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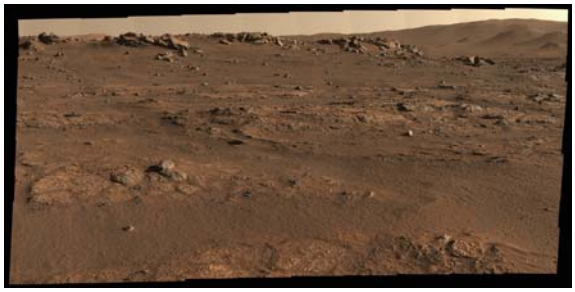
Welcome to ISE 562!



Decision Analysis

Note 1

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- How do you make decisions?
  - Flip a coin?
  - Procedure?
    - Pick the cheapest option?
    - Select the alternative you *wish* or *hope* would be the best?
    - Look for published reviews?
    - Maximize positive impacts?
    - Minimize negative impacts?
    - Combination of good and bad?
    - Pick the choice that others will like?
  - What if all the alternatives are bad?
- Benjamin Franklin's approach?

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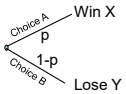
How do you make decisions?

How do you know if *you* made the right choice for *you*? (1min)

What about recommending a choice for your organization?

"We are all slaves to to a matrix of uncertainty." (Dr S)



Decisions occur within a matrix of uncertainty. Often we cannot know the full truth of the data, the outcomes or the consequences.

Choosing to understand and quantify uncertainty will get us closer to the truth…

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- Introductions
  - You
  - Me
- Syllabus
  - See Blackboard for:
    - Announcements, scores
    - Content: lecture notes

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- Syllabus
  - Importance of this course
  - Course Description
  - Suggestions for success
  - Course Prerequisites
  - Course Goal
  - Text
  - Course Requirements and Grading
  - Office Hours
  - Academic Integrity
  - Disability Accomodation
  - Emergency preparedness

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Importance of this course:

- Making choices
  - Individual and time-staged decisions
  - Decisions involving one criterion or multiple criteria
  - Decisions made by a group or multiple groups of decision makers
- Value
  - Defining metrics to quantify the value of alternatives
- Decision biases
  - All the things that can go wrong (and how to spot and prepare for them)

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Course Description

Chapter 1,2, Probability Review	Basic concepts, definitions of probability
Chapter 3, Discrete Bayes Methods	Decision making distributions for discrete random variables
Chapter 4, Continuous Bayes Methods	Decision making distributions for continuous random variables
Chapter 5, Decision Theory, Introduction to Utility Functions	Structuring decision problems
Chapter 6, Value of Information	EVPI, EVSI
Multiattribute decision analysis	Multiple decision variables
Group decision making	Group decision rules
Decision biases	Psychological and behavioral decision issues; framing

What is meant by “decision analysis approach?”

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Decision analysis:

- Application of a framework that identifies an optimal preferred choice which includes a set of alternatives, measurable criteria for the alternatives, and payoffs for the consequences (fixed or uncertain).

This course is about decision making procedures which are not unlike recipes:

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Suggestions for Success:

- Read over the reading assignments before the corresponding lecture.
- Attempt the homework on your own before asking for help.
- Make an honest attempt to understand the material before uttering the words, "I don't get this."
- If having difficulty, see TA or me—we are here to help you.

- *Don't wait until the last minute for anything!*

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Prerequisites:

- A course in probability and statistics
- Working knowledge of algebra; some calculus

Course Goal:

- *Enable the student to formulate, collect, analyze, frame, and interpret decision making information for selecting the "best" alternative action.*

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Text: Winkler, Robert L.,
An Introduction to Bayesian Inference and Decision, Second Edition,
Probabilistic Publishing, Inc., Gainesville, Florida, 2003.

(Note: exams will be open book)

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Course requirements:

Requirement	Point Total
3 Homework assignments @ 10 points	30
Midterm Exam	25
Project*	20
Final Exam	25
Course Total	100

*Miniproject requirements outlined in early April

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Contacts/Office Hours:
Dr S: After class, by zoom appt, or email.
Office: GER ISE hoteling area
Email: jeffs@usc.edu for general communications

TA-Tuesday lec: Tian Qiu
TA-Wednesday lec: Tejaswin Shashikanth
Office hours: TBD

Homework submissions to:
Tuesday class use ise562hwTues@gmail.com
Wednesday class use ise562hw@gmail.com

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Assignment Submissions:

1. You will be randomly paired with another student partner for each homework to submit the assignment jointly.
2. Submit one file for both of you by the due date.
3. Can be pdf's, camera phone pics of handwritten text (multiple pages in ONE file), MS Word, or Excel files.
4. Make sure assignment number and your names are in the file name and in the file. For example:
   - *Hw1_lastname1-firstname1_ lastname2-firstname2.xlsx, docx, pdf*
5. Put your names *inside* the file in case you forget 4.
6. Email the assignment to ise562hwTues@gmail.com (Tuesday section) or ise562hw@gmail.com (Wednesday sections) with the assignment number in the subject line:

*Hw1_lastname1-firstname1_ lastname2-firstname2.****[pdf, xlsx, etc.]

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- Academic Integrity
- Disability accommodation
- Emergency preparedness

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- Tuesday Schedule

Date	Topic	Readings	Assignments/Notes
Tuesday Aug 23	Introduction, Review	Chapter 1, 2	
Tuesday Aug 30	Discrete Bayes Methods	Chapter 3	
Tuesday Sep 6	Continuous Bayes Methods	4.1- 4.9	
Tuesday Sep 13	Decision making criteria and Utility	5.1 - 5.8	
Tuesday Sep 20	Utility concepts	5.9-5.10	HW1 due
Tuesday Sep 27	The Decision Problem, Midterm review	5.9 - 5.10	
Tuesday Oct 4	Midterm		
Tuesday Oct 11	Value of Perfect Information	6.1 - 6.2	
Tuesday Oct 18	Value of Sample Information	6.3	
Tuesday Oct 25	Multiattribute Decision Models	Notes	
Tuesday Nov 1	Multiattribute Decision Analysis; project requirements	Notes	HW2 due
Tuesday Nov 8	Group Decision Making within stakeholder groups; measuring agreement	Notes	
Tuesday Nov 15	Group Decision Making across stakeholder groups; Decision biases 1		
Tuesday Nov 22	Decision Biases 2		
Tuesday Nov 29	Last Class; Improving decision making	Notes	HW3, Projects Due
Thursday Dec 8	Final Exam 2-4pm		

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- Wednesday Schedule

Date	Topic	Readings	Assignments/Notes
Wed. Aug 24	Introduction, Review	Chapter 1, 2	
Wed. Aug 31	Discrete Bayes Methods	Chapter 3	
Wed. Sep 7	Continuous Bayes Methods	4.1- 4.9	
Wed. Sep 14	Decision making criteria and Utility	5.1 - 5.8	
Wed. Sep 21	Utility concepts	5.9-5.10	HW1 due
Wed. Sep 28	The Decision Problem, Midterm review	5.9 - 5.10	
Wed. Oct 5	Midterm		
Wed. Oct 12	Value of Perfect Information	6.1 - 6.2	
Wed. Oct 19	Value of Sample Information	6.3	
Wed. Oct 26	Multiattribute Decision Models	Notes	
Wed. Nov 2	Multiattribute Decision Analysis; project requirements	Notes	HW2 due
Wed. Nov 9	Group Decision Making within stakeholder groups; measuring agreement	Notes	
Wed. Nov 16	Group Decision Making across stakeholder groups; Decision biases 1		
Wed. Nov 23	Thanksgiving Holiday—No Class		
Wed. Nov 30	Last Class: Decision Biases 2; Improving decision making	Notes	HW3, Projects due
Mon. Dec 12	Final Exam 2-4pm		

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Probability and Statistics Review Part I

Decision Analysis

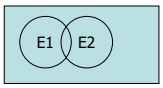
3 branches in probability and statistics
- Descriptive (mean, variance, range,…)
- Inferential (samples, populations, tests of hypothesis)
- Statistical decision theory

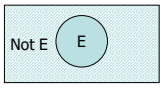
Definitions:
- Event: outcome of a random experiment
- Sample space: set of all possible events
- Probability: a real number mapping the event, E, to a real number P(E) where:
  i. $0 \le P(E) \le 1$
  ii. If S=sample space, then P(S)=1
  iii. For 2 mutually exclusive events E1, E2, $P(E1 \cup E2) = P(E1) + P(E2)$

Some rules
- If E1 and E2 not mutually exclusive, then $P(E1 \cup E2) = P(E1) + P(E2) - P(E1 \cap E2)$

Example

- $P(E) = 1 - P(\text{not } E)$



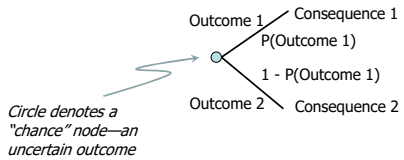


Calculating probabilities
- $P(E) = n_E / N_S$ (relative frequency or "classical" approach)
- Requires known sample space
- Assumes repeatable and stable under "identical" conditions

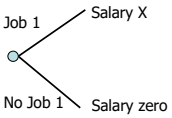
However,
- There are many situations where an event is complex or may have never occurred or occurred only once; the sample space is not countable.
- For these situations we can resort to subjective probability
- P(E) = degree of *belief* that event will occur
- Problem becomes how to measure it

Subjective Probability Methods
- Direct assessment
  - probability of E is 20%
- Odds
  - If odds are a to b that event E occurs, then P(E)= a/(a+b)
  - If odds of a defendant conviction are 4 to 1 in favor of (E=) conviction, then P(conviction)=4/(4+1)= 0.80
  - Or, if P(E) = p, then odds in favor of E are a/b where a=100p to b=100(1-p)
    - If the probability of rain is 0.10, then odds in favor of rain are 100(.10) to 100(.90) or 10 to 90 =10/90=1/9 or 1 to 9 in favor of rain (or 9 to 1 against rain)
    - If the probability of rain is 0.50, then we get 50/50=1/1 or 1 to 1 odds (also called "even" or equal odds).

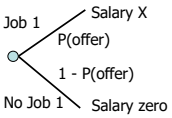
Subjective Probability Methods
- Lotteries. Also called a p-lottery (probability-lottery)
- Uncertain (probabilistic outcome) with two or more consequences
- Are used to estimate subjective probabilities.



Subjective Probability Methods
- Lotteries: we face lottery choices all the time; simplest is two outcomes. For example, getting a job:



- The choice also depends on the probability of an offer:



Subjective Probability Methods

- Lottery assessment of probabilities
  - Suppose we want to estimate the P(rain). We offer the decision maker a choice…

If the DM chooses A then P(rain) < 0.50; if B chosen then P(rain)>0.50

Suppose the DM chooses A; now we offer…

Subjective Probability Methods

- Lotteries
  - Suppose we want to estimate the P(rain). We offer the decision maker a choice…

If the DM chooses A then P(rain) < 0.25; if B chosen then 0.25<P(rain)<0.50

We continue to change p until DM is indifferent between A and B. At that point, P(rain)=P

Subjective Probability Methods

Formal definition of subjective probability is the value P(E) that produces indifference between lotteries A and B for:

Assumption: outcomes cannot be equal (X > Y or Y > X)

Subjective Probability Methods: Fair Bets

A bets $2 that stock will go up

B bets $1 that it will not go up

If A ~ B, odds are 2 to 1 stock will go up, or

P(stock goes up)=2/(2+1)=2/3

- (Note: Can break down if payoffs too high due to preferences affected by risk attitude)

Axioms of subjective probability (to prevent irrational bets)

- Transitivity: If Lottery A > B and B>C, then A>C
- Substitutability: If you are indifferent between two payoffs X and Y (X~Y), then X can be substituted for Y as the payoff in a lottery without changing your preferences with regard to those lotteries.
- All of the above methods attempt to infer the subjective probability through the choices (actions) of the decision maker rather than just asking for the probability.
- Goal is to use a behavioral approach to quantify the judgment.

(We'll come back to subjective probability later in the course)

Probability and Decision Making Framework

- Define the decision maker's alternatives
- Define events (outcomes) and associated probabilities
- Identify the decision variable (cost, time, …)
- Identify the payoffs or costs of each alternative for each outcome
- Compute the expected payoff of each alternative
- Select the "best" alternative

Payoff tables

- Useful for arranging the decision problem for calculation
- Combines alternatives, events, probabilities and payoffs

Alternatives	Event 1	Event 2
	P(Event 1)	P(Event 2)
Decision A	Payoff for A if event 1 occurs	Payoff for A if event 2 occurs
Decision B	Payoff for B if event 1 occurs	Payoff for B if event 2 occurs
Etc.	…	…

Example payoff table for car breakdown (battery light is "on")

- Can drive to get new battery (but may be other problems)
- Can drive home to get new battery and fix myself
- Can go to auto repair shop and pay for solution
- What are the alternatives?

Alternatives	Event 1	Event 2
	P(Event 1)	P(Event 2)
A. Drive to get new battery	Payoff for A if event 1 occurs	Payoff for A if event 2 occurs
B. Drive home to get new battery and fix if generator failed	Payoff for B if event 1 occurs	Payoff for B if event 2 occurs
C. Go to auto repair shop	…	…

What are the uncertain events?

Alternatives	Battery failed	Battery failed & generator failed	Generator failed
	P(Event 1)	P(Event 2)	P(Event 3)
A. Drive to get new battery	Payoff for A if event 1 occurs	Payoff for A if event 2 occurs	Payoff for A if event 3 occurs
B. Drive home to get new battery and fix if generator failed	Payoff for B if event 1 occurs	Payoff for B if event 2 occurs	Payoff for B if event 3 occurs
C. Go to auto repair shop	Payoff for C if event 1 occurs	Payoff for C if event 2 occurs	Payoff for C if event 3 occurs

What are the probabilities of the uncertain events?

Alternatives	Battery failed	Battery failed & generator failed	Generator failed
	0.25	0.15	0.60
A. Drive to get new battery	Payoff for A if event 1 occurs	Payoff for A if event 2 occurs	Payoff for A if event 3 occurs
B. Drive home to get new battery and fix if generator failed	Payoff for B if event 1 occurs	Payoff for B if event 2 occurs	Payoff for B if event 3 occurs
C. Go to auto repair shop	Payoff for C if event 1 occurs	Payoff for C if event 2 occurs	Payoff for C if event 3 occurs

What are the payoffs (costs) for each event?

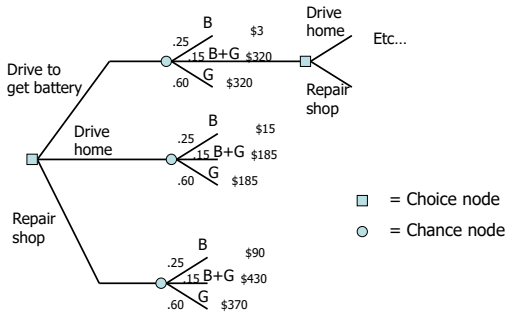
Alternatives	Battery failed	Battery failed & generator failed	Generator failed
	0.25	0.15	0.60
A. Drive to get new battery	$3	$320	$320
B. Drive home to get new battery and fix if generator failed	$15	$185	$185
C. Go to auto repair shop	$90	$430	$370

What are the expected payoffs (costs) for each alternative?

Alternatives	Battery failed	Battery failed & generator failed	Generator failed	Expected Cost
	0.25	0.15	0.60	
Drive to get new battery	$3	$320	$320	$240.75
Drive home to get new battery and fix if generator failed	$15	$185	$185	$142.50
Go to auto repair shop	$90	$430	$370	$309.00

Optimal decision is the one with minimum expected cost: "Drive home and fix"

Can also use decision tree to organize the order of events



Conditional probability: "Event A depends on event B"

P(A|B)= joint probability of both A and B divided by the marginal probability of B or

= P(A and B)/P(B)

Example: let A= flight arrives on time; D=departs on time; and P(D)=0.83; P(A)=0.82; P(A and D)=0.78. Find the P(A|D) and P(D|A).

P(A|D)=P(A and D)/P(D)=0.78/0.83=0.94

P(D|A)=P(D and A)/P(A)=0.78/0.82=0.95

Conditional probabilities are important because events of interest happen because some other event occurred first.

For example:

- The probability of delivering an integrated software app on time depends on the prior delivery of other key subcomponents first.
- The probability of a Class 7 nuclear accident depends on the failure probabilities for the primary and secondary coolant systems (among others).
- Patient probability of death from Covid-19 given not vaccinated with vaccine vs. vaccinated.