Normative Decision Making

2: Normative Decision Making Overview

Decision Making Under Certainty

- We can use a *decision table* to set up the problem and calculate the best choice
- Ratings are on a scale of 1-10, with 10 being best

Criteria	Natural Beauty and Environmental Quality	Strength of Local Economy	Quality of Local Transportation System	Quality of Public Services	Availability of Affordable Housing	Parks and Recreation	W.A.
Weights	.20	.10	.15	.20	.25	.10	
Alt. A	8	7	7	9	5	9	
Alt. B	7	7	7	9	6	10	
Alt. C	3	8	6	5	9	6	
Alt. D	4	9	8	7	3	7	

Decision Making Under Uncertainty

Making decisions about the future when the outcomes of events are probabilistic

Expected Value

Long-run expectation for the value of an alternative. If the decision is made multiple times, it is the average value expected from picking an alternative

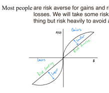
Instead of weights we have probabilities

States of Nature	Strong Growth	Moderate Growth	No Growth	Recession	Expected Value
P(X)	.20	.40	.30	.10	
Large-Cap Growth Stocks	30%	10%	-5%	-25%	
Large-Cap Value Stocks	20%	8%	0%	-10%	
Mid and Small-Cap Stocks	40%	15%	-10%	-35%	

Decision Making and Utilities

Decision Making and Risk

- Most people are risk averse for gains and risk seeking for losses. We will take some risks for gains thing but risk heavily to avoid a sure loss.



Prospect Theory

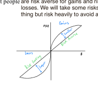
Prospect Theory

Descriptive theory of decision making under uncertainty developed by Daniel Kahneman and Amos Tversky in the late 1970s and early 1980s. It explains people's actual behavior and reveals fatal flaws in classical economic theory (as a descriptive theory).

Kahneman won the Nobel Prize for this theory.

The Risk curve is also called the S-shaped curve of Prospect Theory:

- Most people are risk averse for gains and risk seeking for losses. We will take some risks for gains thing but risk heavily to avoid a sure loss.



Golf Example

In golf, you may decide whether to put for birdie or par.

Comparison of missing the shot for each:
Birdie - missing is a foregone gain
Par - missing is a loss

Many golfers are risk averse, research found that they make 3.6% more putts for par than birdie regardless of distance to the putt

Prospect Theory in Nature

In nature:
Researchers taught monkeys that tokens that can be traded for grapes. Monkeys learned they could wait to trade token for two grapes instead of one.

Monkeys were more likely to trade with researcher who had one grape and added an additional grape rather than someone who had three grapes and removed one even though the result was two grapes either way.

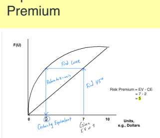
Certainty Equivalent

The sure payoff a person needs to receive to be indifferent between that payoff and a lottery with the same expected value

Risk Premium

The amount of expected value a person will sacrifice to avoid playing a lottery, i.e., to take a sure payoff

Finding Certainty Equivalent and Risk Premium



3: Decision Trees

Definition

For multi-stage decisions involving uncertainty

3 Decision Trees - HBS

☐ A decision is represented by a square, or *decision node*. This node could refer to the decision to invest or not invest, to purchase a piece of equipment or not to purchase, or how much to offer in an auction.

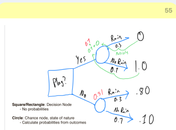
○ Uncertain events are represented with a circle, or *chance node*. Uncertain events may occur before or after, or both before and after, decisions.

◁ *Outcomes* are represented with a triangle. The decision process arrives at an outcome when all uncertainties have been resolved and there are no further decisions to be made; at this point the decision maker knows the payoff he will receive. Outcomes can occur at various stages of a complex decision. For example, if the decision is whether to continue or abandon, the selection of abandonment is an outcome, while the selection of continuance may lead to future decisions or uncertainties.

Step 1: Lay out the alternatives

Step 2: Quantify the uncertainties

Step 3: Specify the Objectives



Square/Rectangle: Decision Node
- No probabilities

Circle: Chance node, state of nature
- Calculate probabilities from outcomes

Decision Table

	Rain	No Rain	Expected Utility
P(x)	.30	.70	
Play	0	1.0	.70
Don't Play	.80	.10	.31

4: Simpson's Paradox

Definition

When aggregated data show different results than the data being combined. The subcategories lead to a different conclusion than their combination.

Simpson's Baseball Paradox

- Derek Jeter — 1995 / 1996
  - At-Bats: 48 / 582
  - Hits: 12 / 183
  - Average: .250 / .314
  - Weights: 0.76 / .924
- David Justice — 1995 / 1996
  - At-Bats: 411 / 140
  - Hits: 104 / 45
  - Average: .253 / .321
  - Weights: .746 / .254
- Summary – Derek Jeter = 0.310; David Justice = 0.270

The summary implies Derek Jeter has a better batting average, but David Justice had a much better average more recently.

4 Aggregated Numbers Obscure Trends - Simpson Paradox- WSJ

Simpson's Paradox reveals that aggregated data can appear to reverse important trends in the numbers being combined.

- Which level of analysis *should* we use?
  Not clear, but sample size plays a role
  - If sample size is large enough you should disaggregate

Normative and Descriptive Analysis of Simpson Paradox - Browne

5: Bayes' Theorem

Definition

Normative method for updating one's prior belief (or prior probability) concerning an outcome given new information

Formula

$$P(A/B) = \frac{P(A)\,P(B/A)}{P(A)\,P(B/A) + P(\text{Not }A)\,P(B/\text{Not }A)}$$

- Where P(A) is known as the prior probability and P(B/A) is the conditional probability of "B" given "A". P(B/A) is also often known as "sample data." P(B) is often measured as a positive result of a test.

6: Algorithms and Linear Models

$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \varepsilon$

$y = b_1x_1 + b_2x_2 + b_3x_3$

Advantages and Disadvantages

- Advantages of Linear Models
  - Apply criteria consistently
  - Unemotional
  - No combination/integration errors
- Disadvantages of Linear Models
  - People most specify criteria and weights
    - Prone to people error, criteria is not always obvious
  - Not always applicable
    - E.g. design and strategy problems
  - More constraints than weaknesses

6-1 Trust an algorithm - International Herald Tribune - NYT

"As long as you have some history and some quantifiable data from past experiences," Snijders said, a simple formula will soon outperform a professional's decision-making skills.

"Unemotional is very important in the financial world," he said. "When money is involved, people get emotional."

Many putative managerial qualities, like experience and intuition, may in fact be largely illusory. In Snijders's experiments, for example, not only do the machines generally do better than the managers, but some managers perform worse over time as they develop bad habits that go uncorrected from lack of feedback.

"There's no evidence whatsoever that I know of that shows more senior managers make better decisions," Snijders said. "Experience has really shown to be relatively worthless when it comes to making more accurate decisions."

"Models will do much better in predicting violence than will parole officers, and in that case, not using them leads to a more dangerous society," he said. "But people really don't believe that the models are as accurate as they are."

"I've never seen any evidence that there is a pattern of decline at all, and it just doesn't fit with the way management literature is going, which is all around the emotional intelligence angle,"

6-2 Buttonwood_Sand_in_the_gears - Economist

2020 has been rotten for "quant" funds, which use powerful computers to sift market data for patterns that might predict future prices. "Long-short" momentum –buying recent winners and selling recent losers–had been one of quant's better strategies this year. Yet on November 9th, when news broke of an effective vaccine for covid-19, it had its worst ever day.

The terrain on which human traders can beat the machines is much diminished. But November 9th shows it is still possible. Chalk it up as a small victory for the species.

. Investors tend to stick to prior views too rigidly and change them only slowly in response to new information. They may give undue emphasis to the price paid for a stock as a marker of its true value and, as a consequence, sell winning stocks too soon and hang on to dud stocks for too long. There is also a contrasting tendency to extrapolate past success. So as well as under-reacting to news, people also over-react to it. Momentum trading seeks to exploit this.

the faster you trade, the less capacity there is for your strategy

6-3 UPS Algorithm - WSJ

Orion is the largest deployment of operations research, and that UPS spent $200 to $300 million to develop it.

The 1,000 page Orion algorithm is an exercise in heuristics, written by a team of 50 UPS engineers in Timonium,

. Orion consists of many components, including a "traveling salesman" algorithm, a familiar tool that calculates the most efficient path between a variety of points, and geographic mapping. What makes Orion unique is the way it puts these elements together, striving for a balance between an optimum result and consistency

unique. Rival FedEx Corp. uses an independent contractor model for its ground network, so it's not ultimately responsible for miles driven to most of its residential stops.

The more than 40% of the company's 55,000 U.S. routes already using the software at that time had been reduced by an average of between seven and eight miles,

. The company can save $50 million a year by reducing by one mile the average aggregated daily travel of its drivers

For example, some drivers don't understand why it makes sense to deliver a package in one neighborhood in the morning, and come back to the same area later in the day for another delivery. But Orion often can see a payoff, measured in small amounts of time and money that the average person might not see.

6-4 Justice by the Numbers - Parole - WSJ

Criminologists say people convicted of crimes like murder often are older when considered for release, making them less likely to reoffend. Inmates convicted of nonviolent crimes like property theft, meanwhile, tend to be younger, more impulsive and adventurous -- all predictors of repeat criminality.

Experts say one reason for the decline is that fewer parolees are returning to prison. About 12% of parolees were re-incarcerated at some point in 2011 compared with 15% in 2006, representing the fifth straight year of decline

Texas, by reputation a tough-on-crime state, has been consistently using risk assessment longer than many states and is boosting the number of prisoners it paroles each year. With its current system, in use since 2001, it released 37% of parole applicants in 2012 versus 28% in 2005 -- some 10,000 more prisoners released in 2012.

fivefold increase in the number of prisoners nationwide from 1978 to 2009, according to the Department of Justice.

Some assessments analyze as many as 100 factors, including whether the offender is married, the age of first arrest and whether he believes his conviction is unfair. In Texas, a rudimentary risk-assessment measures just 10 factors

Mr. Gordon's responses, combined with other factors, made him a moderate risk of reoffending under Texas parole guidelines. Last year, the Texas parole board released some 40% of inmates with that score

"There's a real connection between race and prior criminal history, and a real link between prior criminal history and prediction," Mr. Harcourt said. "The two combine in a toxic and combustive way."

Data such as how many times a person has been incarcerated can act as an unfair proxy for race

7: Conclusion - Normative Decision Making

- As noted, we want to use it whenever we can
- However, the assumptions underlying normative rules mean that they are rarely usable in their pure form in everyday managerial problems
- Exceptions include algorithms and Bayes' Rule, which can be used occasionally to good advantage
- Nonetheless, we can use the tools as guides to help us structure decisions—e.g., decision trees and decision tables—even if the assumptions are violated

- Normative and Descriptive Analysis of Simpson Paradox - Browne

5: Bayes' Theorem 64

- Definition 64
- Formula 64

6: Algorithms and Linear Models 70

- $y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \varepsilon$ 70
- Advantages and Disadvantages 71

6-1 Trust an algorithm - International Herald Tribune - NYT

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- 7: Conclusion - Normative Decision Making

Decision Trees

In the probability tree we just analyzed, Tate did not have to make any decisions, as uncertainty was resolved. She just had to figure out the value of the investment opportunity by calculating the expected monetary value of the probability tree, and having figured out this value, she simply compared it to the cost of investment. How would we modify the analysis to take into account the fact that often we may be able to partially control events by making decisions as time goes on? To analyze a series of decisions where there is uncertainty, decision makers often use a device called a *decision tree*. Like a probability tree, a decision tree represents a chronological sequence of events presented in a simple graphical manner. A decision tree also allows for decisions along the way as uncertainty is resolved. We typically draw the decision tree from left to right, emphasizing the chronological nature of decisions.

Decision trees serve two primary goals. First, they help you decide which decision to make. At each decision node, you will be faced with several alternatives. Using a tree, you will be able to decide which of these alternatives is the right one to choose. Second, the decision tree identifies the value of any particular decision or set of options. For example, you may want to know not only whether you prefer one alternative to another, but by how much. At other times, you might also want to know how valuable the right to make a decision at a particular point is.

There are three important elements in the decision tree:

□ A decision is represented by a square, or *decision node*. This node could refer to the decision to invest or not invest, to purchase a piece of equipment or not to purchase, or how much to offer in an auction.

○ Uncertain events are represented with a circle, or *chance node*. Uncertain events may occur before or after, or both before and after, decisions.

◁ *Outcomes* are represented with a triangle. The decision process arrives at an outcome when all uncertainties have been resolved and there are no further decisions to be made; at this point the decision maker knows the payoff he will receive. Outcomes can occur at various stages of a complex decision. For example, if the decision is whether to continue or abandon, the selection of abandonment is an outcome, while the selection of continuance may lead to future decisions or uncertainties.

The three elements of a decision tree are connected with lines. Although we do not draw them, you can think of the lines as arrows that go from left to right, in the same direction as the chronology of decisions. The lines are often called "branches" because decisions may lead to future decisions, which lead to future decisions . . . and so on.

The order in which the shapes in the decision tree are connected is very important. A square that is followed by a circle, for example, means that the decision is made before the uncertainty is resolved. In contrast, a circle that is followed by a square denotes a decision that occurs after uncertainty is resolved.

A Simple Decision Problem: Tate's Ergonomic Chairs

Let us go back to our simple example to illustrate the principles involved in constructing and solving a decision tree. We saw earlier that Tate was faced with deciding whether to invest $300,000 in a new manufacturing facility when she was unsure whether there would be sufficient demand for the chair it would produce to cover the large investment. She knows that if the market is large, she

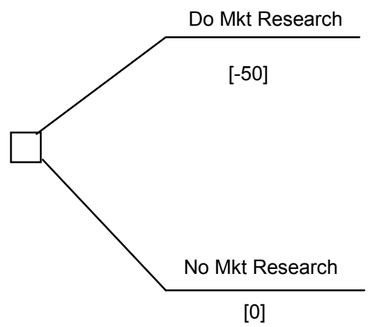
will sell 8,000 chairs at a profit of $100 each, generating a cash flow with present value of $800,000. On the other hand, if the market is small, she will sell only 1,000 chairs, generating a cash flow with a present value of only $100,000.

A market research firm has submitted a proposal to evaluate the potential market for the chair. Tate is confident that this will resolve her uncertainty about whether the market for the chair will be large or small. But she does not know whether it is worth the $50,000 that the firm is asking to carry out the survey. How should she decide whether to pay for the market research?

Designing the Tree

Step 1: Lay out the alternatives Decision trees are designed forwards, one branch at a time, starting with the first decision. Tate must begin by deciding whether to invest in market research or not. (There would be no point in investing in market research after making her investment decision, since the value of the research is in helping to make the investment decision.) Because we start with a decision and there are two alternatives, we draw a square with two lines coming out of it:

Figure E

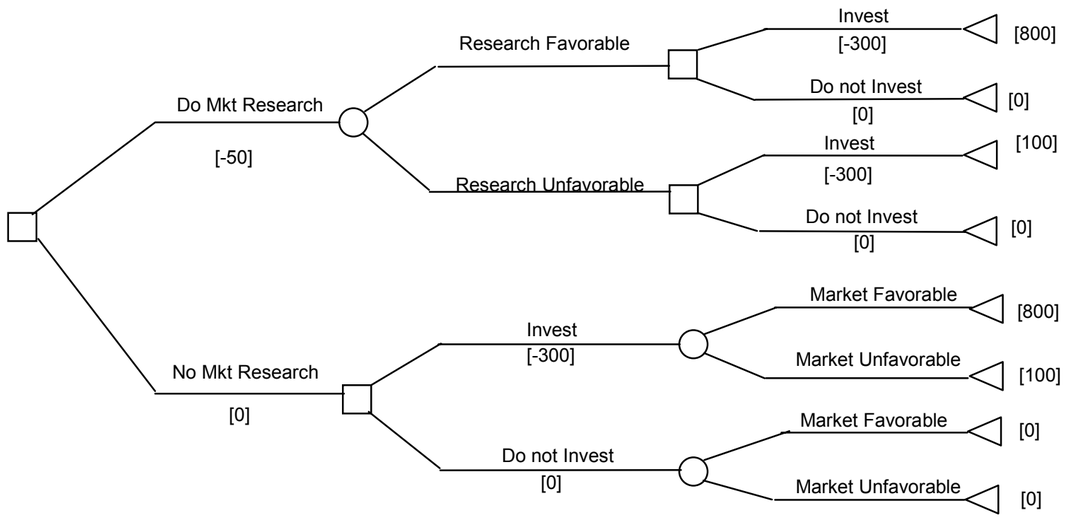


We keep track of costs (and benefits) as they occur. Below the top branch, we note the cost of $50,000. If Tate does no research, she incurs no costs. Thus we write a zero under the bottom branch.

Now what? We start with the top branch. The market research will identify the market opportunities to be either good or bad. Tate is unsure which of these events will occur.

Finally, we repeat these steps for the case for which Tate does not purchase the market research. Notice that this part of the tree contains no further decisions and is just like the probability tree we analyzed earlier. The difference between the upper and lower sections of the tree is that in the lower half Tate must make a decision *before* the uncertainty about the size of the market is resolved, whereas in the upper half she already knows the market size before she makes her investment decision. Therefore, the final decision tree is:

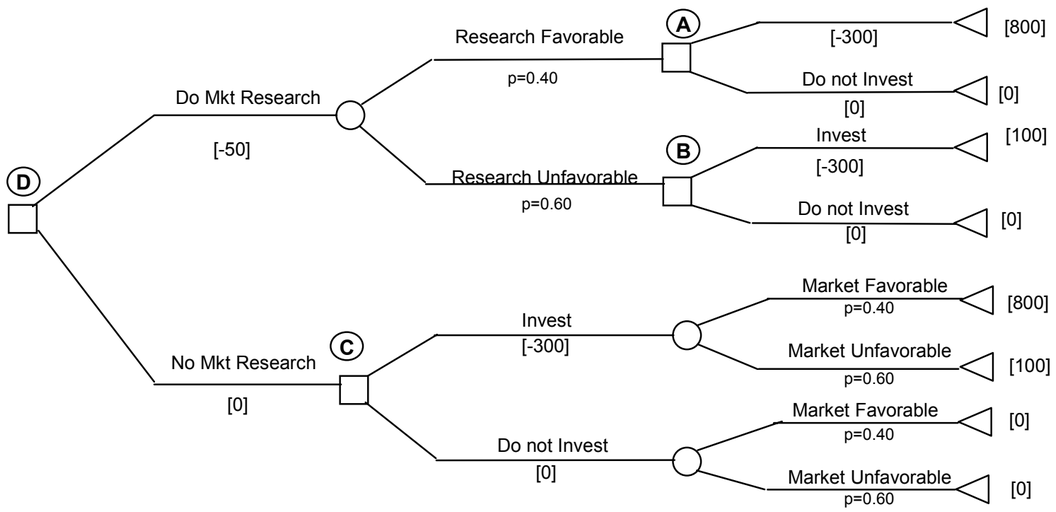
Figure H



Step 2: Quantify the uncertainties As with probability trees, Tate must estimate the probability that each of the branches of uncertain outcomes occurs. We have already done this for the lower half of the tree in the previous section. Recall that Tate believes that the probability that opportunities are good is 0.40 and the probability that opportunities are bad is 0.60.

If we look at the top half of the tree, there is only one chance node, with two outcomes, that corresponds to research saying that sales opportunities are good or bad. Tate believes that the research reports are 100% accurate. So what is the probability that the research says that the market will be large? The research will report a large market precisely when the market actually is large, which, according to Tate, happens with probability 0.40. Similarly, the probability of the research's reporting a small market is 0.60. We now have enough information to fill out the rest of the tree.

Figure I Tate's Decision Tree



For easy reference, we label the important nodes of the decision tree **A**, **B**, **C,** and **D**.

Step 3: Specify the objectives What should Tate's objective be when choosing among alternatives?

In our previous analysis, we assumed that Tate was aiming to make the decision offering the highest monetary value. This choice of objective may appear problematic, because it seems to assume that Tate is *risk neutral*, which is to say, she values a probability tree at its expected monetary value. Tate treated a 40% chance at $800,000 and a 60% chance of $100,000, an expected monetary value of $380,000, as being equivalent to $380,000 for sure. Most people, however, are *risk averse*, meaning that they would prefer to receive the expected value of a gamble to the gamble itself. In Tate's case, it means that she may prefer to invest $300,000 and receive $380,000 for sure than to invest and take her chances. To take a simpler case, most people would prefer to receive $100 for sure than to take a 50% chance at receiving $200.

Nevertheless, the maximization of expected value is a reasonable starting point for most business decisions. Underlying this decision rule are two important assumptions. First, we assume that the decision maker is trying to make the best decision on behalf of diversified investors. If each investor holds only a very small part of his portfolio in Tate's company, the risks that Tate's company takes have very little impact on the investor's overall wealth. Second, we assume that the uncertainties in the tree are not related to the riskiness of the investor's portfolio. In the context of our example, this means that the probability that the market for ergonomic chairs is favorable is not related to the overall performance of the stock market.[2]

Of course, these assumptions may sometimes be violated. If Tate is the sole owner of her company and most of her wealth is tied up in the company, then she may act in a risk-averse way, avoiding investments with a positive expected monetary value if they are very risky. Risk aversion can be incorporated into our analysis by having the decision maker specify a *utility* for each final outcome (a

[2] These intuitions are formalized by the Capital-Asset Pricing Model, or CAPM.

Currents -- The Numbers Guy: When Combined Data Reveal the Flaw of Averages --- In a Statistical Anomaly Dubbed Simpson's Paradox, Aggregated Numbers Obscure Trends in Job Market, Medicine and Baseball

Tuna, Cari . Wall Street Journal , Eastern edition; New York, N.Y. [New York, N.Y]02 Dec 2009: A.21.

ABSTRACT

When Combined Data Reveal the Flaw of Averages --- In a Statistical Anomaly Dubbed Simpson's Paradox, Aggregated Numbers Obscure Trends in Job Market, Medicine and Baseball Ken Ross, a professor emeritus at the University of Oregon and baseball enthusiast, notes in a 2004 book on baseball statistics that in both 1995 and 1996, Derek Jeter of the New York Yankees had a lower batting average for each season than David Justice, then of the Atlanta Braves.

FULL TEXT

Is the current economic slump worse than the recession of the early 1980s?

Measured by unemployment, the answer appears to be no, or at least not yet. The jobless rate was 10.2% in October, compared with a peak of 10.8% in November and December of 1982.

But viewed another way, the current recession looks worse, not better. The unemployment rate among college graduates is higher than during the 1980s recession. Ditto for workers with some college, high-school graduates and high-school dropouts.

So how can the overall unemployment rate be lower today but higher among each group? The anomaly is an example of Simpson's Paradox -- a common but misleading statistical phenomenon rooted in the differing sizes of subgroups. Put simply, Simpson's Paradox reveals that aggregated data can appear to reverse important trends in the numbers being combined.

The jobless rates for each educational subgroup are higher today, but the overall rate is lower because workers are more educated. There are more college graduates, who have the lowest unemployment rate. And there are fewer high-school dropouts, who have the highest unemployment rate.

"It's the magic of weighted averages," says Princeton University economics professor Henry Farber. "We have more skilled workers than we had before, and more-skilled workers are less susceptible to unemployment." Still, he adds, compared with a similarly educated worker in 1983, "the worker today has higher unemployment at every education level."

Simpson's Paradox has fooled many. In the fall of 1973, for instance, the University of California, Berkeley's graduate division admitted about 44% of male applicants and 35% of female applicants. That raised eyebrows

Currents -- The Numbers Guy: When Combined Data Reveal the Flaw of Averages --- In a Statistical Anomaly Dubbed Simpson's Paradox, Aggregated Numbers Obscure Trends in Job Market, Medicine and Baseball

Normative Decision Making

- Specifies how decisions should be made in a rational or economic sense
- Scope of Normative Decision Making
  - Decision making under certainty and uncertainty, decision tables, decision trees, game theory, signal detection theory, linear models (e.g., regression), calibration, economic value of information, linear programming, simulation, algorithmic decision making, the prisoner's dilemma, Bayesian revision, et al.

Decision Making Under Certainty

- A decision is to be made among alternatives, and the outcomes from choosing each alternative are known in advance
- Examples:

- Task is to choose the alternative that best reflects our preferences for outcomes

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Decision Making Under Certainty

- Problem: Where should we locate our new regional office?
- We can use a ***decision table*** to set up the problem and calculate the best choice
- Ratings are on a scale of 1-10, with 10 being best

Criteria	Natural Beauty and Environmental Quality	Strength of Local Economy	Quality of Local Transportation System	Quality of Public Services	Availability of Affordable Housing	Parks and Recreation	W.A.
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Decision Making Under Uncertainty

- Making decisions about the future when the outcomes of events are probabilistic
- Concept of "expected value"

- Changes in process model for decision making under uncertainty

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Decision Making Under Uncertainty

- Problem: What types of stocks should I invest in this year?
- Critical event: Growth of the U.S. economy this year
- Outcomes are predicted returns on investment

States of Nature	Strong Growth	Moderate Growth	No Growth	Recession	Expected Value
P(X)	.20	.40	.30	.10	
Large-Cap Growth Stocks	30%	10%	-5%	-25%	
Large-Cap Value Stocks	20%	8%	0%	-10%	
Mid and Small-Cap Stocks	40%	15%	-10%	-35%	

Multiply .06 .04 -.015 -.025 Sum .04 = 4%

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Decision Making and Utilities

- Do people make decisions based only on monetary value?

  No - Happiness, effort, altruism, societal good are also factors

- Utilities

  Reflects people's preferences for outcomes. "Utile" is a unit of preference.

  Important because it helps us understand how people view risk

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Decision Making and Risk

- What is risk?

  - Variance
  - Likelihood and extent of loss
  - Uncertainty and ambiguity

- Attitudes toward risk

  - Affects preferences, judgements, and decision making

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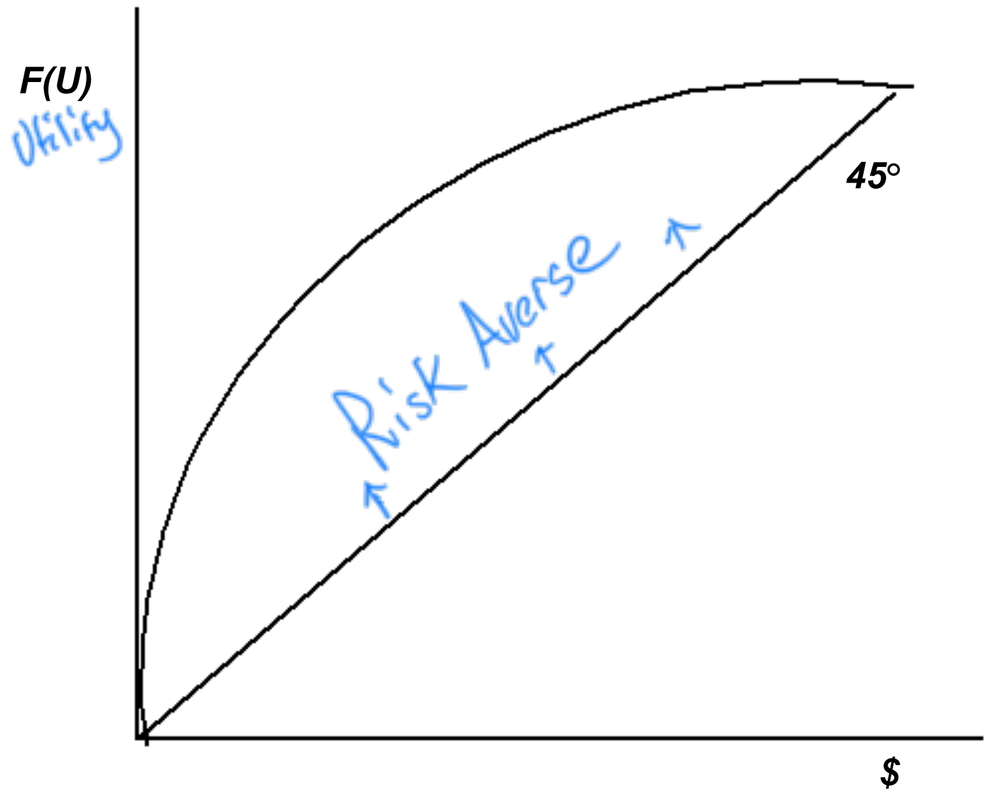
Decision Making and Risk

Risk Averse Utility Curve



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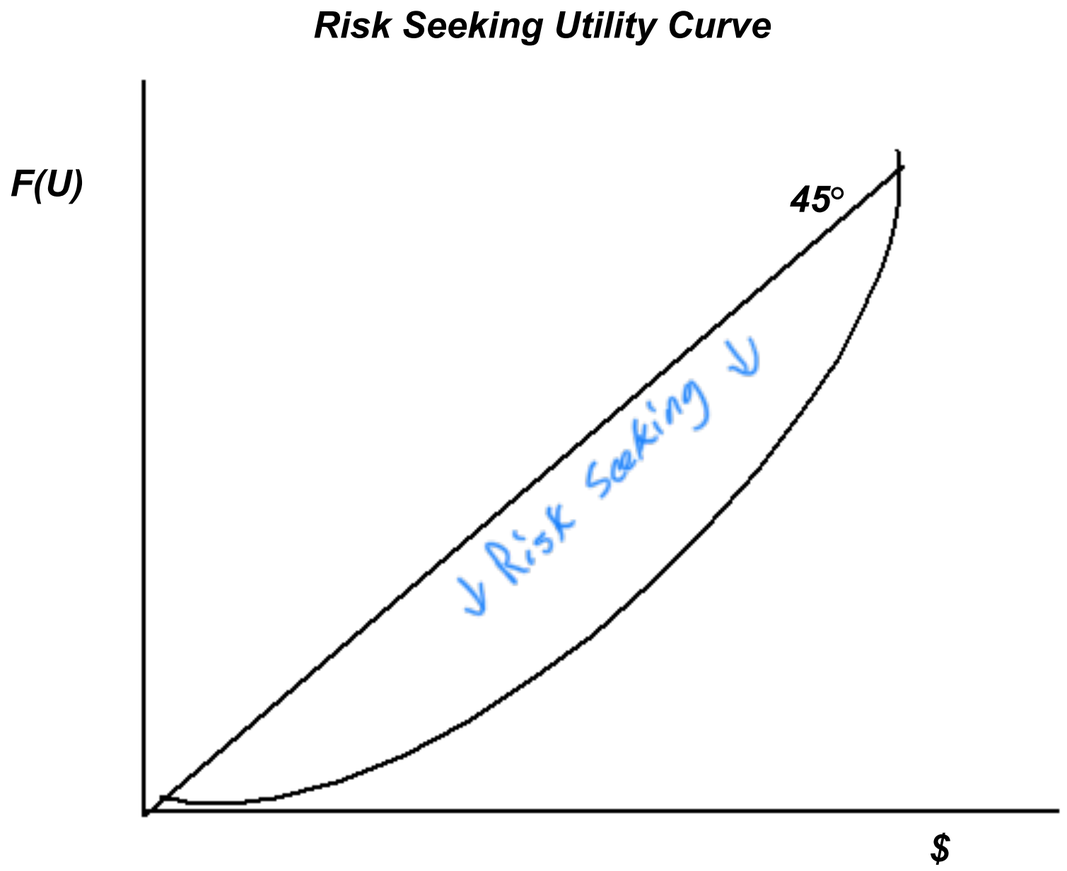

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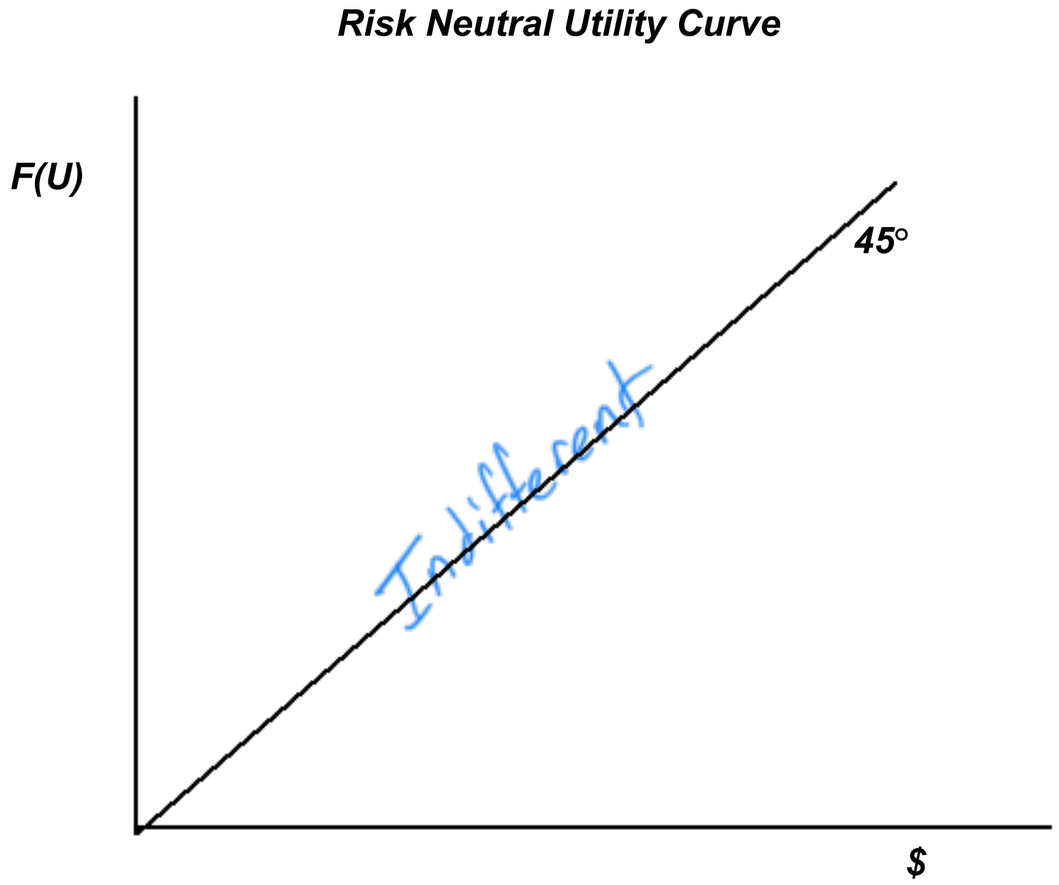

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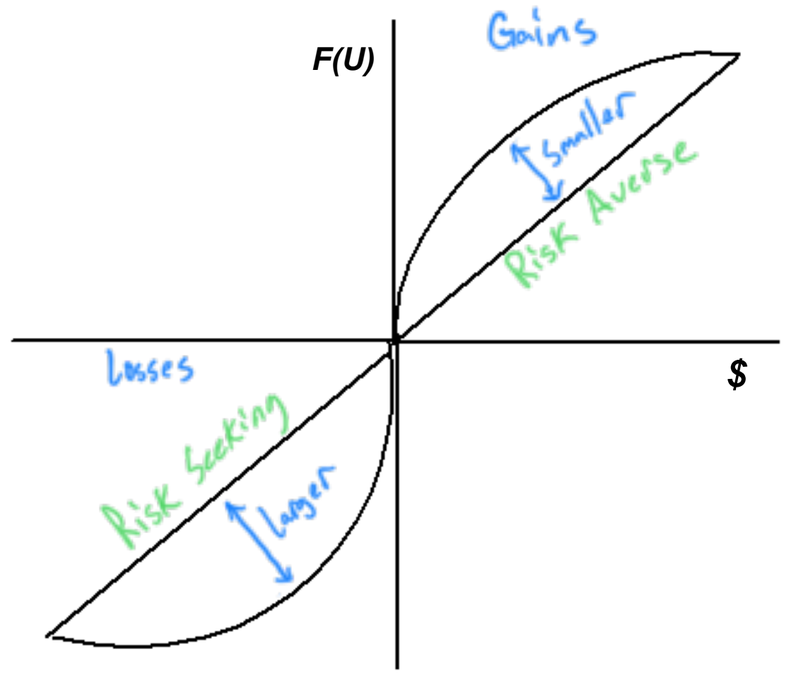
Decision Making and Risk

- Most people are risk averse for gains and risk seeking for losses. We will take some risks for gains thing but risk heavily to avoid a sure loss.



Decision Making and Risk

- How does this impact our utilities for outcomes?

  Gains are valued more highly and losses are felt more painfully than they should be

- How does this impact our assessments of risk?

  - Many consider risk to be likelihood and extent of loss rather than variance
  - Loss aversion is more common

- How does this impact our decision making?

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Prospect Theory

- Prospect Theory is a descriptive theory of decision making under uncertainty developed by Daniel Kahneman and Amos Tversky in the late 1970s and early 1980s. It explains people's actual behavior and reveals fatal flaws in classical economic theory (as a descriptive theory). Kahneman won the Nobel Prize for this theory.
- The function shown several slides previously is referred to as the "S-shaped curve of Prospect Theory"

Prospect Theory

- Example

In golf, you may decide whether to put for birdie or par.

Comparison of missing the shot for each:
- Birdie - missing is a foregone gain
- Par - missing is a loss

Many golfers are risk averse, research found that they make 3.6% more putts for par than birdie regardless of distance to the putt

Prospect Theory

- Prospect Theory, it turns out, may be a fundamental behavioral principle of much of life on earth

In nature:
Researchers taught monkeys that tokens that can be traded for grapes. Monkeys learned they could wait to trade token for two grapes instead of one.

Monkeys were more likely to trade with researcher who had one grape and added an additional grape rather than someone who had three grapes and removed one even though the result was two grapes either way.

- https://itunes.apple.com/us/podcast/ted-radio-hour/id523121474?mt=2&i=327972947

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Certainty Equivalents and Risk Premiums

- There are several ways to define a certainty equivalent and a risk premium. We will use the following definitions.
- Certainty Equivalent – the sure payoff a person needs to receive to be indifferent between that payoff and a lottery with the same expected value
- Risk Premium – the amount of expected value a person will sacrifice to avoid playing a lottery, i.e., to take a sure payoff

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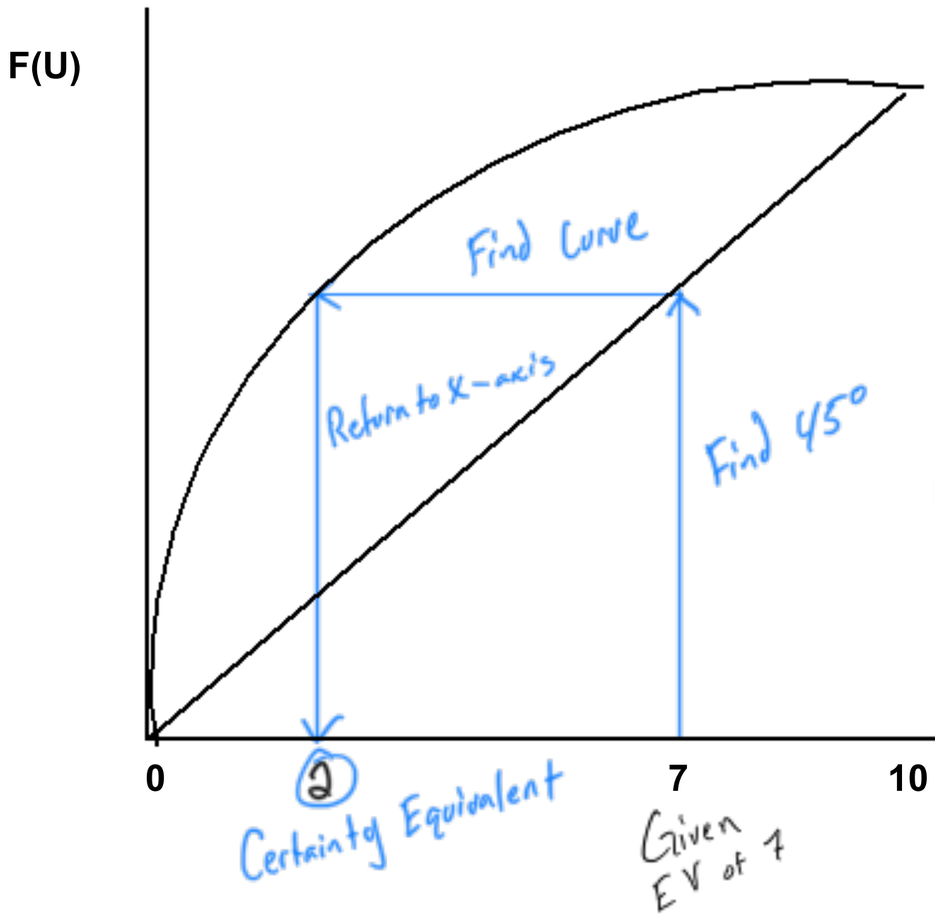
Certainty Equivalents and Risk Premiums



Risk Premium = EV - CE
= 7 - 2
= 5

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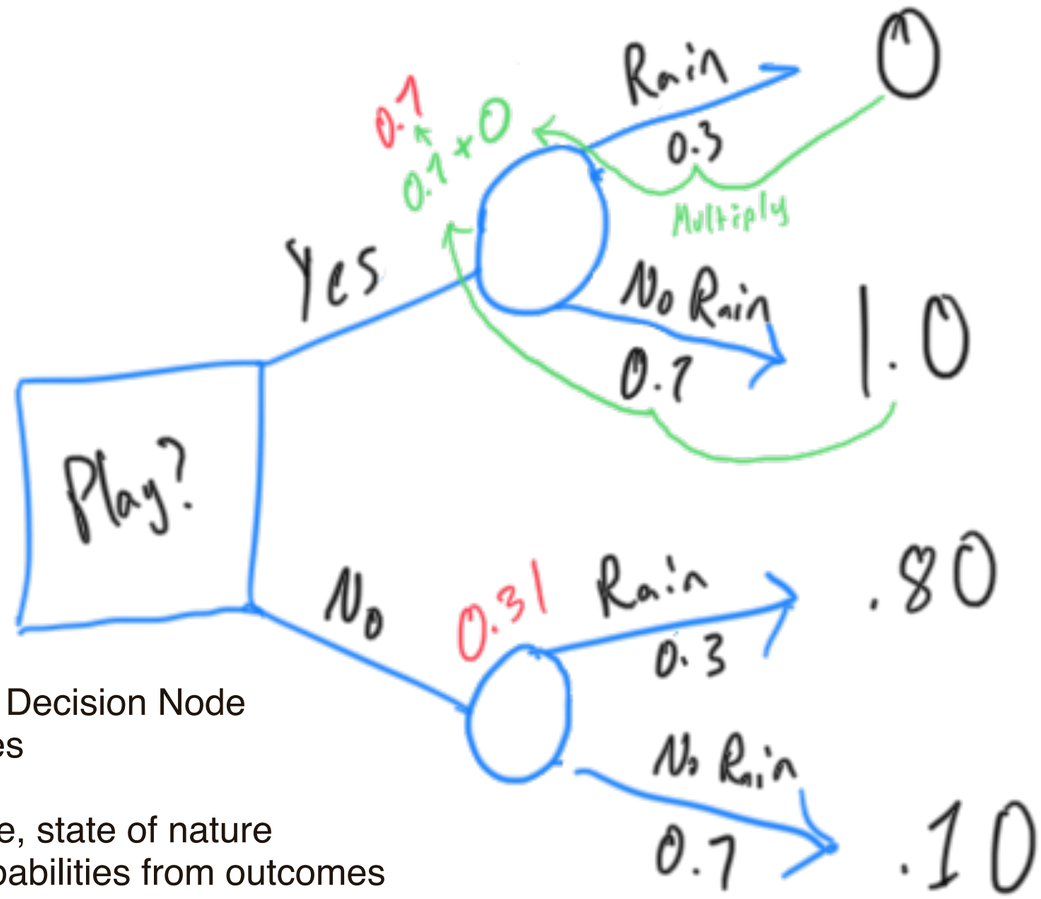
Decision Trees

- Example - Should we play tennis tomorrow?
  - Most important event - Will it rain?
  - States of Nature - Rain, No Rain
  - Probabilities - Rain $=0.3$, No Rain $=0.7$
  - Alternatives - Play, Don't Play
  - Outcomes (Note: Utility is on a scale of 0 to 1)
    - Play and Rain = 0 utility
    - Play and No Rain = 1 utility
    - Don't Play and Rain = 0.8 utility
    - Don't Play and No Rain = 0.1 utility
  - Note that this is a single-stage decision and is used only to illustrate the structure of the tree

Decision Tree Example



Square/Rectangle: Decision Node
- No probabilities

Circle: Chance node, state of nature
- Calculate probabilities from outcomes

Simpson's Paradox

- Simpson's Paradox
  - "When Combined Data . . ." article

When aggregated data show different results than the data being combined

The subcategories lead to a different conclusion than all conclusions combined

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Simpson's Paradox

Derek Jeter	1995	1996
At-Bats	48	582
Hits	12	183
Average	.250	.314
Weights	0.76	.924

$.076 \cdot .250 + .924 \cdot .314 = 0.310$

Simpson's Paradox

- David Justice 1995 1996
  - At-Batts 411 140
  - Hits 104 45
  - Average .253 .321
  - Weights .746 + .254 = .270

- Summary – Derek Jeter = 0.310
  David Justice = 0.270

Simpson's Paradox

- Which level of analysis *should* we use?

  Not clear, but sample size plays a role

  - If sample size is large enough you should disaggregate

- If you are interested in an academic treatment of Simpson's Paradox, you can see
  - Curley, Shawn P. and Glenn J. Browne. "Normative and Descriptive Analyses of Simpson's Paradox in Decision Making." *Organizational Behavior and Human Decision Processes*, 84, 2001, pp. 308-333.

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Bayes' Theorem

- Bayes' Theorem is a normative method for updating one's prior belief (or prior probability) concerning an outcome given new information
- Bayes' Theorem: P(A/B) =

$$P(A/B) = \frac{P(A)\,P(B/A)}{P(A)\,P(B/A) + P(\text{Not A})\,P(B/\text{Not A})}$$

  - Where P(A) is known as the prior probability and P(B/A) is the conditional probability of "B" given "A". P(B/A) is also often known as "sample data." P(B) is often measured as a positive result of a test.

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Algorithms and Linear Models

- Linear Models and Linear Combinations
  - $y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \varepsilon$
  - $y = b_1x_1 + b_2x_2 + b_3x_3$
- Example (a linear combination)
  - Who will be successful in graduate school?

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Algorithms and Linear Models

- Advantages of Linear Models

  - Apply criteria consistently
  - Unemotional
  - No combination/integration errors

- Disadvantages of Linear Models

  - People most specify criteria and weights
    - Prone to people error, criteria is not always obvious
  - Not always applicable
    - E.g. design and strategy problems
  - More constraints than weaknesses

Algorithms and Linear Models

- Used extensively in both manufacturing and service industries

  Loan apps, admissions, animal breeding, auto insurance, etc

- Please look at the readings for algorithms

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Normative Decision Making

- Bottom line on normative decision making
  - As noted, we want to use it whenever we can
  - However, the assumptions underlying normative rules mean that they are rarely usable in their pure form in everyday managerial problems
  - Exceptions include algorithms and Bayes' Rule, which can be used occasionally to good advantage
  - Nonetheless, we can use the tools as guides to help us structure decisions—e.g., decision trees and decision tables—even if the assumptions are violated

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The New York Times

Trust an algorithm with your business? - Technology - International Herald Tribune

By Douglas Heingartner

July 18, 2006

AMSTERDAM — Do you think your high-paid managers really know best? A Dutch sociology professor has doubts.

The professor, Chris Snijders of the Eindhoven University of Technology, has been studying the routine decisions that managers make and is convinced that computer models, by and large, can do it better. He even issued a challenge late last year to any company willing to pit its humans against his algorithms.

"As long as you have some history and some quantifiable data from past experiences," Snijders said, a simple formula will soon outperform a professional's decision-making skills.

"It's not just pie in the sky," Snijders said. "I have the data to support this."

Some of his experiments from the past two years have looked at the results that purchasing managers at more than 300 organizations got when they placed orders for computer equipment and software. Computer models given the same

Computer-based decision-making has also grown increasingly popular in credit scoring, the insurance industry and some corners of Wall Street.

The main reason for computers' edge is their consistency, or rather humans' inconsistency, in applying their knowledge.

"People have a misplaced faith in the power of judgment and expertise," said Greg Forsythe, a senior vice president at Schwab Equity Ratings, which uses computer models to evaluate stocks.

The algorithms behind so-called quant funds, Forsythe said, act with "much greater depth of data than the human mind can."

"They can encapsulate experience that managers may not have," he said.

And critically, models do not get emotional.

"Unemotional is very important in the financial world," he said. "When money is involved, people get emotional."

Many putative managerial qualities, like experience and intuition, may in fact be largely illusory. In Snijders's experiments, for example, not only do the machines generally do better than the managers, but some managers perform worse over time as they develop bad habits that go uncorrected from lack of feedback.

"There's no evidence whatsoever that I know of that shows more senior managers make better decisions," Snijders said. "Experience has really shown to be relatively worthless when it comes to making more accurate decisions."

Other cherished decision aids, like meeting in person and poring over dossiers, are of equally dubious value when it comes to making more accurate choices, some studies have found, with face-to-face interviews actually degrading the quality of an eventual decision.

"People's overconfidence in their ability to read someone in a half-an- hour interview is quite astounding," said Michael Bishop, an associate professor of philosophy at Northern Illinois University who studies the social implications of these models.

And the effects can be serious.

"Models will do much better in predicting violence than will parole officers, and in that case, not using them leads to a more dangerous society," he said. "But people really don't believe that the models are as accurate as they are."

Models have other advantages beyond their accuracy and consistency.

They allow an organization to codify and centralize its hard-won knowledge in a concrete and easily transferable form, so it stays put when the experts move on. Models also can teach newcomers, in part by explaining the individual steps that lead to a given choice. They are also faster than people, are immune to fatigue and give the human experts more time to work on other tasks beyond the current scope of machines.

Not everyone is convinced that managers are incorrigibly myopic.

"I've never seen any evidence that there is a pattern of decline at all, and it just doesn't fit with the way management literature is going, which is all around the emotional intelligence angle," said Laura Empson, the director of the Clifford Chance Center of the Said Business School at Oxford University.

At UPS, the Algorithm is the Driver --- Turn right, turn left, turn right: Inside Orion, the 10-year effort to squeeze every penny from delivery routes

Rosenbush, Steven; Stevens, Laura . Wall Street Journal , Eastern edition; New York, N.Y. [New York, N.Y]17 Feb 2015: B.1.

ProQuest document link

ABSTRACT

Orion consists of many components, including a "traveling salesman" algorithm, a familiar tool that calculates the most efficient path between a variety of points, and geographic mapping. [...]management and information technology expert Thomas H. Davenport, a distinguished professor at Babson College near Boston,believes Orion is the largest deployment of operations research, and that UPS spent $200 to $300 million to develop it.

FULL TEXT

TIMONIUM, Md. -- Here's a math problem for you. Each United Parcel Service Inc. driver makes an average of 120 stops per day. There are 6,689,502,913,449,135,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 alternatives for ordering those stops.

Which option is the most efficient, after considering variables such as special delivery times, road regulations, and the existence of private roads that don't appear on a map?

Even if an optimal answer exists, the human mind will never figure it out. And while experts at UPS have been giving the problem their best shot for more than a century, the company is shifting that work over to a computer platform called Orion, which is 10 years and an estimated hundreds of millions of dollars in the making. "Can a human really think of the best way to deliver 120 stops? This is where the algorithm will come in. It will explore paths of doing things you would not, because there are just too many combinations," says Jack Levis , senior director of process management at UPS.

The 1,000 page Orion algorithm is an exercise in heuristics, written by a team of 50 UPS engineers in Timonium, Md. Instead of searching for the optimal, or best possible answer, heuristics is the search for the best answer one can find, the results continually refined over time, based on experience. Orion consists of many components, including a "traveling salesman" algorithm, a familiar tool that calculates the most efficient path between a variety of points, and geographic mapping. What makes Orion unique is the way it puts these elements together, striving for a balance between an optimum result and consistency, according to Mr. Levis. "Customers and drivers like consistency. Orion has to know when to give up a penny to make the results more stable," Mr. Levis said.

None of the solutions that Orion spews out are big or dramatic. It is all about saving a dollar or two here and there.

At UPS, the Algorithm is the Driver --- Turn right, turn left, turn right: Inside Orion, the 10-year effort to squeeze every penny from delivery routes

1

But in a network with 55,000 routes in the U.S. alone, that adds up. "In our business, small things mean a lot. If you can reengineer process, the gains will be greater than you think," Mr. Levis said.

Such savings matter to UPS, which is struggling with a tighter-margin business and a union workforce that is compensated at the high end of the industry scale. Its challenges are unique. Rival FedEx Corp. uses an independent contractor model for its ground network, so it's not ultimately responsible for miles driven to most of its residential stops.

A Changing Business E-commerce has shifted more and more of UPS's delivery stops to residences, and those packages are expected to make up half of all deliveries by 2018. It's a radical change from 15 years ago, when drivers would drop off several packages at a retailer. Now, they make scattered stops to drop off one package at houses in a neighborhood, driving further and taking up more time.

On Nov. 13, UPS CEO David Abney said he expected Orion to save the company $300 million to $400 million a year, once it is fully implemented in 2017. The more than 40% of the company's 55,000 U.S. routes already using the software at that time had been reduced by an average of between seven and eight miles, the company said. The company can save $50 million a year by reducing by one mile the average aggregated daily travel of its drivers. Those savings are critical as UPS tries to boost earnings growth, which has been in the 5% range in recent years and dipped in 2014, as low-margin deliveries related to e-commerce become more prevalent and the company scrambles to figure out how to manage its holiday season.

While Mr. Abney cautioned that at least some of Orion's gains would be offset by rising costs related to delivery of its customers' e-commerce orders, he is targeting per-share earnings growth of more than 50% over the next five years. The company lowered its 2015 outlook earlier this month.

UPS won't say how much money it has invested in Orion. But management and information technology expert Thomas H. Davenport, a distinguished professor at Babson College near Boston,believes Orion is the largest deployment of operations research, and that UPS spent $200 to $300 million to develop it.

How Orion works

A driver -- in this case, let's use the example of Tim Ahn, who has been a full-time driver for 20 years, currently with a route in Gettsyburg, Pa. -- would use his UPS tablet, known within the company as a delivery information acquisition device, or DIAD, to punch in at the beginning of his shift, as he does now. The DIAD would show him two possible ways to make his deliveries, one using Orion, and one using the current combination of work rules, procedures and analytic tools that are used to establish the order of package deliveries. He can choose to work in either way, but if he decides not to use Orion, he will be asked to explain the decision.

Orion already has been at work for hours, though. It may have reordered Mr. Ahn's schedule of stops for the day hundreds of times, as packages were added to the list assembled before he arrives at work, and as customers used the company's My Choice self-service platform to change the time or location of their deliveries. UPS says My Choice membership has grown steadily since its launch in 2011 to 12.9 million today.

At one point, Mr. Ahn was scheduled to start his route at 8:45 a.m., making 125 deliveries and traveling 117.85 miles during the day. But now Customer 1 wants a package delivered between 11 a.m. and 1 p.m. That stop was originally scheduled by Orion for 1:25, so Orion has to recalculate. It considers up to 200,000 of the best options before settling on one. The package will now be delivered by 12:30 p.m., adding 1.39 miles to the day's route, at a

cost to UPS of $1.99. It takes Orion and the network about eight seconds to return an answer.

Now, Customer 2 specifies that a package that Orion originally scheduled for delivery by UPS at 3:51 p.m. must take place between 4:30 p.m. and 6:30 p.m. Orion considers a range of options before settling on a delivery order that arranges the delivery for 4:46 p.m., adding 1.64 additional miles and $2.77 in cost.

Orion is a useful tool, according to Mr. Ahn. "Orion had me do things in the morning I would not think of doing, and it saved me miles later in the day," he said.

Rough Patches

The deployment of Orion isn't always so smooth, though. That is where Mr. Levis comes in. As project manager, he is responsible for getting people and machines to work together. During the earlier stages of writing the Orion algorithm, it was Orion that had to learn to accommodate people.

"The project was nearly killed in 2007, because it kept spitting out answers that we couldn't implement," Mr. Levis recalls. The earliest versions of Orion focused on getting the best mathematical results, with insufficient regard for the interests of the driver or the customer, who value some level of routine. For example, regular business customers who receive packages on a daily basis don't want UPS to show up at 10 a.m. one day, and 5 p.m. the next. And a customer who is expecting a shipment of frozen food needs delivery as soon as possible, even if efficiency demands that someone gets priority.

To get the project back on track, UPS chief scientist Ranga Nuggehalli turned to Bob Santilli, a senior project manager, asking him to describe a perfect route. Several weeks later, Mr. Santilli came back with the results of his effort, which produced a model plan of stops for drivers on a route in Lancaster, Pa. The engineering team extracted proprietary rules from the Santilli route and built them into Orion.

"By April or May of 2007, he had the first working version of Orion, which balanced consistency and optimality. It had to do with keeping the driver in a path. The route should flow. That is what we learned. That is what brings consistency. Orion can make exceptions to the flow, but it has to do so in an intelligent manner and it can't make an unlimited number of exceptions," Mr. Levis said.

The process of balancing Orion's logic with the real-world experience of drivers is built into the rollout of the project. A team of 700 trainers is working its way through all 55,000 U.S. routes, deploying Orion to one UPS facility at a time, a process expected to be more than 70% complete by the end of the year.

It takes about six days to train a driver. The first day of training is spent fixing maps, as the trainers pour over satellite images and talk to drivers about minute details of their routes. On the third day, the trainers ride the route themselves in a rental car. On the fourth and fifth day, the trainers ride with the driver, and try to figure out what Orion is getting wrong about the route. More revisions are made on the fifth day, and a final ride-along occurs on day six.

Driver reaction to Orion is mixed. The experience can be frustrating for some who might not want to give up a degree of autonomy, or who might not follow Orion's logic. For example, some drivers don't understand why it makes sense to deliver a package in one neighborhood in the morning, and come back to the same area later in the day for another delivery. But Orion often can see a payoff, measured in small amounts of time and money that the average person might not see.

Buttonwood Sand in the gears

The lesson from the most recent quant quake

WHAT IS IT like to lose to a machine? In 1997 the world's best chess player, Garry Kasparov, was beaten by Deep Blue, a $10m super-computer made by IBM. Twenty years later he wrote "Deep Thinking", a book about the experience. What comes across vividly is how exhausting each game was. Chess players, even great ones like Mr Kasparov, get tired and frustrated. Doubts begin to creep in. By contrast, Deep Blue just needed the occasional reboot.

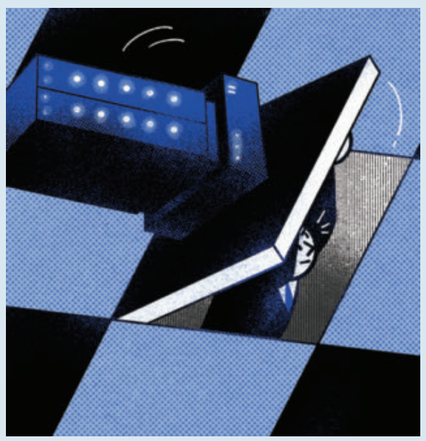
Now turn the tables. What is it like to win against the machines? By New Year's Eve the least smart buy-and-hold investor in an index fund might be able to boast of such a victory. For 2020 has been rotten for "quant" funds, which use powerful computers to sift market data for patterns that might predict future prices. "Long-short" momentum—buying recent winners and selling recent losers—had been one of quant's better strategies this year. Yet on November 9th, when news broke of an effective vaccine for covid-19, it had its worst ever day.

Quants rely on history. If something happens that is without precedent, such as a vaccine in a pandemic, they have a problem. No doubt a few quant hedge funds are nursing heavy losses. And perhaps a few discretionary funds have made a killing. The terrain on which human traders can beat the machines is much diminished. But November 9th shows it is still possible. Chalk it up as a small victory for the species.

It is no small irony that momentum trading takes advantage of human weaknesses. One of these is "conservatism bias". Investors tend to stick to prior views too rigidly and change them only slowly in response to new information. They may give undue emphasis to the price paid for a stock as a marker of its true value and, as a consequence, sell winning stocks too soon and hang on to dud stocks for too long. There is also a contrasting tendency to extrapolate past success. So as well as under-reacting to news, people also over-react to it. Momentum trading seeks to exploit this.

A lot of long-short strategies, including momentum, rank stocks by a particular attribute and then buy the top decile (or quintile) of the group and sell the bottom one. This requires machines. Sorting through thousands of securities quickly is beyond the meagre talents of a living, breathing portfolio manager. It requires algorithms that first establish and then fine-tune the optimal period over which to do the sorting. And it needs speedy and seamless access to automatic trading platforms and market data. You would not want to do all this by hand and brain.

In chess, the brute force of computing power eventually wins out. In investing, the strength of synthetic traders is in dealing with reams of information that is machine-readable, such as tick-by-tick stock prices. The most powerful machines



can make sense even of unstructured ("big") data. But an event like the discovery of a vaccine can flummox even the smartest of them. Humans retain an edge. They are able to winnow down endless possibilities using mental shortcuts. They can imagine scenarios that the past has not thrown up—scenarios such as "a vaccine may become available soon, given the amount of money and effort being thrown at it"; and "news of such a vaccine might spark a sell-off in 'stay-at-home' shares and a rally in 'get-out-of-the-house' shares".

But why were the moves in prices so dramatic? A good rule of thumb, says one quant guru, is that the faster you trade, the less capacity there is for your strategy. A speedy trading strategy, such as momentum, relies on liquid markets to keep turnover costs in check. The strategy can become crowded. And when the quants suffer losses, they may be forced by risk-management rules to close their positions. As everyone rushes to get out at the same time, it makes for extreme price movements. This is in part why sophisticated quant funds are constantly evolving. They look for unique datasets on which to train their machines. Or they try to come up with new ways to parse weaker signals that others cannot detect in the market noise.

The quants have had a rough time, but they are hardly in retreat. Their domain will only expand. The margin of advantage for discretionary trading—for human ingenuity, in other words—will shrink. It is worth remembering that the first time Mr Kasparov played against Deep Blue, in 1996, he won. Now, as he has pointed out, you can download free chess engines that are far more powerful. We should savour victories over the machines while we can.

share price rose by 3% on the day the deal was announced.

BBVA's investors were even more enthusiastic. Its share price jumped by 20% on the day. Britta Schmidt of Autonomous, a research firm, estimates the net value gained at about €8bn ($9.5bn), or 40% of the bank's market capitalisation. The sale will shore up its core-capital ratio by nearly three percentage points, to 14.5%, well above the level demanded by regulators.

A chunk of the bounty may go towards acquisitions closer to home, fuelling a long-awaited wave of consolidation in Europe's overbanked markets. BBVA's American exit makes its portfolio disproportionately exposed to emerging markets, giving it a reason to invest at home. It may also help that, since July, the European Central Bank has encouraged banks to recognise an accounting gain, known as negative goodwill, which they generate when they buy a rival at a lower price than the book value of its assets. Such "badwill", in turn, can be used to offset restructuring charges. Investors seem to believe that BBVA's talks with Sabadell will succeed: Sabadell's share price jumped by 16% on the PNC news, and a further 9% after PNC and BBVA said that due diligence had begun.

Transatlantic divestitures, meanwhile, will probably continue. European banks operating in America should either go big or give up, says Adrian Cighi of Credit Suisse, a bank. Analysts expect HSBC, Europe's largest bank by assets, to signal a partial exit when it releases its results in February. Santander and BNP Paribas, the other European banks with a big American presence, say they do not want to sell. The PNC deal, however, may make shareholders think focus is not such a bad idea. ■

Criminologists say people convicted of crimes like murder often are older when considered for release, making them less likely to reoffend. Inmates convicted of nonviolent crimes like property theft, meanwhile, tend to be younger, more impulsive and adventurous -- all predictors of repeat criminality.

The resulting parole decisions also often contradict the wishes of victims of violent crimes and their families. Mr. Murphy's release in June last year came as a shock to family members of his victim, Andrew Pitkin, and they criticized the decision sharply. They feared Mr. Murphy, who had stabbed Andrew 33 times, could kill again.

"The nature of the crime was impulsive, something spur-of-the-moment, and it makes you question what someone is capable of doing," said Rob Pitkin, Andrew's father. "Frankly, I think he should serve a lifetime."

Wider acceptance of computerized risk assessments, along with other measures to reduce state corrections budgets, has coincided with the first declines in the national incarceration rate in more than a decade.

The number of inmates in state and federal facilities fell nearly 1% in 2011 to 1.6 million, after edging down 0.1% in the prior year. The 2011 decline came entirely from state prisons, which shed 21,600 inmates, offsetting an increase of 6,600 federal prisoners. Preliminary 2012 data shows an even larger fall in state inmates of 29,000.

Experts say one reason for the decline is that fewer parolees are returning to prison. About 12% of parolees were re-incarcerated at some point in 2011 compared with 15% in 2006, representing the fifth straight year of decline, according to Justice Department data.

Texas, by reputation a tough-on-crime state, has been consistently using risk assessment longer than many states and is boosting the number of prisoners it paroles each year. With its current system, in use since 2001, it released 37% of parole applicants in 2012 versus 28% in 2005 -- some 10,000 more prisoners released in 2012.

Officials in Michigan credit computerized assessments, introduced in 2006 and adopted statewide in 2008, with helping reduce the state's prison population by more than 15% from its peak in 2007 and with lowering the three-year recidivism rate by 10 percentage points since 2005.

Still, experts say it is difficult to measure the direct impact of risk prediction because states have also taken other steps to rein in corrections costs, such as reducing penalties for drug offenses and transferring inmates to local jails.

Michigan's assessments withstood a legal challenge in 2011, when prosecutors sought to reverse the parole of Michelle Elias, who had served 25 years for murdering her lover's husband. A lower court, siding with the prosecutor, ruled the parole board hadn't placed enough weight on the "egregious nature of the crime," court documents say. The Michigan Court of Appeals overturned the decision and upheld Ms. Elias's release.

Yet earlier this month, the same appeals court ruled the Michigan parole board had abused its discretion by releasing a man convicted of molesting his daughter. He hadn't received sex-offender therapy while in prison, but three assessments, including one using Compas, had deemed him a low risk of reoffending. The appeals court, in an unpublished decision that echoed a lower court, said that Compas could be manipulated if presented "with inadequate data or individuals who lie."

The Compas software designer, Northpointe Inc., says the assessments are meant to improve, not replace, human intelligence.

Tim Brennan, chief scientist at Northpointe, a unit of Volaris Group, said the Compas system has features that help detect lying, but data-entry mistakes or inmate deceptiveness can affect accuracy, he said. The company says that officials should override the system's decisions at rates of 8% to 15%.

Many assessment systems lean heavily on research by criminologists including Edward Latessa, professor at the Center for Criminal Justice Research at the University of Cincinnati. Parole boards, typically staffed with political appointees, have lacked the information, training and time to make sound decisions about who should be released, Dr. Latessa said. The process, he said, is one factor contributing to the population surge in the nation's prisons, including a fivefold increase in the number of prisoners nationwide from 1978 to 2009, according to the Department of Justice.

"The problem with a judge or a parole board is they can't pull together all the information they need to make good decisions," said Dr. Latessa, who developed an open-source software assessment system called ORAS used in Ohio and other states.

Ohio adopted ORAS last year as the result of legislation aimed at addressing overcrowded prisons and containing corrections spending. Dr. Latessa does paid consulting work with state corrections agencies but isn't paid for use of the system. "They look at one or two things," he said. "Good assessment tools look at 50 things."

Some assessments analyze as many as 100 factors, including whether the offender is married, the age of first arrest and whether he believes his conviction is unfair. In Texas, a rudimentary risk-assessment measures just 10 factors. Data gathered in interviews with inmates is transmitted to the offices of Texas parole board members, who vote remotely, often by computer.

Willie Gordon, 25, was convicted of burglary and placed on probation in 2010. Last year, after testing positive for smoking marijuana, his probation was revoked and he received a three-year prison sentence. In February, as part of his parole application at the Hutchins State Jail off the Lyndon B. Johnson Freeway in Dallas, he sat in a small office and answered a parole officer's questions.

Each response was worth a predetermined number of points, which would add up to his risk score. The more points, the higher the risk. A total of nine points would deem him a high risk for committing a new crime; 16 would put him in the highest-risk category.

"What was the last grade that you completed in school?" asked Mandi Honza, a 14-year veteran of the Texas parole system who administered the test. "I completed high school," Mr. Gordon said. Ms. Honza deducted a point.

Mr. Gordon's age at the time of his offense, 19, added one point. Research shows younger prisoners are more likely to return to prison. If he had been 17, he would have received two points; if 26, none.

His crime, a property theft, added another two points. Had it been rape or murder, he would have received none. Texas considers burglary offenders more likely to repeat because the crime typically reflects planning and intent rather than an emotional outburst characteristic of many violent acts.

"Some people are surprised to learn that offenders who we think of as the worst offenders -- murderers and sex offenders -- have some of the lowest recidivism rates," said Lee Seale, former director of internal oversight and research at the California Department of Corrections and Rehabilitation.

Mr. Gordon said his interaction with the judicial system seemed "electronic." He had hoped to tell the parole board how he had changed since the burglary, in which he and a friend had stolen electronics from an unoccupied home. Despite the failed drug test, he had enrolled in college, found a job and entered into a serious relationship, he said.

"Basically, I just have to have faith in the computer," he said, clutching a stack of letters of from his family in support of his release.

Mr. Gordon's responses, combined with other factors, made him a moderate risk of reoffending under Texas parole guidelines. Last year, the Texas parole board released some 40% of inmates with that score. A Dallas County judge released Mr. Gordon on the condition that he complete five years of supervised probation.

Parole officials say assessment scores are just one factor they consider. Some experts say relying on statistics can result in racial bias, even though questionnaires don't explicitly ask about race.

Data such as how many times a person has been incarcerated can act as an unfair proxy for race, said Bernard Harcourt, a University of Chicago professor of law and political science. "There's a real connection between race and prior criminal history, and a real link between prior criminal history and prediction," Mr. Harcourt said. "The two combine in a toxic and combustive way."

Christopher Baird, former head of the National Council on Crime and Delinquency, said statistical tools are best used to help set supervision guidelines for parolees rather than determine prison sentences or decide who should be released. "It's very important to realize what their limitations are," said Mr. Baird, who developed one of the earliest risk-assessment tools, for the state of Wisconsin in the late 1970s. "That's lost when you start introducing the word 'prediction' and start applying that to individual cases."

Mr. Murphy was tried as an adult and convicted in the 1984 killing of his younger neighbor. The two boys were walking Mr. Murphy's dogs in the woods near Peru, N.Y., when the younger boy tripped on one of the dogs. Years later, Mr. Murphy told the parole board that Andrew had kicked the dog, which sent him into a rage. He disemboweled the boy with a folding knife.

Sentenced to prison for nine years to life, Mr. Murphy was first eligible for parole in his early 20s. Parole board members had denied Mr. Murphy 11 times, citing the grisly nature of the crime and his apparent lack of understanding of why he had killed.

Mr. Murphy delayed his 12th parole hearing last year so he could receive the Compas assessment, according to a hearing transcript. Through his attorney, Mr. Murphy declined repeated requests for comment for this story.

At the hearing, Mr. Murphy acknowledged his offense "stretches the limits of human understanding" but pleaded with the board not to let the crime define who he had become in the 28 years since.

Henry Lemons, one of two parole-board members who had voted to free Mr. Murphy, said the Compas assessment provided useful context.

"Making a decision on someone's life is extremely difficult," said Mr. Lemons, a former New York City Police Department detective who has since left the board. "You have to try to make a real quick decision during a 20-minute or half-hour interview with a person and consider his history and his likelihood of reoffending."