NE529
RISK ASSESSMENT
Risk Management
7

R. A. Borrelli

University of Idaho

Idaho Falls Center for Higher Education

University of Idaho
Department of Nuclear Engineering and Industrial Management

Learning objectives

Demonstrating basic risk management concepts

Applying risk management to common problems

Analyzing outcomes that effectively manage or mitigate risk

Assessing risk level in terms of tolerance or preference

Choosing the appropriate management options

My own material

Learning nodes

What is risk management?

Strategies

Net Present Value (NPV)

Decision trees
- Example
- Evaluating decisions

Bridge modifications
- Upfront costs
- Expected value

Hurwicz criterion

Land use

Utility theory

Expected utility

Data fitting

Revisit land use

Arrow-Pratt coefficient

Multiple attributes

More learning nodes

Analytical Hierarchy Process (AHP)

Procedure

Yucca mountain

Buying a car

Apartment

Fuzzy logic

Risk perception and communication

What is risk management?

Risk management is a formalized means of developing, selecting, and managing options for addressing risks

Project Management Institute Body of Knowledge gives three definitions

(1) Formal process by which risk factors are systematically identified, assessed, and provided for

(2) Formal, systematic method of managing that concentrates on identifying and controlling areas or events that have a potential for causing unwanted change

(3) Art and science of identifying, analyzing, and responding to risk factors throughout the life of a project and in the best interest of its objectives

Strategies

There are several strategies to manage risk

Transfer risk to another party

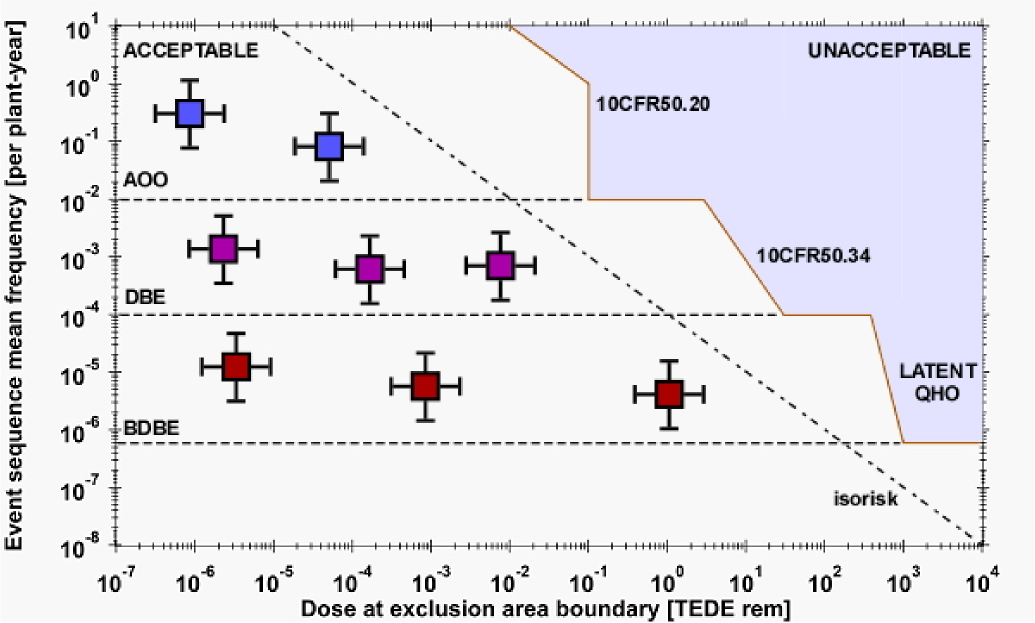
Avoid risk

Reduce frequency

Reduce consequences a particular event

Regulations provide acceptable level of risk

Now, we include environmental justice



ACCEPTABLE
UNACCEPTABLE
AOO
DBE
BDBE
10CFR50.20
10CFR50.34
LATENT
QHO
isorisk
Event sequence mean frequency [per plant-year]
Dose at exclusion area boundary [TEDE rem]

Net Present Value (NPV)

Net Present Value (NPV) is an important criterion for management

What is the relationship between 1 dollar today and 1 dollar tomorrow?

Cost is typically the motivating factor in selecting options

Not always the best though

Expenditures and revenues occur over life cycle

For NPPs much of the expenditures are up front but big

NPV measures present value of various cash flows in different periods in the future

Rate at which future cash flows are discounted is determined by the discount rate

$NPV > 0$ – Wealth maximization principle

$$NPV = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \tag{1}$$

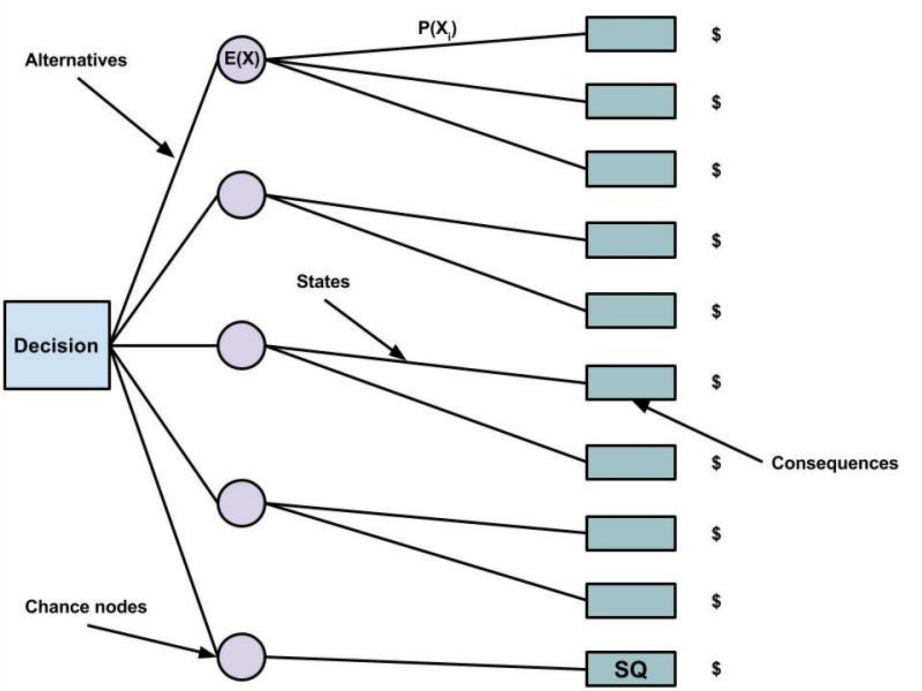
Maximize the current value of the investors net wealth

Shareholders in an energy company to build a new reactor

Current discount rates contained in OMB Circular A-94, Appendix C

Must consider all relevant cash flows throughout the decision life cycle

Decision trees


Alternatives
E(X)
P(X_i)
$
$
$
$
$
States
Decision
$
$
Consequences
$
$
Chance nodes
SQ
$

How many decisions with complete certainty have you ever made?

All decisions carry risk

You're making decisions with imperfect knowledge

Does a good decision always guarantee a good outcome?

Almost all decisions involve some level of uncertainty

Consequences may be large or insignificant

Use of a decision tree can aid in strategic thinking

Decision making with uncertainty

Quantitative reasoning

Frank Knight (1921) famed text on the topic

Example

What’s your decision?

Win 100 dollars calling the roll of a die even or odd

35 dollar buy in

I can afford to lose 35 dollars

I could really use 100 dollars

I don’t gamble

Is 35 dollars a good buy in?

What would you negotiate?

Decision analysis forces you to think carefully

Discern true nature of the decision problem by constructing a tree

Nature of the sequential interaction of decisions and chance events

Can only choose opportunities (pathways) not outcomes

The outcomes are what they are

How do we evaluate a decision?

Decide on the decision criterion – is it money (loss or gain)? Fatalities? Accidents? Dose?

Decide on a model to evaluate the criteria – Expected value, Utility theory

Certainty Equivalent is when you are indifferent between a deal with at least two opportunities and a guaranteed sum of money

Risk tolerance is on either side of that

Ideally you would want to know the outcome beforehand

That is why you count cards

Distinguish between good decisions and good outcomes

Good decisions balance good and bad outcomes in accordance with risk attitudes

Heterogeneity

Range of different outcomes

How bad is bad

How much worse is one than the other

Relating Probabilities to Probabilities

Small probabilities

Intuitive tendencies aren't typically correct

Complexity

Multiple outcomes and multiple probabilities

Risk aversion is a psychological concept to settle for a lower return for a greater certainty of outcomes

People are not indifferent to uncertainty

Stems from uneven preferences for different outcomes

Decreased chance of losing money

I don't like losing 100 dollars for the chance to gain 250 dollars

I would rather try to gain 500 dollars even if I could lose 150 dollars

Risk averse individuals will pay risk premiums to avoid uncertainty – fear loss and seek sureness

Buy the half a point on a 7.5 line in football

Risk neutral are indifferent to uncertainty

Expected value criterion is useful generally in the case where the decision maker is risk neutral

Utility theory offers an alternative to the expected value approach

Risk lovers hope to win big and don't mind losing as much

Risk lover seeks to maximize the maximum gain – maximax

Conservative decision maker seeks to maximize the minimum gain or minimize the maximum loss – maximin minimax

How is this done?

Choose between a fixed sum of money k and lottery in which the expected prize is k, you are indifferent

Risk averse takes the fixed sum

Risk seeker takes the lottery

Get 100 dollars up front, or go for the lottery where the coin flip gives you 200 dollars on heads

Expected value is not a good criterion for people who dislike risk

A risk premium is the amount paid by a (risk averse) individual to avoid risk

Insurance premiums

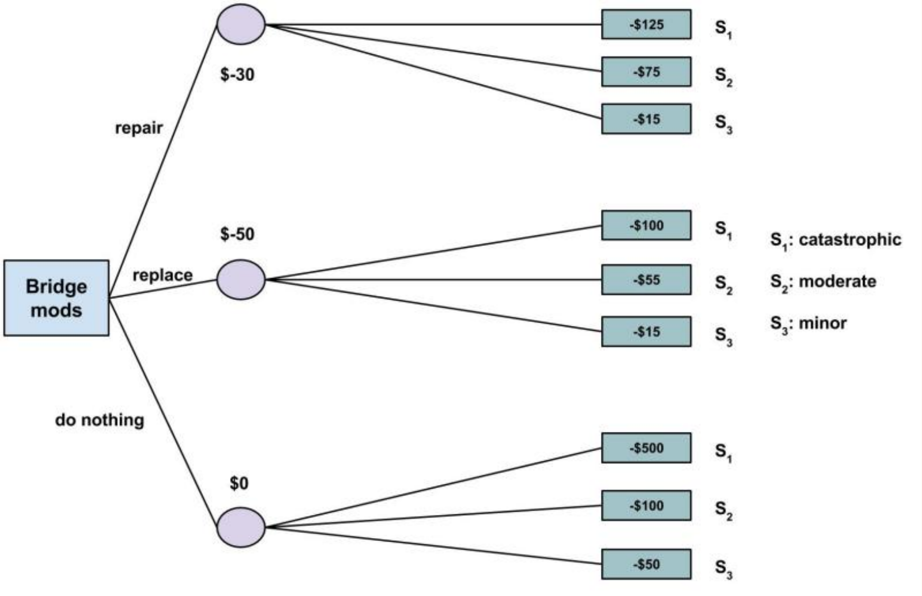
Higher fees paid by owner to reputable contractors

Higher charges by contractor for risky work

Lower returns from less risky investments

Warranty?

Bridge modifications


Bridge mods
repair
$-30
-$125
S1
-$75
S2
-$15
S3
replace
$-50
-$100
S1
-$55
S2
-$15
S3
S1: catastrophic
S2: moderate
S3: minor
do nothing
$0
-$500
S1
-$100
S2
-$50
S3

Upfront costs

What is the best decision for bridge modifications?

Maximize the minimum gain

Minimize the maximum loss

Maximize the maximum gain

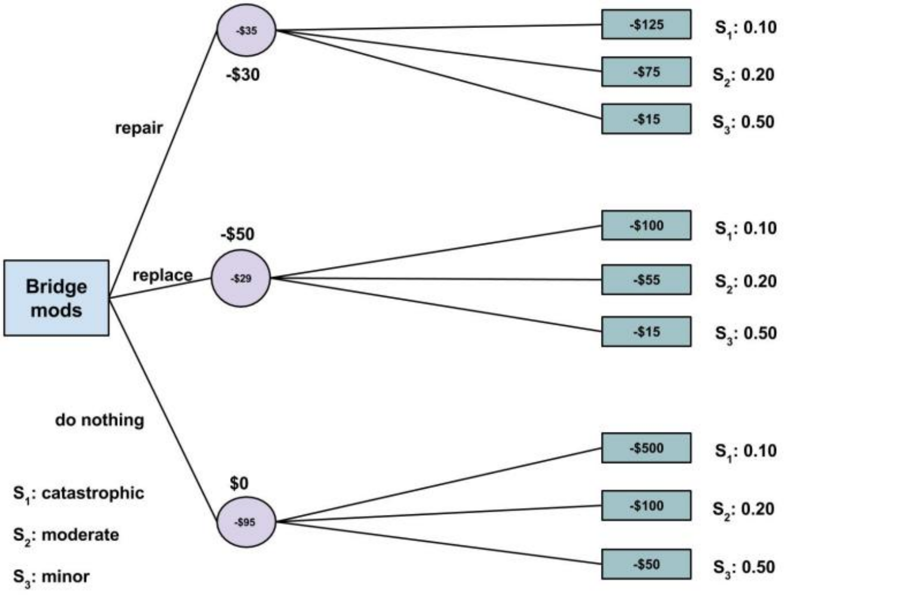
‘Do nothing’ decision must be included

30M cost to repair

50M cost to replace

Different losses based on the scenario and decision made

Expected value



Bridge mods
repair
-$35
-$30
replace
-$50
-$29
do nothing
$0
-$95
-$125
S$_1$: 0.10
-$75
S$_2$: 0.20
-$15
S$_3$: 0.50
-$100
S$_1$: 0.10
-$55
S$_2$: 0.20
-$15
S$_3$: 0.50
-$500
S$_1$: 0.10
-$100
S$_2$: 0.20
-$50
S$_3$: 0.50
S$_1$: catastrophic
S$_2$: moderate
S$_3$: minor

How does the use of expected value affect decision making?

The do nothing option has the largest loss

Going just by expected loss replacing the bridge is the best option

Are there other factors affecting the decision besides money?

What other metrics could be used?

For more complicated analysis, Bayes theory is often applied

Hurwicz criterion

Hurwicz criterion models a range of decision-making attitudes from conservative to optimistic

$$v(a_i, s_j) \equiv payoff \tag{2}$$

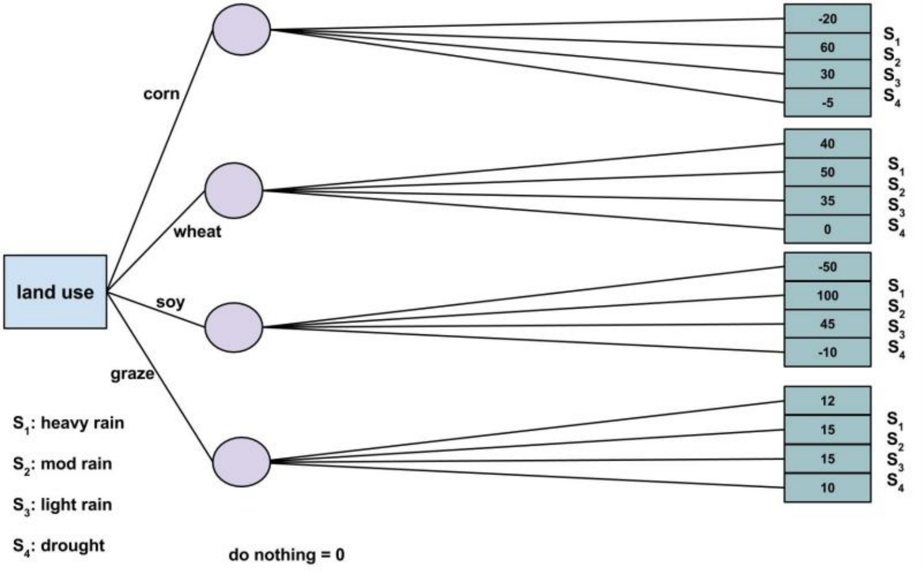
$$Max(\alpha \; max \; v(a_i, s_j) + (1 - \alpha) \; min \; v(a_i, s_j)) \tag{3}$$

$\alpha = 0$ – minimax; risk averse

$\alpha = 1$ – maximax; risk seeking

Maximize by taking the derivative and finding the optimality index and measure risk aversion

Land use


land use
corn
wheat
soy
graze
-20
60
30
-5
40
50
35
0
-50
100
45
-10
12
15
15
10
S_1
S_2
S_3
S_4
S_1: heavy rain
S_2: mod rain
S_3: light rain
S_4: drought
do nothing = 0

How can we determine the best option for land use?

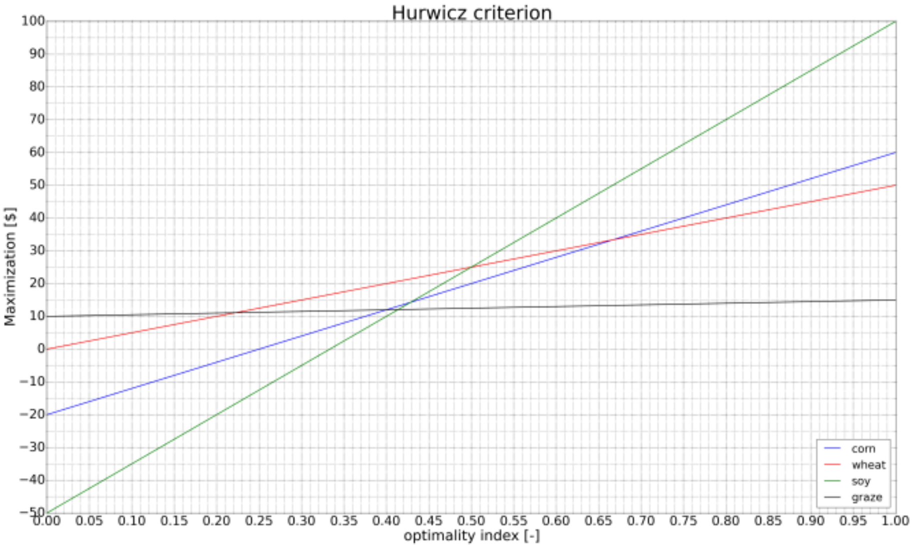
I did not include the do nothing option because I assumed doing nothing would result in zero for all scenarios, but there could be a lease on the land

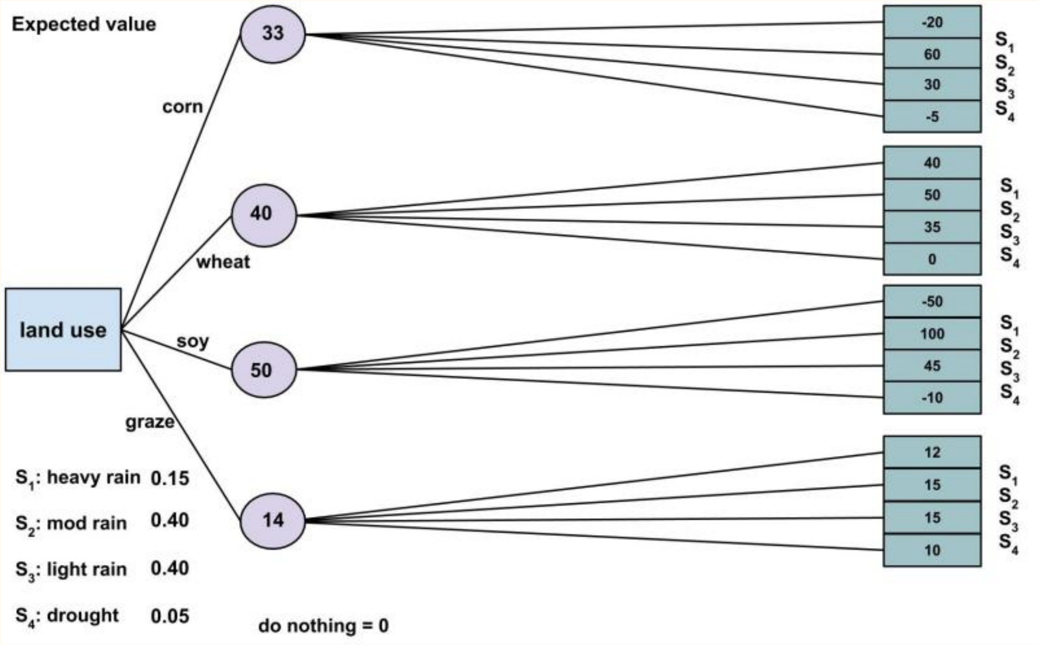
$$M(a_1) = 60\alpha - 20(1 - \alpha) \tag{4}$$

$$M(a_2) = 50\alpha - 0(1 - \alpha) \tag{5}$$

$$M(a_3) = 100\alpha - 50(1 - \alpha) \tag{6}$$

$$M(a_4) = 15\alpha - 10(1 - \alpha) \tag{7}$$


Hurwicz criterion
Maximization [$]
optimality index [-]
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
corn
wheat
soy
graze


Expected value
land use
corn
wheat
soy
graze
33
40
50
14
-20
60
30
-5
40
50
35
0
-50
100
45
-10
12
15
15
10
S_1
S_2
S_3
S_4
S_1: heavy rain 0.15
S_2: mod rain 0.40
S_3: light rain 0.40
S_4: drought 0.05
do nothing = 0

Utility theory

Uncertain prospects are worth less in utility terms than certain ones, even when expected tangible payoffs are the same

Flip a coin

heads = 10M

tails = -9M

E(G) = 0.5M

So it’s a high expected payoff – no way you play the game though

Flip a coin and get 2^n for every tails in a row

How much would you pay to buy in?

E(1 flip) = 1 dollar

E(2 flip) = 2 dollars

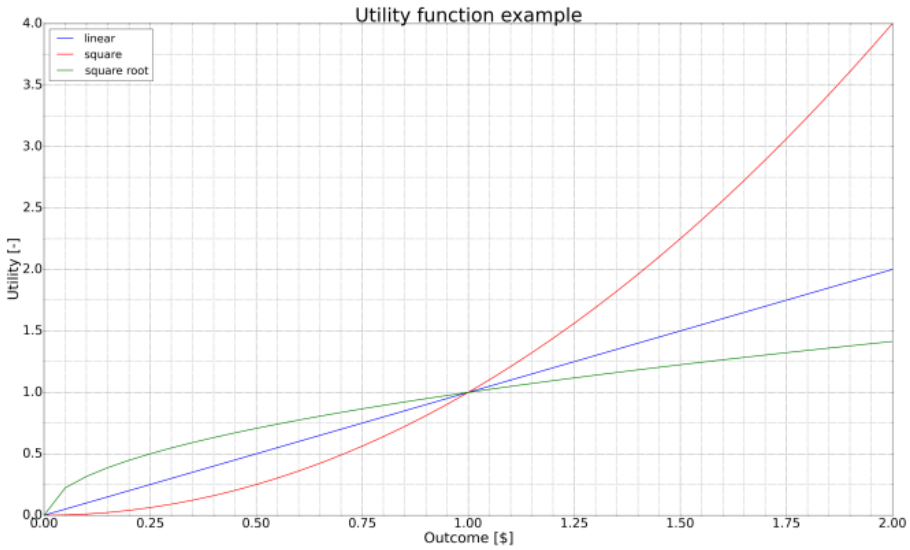
E(G) = infinite

St. Petersburg paradox

We want to be able to measure these preferences with sound models

Utility functions translate outcomes ($) into pure numbers to calculate certainty equivalents consistent with a decision maker's attitude toward risk taking

Utility of a consequence is a quantification of a person's relative preference for that consequence


Utility function example
linear
square
square root
Utility [-]
Outcome [$]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00

Expected utility

Utility theory can give a measure of your buy in

Consider a coin flip for a 2 dollar prize

Use expected utility instead of expected value

$$E(u) = 0.5\,u(0) + 0.5\,u(2) \tag{8}$$

$$u(x) = x \rightarrow E(u) = 1 \tag{9}$$

$$u(x) = x^2 \rightarrow E(u) = 2 \tag{10}$$

$$u(x) = \sqrt{x} \rightarrow E(u) = 0.71 \tag{11}$$

Expected utility for risk seeker is higher

Take the inverse of the utilities to determine your buy in

$$f(E(u)) \equiv u^{-1} \tag{12}$$

$$f(1) = 1 \tag{13}$$

$$f(2) = 1.41 \tag{14}$$

$$f(0.71) = 0.50 \tag{15}$$

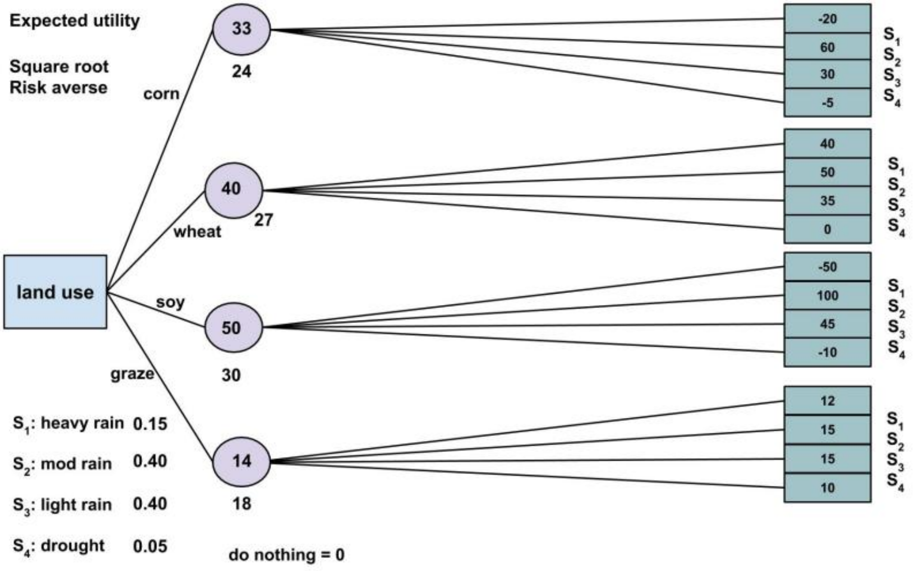
Buy in is based on level of personal risk

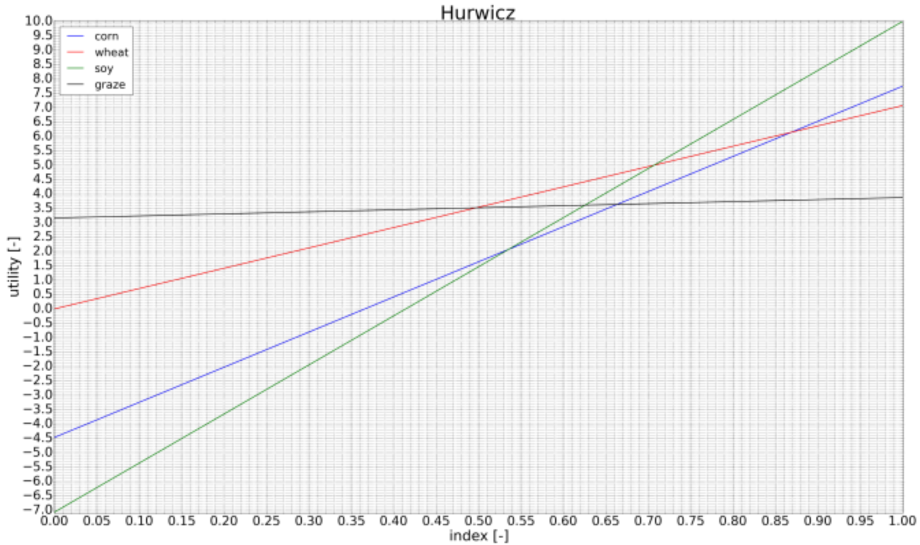
Data fitting

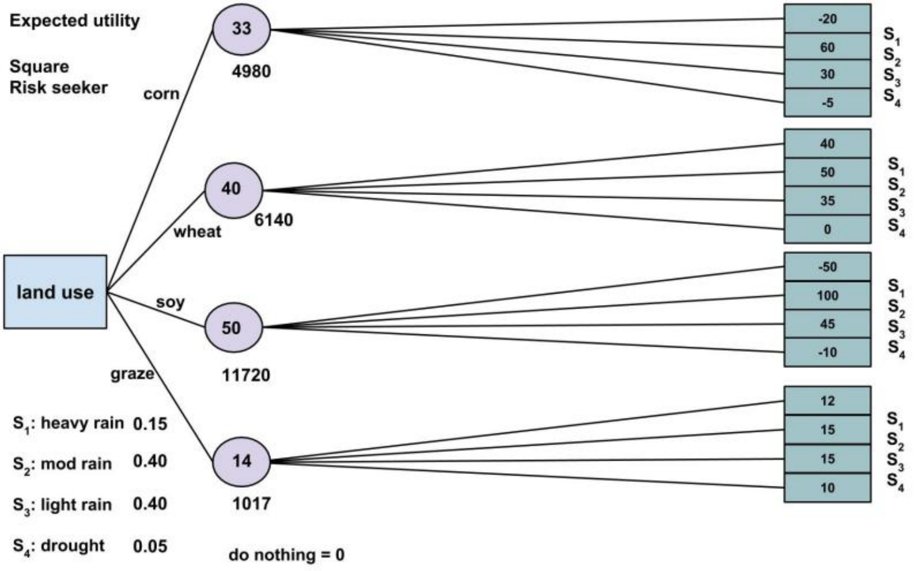
Derive a utility function by data fit to determine risk level

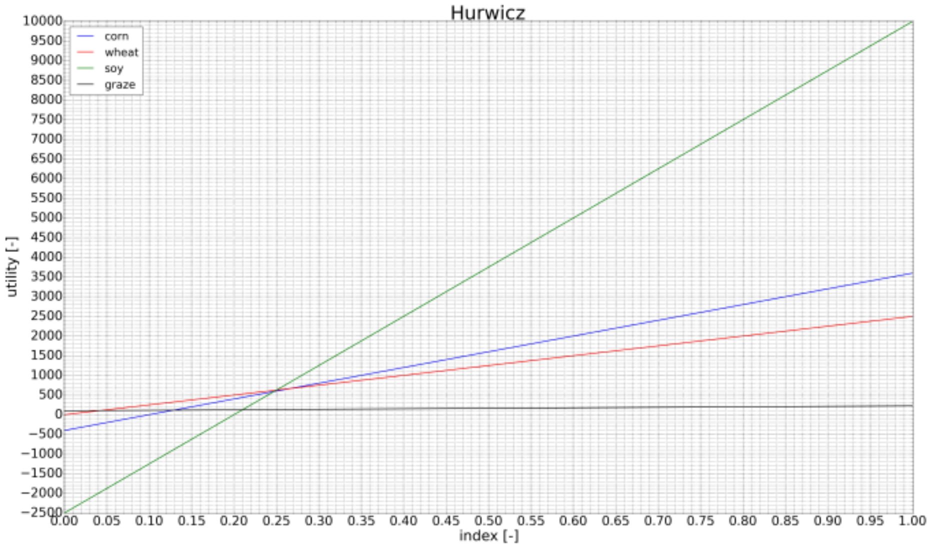
$$\begin{aligned} \pi(x) &\equiv a\,u(x) + b \\ 0 \leq \pi &\leq 1 \\ a &> 0 \end{aligned} \tag{16}$$

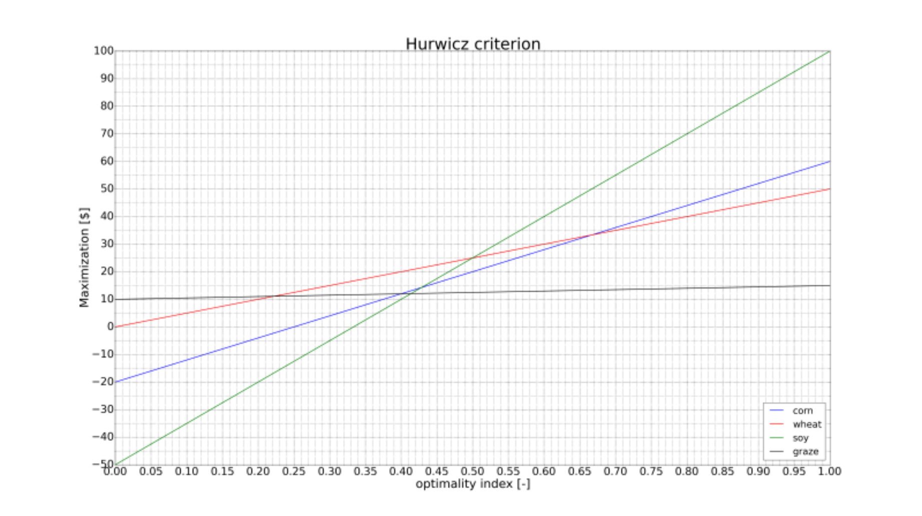
Revisit land use


Expected utility
Square root
Risk averse
corn
33
24
-20
60
30
-5
S1
S2
S3
S4
40
27
wheat
40
50
35
0
land use
soy
50
30
-50
100
45
-10
graze
14
18
12
15
15
10
S1: heavy rain 0.15
S2: mod rain 0.40
S3: light rain 0.40
S4: drought 0.05
do nothing = 0


Hurwicz
corn
wheat
soy
graze
utility [-]
index [-]
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
−4.0
−4.5
−5.0
−5.5
−6.0
−6.5
−7.0
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00


Expected utility
Square
Risk seeker
land use
corn
wheat
soy
graze
33
4980
40
6140
50
11720
14
1017
-20
60
30
-5
40
50
35
0
-50
100
45
-10
12
15
15
10
S1
S2
S3
S4
S1: heavy rain 0.15
S2: mod rain 0.40
S3: light rain 0.40
S4: drought 0.05
do nothing = 0


Hurwicz
corn
wheat
soy
graze
utility [-]
index [-]
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
−500
−1000
−1500
−2000
−2500
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00


Hurwicz criterion
Maximization [$]
optimality index [-]
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
corn
wheat
soy
graze

Arrow-Pratt coefficient

The Arrow-Pratt coefficient measures risk aversion

$$r_A(x) \equiv -\frac{u''(x)}{u'(x)} \tag{17}$$

$$u(x) = x^2 \rightarrow r_A(x) = -\frac{1}{x} \tag{18}$$

$$u(x) = \sqrt{x} \rightarrow r_A(x) = \frac{1}{2x} \tag{19}$$

$$u(x) = 1 - e^{-\lambda x} \rightarrow r_A(x) = \lambda \tag{20}$$

Who is the most risk averse?

What is risk aversion like as wealth increases?

r_A is positive for risk averse individuals

Measure of curvature of preference scaling function

Certainty equivalent is less for the more curved function

Square root, Weibull, power law, ln(x) are common risk averse utility functions

The higher coefficient, the more favorable odds the investor will demand in order to be willing to accept the risky bet

Multiple attributes

What happens when you have to measure utility for multiple attributes?

$u(x_1, x_2, x_3, ..., x_n)$

Previously we have been trying to find the utility of wealth

What else would we want to characterize in terms of utility?

$$u(x_1, x_2, x_3, \ldots, x_n) = \sum_{i=1}^{n} w_i \; u_i(x_i) \; 0 \leq w_i \leq 1 \tag{21}$$

Assumes independence of attributes (preferences) and linearity

Postulate assumptions about the preference attitudes of the decision maker

Derive functional forms of multiattribute utility function consistent with assumptions

Analytical Hierarchy Process (AHP)

AHP is a multiattribute decision analysis method that uses subjective judgments

Decision-making with the AHP

The analytic hierarchy process – what it is and how it is used

Alternate approach to expected utility

Really good for multi criteria

Identify goal

Establish criteria affecting goal

Derive factors affecting each criteria

Generate alternatives

AHP procedure

Make pairwise comparisons with alternatives under each criteria

Make a relative assessment between two items at a time (only 2)
Use objective information if possible

1 – elements are equally important
3 – one element is weakly more important
5 – one element is strongly more important
7 – one element is demonstrably important
9 – one element is absolutely more important
Values of 2,4,6,8 are compromises between defined categories

Then arrange values into a matrix

AHP is fairly qualitative and requires kind of expert judgment

Derive consistency ratio less than 0.100

AHP does not require perfect consistency

Provides a measure of consistency

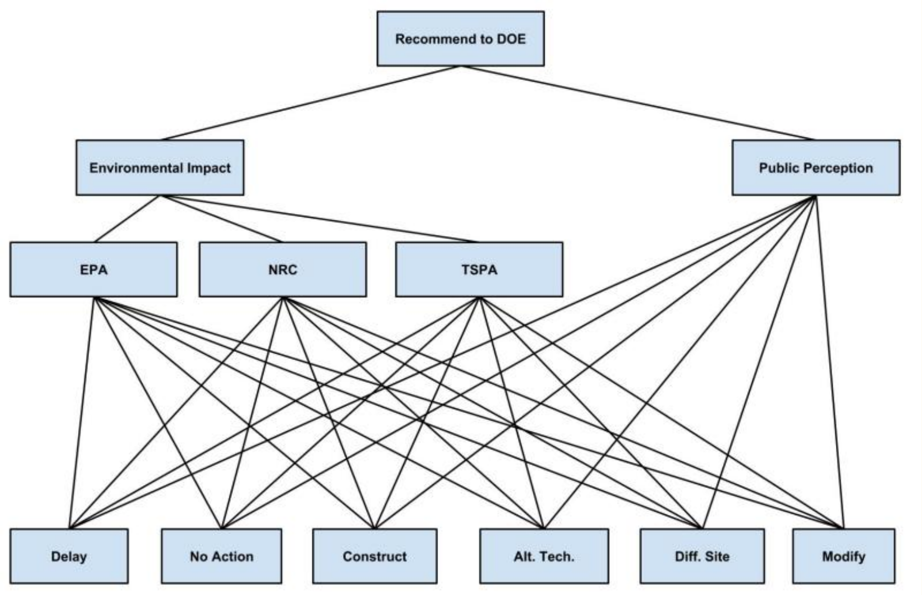
Develop weights based on criteria and score each alternative

Saaty suggests that hierarchies be limited to six levels and nine items per level.

Psychological result that people can consider 7 +/- 2 items simultaneously

You can actually compare apples and oranges so tell people to shut up when they say that

Yucca mountain


Recommend to DOE
Environmental Impact
Public Perception
EPA
NRC
TSPA
Delay
No Action
Construct
Alt. Tech.
Diff. Site
Modify

This first try was overly complicated

Goal – recommendation to DOE
Criteria – environmental impact and public perception
Under environmental impact I put EPA, NRC compliance

Alternatives
Delay – delay to accept and construct
No action – do nothing
Alt. Tech. – alternative technologies (didn't consider CISFs at the time)
Diff. site – start over with a different site
Modify – modify repository design (drip shield, backfill)

Five criteria and six alternatives is a lot of pairwise comparisons

Simplify this diagram

Could lead to high inconsistency

No action 1

Onsite storage under institutional control for 10000 y

No action 2

Onsite storage under institutional control for 100 y

Combine delay and modify so they can modify existing design while delaying shipments

In hindsight, with CISFs, this would change a lot

$$\begin{array}{cc} & \begin{array}{cc} ENV & PP \end{array} \\ \begin{array}{c} ENV \\ PP \end{array} & \begin{bmatrix} 1 & 1/3 \\ 3 & 1 \end{bmatrix} \end{array} \tag{22}$$

$$\begin{bmatrix} ENV \\ PP \end{bmatrix} = \begin{bmatrix} 0.25 \\ 0.75 \end{bmatrix} \tag{23}$$

$$
\begin{bmatrix}
ENV & NA1 & NA2 & ALT & DIF & CST & D/M & EIG \\
NA1 & 1 & 5 & 3 & 3 & 2 & 1/2 & 0.2572 \\
NA2 & 1/5 & 1 & 1/3 & 1/3 & 1/3 & 1/5 & 0.0464 \\
ALT & 1/3 & 3 & 1 & 1 & 1/2 & 1/3 & 0.0997 \\
DIF & 1/3 & 3 & 1 & 1 & 1/3 & 1/3 & 0.0950 \\
CST & 1/2 & 3 & 2 & 3 & 1 & 1/2 & 0.1766 \\
D/M & 2 & 5 & 3 & 3 & 2 & 1 & 0.3251
\end{bmatrix} \tag{24}
$$

$CI = \frac{6.1789-6}{6-1} = 0.0358$

$CR = 0.289$

$$
\begin{bmatrix}
PP & NA1 & NA2 & ALT & DIF & CST & D/M & EIG \\
NA1 & 1 & 5 & 3 & 5 & 1 & 1/3 & 0.2392 \\
NA2 & 1/5 & 1 & 1/2 & 1/2 & 1/2 & 1/5 & 0.0551 \\
ALT & 1/3 & 2 & 1 & 1/2 & 1/2 & 1/3 & 0.0825 \\
DIF & 1/5 & 2 & 2 & 1 & 1/3 & 1/3 & 0.0930 \\
CST & 1 & 2 & 2 & 3 & 1 & 1/2 & 0.1803 \\
D/M & 3 & 5 & 3 & 3 & 2 & 1 & 0.3500
\end{bmatrix} \tag{25}
$$

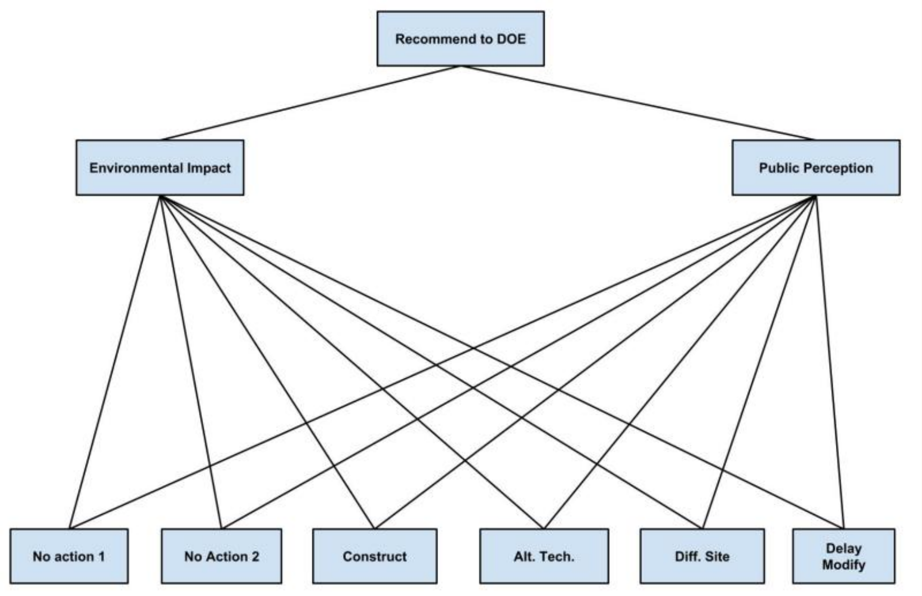
$CI = \frac{6.3716-6}{6-1} = 0.0743$

$CR = 0.599$

$$\begin{bmatrix} PP : ENV\ (3:1) & EIG \\ NA1 & 0.242 \\ NA2 & 0.055 \\ ALT & 0.090 \\ DIF & 0.098 \\ CST & 0.178 \\ D/M & \mathbf{0.338} \end{bmatrix} \tag{26}$$

$$
\begin{bmatrix}
PP : ENV\,(1:1) & EIG \\
NA1 & 0.247 \\
NA2 & 0.052 \\
ALT & 0.094 \\
DIF & 0.097 \\
CST & 0.177 \\
D/M & \mathbf{0.332}
\end{bmatrix}
\tag{27}
$$

$$\begin{bmatrix} PP : ENV\ (1:3) & EIG \\ NA1 & 0.251 \\ NA2 & 0.050 \\ ALT & 0.097 \\ DIF & 0.097 \\ CST & 0.177 \\ D/M & \mathbf{0.328} \end{bmatrix} \tag{28}$$


Recommend to DOE
Environmental Impact
Public Perception
No action 1
No Action 2
Construct
Alt. Tech.
Diff. Site
Delay
Modify

This AHP is more straightforward

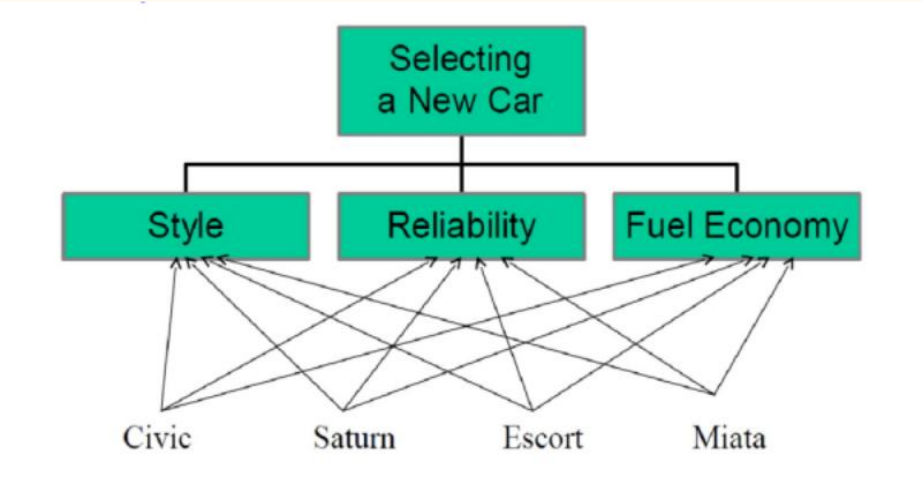
NRC criterion removed because it kicks in after construction

EPA criterion folded into Environmental Impact

No action split into 1 and 2 based on analysis of environmental impact statement

Delay and Modify can be combined

Buying a car


Selecting a New Car
Style
Reliability
Fuel Economy
Civic
Saturn
Escort
Miata

Anything missing?

Derive AHP pairwise matrix

$$
\begin{array}{c c}
 & \begin{array}{ccc} A1 & A2 & A3 \end{array} \\
\begin{array}{c} A1 \\ A2 \\ A3 \end{array} &
\begin{bmatrix}
a_{11} & a_{12} & a_{13} \\
a_{21} & a_{22} & a_{23} \\
a_{31} & a_{32} & a_{33}
\end{bmatrix}
\end{array}
\tag{29}
$$

$$a_{ii} = 1$$

$$a_{ij} = a_{ji}^{-1}$$

Make pairwise comparisons

	Style	Reliability	Fuel Economy
Style	1/1	1/2	3/1
Reliability	2/1	1/1	4/1
Fuel Economy	1/3	1/4	1/1

Calculate weights

$$\begin{bmatrix} STY \\ REL \\ FE \end{bmatrix} = \begin{bmatrix} 0.3196 \\ 0.5584 \\ 0.1220 \end{bmatrix} \tag{30}$$

Let’s check the consistency of the criteria

$$CI = \frac{3.0183 - 3}{3 - 1} = 0.0091$$
$$CR = 0.158$$

Divide below for n criteria

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

To rank the criteria, determine the eigenvector

$$\underline{\underline{A}}\,\underline{x} = \lambda \underline{x} \tag{31}$$

$$|A - \lambda I| = 0 \tag{32}$$

Find *normalized* eigenvector for greatest eigenvalue (real valued)

Eigenvalue should be slightly $> n$

python of course (one line of code) but plenty of online tools

There are n eigenvalues/vectors for an n x n matrix

Because the judgment cannot be truly consistent, we assume it exhibits a small perturbation and can satisfy the eigenvalue equation

Measure consistency to prove this

Deviation should only be small

Ranking Alternatives

Style	Civic	Saturn	Escort	Miata
Civic	1	1/4	4	1/6
Saturn	4	1	4	1/4
Escort	1/4	1/4	1	1/5
Miata	6	4	5	1

Priority vector

$$\begin{bmatrix} 0.13 \\ 0.24 \\ 0.07 \\ 0.56 \end{bmatrix}$$

Reliability	Civic	Saturn	Escort	Miata
Civic	1	2	5	1
Saturn	1/2	1	3	2
Escort	1/5	1/3	1	1/4
Miata	1	1/2	4	1

$$\begin{bmatrix} 0.38 \\ 0.29 \\ 0.07 \\ 0.26 \end{bmatrix}$$

Fuel Economy		Miles/gallon	Normalized
	Civic	34	.30
	Saturn	27	.24
	Escort	24	.21
	Miata	28	.25

$$
\begin{array}{c}
\\ \text{Civic} \\ \text{Saturn} \\ \text{Escort} \\ \text{Miata}
\end{array}
\begin{array}{c}
\begin{array}{ccc} \text{Style} & \text{Reliability} & \text{Fuel Economy} \end{array} \\
\begin{bmatrix} .13 & .38 & .30 \\ .24 & .29 & .24 \\ .07 & .07 & .21 \\ .56 & .26 & .25 \end{bmatrix}
\end{array}
\times
\begin{bmatrix} .30 \\ .60 \\ .10 \end{bmatrix}
=
\begin{bmatrix} .30 \\ .27 \\ .08 \\ .35 \end{bmatrix}
$$

Priority matrix

Factor Weights

Then for some reason they brough in cost at the end

	Cost	Normalized Cost	Benefits	Cost/Benefits Ratio
CIVIC	$12K	.22	.30	0.73
SATURN	$15K	.28	.27	1.04
ESCORT	$ 9K	.17	.08	2.13
MIATA	$18K	.33	.35	0.94

Do not agree

No pairwise comparison of cost with other criteria

Apartment

Variable list

WC – walk to campus - 30 min
RC – ride to campus - 15 min
WG – walk to groceries - 15 min
RG – ride to groceries
WIC – walk in closet
2U – 2 utilities included
NOU – no utilities included
2+U – more than 2 utilities included
ES – extra storage

R1 – 600 - 699
R2 – 700 - 799
R3 – 800 - 899
S1 – 250 - 349 sq ft
S2 – 350 - 449 sq ft
S3 – 450+ sq ft
MISC – quality, laundry, etc.

	WC	RC	WG	RG	WIC	2U	NOU	2+U	ES	R1	R2	R3	S1	S2	S3	MISC
WC	1.00	5.00	0.20	1.00	0.20	0.20	2.00	0.14	0.20	0.20	0.33	2.00	2.00	0.33	0.20	0.33
RC	0.20	1.00	0.20	2.00	0.33	0.33	1.00	0.14	0.33	0.33	0.50	2.00	2.00	0.50	0.33	0.33
WG	5.00	5.00	1.00	5.00	0.33	0.33	2.00	0.20	0.33	0.50	3.03	4.00	2.00	1.00	2.00	0.50
RG	1.00	0.50	0.20	1.00	0.20	0.14	1.00	0.14	0.33	0.20	3.03	3.03	3.03	0.33	0.33	0.33
WIC	5.00	3.00	3.00	5.00	1.00	0.50	3.03	0.20	1.00	0.33	2.00	3.33	5.00	3.03	3.03	2.00
2U	5.00	3.00	3.00	7.00	2.00	1.00	3.03	0.20	3.03	2.00	3.03	5.00	2.00	3.03	3.03	2.00
NOU	0.50	1.00	0.50	1.00	0.33	0.33	1.00	0.14	3.03	3.03	0.20	0.14	0.33	0.33	0.33	0.33
2+U	7.00	7.00	5.00	7.00	5.00	5.00	7.00	1.00	5.00	3.03	5.00	5.00	5.00	5.00	5.00	5.00
ES	5.00	3.00	3.00	3.00	1.00	0.33	0.33	0.20	1.00	0.33	2.00	5.00	0.20	0.33	0.33	3.03
R1	5.00	3.00	2.00	5.00	3.00	0.50	0.33	0.33	3.00	1.00	3.03	5.00	5.00	5.00	5.00	3.03
R2	3.00	2.00	0.33	0.33	0.50	0.33	5.00	0.20	0.50	0.33	1.00	3.03	3.03	3.03	3.03	3.03
R3	0.50	0.50	0.25	0.33	0.30	0.20	7.00	0.20	0.20	0.20	0.33	1.00	0.20	0.20	0.20	0.20
S1	0.50	0.50	0.50	0.33	0.20	0.50	3.00	0.20	5.00	0.20	0.33	5.00	1.00	0.33	0.33	0.33
S2	3.00	2.00	1.00	3.00	0.33	0.33	3.00	0.20	3.00	0.20	0.33	5.00	3.00	1.00	0.33	0.33
S3	5.00	3.00	0.50	3.00	0.33	0.33	3.00	0.20	3.00	0.20	0.33	5.00	3.00	3.00	1.00	2.00
MISC	3.00	3.00	2.00	3.00	0.33	0.50	3.00	0.20	0.33	0.33	0.33	5.00	3.00	3.00	0.50	1.00

$$n = 16$$
$$CI = 0.327148$$
$$\lambda_m = 20.907222$$
$$CR = 0.2046$$

$$\underline{\lambda} = \begin{bmatrix} 0.084582 \\ 0.075686 \\ 0.190081 \\ 0.073716 \\ 0.271129 \\ 0.335294 \\ 0.123018 \\ 0.657367 \\ 0.179078 \\ 0.355715 \\ 0.195451 \\ 0.080527 \\ 0.127037 \\ 0.155506 \\ 0.197643 \\ 0.172291 \end{bmatrix} \tag{33}$$

Normalized eigenvector

WC – 0.025834
RC – 0.023116
WG – 0.058055
RG – 0.022515
WIC – 0.082810
2U – 0.102407
NOU – 0.037573
2+U – 0.200777
ES – 0.054695

R1 – 0.108644
R2 – 0.059696
R3 – 0.024595
S1 – 0.038800
S2 – 0.047496
S3 – 0.060365
MISC – 0.052622

Fuzzy logic

Fuzzy (set theory) logic captures the truth in ‘usually’

Boolean logic states that a concept is either true or false – $1 \equiv \textit{true}$, $0 \equiv \textit{false}$

Fuzzy logic posits that a concept possesses a degree of truth varying between 0 and 1

Applicable to vague, or subjectively judged, concepts

The coffee is hot

It could be scorching or mildly hot

Fuzzy logic represents uncertain information

Focuses on formal principles of approximate reasoning or imprecise modes of reasoning

Captures uncertainty inherent in subjective judgements

Procedure

Define linguistic variables

Very High, High, Moderate, Low, Very Low

Or the AHP scale

Map the linguistic variables to membership functions

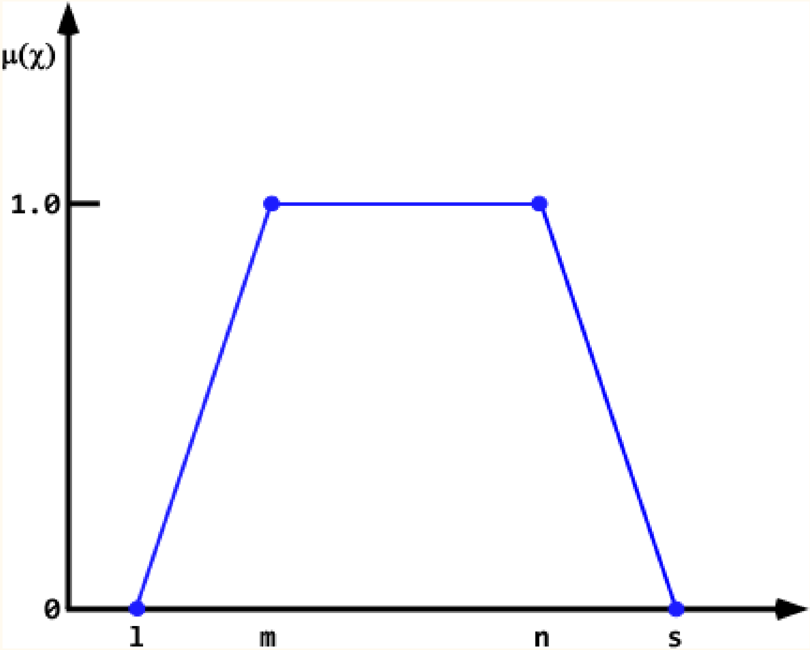
Used when there are a lot of people making judgements

Fuzzy rules (if-then) are derived if needed

If X is Low and Y is High, then the result is Moderate, etc., for all the combinations

$$\tilde{\chi} \equiv (l, m, n, s) \tag{34}$$

$$\mu(\chi) = \begin{cases} 0 & \chi < l \\ \frac{\chi - l}{m - l} & l \leq \chi \leq m \\ 1 & m \leq \chi \leq n \\ \frac{s - \chi}{s - n} & n \leq \chi \leq s \\ 0 & \chi > s \end{cases} \tag{35}$$


μ(χ)
1.0
0
l
m
n
s

Mapping the five point scale

Very high – (4,4.5,5,5) (7,8,9,10)

High – (3,3.5,4.5,5) (5,6,7,8)

Moderate – (2,2.5,3.5,4)(3,4,5,6)

Low – (1,1.5,2.5,3) (1,2,3,4)

Very Low – (1,1,1.5,2) (0,1,2,3)

More math

Typically, take the geometric mean of the membership functions to aggregate them into a single membership function

Take the centroid of the function to obtain the final ‘crisp number’

The end result could just be a ranking of criteria, measure of risk, etc.

The fuzzy math takes into account the uncertainties in the judgements

Fuzzy AHP

Risk perception and communication

Effective communication of risk involves understanding risk perception

What we had done to these people was just outrageous. We had frightened them so bad, they thought they were going to die.
–NRC official describing government communication during Three Mile Island

Public perceives and responds to risky situations based on emotion in addition to facts (which is fine)

Sabine Roeser is the expert in the role of emotion and risk

Emotion is a rational process

Nuclear risk is the most difficult risks and nuclear experts have to be the most socially literate

Emotion can play a bigger role in the way people perceive risks, than reason and rational thinking.
–Paul Slovic, Affect heuristic

Emerging technologies exhibit a different paradigm and require different approaches

I don’t like use of ‘the public’ because it frames a us v them mentality

Aren’t we all the public

Nuclear engineering is unique because of ‘historical inertia’

The unleashed power of the atom has changed everything except our modes of thinking, and thus we drift toward unparalleled catastrophes. We shall require a substantially new manner of thinking if humanity is to survive.
–Einstein, August 1964 New York Times Magazine

Consensus is tricky. Disagreement has always been a part of science. However, I find now that in the era of ‘armchair’ science - many people just don’t understand the scientific process, the peer-review process, etc. They see thing more like a legal system and reasonable doubt. If there is reasonable doubt or slight uncertainty, they think the basic scientific premise is flawed. Science doesn’t work that way.
–Marshall Shepherd, 2013 President American Meteorological Society

Complaining about it isn’t fixing it

Nuclear and radiological risks feel more frightening to the public

If they don’t feel ‘safe’ then they aren’t safe so it doesn’t matter what the facts are

These characteristics must be acknowledged in order to effectively manage public behavior (slide 6)

Ridiculously arrogant and could not be more wrong

Meet people where they are

What is important to others may not be what you think it is

What affects risk perception?

Media attention
Familiarity
Scientific certainty
History or historical inertia
Reversibility
Trust
Benefits
Fairness of risk distribution
Nature of risk
Catastrophic potential v chronic (low probability/high consequence – high probability/low consequence)
Uncertainty
Fear
Influence on children and future generations

What else affects risk perception?

Voluntary v involuntary risk

Driving a car v flying even though flying is lower risk and the airlines are organized crime syndicates

The risk manager must . . . deal not only with risk perceived through science, but also with virtual risk – risks where the science is inconclusive and people are thus liberated to argue from, and act upon, preestablished beliefs, convictions, prejudices and superstitions. (Risk Management Magazine)

Establishing trust is the primary factor in effective communication

Admit when mistakes have been made

Avoid secrets

Dialogue and respect for audience feelings must be sincere

Veracity = sincere AND honest

Oh, I'm just being honest. No, you're being a bag.

Do not tell people how they should feel

That makes me feel angry!

Do not over reassure either though

CDC recommends preparing for the following risk questions when dealing with the public

Why did this happen?

Why wasn’t this prevented?

What else can go wrong?

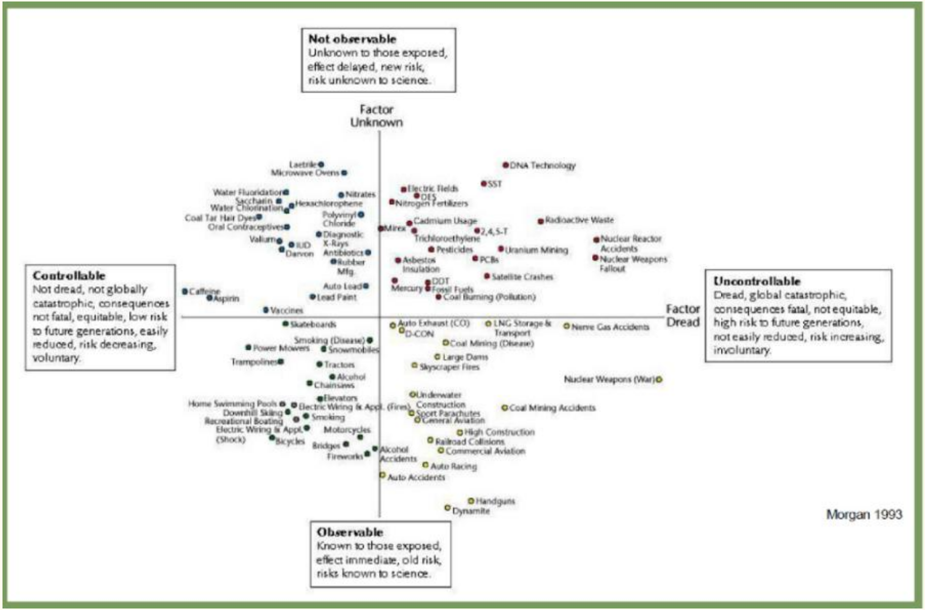
When were you notified about this?

What does this information mean?

How are ill going to get help?

What can we expect?

What bad things aren’t you telling us?


Not observable
Unknown to those exposed, effect delayed, new risk, risk unknown to science.
Factor Unknown
Controllable
Not dread, not globally catastrophic, consequences not fatal, equitable, low risk to future generations, easily reduced, risk decreasing, voluntary.
Uncontrollable
Dread, global catastrophic, consequences fatal, not equitable, high risk to future generations, not easily reduced, risk increasing, involuntary.
Factor Dread
Observable
Known to those exposed, effect immediate, old risk, risks known to science.
Laetrile
Microwave Ovens
Water Fluoridation
Saccharin
Water Chlorination
Hexachlorophene
Nitrates
Coal Tar Hair Dyes
Oral Contraceptives
Polyvinyl Chloride
Diagnostic X-Rays
Valium
IUD
Darvon
Antibiotics
Rubber Mfg.
Caffeine
Aspirin
Auto Lead
Lead Paint
Vaccines
DNA Technology
SST
Electric Fields
DES
Nitrogen Fertilizers
Cadmium Usage
Mirex
Trichloroethylene
2,4,5-T
Radioactive Waste
Nuclear Reactor Accidents
Nuclear Weapons Fallout
Pesticides
Uranium Mining
Asbestos Insulation
PCBs
Satellite Crashes
Mercury
DDT
Fossil Fuels
Coal Burning (Pollution)
Skateboards
Smoking (Disease)
Power Mowers
Snowmobiles
Trampolines
Tractors
Alcohol
Chainsaws
Elevators
Home Swimming Pools
Electric Wiring & Appl. (Fires)
Downhill Skiing
Recreational Boating
Smoking
Electric Wiring & Appl. (Shock)
Motorcycles
Bicycles
Bridges
Fireworks
Alcohol Accidents
Auto Exhaust (CO)
D-CON
LNG Storage & Transport
Nerve Gas Accidents
Coal Mining (Disease)
Large Dams
Skyscraper Fires
Nuclear Weapons (War)
Underwater Construction
Sport Parachutes
General Aviation
Coal Mining Accidents
High Construction
Railroad Collisions
Commercial Aviation
Auto Racing
Auto Accidents
Handguns
Dynamite
Morgan 1993

No single level of risk that society finds acceptable

This is why there are regulations, but people may not accept that either

Risks that society is prepared to accept or tolerate will vary from situation to situation

Localities v Las Vegas for Yucca Mountain

Just about every waste repository case was a failure in communication – Japan, South Korea

Community needs to be involved – Finland, Sweden

Long time scales, irreversibility, complexity hard to communicate

Learning how to talk to people isn't so easy

Talk local and personal

Talk about concrete facts and issues, not abstract

Talk about what is happening now, not later

Emphasize trade offs with risks and benefits

Talk about increasing consequences if delaying and doing nothing – If that's actually true

Talk about manageable solutions

Meet people where they are

Social scientists are critically important – DOE CISF funding was social science-led. Shocker.

EPA has seven cardinal rules of risk communication

Accept and involve the public as a legitimate partner

Listen to the audience – Meet people where they are

Be honest, frank, and open – Veracity

Coordinate and collaborate with other credible sources

Meet the needs of the media

Speak clearly and with compassion – Not everyone can do this

Plan carefully and evaluate performance