Introduction to Engineering Systems, ESD.00

Lecture 5

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Uncertainty-- outline

- Introduction
- Examples of uncertainty from the three projects
- Fundamentals
- Queuing
- “How little mistakes lead to big differences in outcomes?”--snowstorms, tsunamis and global climate change
- Lotteries-- utility
- Annuities
- Bayes’ theorem

CSS characteristics

- Nonlinearity
- Feedback
- *Uncertainty*
- Emergent properties

Uncertainty

- “Life is uncertain; eat dessert first
  - Anonymous (a refrigerator magnet)

Uncertainty

- There is no such thing$_{as}$ past possibilities and no such thing as future facts.

de Jouvenal (French philosopher)

Uncertainty

- The goal of forecasting is not to predict the future but to tell you what you need to know to take meaningful action in the present.
- .....Forecasting looks at how hidden currents in the present signal possible changes in direction for companies, societies and the world at large..... a forecast must have a logic to it.

Paul Saffo (HBR article entitled “Six Rules for Effective Forecasting”)

Uncertainty

- Complex, sociotechnical systems (CSSs) are dynamic and internally interconnected, as well as interconnected with other complex dynamic systems (e.g., the environment, the economy).
- They vary in space and time (at different time scales for different components). Service is provided on complex networks. CSSs **are stochastic in nature.**

Joseph Sussman, *Introduction to Transportation Systems*

Uncertainty in your projects

- Internet Governance
- Air/HSR
- The Stroke Care Chain

Internet Governance

Uncertainties

Demand

Air/HSR

Uncertainties

Demand

Stroke Care Chain

Uncertainties

Demand

Uncertainty: the basics

Random Variables

- Discrete-- Discrete probability distribution
- Continuous-- probability density function (pdf)

Moments

- Mean
- Variance

Uncertainty: the basics

Independence

Y= X1+X2, where X1 and X2 are random variables

Mean Y= Mean X1 + Mean X2 (always true whether or not X1 and X2 are independent)

Variance Y = Variance X1 + Variance X2 (true ***only if*** X1 and X2 are independent)

Uncertainty: the basics

The Normal Distribution

Central Limit Theory

Some examples: distribution of heights and weights in the U. S.

Uncertainty: the basics

But not everything can be characterized by a normal distribution

A good example: Wealth

"Fat tails"-- you have Bill Gates and Warren Buffet out there at $50 Billion

If heights had "fat tails", in the U. S. with its 300 Million people, you would expect to find a few people 50 feet tall.....

Uncertainty: the basics

Queuing Theory

- Interarrival times
- Service times
- Traffic intensity
- Examples

Uncertainty: the basics

"How little mistakes lead to big differences in outcomes?"--snowstorms and tsunamis

See two teaching notes

Uncertainty:

Lecture 6, # 2 on uncertainty

Uncertainty:Global Climate Change

Global Climate Change

People disagree, but everyone agrees there is a lot of uncertainty

Let’s think about the kinds of uncertainty and how we could decide what to do

Decision-making under uncertainty

Decision-making under uncertainty

Lottery

I give you a choice:

$10

or nothing with probability = .5 and $20 with probability = .5

What do you pick?

Decision-making under uncertainty

Decision-making under uncertainty

Lottery

I give you a choice:

$10,000

or nothing with probability = .5 and $20,000 with probability = .5

What do you pick?

The concept of utility-- for most people, it's non-linear and it's asymmetric

What would the probability of $20,000 have to be for you to accept the lottery and not the $10,000 with certainty?

Uncertainty: Annuities

Annuities

- Buy an annuity for $X
- You get $Y/ year for the rest of your life....

Why it is a [good, bad] deal for you?

Why it is a [good, bad] deal for the company that sold you're the annuity?

What might you do instead of buying an annuity?

Uncertainty: High-impact, low probability events

Very high-impact, Very low-probability events

Example--meteor strikes the earth

What should/can we do about that? It could be an extinction event

Uncertainty: Bayes' Theorem

Bayes' Theorem

Conditional probabilities

P(event A happens)= [P(event A/given B occurs) for all possible outcomes of B] * P(each possible outcome of B)]

Uncertainty: Bayes' Theorem

The MIT Snow Day example

Uncertainty: Bayes' Theorem

The birthday example: How many birthdays until a match?

More on Decision-making Under Uncertainty:

Decision-making under uncertainty

- Decision trees

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