Lecture #39

ERDM

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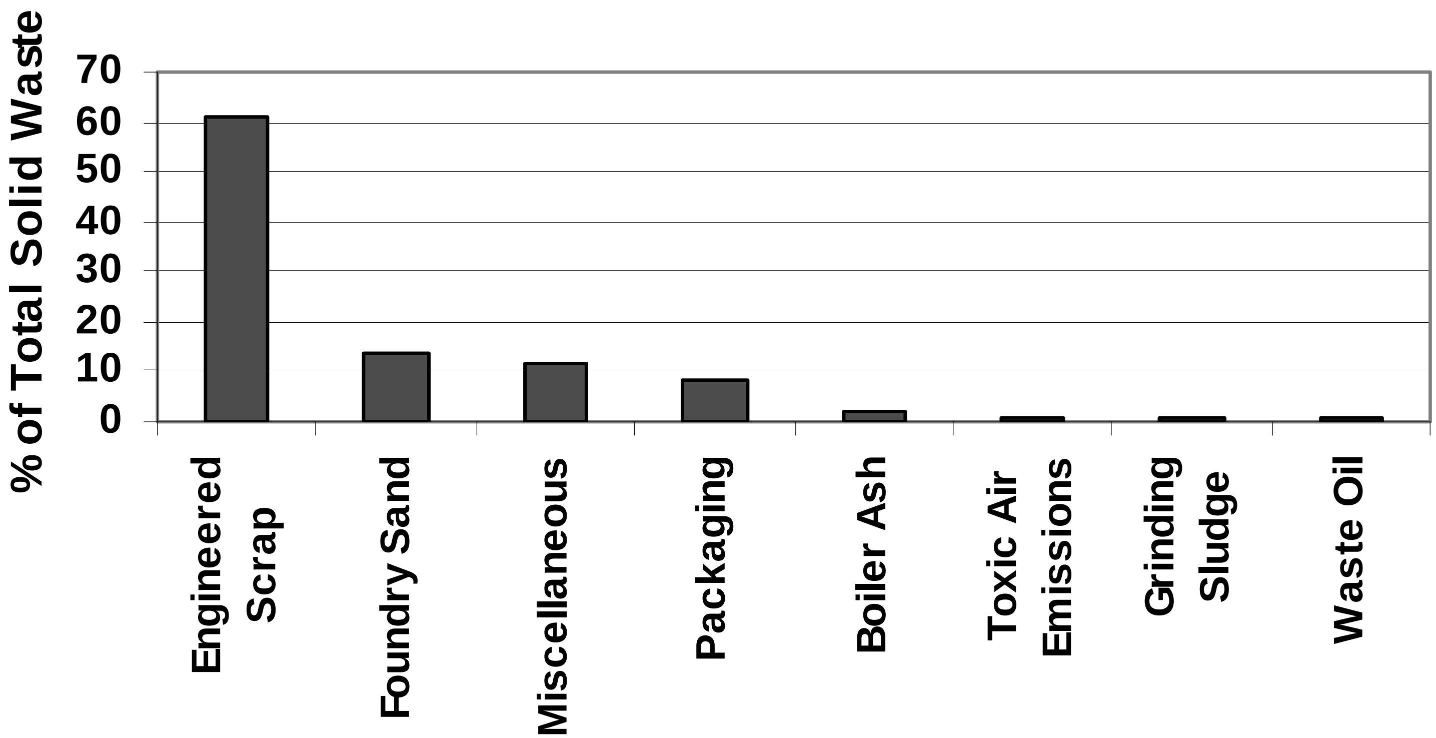
Decision-Making -- Introduction

(adapted from http://www.mindtools.com/pages/main/newMN_TED.htm)

- **Selecting the most important issue - Pareto Analysis**
- **Evaluating the relative importance of different factors - Pairwise Comparison Analysis (PCA)**
- **Selecting best alternatives - Tabular Analysis - QFD**
- **Choosing between options by projecting likely outcomes - Decision Trees**
- **Weighing pros & cons of a decision: +/- Tally Sheet**
- **Analyzing the pressures for and against change - Force Field Analysis**
- **Decisions from multiple viewpoint - Six Thinking Hats**
- **Seeing whether a change is worth making - Cost/ Benefit Analysis**

Pareto Analysis



Where should we place our effort to get the best return??

Pairwise Comparison Analysis

- **In a DFE study of a product/process we identify the following factors as important:**

T: Time

C: Cost

M: Materials

E: Energy

S: Structure (i.e., modularity of the design)

- **Definitions: Absolute importance of a factor: g_i**

  Relative importance: $r_{i,j}$; $g_i = r_{i,j} * g_j$

As an example, let's say that global importance of time is 0.1 and energy is 0.4, or $g_{energy} = r_{i,j} * g_{time}$ then $r_{energy,time} = 4$

If we compare each of the factors in groups of two we can summarize the relative importances in a table

	T	C	M	E	S
T	1	3.00	7.00	4.00	7.00
C	0.33	1	0.20	0.33	0.50
M	0.14	5.00	1	4.00	5.00
E	0.25	3.00	0.25	1	2.00
S	0.14	2.00	0.20	0.50	1.00

Note that the matrix is reciprocal across the diagonal (the index i refers to column & j refers to row)

So, M & S are each 7 times more important than T

That would mean that M & S are equally important, right??

No, a direct comparison of M & S shows that S is 5 times more important than M.

What's the problem? -- the pairwise comparisons are not consistent

Several approaches have been suggested to address this problem....

We could use the least squares method to find the g's

What do we know about g_1 ??

$g_1 = r_{1,1} * g_1$

$g_1 = r_{1,2} * g_2$

$g_1 = r_{1,3} * g_3$

$g_1 = r_{1,4} * g_4$

$g_1 = r_{1,5} * g_5$

reference C. Whitmer (MTU)

$$g_1 = \frac{\sum_{j=1}^{5} r_{1,j} \cdot g_j}{5}$$

want g values that min error

Need to simultaneously solve for all g’s & require g’g = 1

Or, if just a ranking of the factors is sufficient...

	T	C	M	E	S
T	1	3.00	7.00	4.00	7.00
C	0.33	1	0.20	0.33	0.50
M	0.14	5.00	1	4.00	5.00
E	0.25	3.00	0.25	1	2.00
S	0.14	2.00	0.20	0.50	1.00
Total	2.32	14.00	8.65	9.83	15.5

Add the columns to get the total.

Ranking: S -- C -- E -- M -- T

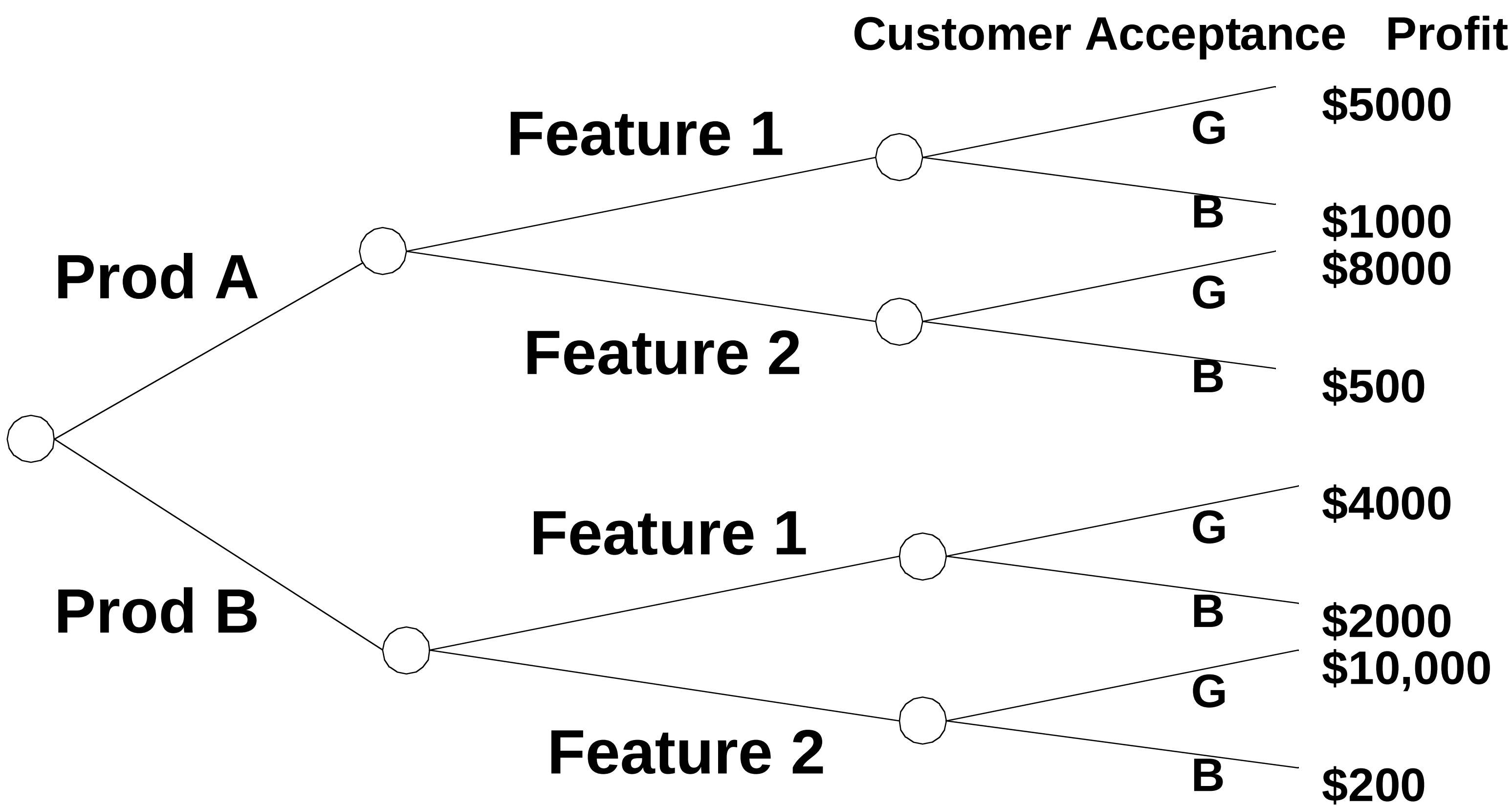
Tabular Analysis - e.g., QFD

Wants	Priority	Jar of Fireflies	Flash-light	Candle	Clapper on Room Lamp	Glow Stick
Light	6	0	2	2	3	1
Localized	4	3	3	3	0	3
Easy to Use	3	1	3	0	3	3
Inexpensive	5	3	2	2	2	0
Long Lasting	1	0	2	1	3	1
Environment	2	3	2	1	2	0
Total		36	49	37	44	28

0: Worst -- 3: Best

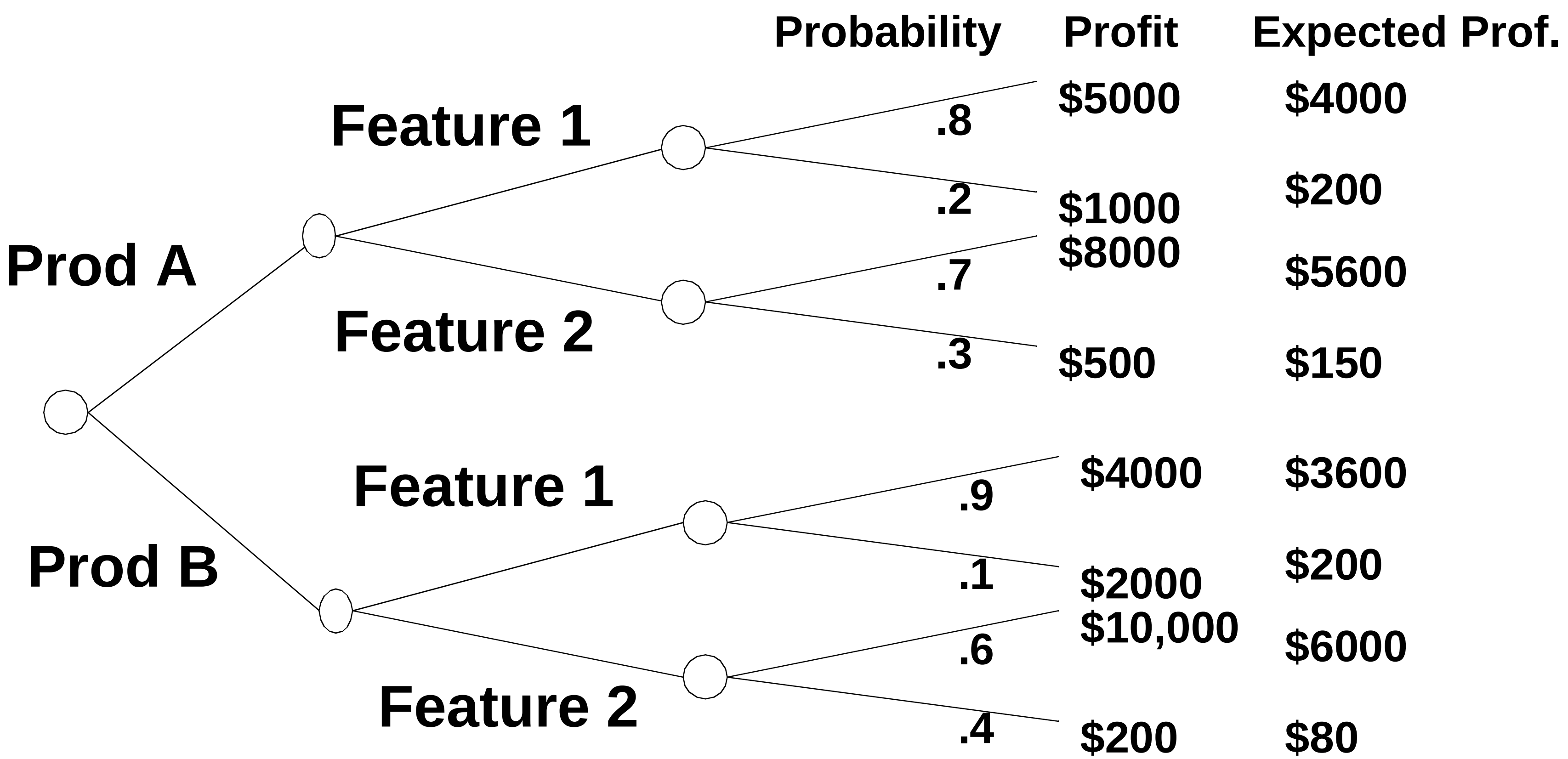
Priority could be specified to be one for all "wants"

Decision Trees



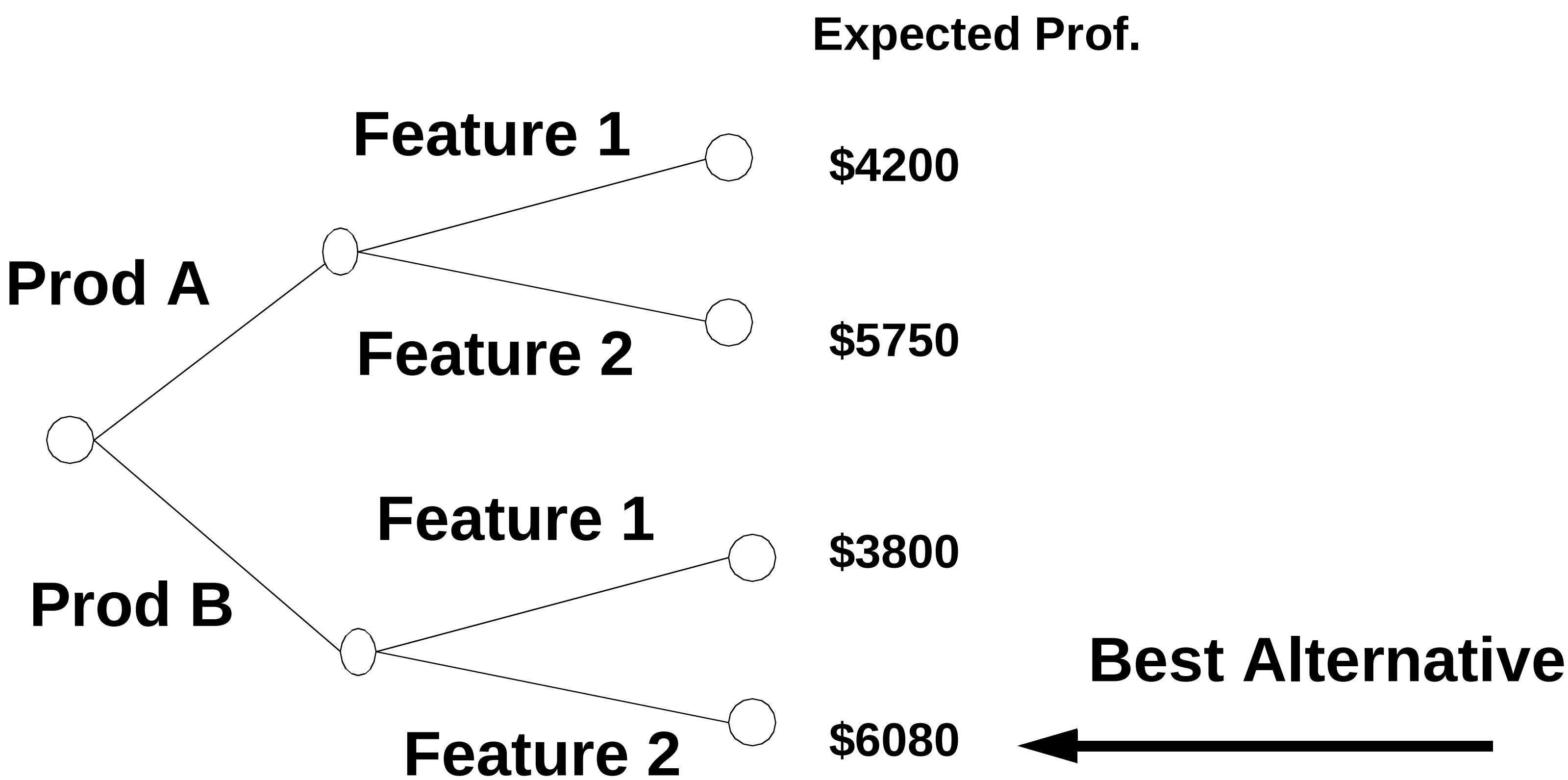
Calc. expected profit for each outcome

Decision Trees



Calc. expected profit for each prod/feature combo.

Decision Trees



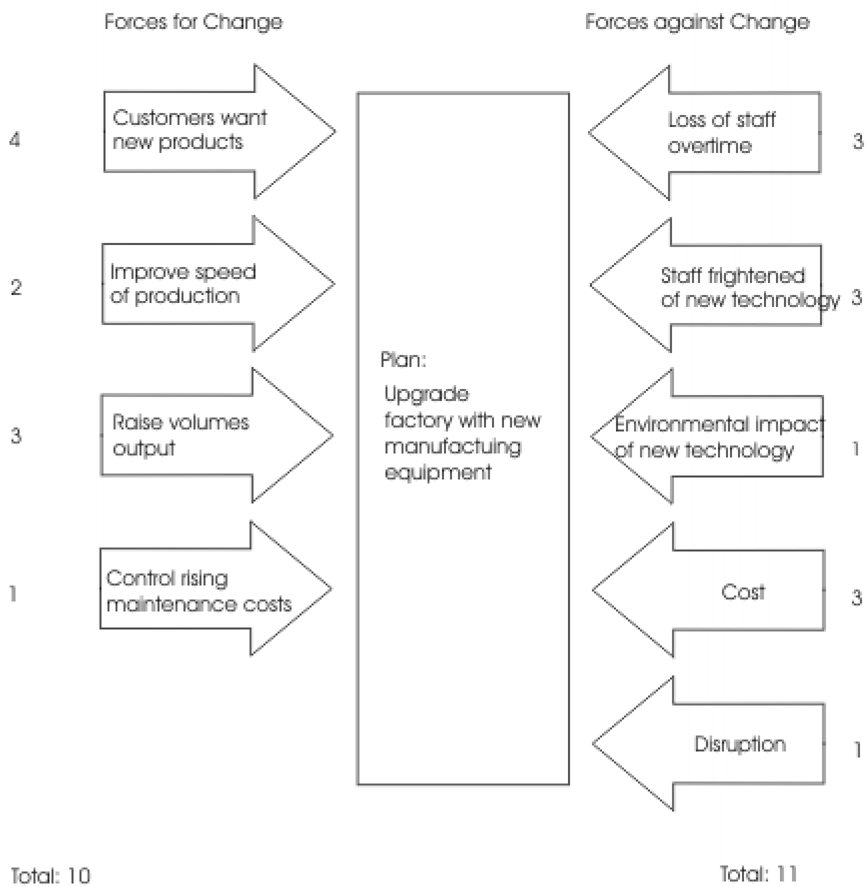
Plus / Minus Tally Sheet

- **A professional is deciding where to live. Her question is "should she move to Detroit from Houghton?"**

Plus	Minus
More going on (+5)	Have to sell house (-6)
Easier to see friends (+5)	More pollution (-3)
Easier to get places (+3)	Less space (-3)
	Crime (-2)
	More difficult to get to work? (-4)
+13	-18

The minuses outweigh the pluses in this example!!

Force Field Analysis



An additional benefit is that by explicitly enumerating the forces for & against change, your next step(s) may be clearer.

You may be able to: increase forces for or reduce forces opposing the change.

6 - Hat Thinking

- Calls for looking at the problem from different viewpoints

Cost / Benefit Analysis

- Perform a financial analysis of the proposed action.

Optimization Methods

- Calculus
- Linear Programming
- Non-linear Programming
- Integer Programming
- Geometric Programming
- Dynamic Programming
- Multiple Criteria Decision Making

Decision-making

- **Overview: select values for decision variables, $x_1, x_2, \ldots, x_n$, that optimize some objective, Z.**

$$Z = f(x_1, x_2, \ldots, x_n)$$

- **Of course, often have restrictions that limit the design space.**

$$b_1 \leq g_1(x_1, x_2, \ldots, x_n)$$
$$b_2 \leq g_2(x_1, x_2, \ldots, x_n)$$
$$b_3 \leq g_3(x_1, x_2, \ldots, x_n)$$

Calculus

- **Identify the objective function: What is it that we want to minimize or maximize?**
  Let's say we want to maximize the output from a process given a fixed set of resources. One "decision variable", x

  $$O = 10 + 30x - 3x^2$$

  Of course we know how to solve this....

  If there are constraints: use lagrange multipliers

Linear Programming -- Steps

1. **Identify the objective function: Again, what do we want to minimize or maximize?**

   Let's say we want to maximize the profit, P, associated with new and remanufactured products
   Max: $P = 10*N + 5R$

2. **What are the constraints?**
   Raw matl.: $4N + 1R \leq 200$
   Energy: $6N + 4R \leq 360$
   Logistics: $2N + 3R \leq 240$
   Non-negativity: Both N and R ≥ 0

LP & Additional Comments

- **Linear programming requires linear (or at least linearizable) objective function AND constraints.**
- **Non-linear programming**
  - **Beyond scope of course**
  - **Look for computer code to help (e.g., MATLAB)**
  - **Geometric programming is a special case**
- **We've talked about Integer Programming?!? Exact solutions for general case are VERY difficult.**
- **Dynamic programming: very cool - no time to discuss**

Multiple Criteria Decision Making

Examples:

- **Multiple Objectives (need models for these):**

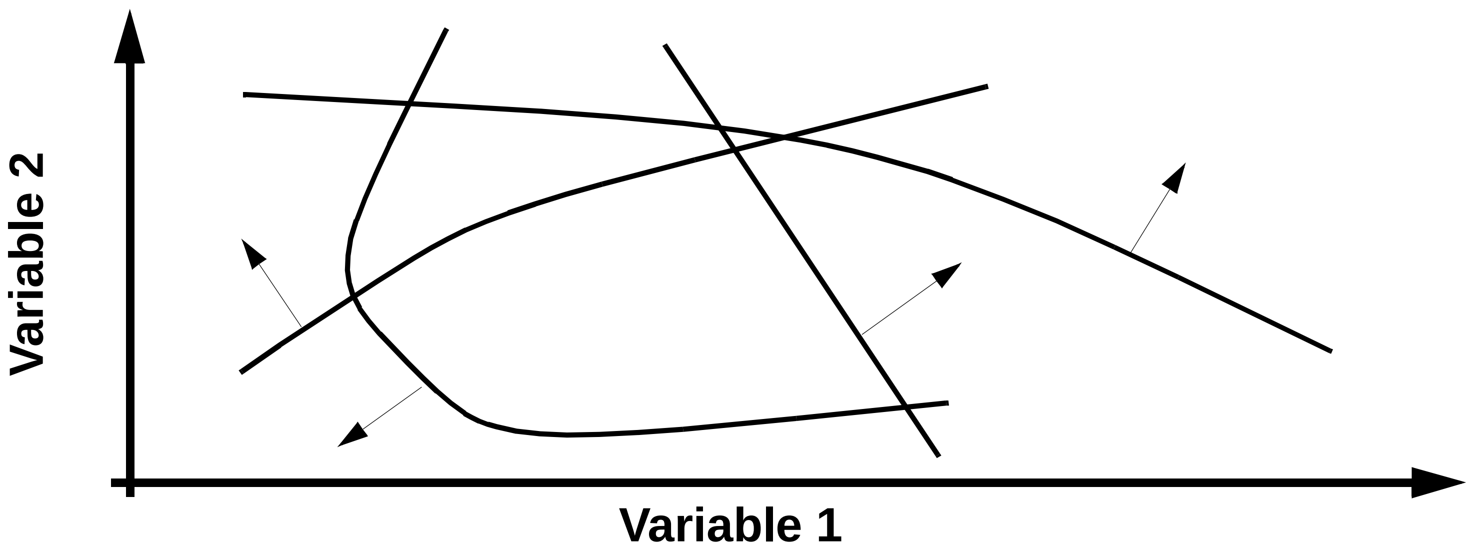
  Minimize: Cost, materials, energy, waste, time

  Maximize: Product function, service life, potential for reuse/remanufacture/recycle, modularity

- **Constraints (need models for these as well): ????**

Multi-Criteria Optimization

- **Let's say we have several performance measures or objectives that we wish to simultaneously optimize:** $z_1, z_2, \ldots, z_m$



Multi-Criteria Optimization (cont.)

- **As we might expect, the objectives are conflicting. What to do???**

  One approach: use a weighted objective:

  $$Y = W_1 Z_1 + W_2 Z_2 + \dots$$

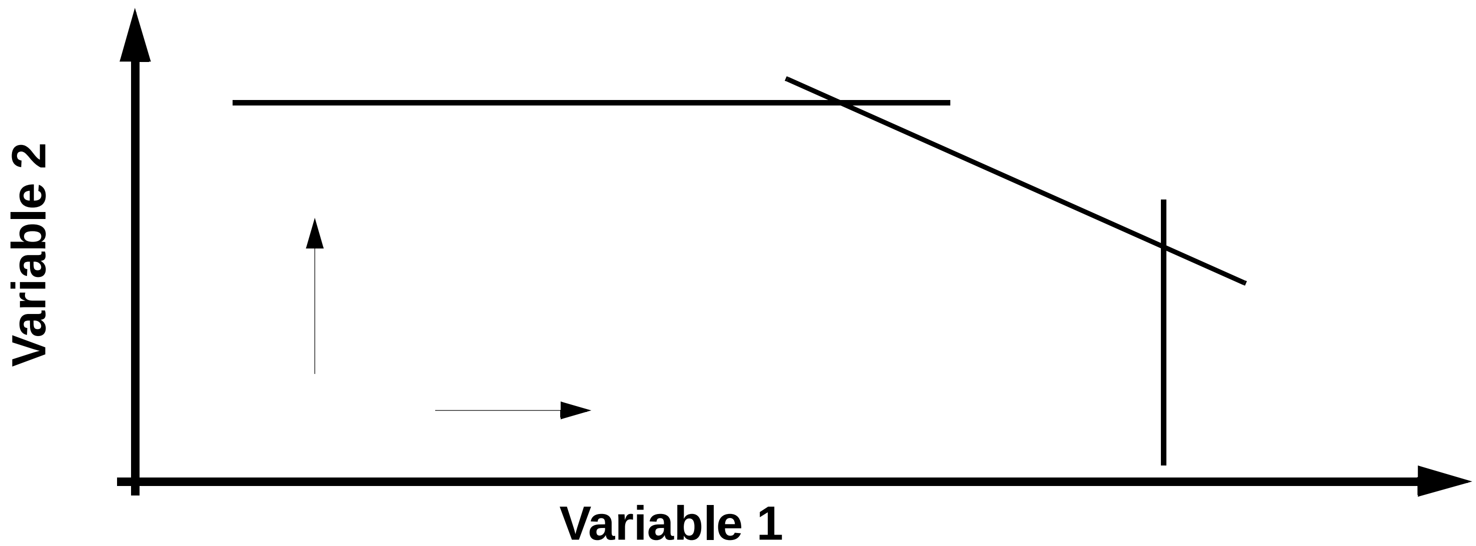
  Weights put different importance on the performance measure and place diverse metrics on equal footing. Objectives must be consistent (e.g., Max).

  Optimize Y!! Subject, of course, to the constraints on the design variables.

Multi-Criteria Optimization (cont.)

Other ideas:

- **Goal programming**
- **Non-dominated sets**



Selecting Weights

- **The weighted objective approach seems promising. How do we pick the weights??** $W_1, W_2, \ldots, W_m$**.**

- **If all the objectives are somehow converted into the same units (say dollars or eco-dollars) this may help. But, this does not address the problem that we may value some objectives more than others, e.g., product cost vs. energy cost.**

- **Saaty (1990) in his text, *The Analytic Hierarchy Process*, proposes the use of a <u>Pairwise Comparison Approach</u> to obtain the weights.**

Decision-Making

The flavor of decision-making discussed today...

- **Largely focused on situation where some mathematics / rigor can be applied to the problem**

- **Emphasis is on one person coming up with an answer**

- **For situations where more than one person is involved or objectives / constraints less well defined -- see the social scientists!**