% of Total Capital Investment	42,870
Total Capital Investment		285,798

Production Costs – Max ROI

Component	Basis for Estimate	Cost ($/yr)
I. MANUFACTURING COST		
A. Direct production costs		
1. Raw materials		99,084
2. Operating labor	2 men(1 skilled, 1 common)/shift, 2 shifts/day, 260 days/yr, 8 hours/shift, $25/hr for skilled and $15/hr for common	166,400
3. Direct supervisory and clerical	15% of Operating labor	24,960
3. Utilities		
Process electricity	50000 kWh, $ 0.045/kwh	2,250
Facility electricity	Estimated to be 20000 kwh, $ 0.045/kwh	900
4. Maintenance and repair	7% of FCI	17,005
5. Operating Supplies	15% of Maintenance and repair	2,551
7. Laboratory charges	15% of Operating labor	24,960
8. Patents and Royalties	assumed to be zero	0
Subtotal		**338,109**
B. Fixed charges		
1. Local taxes	Average populated area, 2% of FCI	4,859
2. Insurance	1% of FCI	2,429
Subtotal		**7,288**
C. Overhead Costs	50% of Operating labor, Supervision, and Maintenance	**104,182**
II. GENERAL EXPENSES		
A. Distribution and selling costs	5% Total product cost	28,236
B. Research and development	5% of Direct production costs	16,905
C. Advertisement	Will decide advertisement later	70,000
Subtotal		**115,142**
TOTAL ANNUAL PRODUCT COST	Manufacturing cost + General expenses	**564,721**

Perfume Results

Formula of Perfume - Max Happiness ~ 80%

PERFUME FORMULATION		
Ingredients	**Volume%**	**Function**
Ethanol	76.5	Solvent
DI Water	8.5	Diluent
Peony	0.50	Top Note
Lemon	2.32	Top Note
Honeysuckle	0.50	Middle Note
Hibiscus	0.50	Middle Note
Rose	0.50	Middle Note
Amber	1.09	Base Note
Vanilla	1.09	Base Note
Sandalwood	3.85	Base Note
African Musk	4.65	Base Note

Maximum Happiness Decision

- Based on project life of 10 years and Max ROI @ 80% Happiness
- Revenue: **$ 600**
- Total Capital Investment: **$286,000**
- Total Annual Production Cost: **$500,000**
- Total Profit: **-$315,000**
- Return on Investment: **-110.43%**

Formula of Perfume ~ 75% Happiness

PERFUME FORMULATION		
Ingredients	Volume%	Function
Ethanol	76.5	Solvent
DI Water	8.5	Diluent
Peony	0.26	Top Note
Lemon	2.98	Top Note
Honeysuckle	0.26	Middle Note
Hibiscus	0.26	Middle Note
Rose	0.26	Middle Note
Amber	1.73	Base Note
Vanilla	1.73	Base Note
Sandalwood	6.99	Base Note
African Musk	0.54	Base Note

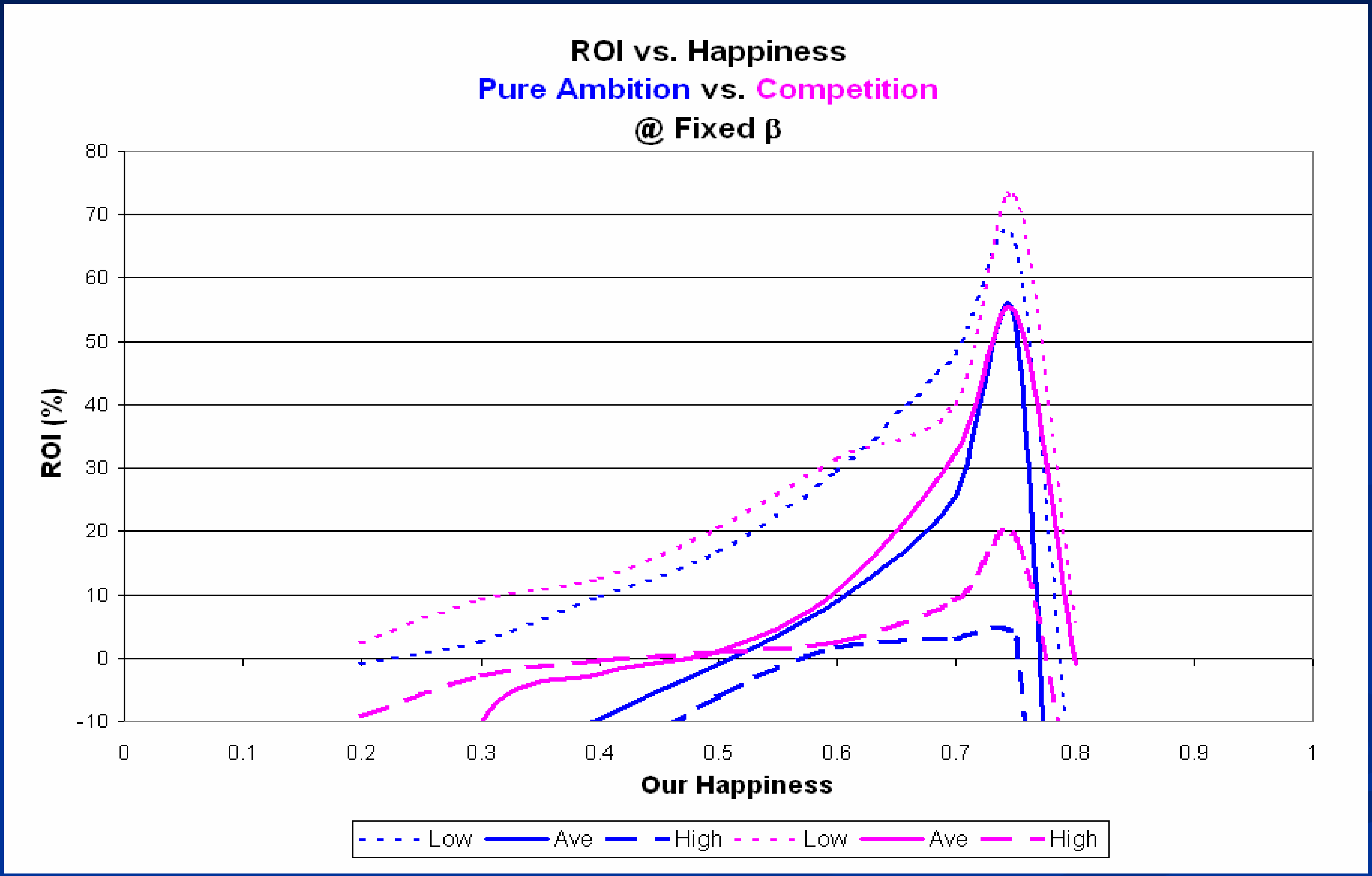
Most Profitable Decision

- Based on project life of 10 years and Max ROI @ 75% Happiness
- Revenue: **$ 820,000**
- Total Capital Investment: **$255,000**
- Total Annual Production Cost: **$565,000**
- Net Profit: **$170,000**
- Return on Investment: **56.91%**

Market Scenarios

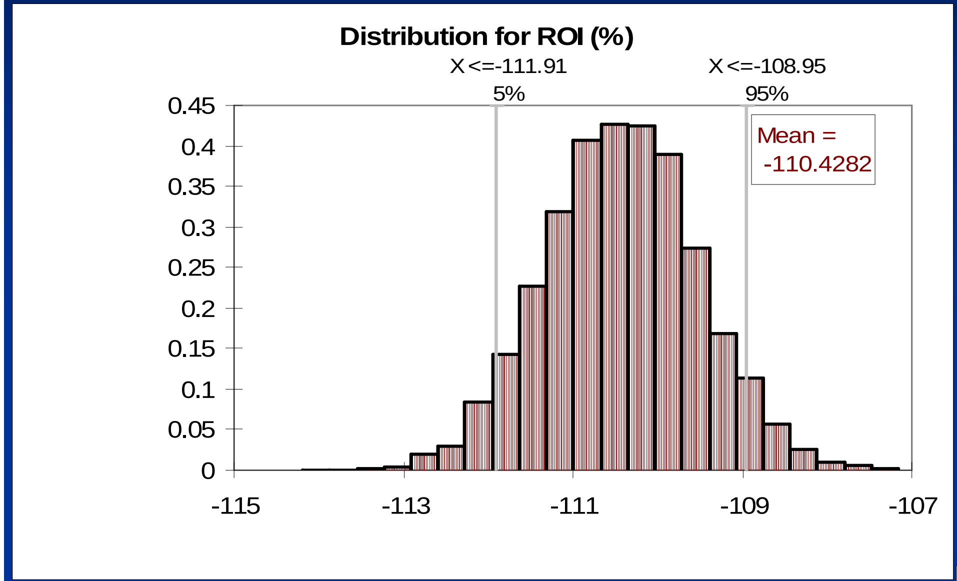
- Three economic scenarios in question
  - High economic pricing on raw materials
  - Average economic pricing on raw materials
  - Low economic pricing on raw materials
- A standard deviation of 20% was assumed
- Raw materials contribute a large percentage of cost for calculating the total product cost

ROI vs. Happiness



ROI vs. Happiness at differing economic scenarios

Risk Analysis for Max Happiness



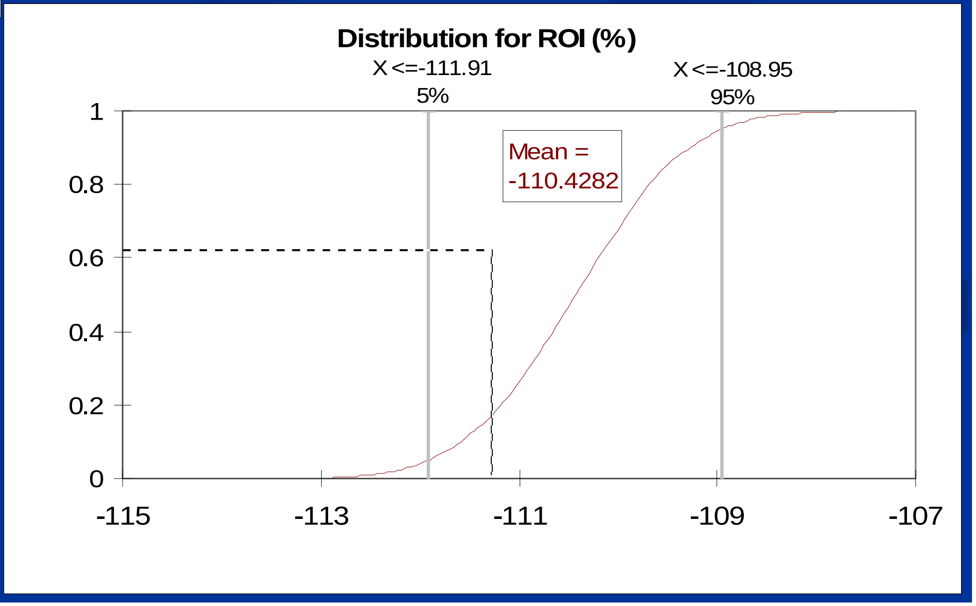
Mean ROI: -110.43 %

Probability of Occurrence:

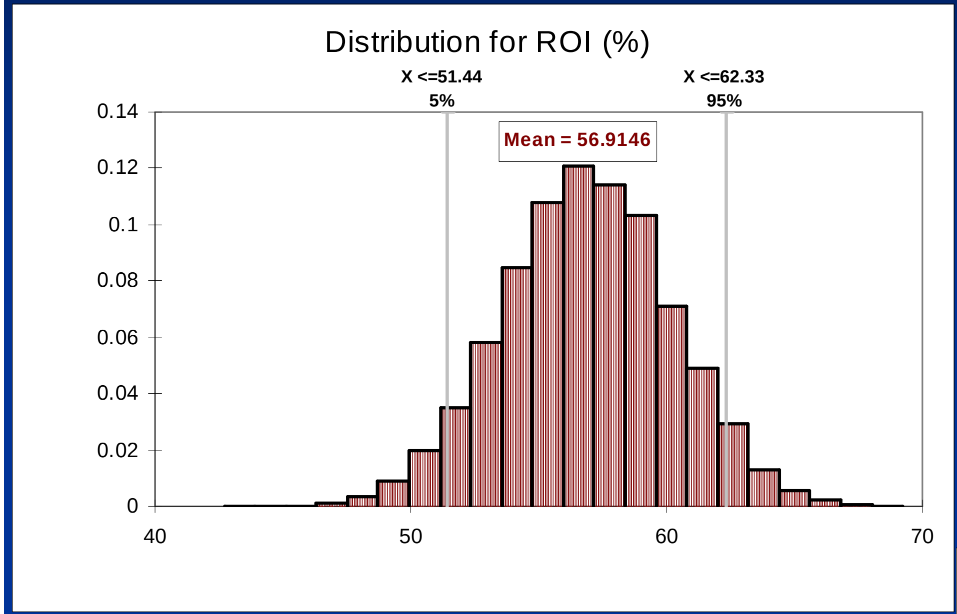
~ 40 %

Cumulative Probability

100% Chance of losing money



Risk Analysis for Maximum ROI



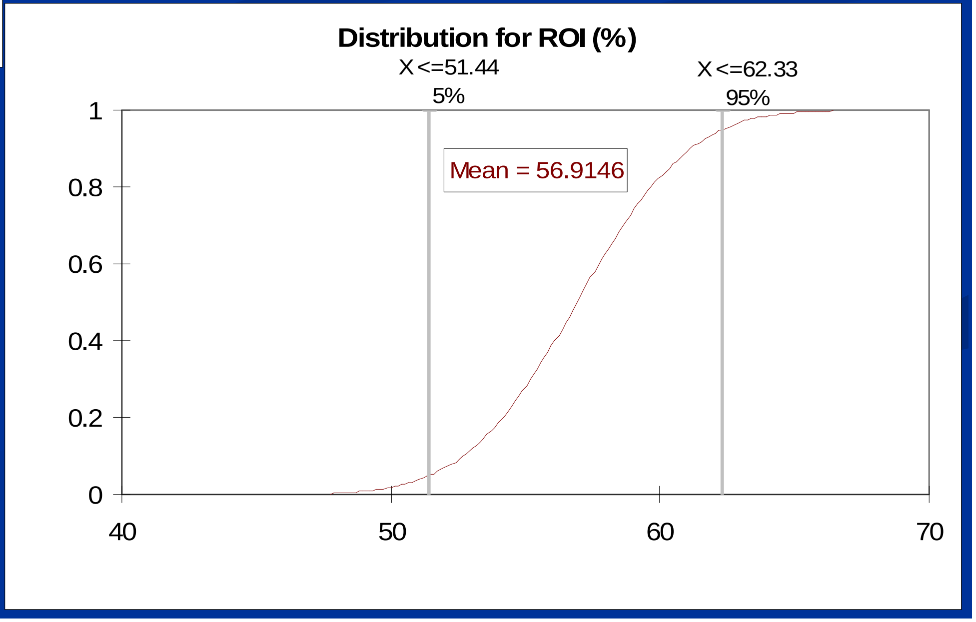
Mean ROI: 59.91 %

Probability of Occurrence:

~ 12%

Cumulative Probability

100% Chance of gaining money



MiniMax Regret

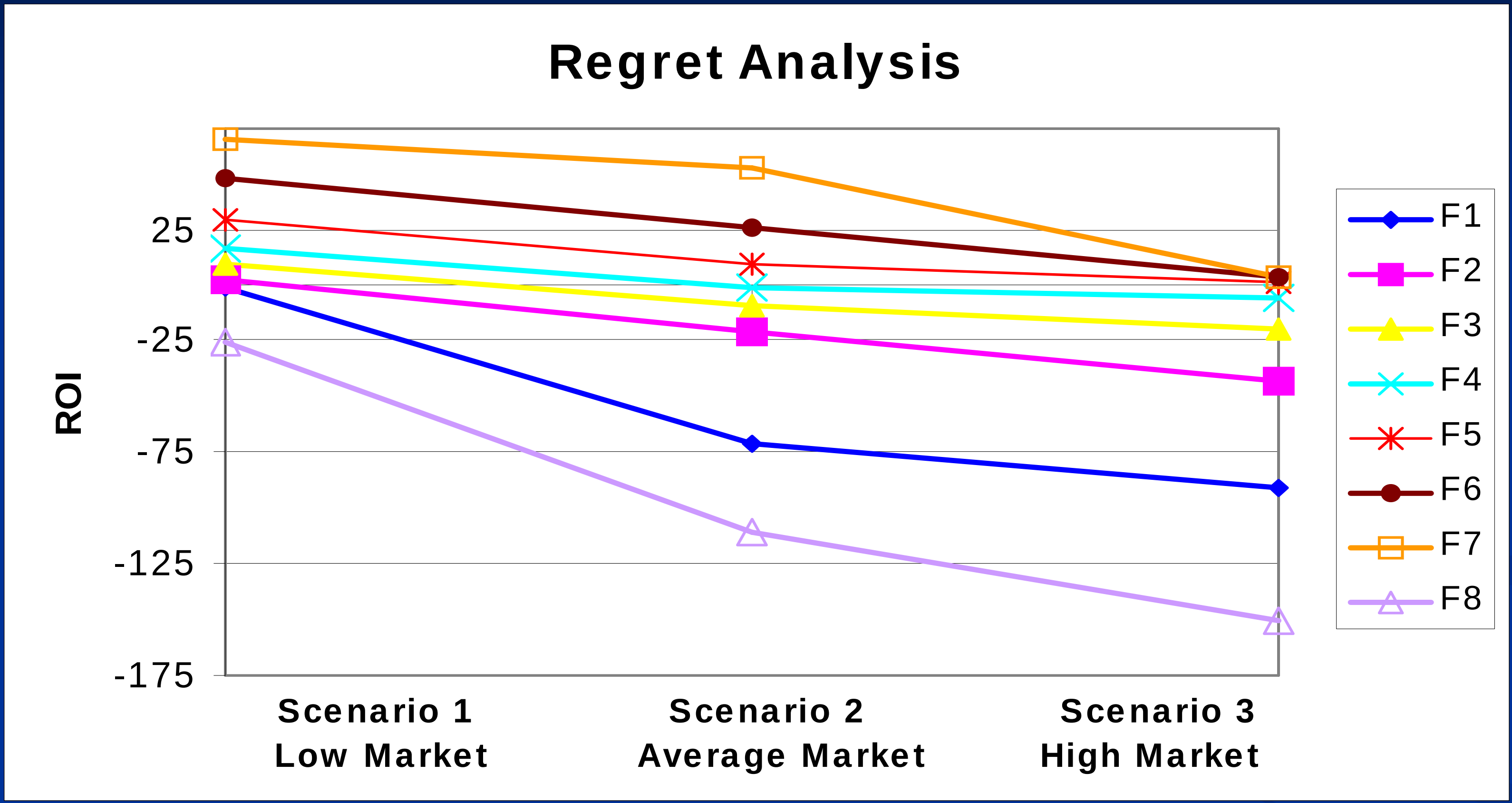
- A regret analysis was performed on low, medium, and high market values for raw material cost

ROI						
	Low	Med	High	Ave	Max	Min
F1	-0.84	-150.12	-90.51	-80.49	-0.84	-150.12
F2	2.64	-20.65	-42.69	-20.2333	2.64	-42.69
F3	9.59	-9.61	-19.25	-6.42333	9.59	-19.25
F4	16.85	-0.92	-5.91	3.34	16.85	-5.91
F5	29.62	9.12	1.64	13.46	29.62	1.64
F6	48.26	25.65	2.94	25.61667	48.26	2.94
F7	65.25	52.85	3.15	40.41667	65.25	3.15
F8	-25.68	-110.83	-200.65	-112.387	-25.68	-200.65
MAX	65.25	53.62	19.62	40.41667	65.25	3.15

Regret				
	Low	Medium	High	MAX
F1	66.09	203.74	110.13	203.74
F2	62.61	74.27	62.31	74.27
F3	55.66	63.23	38.87	63.23
F4	48.4	54.54	25.53	54.54
F5	35.63	44.5	17.98	44.5
F6	16.99	27.97	16.68	27.97
F7	0	0.77	16.47	16.47
F8	90.93	164.45	220.27	220.27
			MIN	16.47

- Based on MiniMax analysis F7 is the optimum choice

Regret Analysis



- A regret analysis was performed on the perfume formulations at the three economic scenarios
- Traditional – F7 Optimistic – F7 Pessimistic – F7

Conclusions

Pure Ambition is profitable!

Based on the following parameters:

- 75% Happiness
- Demand = 13,300 people
- Price = $60/bottle

Questions?