Teaching Analytical Thinking

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Students in Duke University's undergraduate and graduate public policy programs take a course called, informally, Analytical Thinking for Busy Decision Makers. The course emphasizes the basic concepts of analytical thinking, including the decomposition of complex problems, the logic of drastic simplification, the dynamics of first-cut and successive-cut analyses, the importance of being specific, the rationale for working with numbers, and the analytics of guesstimation. This article describes the philosophy and general nature of the course and concludes with some sample homework exercises.

How can you systematically organize your thinking about puzzling decisions to make the best use of limited time and data? This is the fundamental question addressed by a course, known unofficially as Analytical Thinking for Busy Decision Makers,[1] that we teach at Duke University's Institute of Policy Sciences and Public Affairs. The emphasis is not on how other people actually make their decisions but on how *you* can make better decisions.

The course focuses on problems faced by "busy" decision makers, that is, decision makers who lack the time, and usually the extensive statistical data, for in-depth analyses. Consequently, we stress ways of using personal judgments and "guesstimates" in resolving decision dilemmas.

Our objective is not to detail the mathematics of a collection of analytical techniques but to explain, in terms a student can understand, the concepts of analytical thinking. In other words, the course focuses not on the *technology* but on the *philosophy* of decision

1. This is also the title of a book that the authors are writing and that will be published by Basic Books in 1977. Some of the material in this article is excerpted from the introduction to that book.

analysis.[2] A few widely useful techniques are described to illustrate basic concepts, but the emphasis is on the concepts. A student who understands these basic ideas will be able to learn or devise the specific techniques he or she needs for some particular problem.

The concepts explained in the course are illustrated by a large number of real problems, drawn not only from public policy but from other areas as well, including business, medicine, law, engineering, architecture, military strategy, sports, and personal decision making. Here are some of the problems analyzed:

- Which housing plan should a mayor submit for funding?
- Should a young woman accept an out-of-court settlement in a malpractice suit?
- Should a business firm start marketing a new product?
- Which job should a college graduate accept?
- Should the president veto or sign a tax bill passed by Congress?
- Should a woman who may be a hemophilia carrier remain childless, try to adopt a child, or give birth to her own child?
- Should a manufacturer shift from gas to coal?
- Should a congressman try to get his party's senate nomination?
- How should a cardiologist treat a case of coronary artery disease?
- Which of two naval procurement plans should the secretary of defense support?
- Should a college football team kick or run after scoring a touchdown?
- Should a corporation appeal a patent-infringement settlement?
- Should the aide to a political leader commit perjury to protect his boss's career?

This is the first course required in Duke's undergraduate curriculum in public policy studies. An essentially similar course is required in the first semester of the master's degree program.

Rationale for the Course

We offer this course for several reasons. First, nearly all of the students in Duke's public policy program will enter a decision-

2. For an explanation of the details of decision analysis, see Howard Raiffa, *Decision Analysis: Introductory Lectures on Choices under Uncertainty* (Reading, Mass.: Addison-Wesley, 1968); John W. Pratt, Howard Raiffa, and Robert Schlaifer, *Introduction to Statistical Decision Theory* (New York: McGraw-Hill, 1965); and Robert Schlaifer, *Analysis of Decisions under Uncertainty* (New York: McGraw-Hill, 1969).

making profession, either in government, in and out of government, near government, or in business, law, or medicine.

Second, most decision makers, regardless of their field, are busy; they have to make their decisions in a fairly short time and on the basis of limited information. As Walter D. Scott, associate director of the Office of Management and Budget, recently remarked, "You have to be able to make big decisions by 3 o'clock the same afternoon even if you haven't had a chance to do all the homework you want."[3] If you "spend two years studying something," Oregon's former Governor Tom McCall observed, "by the time you conclude it's a good thing to do, the best time for doing it may have passed."[4]

Third, the problems of busy decision makers, like the problems listed above, seem *real* to students. We select the problems used in the course from fields that interest the students and are somewhat familiar to them; our hope is that the students will be able to imagine themselves as the people who actually have to make the decisions.

Fourth, because the problems of busy decision makers must be analyzed in a few hours or less, it is realistic to assume that extensive data are unavailable or that there is no time for an elaborate statistical analysis. Consequently, such problems readily lend themselves to an hour's class discussion or to homework assignments.

Fifth, relatively simple mathematical techniques are appropriate for analyzing decision problems when time is short and the data sparse. Thus, the course is able to focus on the *concepts* of analytical thinking without getting bogged down in the details of complicated mathematics. This emphasis on the fundamental ideas of an analytical thought process helps motivate and prepare students for later courses that present the techniques of more sophisticated "researched analysis."

In short, we focus on problems faced by busy decision makers because these are just the sort of problems that many of our students will have to handle in their professional careers and, more important, because they provide a very convenient context for teaching the concepts of analytical thinking. Because the *problems* are easy to teach—they seem real, they must be resolved quickly, and the ap-

3. Quoted by Philip Shabecoff in "Budget Maker Switched from Millions to Billions," *New York Times,* 5 February 1974.

4. Quoted by E. J. Kahn, Jr., in "Letter from Oregon," *New Yorker,* 25 February 1974, p. 97.

propriate decisional techniques are relatively simple—our teaching can be directed to the *ideas* of analytical thinking.

Many of our students will function more frequently as staff assistants or policy analysts than as decision makers. Some of the analytical methods they will need, methods that may be time-consuming or that may require extensive statistical data, are taught in subsequent courses in the program. The relationship of decision analysis to these methods of "researched analysis" seems roughly analogous to the relationship of arithmetic to algebra. It makes sense to teach arithmetic first, because it is easier for students to "get into" arithmetic; and, in studying arithmetic, students learn certain concepts that make algebra easier. Similarly, we think it makes sense to teach analytical thinking for busy decision makers before teaching analytical thinking for researchers and policy analysts. This by no means implies that we think decision analysis is more important than researched analysis or that we think our students will be decision makers more often than they will be advisors. Indeed, Duke's public policy students are required to take only this course on decision analysis but several courses on researched analysis.

Two Common Misconceptions among Students

Needless to say, in this first course required of them, many of our freshmen and sophomores are disturbed by the emphasis on analytical thinking. They expected to spend the semester reading the *New York Times* and the *Washington Post,* talking about Ted Kennedy and Jerry Brown, debating the opinions of James Reston and Eric Sevareid, and solving the great social problems of the day. By the end of the semester, however, nearly all of them understand the importance of analytical thinking about policy decisions and many of them are using the basic ideas of decision analysis introduced in the course to analyze their own personal decision problems.

In the past, this often led to a second misconception: some students began to think that decision analysis was the panacea that would solve *all* problems. Then they became disillusioned when they discovered a problem where drawing a decision tree did not seem very helpful. So now we repeatedly emphasize, throughout the course, that while the concepts of analytical thinking are generally useful, the techniques of decision analysis (as we teach them) are helpful only for a limited, if important, range of problems. We explain that it is important to study the techniques not so much for their usefulness qua techniques but because they illustrate the concepts of analytical thinking. At the same time, we do stress the particular utility of the techniques for important and puzzling dilemmas that must be resolved quickly and on the basis of limited information.

ORGANIZATION OF THE COURSE

What turns a decision maker's problem into a dilemma? Three major factors, it appears, and the course is organized around them.

First, the decision maker may not know the precise consequences of the alternative decisions. Perhaps the consequences depend on some future event that may or may not happen: an oil wildcatter, for example, may need to decide whether or not to drill for oil when he does not know if the result will be a dry well, a strike, or a gusher; or a patient may have to decide whether to undergo an eye operation that might improve her vision or leave her blind. In other cases, the consequences of a decision may depend on other, future, decisions. This is what makes games like chess or checkers—and real-life "games" involving military, diplomatic, or business strategy—so challenging. The decision may not even involve an opponent; its consequences may depend on future choices to be made by the decision maker himself. For example, a business executive's current decision about whether or not to test market a new product will depend upon how he plans to decide whether to drop the product or move to full-scale production and distribution. If the product will be dropped unless there is widespread demand, and if the executive predicts that test marketing the product has only a ten percent chance of demonstrating such consumer demand, then the initial decision may be not to test market. But if the product can be profitably marketed nationwide with only a minimum of consumer interest, and if the executive predicts that there is a 75 percent chance of test marketing uncovering this level of demand, then the initial decision may be to undertake the test. In these cases, to think analytically in order to make your current decision, you must determine how you will make your relevant future decisions.

The first two sections of this course focus on dilemmas in which the decision is puzzling because the consequences of the alternatives are unknown. Part I, "The Basics of Decision Analysis," introduces the concepts for structuring such problems; and Part II, "Assessing and Working with Probabilities," describes how a decision maker can organize his thinking to make the necessary predictions.

The second major factor that can make a problem puzzling is a clash between competing objectives. For example, how does a congressman decide how to vote on a bill that he thinks will help reduce unemployment but increase inflation? Similarly, should a consumer buy an expensive car with special safety and comfort features or a less costly model without them? Part III, "Evaluating Consequences," describes some useful concepts for dealing with competing objectives.

The third major factor might be called "complexity." Some decision problems are so complicated that they are hard to pin down and define precisely; there are too many alternatives, too many possible consequences, too many objectives. For instance, countless decisional possibilities and considerations may bewilder an architect designing a hospital or a lawyer designing a crime-prevention program. Throughout this course, but especially in Part IV ("Analyzing Your Analysis"), we introduce ways of systematically cutting a problem of mind-boggling complexity down to manageable size.[5]

THE CONCEPTS OF ANALYTICAL THINKING

We want to convince students, then, that in the face of complex problems involving competing objectives, consequences clouded in uncertainty, and limited time, they need not rely on intuition, snap judgments, or simplistic decisional rules. Certainly, we explain, they can always make what Professor Alexander Gerschenkron calls an "Oh, hell decision." Explains Gerschenkron, "You weigh the pros and cons and then you make an 'Oh, hell' decision. Oh, hell, I'll do it. Oh, hell, I won't." When Gerschenkron was working at

5. In his book *The Cybernetic Theory of Decision* (Princeton, N.J.: Princeton University Press, 1974), John Steinbrunner defines a complex decision problem as one in which (1) two or more values are affected by the decision, and there is a trade-off between them such that a greater return to one value can be obtained only at a loss to another; (2) there is uncertainty; and (3) the power to make the decision is spread over a number of individual actors or organizational units (p. 16). Since we assume in our course that the decision maker has the responsibility and authority to make the decision, we do not include the last factor in our definition of a complex decision problem.

the Federal Reserve Board, he was invited to join the Harvard economics department. After worrying about the decision for several weeks, he simply said, "Oh, hell, I'll go to Harvard."[6]

But what if the problem is more puzzling (and important) than deciding to go to Harvard? Using five basic concepts and some methods based on them, a decision maker can think analytically about a problem in such a way that his limited time and information are put to the best possible use. More than decision analysis itself, our course emphasizes these five basic imperatives for intelligent analysis: think, decompose, simplify, specify, rethink.

1. Think!

The time spent on a decision problem is divided between two basic tasks: thinking about the problem; and gathering and processing information. Most students devote 99 percent of their time to the second task—they talk to people about the problem, they read relevant material, they develop complex models or theories, they carry out elaborate calculations. Now these activities may be useful, but a decision maker can usually reach a more intelligent decision if he spends more of his time thinking hard, trying to understand the nature of the problem. We tell our students that in most cases at least half their time should be devoted to thinking.

"Model simple; Think complex," admonishes Garry Brewer, editor of *Policy Sciences*.[7] The difficulty with much analysis, especially when done by "quantitative types," is that the analysis is so complex that its relationship to the problem to be solved is obscure—even to the analyst. The model itself (that is, the structure of the analysis) becomes the driving force. The analyst spends the great bulk of his time developing an elaborate model and carrying out lengthy calculations; thinking intently about the problem gets short shrift.[8] We are continually amazed, for example, by the willingness of our students, in tackling their homework, to construct complex analytical

6. Quoted by Israel Shenker in "Harvard's 'Scholarly Model' Ending Its Career," *New York Times*, 19 June 1975.

7. The quote is from a talk Brewer gave at Duke University on December 3, 1973.

8. For a discussion of the relationship between formal models and real policy problems, see Ralph E. Strauch, " 'Squishy' Problems and Quantitative Methods," *Policy Sciences* 6, no. 2 (June 1975): 175–84; and *idem*, "A Critical Look at Quantitative Methodology," *Policy Analysis* 2 (Winter 1976): 121–44.

models and, in an effort to produce some kind of answer, to perform the long calculations these models require. Then, during the late night hours, when these calculations (and the inevitable mistakes) are made, the students lose all grasp of the meaning of the problem and the purpose of the analysis.

Thus, our course emphasizes simple models. Complex models usually prevent complex thinking. As Charles Hitch indicates in his *Decision Making for Defense,* complex thinking is what really counts:

> The hardest problems for the systems analyst are not those of analytic techniques. In fact, the techniques we use in the Office of the Secretary of Defense are usually rather simple and old-fashioned. What distinguishes the useful and productive analyst is his ability to formulate (or design) the problem; to choose appropriate objectives; to define the relevant, important environments or situations in which to test the alternatives; to judge the reliability of his cost and other data; and finally, and not least, his ingenuity in inventing new systems or alternatives to evaluate.[9]

Donald C. Eteson, of Worcester Polytechnic Institute, has characterized the use of complex calculations without appropriate thinking as "the brute force and ignorance technique."[10] This technique almost always leads to the wrong answer or, at best, the right answer to the wrong problem. We continually push our students to think about the appropriateness of their analysis to the actual dilemma, the resolution of which is, after all, the purpose of all their work.

Part of the job of thinking involves continually checking to see whether the information being used and the results obtained make sense. In particular, it is important to get students into the habit of checking on whether a number is reasonable. As Max Singer has pointed out, far too many analyses are based on numbers that are ridiculously high or low.[11] Ideally, students should check all the numbers they see or hear, even when they are half asleep.

To make this point we often tell a story about one of our friends,

9. Charles Hitch, *Decision Making for Defense* (Berkeley and Los Angeles: University of California Press, 1965), p. 54.

10. Professor Eteson has often used this phrase to ridicule students who develop silly, complicated solutions to his electrical engineering problems.

11. Max Singer, "The Vitality of Mythical Numbers," *The Public Interest,* no. 23 (Spring 1971), pp. 3–9.

who usually wakes up slowly to the sound of his radio. But one morning he awoke with a start. His interest was caught by some numbers being used on a talk show about alcoholism. As the show ended, the host summed up: "There are 50 million alcoholics in the United States." "And don't forget," added the guest, the expert on alcoholism, "you have to multiply that number by five to take into account friends and other family members, to get the total number of people in the U. S. affected by alcoholism." Our friend immediately multiplied the numbers in his still sleepy head and came up with "more people than there are in the entire country!" Later, he checked an almanac; the figures published by the U. S. Department of Health, Education, and Welfare put the number of alcoholics in the U. S. at 9 million.

Today, most Americans and clearly all policymakers (whether in government or elsewhere) are "literate." But how many are "numerate"? How many can make simple calculations and interpret simple numbers? How many corporate executives can read and understand the tables and charts prepared by their planning staffs? How many U. S. senators can make useful back-of-the-envelope calculations to check out numerical statements made by lobbyists? And how many make a practice of doing so?

These are the types of habits we are trying to encourage, for, as Richard J. Zeckhauser of Harvard argues, "one of the best tools of policy analysis is long division." Why? Because it is the simplest method for answering the question: "How much did I accomplish for how much?"[12] Thinking analytically about most decisions requires an ability to handle simple numbers—a fluency in the elementary language of mathematics.

2. Decompose!

The word "analyze" is derived from an ancient Greek word meaning "decompose," "break up," "separate the whole into its component parts." This is the key to any complex decision problem: decompose it into its component parts, work with these individual components, and then recombine the results to make your decision.

The process of decision decomposition is analogous to the method most people—at least those who have misplaced their

12. From a talk Zeckhauser gave at Duke University on November 25, 1974.

pocket calculators—employ to multiply multidigit numbers. Few people can multiply 3,479 by 5,463 in their heads. So, to solve the problem, most people do the simple work of systematically decomposing it on a piece of paper: they write the problem down, break it up into its parts (3 times 9, 3 times 7, and so on), and then add these parts together to get the final result. Similarly, most people are willing to use other techniques of systematic decomposition—such as long division or the method for taking square roots—when faced with other kinds of arithmetical problems.

A decision maker should be equally willing to structure a problem by writing each of its components down on a piece of paper in an orderly way. Our course illustrates some systematic methods for doing this—methods that are to decision making what multiplication and long division are to arithmetic.

Unfortunately, most students are reluctant to submit their own problems to this conscious and systematic decomposition. Apparently, they feel that decision making is a natural talent that does not require structure. Or perhaps they feel a little silly and self-conscious about organizing their thinking on paper. As John Steinbrunner has pointed out, however, the human mind often does not work in an analytical fashion. For complex problems that involve uncertainty and trade-offs between important objectives, the cognitive process of the mind seeks to deny the existence of the uncertainty by establishing strong beliefs about the future with, for example, the logic of analogy, and to deny the existence of competing objectives by pursuing both values in separate, but contradictory, ways.[13] Thus, self-discipline is required to ensure that no important uncertainty or trade-off is ignored. For this, a pencil and paper are most helpful.

We do not ask the students to take our word on faith. We encourage them to undertake a simple experiment to demonstrate the efficacy of analysis. Whenever they confront a puzzling decision problem, we ask them first to make the decision "in your head." Then, we hope, they will sit down with pencil and paper and use the ideas of systematic decomposition described in the course. In most cases, they will find that the second approach yields a "better" decision.

What should the students consider a "better" decision? One that is truly consistent with their preferences and beliefs. One with which

13. See Steinbrunner, *Cybernetic Theory,* particularly chapter 4.

they feel comfortable. Later, they may be disappointed when an event they thought unlikely actually occurs and produces the least desirable consequence, or they may regret that they did not understand some of the factors that made the event more probable than not. But, we tell them, "Our hope is that, looking back and remembering that you had only limited time and information, you will still think you did your best—that, having thought analytically, you will not regret the way you resolved the problem."

3. Simplify!

Most important problems of decision making are too complicated to analyze completely. A complete analysis would involve—

1. specifying all possible alternative decisions;
2. predicting all possible consequences of each alternative;
3. estimating the probability of each consequence;
4. appraising the desirability of each consequence;
5. calculating which alternative decision yields the most desirable set of consequences.

As Charles Lindblom of Yale has made clear, this represents an ideal rationality that man, with his limits of time, information, and intellectual capacity, will never attain.[14] For example, a complete analysis of how much money to place in the federal budget for cancer research would have to include, among other things, consideration of all the other possible ways of using this money (e.g., for kidney research, educational research, salaries for military personnel, lower taxes) and all the possible implications of these alternatives (the future of the Papacy, the profitability of uranium mining, the prospects for interplanetary travel, the popularity of rock music, etc.).[15]

Since it is impossible to take into account all the factors that may be relevant, you must simplify. Indeed, you must *drastically* simplify. You must isolate the really important from the inconsequential; you must decide which few factors to include in your "first-cut" analysis and which additional factors to include in your "second-

14. Charles E. Lindblom, "The Science of Muddling Through," *Public Administration Review* 19, no. 2 (Spring 1959): 79–88.

15. For an amusing exercise that dramatizes this point, see the question on economics in "Test for Systems Analysts," *Modern Data,* August 1973.

cut" analysis—if there is time for a second cut. The objective is to isolate the most critical factors and to describe their essential relationships. The ideas of decision analysis provide the framework for this task.

Most students find the "logic of simplification" a difficult concept. They feel uncomfortable about leaving things out of their analysis. Consequently, they try to consider as many factors as they can in the time they have available. The problem is that this leaves very little time to recombine all the factors to make the decision. And the more factors considered, the more time this synthesizing stage takes. Many students feel that they can perform the synthesis rapidly, in their heads, but a substantial body of psychological research indicates that there are stringent limits to the amount of information the mind can process.[16] If a person thinks about a hundred different considerations influencing a decision and then tries to make the decision without systematically organizing all of them with the help of a pencil, some paper, and some analytical concepts, the decision will inevitably be based on very few of the considerations, perhaps only four or five.

Simplification at the outset usually results in better decisions. As we emphasize throughout this course, the basic procedure is first to determine the most crucial factors and then to use the ideas of decision analysis to bring each of these factors to bear on the problem. If more time is available, other considerations can be added in an orderly manner to the first-cut analytical structure.

4. Specify!

Decisions depend on judgments about the probabilities of events and the desirabilities of consequences. A decision maker should

16. For the research on this matter, one of our colleagues, Professor Gregory Fischer, suggests the following references: Lewis R. Goldberg, "Man versus Model of Man," *Psychological Bulletin* 73, no. 6 (1970): 422–32; L. W. Miller, R. J. Kaplan, and W. Edwards, "Judge: A Value-Judgment-Base Tactical Command System," *Organizational Behavior and Human Performance* 2, no. 4 (November 1967): 329–74; Herbert Moskowitz, "R&D Manager's Choices of Development Policies in Simulated R&D Environments," *IEEE Transactions on Engineering Management,* Vol. EM–19, no. 1 (February 1972): 22–30; Paul Slovic and Sarah Lichtenstein, "Comparison of Bayesian and Regression Approaches to the Study of Information Processing in Judgment," *Organizational Behavior and Human Performance* 6 (1971): 649–744; and Amos Tversky and Daniel Kahneman, "Judgment under Uncertainty: Heuristics and Biases," *Science* 185, no. 4157 (1974): 1124–31.

specify such judgments as precisely and unambiguously as possible.

Consider first the case of probability judgments. For nearly all puzzling problems, the decision maker will be uncertain about the consequences of a decision; after all, no one can foresee the future perfectly. But in most cases the uncertainty will be so critical that the decision maker will want to consider explicitly the most likely outcomes of the alternative decisions and the probabilities of ending up with these outcomes. In certain special circumstances, he may have some statistical data with which to calculate these probabilities. For example, previous experience may indicate that the probability of a spare part being defective is 0.005, or that the probability of a taxpayer in the $15,000 to $20,000 bracket cheating on his federal income tax return is 0.018. In such cases, it clearly makes sense to work with numerical probabilities.

For most problems, however, relevant statistical data are not available. Here we must rely on subjective probability assessments, or "probability guesstimates." Such assessments are based on data—not on statistical data that can be processed by formal mathematical methods, but on data that consist of relevant bits and pieces of information that the decision maker has in his head or can look up.

Most students describe such probability assessments with words or phrases like "probably," "unlikely," "almost certainly," or "hardly any chance." But these terms are ambiguous: most people use the word "probably" to describe a fairly wide range of probabilities; furthermore, various studies have shown that some people use "probably" to mean something like a 50 to 60 percent chance, while others take it to mean at least a 90 percent chance.[17]

Numerical probability assessments have the advantage over such words and phrases in that they are much more specific: 101 numbers are available to describe probabilities from 0 percent to 100 percent to the nearest percent. Furthermore, they are unambiguous (the meaning of a 70 percent chance can be clearly defined); and they permit a decision maker to perform certain arithmetic calculations that may help determine the preferred decision.

Two types of students tend to be particularly reluctant to accept the use of subjective probability assessments. The first type includes

17. For an exploration of the meaning of probability words to different people, see our *Analytical Thinking for Busy Decision Makers* (New York: Basic Books, forthcoming), chap. 6.

science and engineering students who have been rigorously trained in the use of objective statistical data. Such data, we must point out to them, are often unavailable or simply do not exist. In these cases, one must rely on subjective probability assessments. The only question is whether to make these assessments consciously and explicitly or to use some unconscious, intuitive process. The former tends to lead to better decisions.

The other students who tend to be uncomfortable with subjective, numerical probability assessments are those in literature, history, languages, and the fine arts who have had little exposure to mathematics. They are bothered not by the subjective nature of the assessments but by their being expressed as numbers. But "a ninety-five percent chance," we point out, is just as good an English phrase as "extremely likely." Indeed, it is better, at least in cases where precision of expression is important, because it is more specific.

According to the eminent stylists William Strunk and E. B. White, "the surest way to arouse and hold the attention of the reader is by being specific, definite and concrete. The greatest writers—Homer, Dante, Shakespeare—are effective largely because they deal in particulars and report the details that matter. Their words call up pictures."[18] The purpose of language is the communication of ideas, of images. Of what value, then, is the phrase "it will probably rain tomorrow" if the speaker means that there is a ninety percent chance of rain while the listener pegs it at slightly more than 50 percent? "Since writing is communication, clarity can only be a virtue."[19]

Significantly, words like "probably" or "unlikely" may reflect more than imprecise communication. They may reflect imprecise thought. The student who says "it will probably rain tomorrow" never really bothered to determine exactly how likely it was to rain. He used the word 'probably" to mask his unwillingness to think carefully about this uncertainty. According to George Orwell, our language "becomes ugly and inaccurate because our thoughts are foolish, but the slovenliness of our language makes it easier for us to have foolish thoughts."[20] One of the advantages of using precise

18. William Strunk, Jr., and E. B. White, *The Elements of Style,* 2d ed. (New York: Macmillan, 1972), p. 15.
19. *Ibid.,* p. 71.
20. George Orwell, "Politics and the English Language," in *The Orwell Reader* (New York: Harcourt Brace Jovanovich, 1956), p. 355.

probabilities—ten percent, seventy-five percent, etc.—is that before the student can use them he must think.

In addition to making judgments about uncertainties, the decision maker must evaluate the desirability of each of the possible outcomes of each alternative decision. He might initially describe his preference for each outcome by writing a few sentences or paragraphs about it. To make a decision, however, he will have to determine the *relative* desirability of the various outcomes. In doing this, decision makers often make lengthy appraisals and then summarize them with short descriptions. But, again, phrases like "not so bad" or "highly desirable" or "better than nothing" are ambiguous.

By using numerical preference-values, in the ways described in this course, students can enrich and refine their vocabulary for describing their relative preferences. In the analysis of important, puzzling decision problems, precision of thought and expression are clearly essential. Furthermore, by specifying preferences in numerical form, students have the powerful logic of mathematics to help them assemble and process the information and reach a decision that is truly consistent with their beliefs.

Although those who are unable or unwilling to use numbers to think about probabilities and preferences may lose themselves in a maze of confusingly imprecise thoughts, those who insist on including only those factors that can be measured with confidence bias their analyses in a futile search for objectivity. Edward Banfield talks about this in his study of a decision on the location of a Chicago hospital:

> There is likely to be a systematic bias in a technician's choice of value premises. He will . . . minimize the importance of those elements of the situation that are controversial, intangible, or problematic. He will favor those value premises upon the importance of which there is general agreement (e.g., travel time), and he will ignore or underrate those that are controversial or not conventionally defined (e.g., eliminating racial discrimination); he will favor those that can be measured, especially those that can be measured in money terms (e.g., the cost of transportation), and he will ignore or underrate those that are intangible and perhaps indefinable as well (e.g., the mood of a neighborhood); he will favor those that are associated with reliable predictions about the factual situation (e.g., the premise of accessibility is associated with relatively reliable predictions about population movements and con-

sumer behavior), and he will ignore or underrate those that are associated with subjective judgments of probability (e.g., that it will be harder to get political approval for a South Side site).[21]

The analytical framework presented in this course *requires* students to consider the intangible as well as the measurable. The ideas of decision analysis demand that a student incorporate not only predictions about which he is quite confident but also those about which he is highly uncertain. But before he can analyze any of the factors—measurable or intangible, certain or uncertain—he must determine which are the most important.

Unfortunately, in their search for objectivity, students with "quantitative" backgrounds permit what is measurable to determine what is important. Pollster Daniel Yankelovich complained about this in his description of "The McNamara Fallacy":

> The first step is to measure whatever can be easily measured. This is okay as far as it goes. The second step is to disregard that which can't be measured or give it an arbitrary quantitative value. This is artificial and misleading. The third step is to presume that what cannot be measured easily really isn't very important. That is blindness. The fourth step is to say that what cannot be easily measured really doesn't exist. This is suicide.[22]

When analysts let their technical capabilities substitute for their own judgment, it is the numbers, the quantifiable factors, that become the driving force. As Moynihan complains, "Statistics are used as mountains are climbed: because they are there."[23]

Decisions should be based upon those factors that the decision maker believes to be most important, not upon those for which he finds it easiest to collect statistics. This is Alain C. Enthoven's first principle of policy and program analysis: "Good analysis is the servant of judgment, not a substitute for it."[24]

To make analysis serve judgment, we structure our course by

21. Edward C. Banfield, *Political Influence: A New Theory of Urban Politics* (Glencoe, Ill.: Free Press, 1961), pp. 330–31.

22. Quoted by "Adam Smith" in "The Last Days of Cowboy Capitalism," *Atlantic Monthly*, September 1972, p. 54.

23. Daniel P. Moynihan, *Maximum Feasible Misunderstanding* (New York: Free Press, 1969, paperback edition), p. 30.

24. Alain C. Enthoven, "Ten Practical Principles for Policy and Program Analysis," in *Benefit-Cost and Policy Analysis, 1974,* eds. Richard Zeckhauser et al. (Chicago: Aldine, 1975), p. 456.

discussing the imperative of simplification before the imperative of specification. The student cannot specify his judgments about the important elements of his decision until he simplifies the problem so that he is dealing only with its most important features.

To use decision analysis, you must decide what uncertainties and what outcomes will most directly influence your decision; and then you must make explicit, to yourself if not to others, what your predictions and preferences are. Obviously, many of these judgments will be subjective. In this course, we do not deny that; indeed, we stress it. For if the decision is the student's to make, then it is the student's judgments that are important. The purpose of using a few numbers is to force the student to think carefully and precisely about these judgments.

Similarly, we make no claim that the numbers used in a decision analysis are objective measurements. Rather, we emphasize decision problems where measurable data are not available. But we urge the students to exploit numbers, when it makes sense to do so, in order to specify their judgments as completely and precisely as possible. At the same time, we warn them that their numbers should not be the product of arbitrary and thoughtless quantification: "Don't let the numbers push you around—push *them* around!"

5. Rethink!

The catch-22 of decision making is this: *decision problems worth solving do not have a solution.* As emphasized in the discussion of simplification, all decision analyses are incomplete. To analyze a problem completely, we would have to consider *all* the alternative courses of action, *all* the possible consequences of *each* of these alternatives, and the likelihood and desirability of *each* possible consequence—an impossible task, given our limits of time, data, and intellect. Consequently, it is impossible to reach "the correct solution" to any real-life decision problem.

An important corollary follows: no real-life decision can be made objectively. Because no analysis can ever be made complete, all decisions ultimately must rest on a number of personal, subjective judgments.[25]

First, subjective judgments must be made as to which factors and

25. As Strauch notes (" 'Squishy' Problems," p. 183), "Subjectivity thus means both the use of judgment, and it means a prejudiced approach to a problem, trying to come to a particular answer." We, of course, are using the first definition.

alternative decisions to consider. Second, subjective judgments must be made about the probability values used. This is the case even when objective data are available to help estimate the probabilities. Objective data necessarily concern past events, but the probabilities to be assessed concern future events. Thus, at the very least, subjective judgments must be made as to whether the future will be sufficiently similar to the past. In most cases there are no exact precedents for future events; thus, the conclusions drawn from a statistical analysis of past data must be combined with some subjective guesstimates about the future in order to assess the probabilities of future events. Finally, subjective judgments must be made about the preference values used. Economists use money to measure the value of goods purchased in an open, free, and perfect market—a useful but nonexistent ideal. It is possible, of course, to convert the value of any outcome into a monetary equivalent, no matter how distasteful such an undertaking may be, but it is not possible to claim that the resulting measure of value is objective. Moreover, the *decision* to use money or any other objective index of value to define your preferences is necessarily subjective.

In this matter of the inherent subjectivity of preference-values, we ask the following of our students: "Can you think of any set of three possible consequences about whose relative merits all four billion people now living would agree?" Then we point out to them that their individual views of morality and justice, as well as their desires for personal happiness, all influence their subjective preferences.

Because all analyses are incomplete and ultimately based on subjective judgments, we present analytical decision making as a creative process of discovery. In the first stage of this process the analyst thinks about the problem, decomposes it into its basic elements, simplifies these elements so that the problem is manageable, specifies his judgments of the likelihood and desirability of the most important possible outcomes of the few alternative decisions he has considered, and then works with this structure and these judgments to reach a "first-cut" decision.

In the second stage he *rethinks* the problem and his analysis. The first-cut analysis does not provide the ultimate answer. If he has more time and feels that the decision needs more analysis, he will want to think more carefully about his assumptions and judgments, change them as he sees fit, and perhaps perform some side calculations and collect some more data to help improve them.

Now he has reached a "second-cut" decision. If he has more time and is still troubled or puzzled about the decision, he can rethink again for a "third-cut" analysis and perhaps even go on to a "fourth cut." At no point will he ever reach *the* best decision, because he will never be able to analyze the problem completely. The more he works on it, however, the more he will discover and the better his decision will be.

Well, when does he stop? We do not tell our students to keep on rethinking the problem indefinitely. The general rule, as stated by John Rawls of Harvard, is that "we should deliberate up to the point where the likely benefits from improving our plan are just worth the time and effort of reflection."[26] In other words, continue only as long as the expected costs of further analysis are less than the expected benefits. The fourth part of the course, "Analyzing Your Analysis," presents some ideas to help students determine when and how they should continue to rethink; for example, we discuss the $pd > c$ rule, the expected value of perfect and sample information, and sensitivity analysis.

As a creative process of discovery, guided by subjective judgment, decision making is essentially an art. Consequently, we point out, experienced decision makers who have developed their wisdom and judgment through extensive on-the-job training will, other things being equal, outperform novices. But this does not imply that the systematic analysis of a decision problem is foolish or futile. Analysis, even if it is necessarily incomplete and largely subjective, almost always yields decisions that the decision maker finds preferable to his initial, holistic, intuitive judgment. Other things being equal, decision makers who understand and use the concepts and methods of decision analysis will tend to make more intelligent decisions than will their fellows who rely on hunches, intuition, and snap judgment. Wisdom and experience, always the guiding forces, can be significantly enhanced by the thoughtful use of systematic analysis. This is true even if the decision maker has little time or data available. Our basic message is that analytical thinking can help even the busiest decision maker.

26. John Rawls, *A Theory of Justice* (Cambridge, Mass.: Harvard University Press, 1971), p. 418.

HOMEWORK ASSIGNMENTS

The concepts of analytical thinking are easy to state but difficult to apply. The best way we know to teach them is to have the students practice thinking analytically about a variety of decision problems. Consequently, at every meeting of the class, at least one and often several problems are discussed; and at least once a week the students are assigned decision problems as homework exercises. Every idea introduced in the course is applied, in class and in homework, to several real decision problems.

Designing good homework problems—problems that make the students think—is not easy. If you describe the decision problem and then ask the student to list his assessments of probabilities and preference-values, his solution is mechanical; he merely folds back the decision tree. If you ask him to analyze a problem he faces himself, you have no way of knowing whether he has thought seriously about the problem or merely jotted down a few arbitrary numbers. The following pages contain some of the exercises we use, with some notes about where they fit in the course. None of the exercises are ideal, but we do hope that they force the student to think analytically.

1. Ruth Mason's Dilemma

The first day of class is devoted to an overview that makes essentially the points covered in this article. To convince students that the methods of decision analysis are useful, we assign a fairly complex problem as a homework exercise, due the second day of class. One problem we have used in this way centers on the following case study in bioethics.[27] *Later in the course we come back to the case and reanalyze it using the methods of decision analysis.*

> Ruth Mason's sister has just had a child—a boy. Within hours it is clear that the child has classic hemophilia. Among the children of Ruth's sisters he is the second son to be born with hemophilia. Because hemophilia of this kind (type A) is caused by a gene on the X-chromosome which is passed from mother to daughter, Ruth has a one in two chance of being a carrier herself. If she is, approximately half of her

27. This case was prepared by Robert Veatch on the basis of an actual situation. See Robert M. Veatch, Sissela Bok, and Marc Lappé, "Options in Dealing with the Threat of Hemophilia," *The Hastings Center Report* 4, no. 2 (April 1974).

male offspring would receive the X-chromosome with the hemophilia gene and half of her daughters would be carriers like herself; the other half would be normal. She had been planning to have a child and now wants desperately to know what she can do in these circumstances.

Her obstetrician tells her about a new test which she could take before becoming pregnant to determine if she were a carrier of hemophilia. He emphasizes that if the test were positive, it definitely means she has the gene, but that it would only pick up 80–95 percent of the women who are carriers. Should she become pregnant, the obstetrician informs her that a prenatal test called amniocentesis could be done around the 16th week of her pregnancy which would tell her within days whether or not she was carrying a male fetus. In the current state of our technology, however, he points out that there would be virtually no way to ascertain whether the fetus was normal or destined to be a hemophiliac. The doctor tells Ruth that she could then choose an abortion during the second trimester of her pregnancy. Ruth realizes that if she were positively identified as a carrier, she would then be faced with the prospect of an abortion where there would be a 50:50 chance of aborting a hemophiliac male—or a normal son. And if she were negative, she still couldn't be sure of not having a hemophiliac because the carrier detection test misses almost one in every five who have the hemophilia gene.

Ruth Mason decides to find out more about the disease and calls the National Hemophilia Foundation which tells her of new developments in the care and treatment of hemophiliac boys. There is a new means of preparing the anti-clotting factor (cyoprecipitate) and home therapy programs which greatly reduce the cost of home treatment to approximately $6,000 per year. She also learns that a prophylactic schedule of treatments greatly reduces the insidious bleeding which in the past caused much of the disability (by causing joint problems) experienced by hemophiliacs. She returns to the obstetrician, troubled and confused. Should she go ahead and take the test to determine if she is a carrier? How should she go about deciding whether or not to become pregnant and possibly have to abort?[28]

Before considering these decisions, it may be helpful to describe Ruth in a little more detail. She is 28 years old and is an honors graduate of the University of Michigan and of the Vanderbilt Law School. She works for a large, prominent San Francisco law firm. Her husband, whom she married two years ago, is a nuclear engineer associated with Stanford University. Ruth's obstetrician is a

28. *Ibid.*, pp. 8–10.

well-known senior physician whom she trusts and respects. Ruth is an Episcopalian and her husband is a Methodist, although they only attend church occasionally. They consider themselves political independents and usually favor candidates who are liberal Democrats or progressive Republicans.

Write a short memo, of less than 1,000 words, advising Ruth Mason as to how she should go about thinking about her dilemma. In order to help her, include in your memo a description of how *you* would think about it and what your decision would be if you were Ruth Mason.

Your memo should be as concise, but also as specific, as possible. It should be to the point and well written. And it should be neat, preferably typed.

2. The Prototypal Decision Problem

The simplest type of decision dilemma involves just two alternatives. The outcome of the first is certain and of middling desirability. The outcome of the second is uncertain; it will be either highly desirable or highly undesirable. We spend the second day of class discussing this prototypal problem, which can be diagrammed as shown in figure 1. One of the assignments handed out after this class is the following:

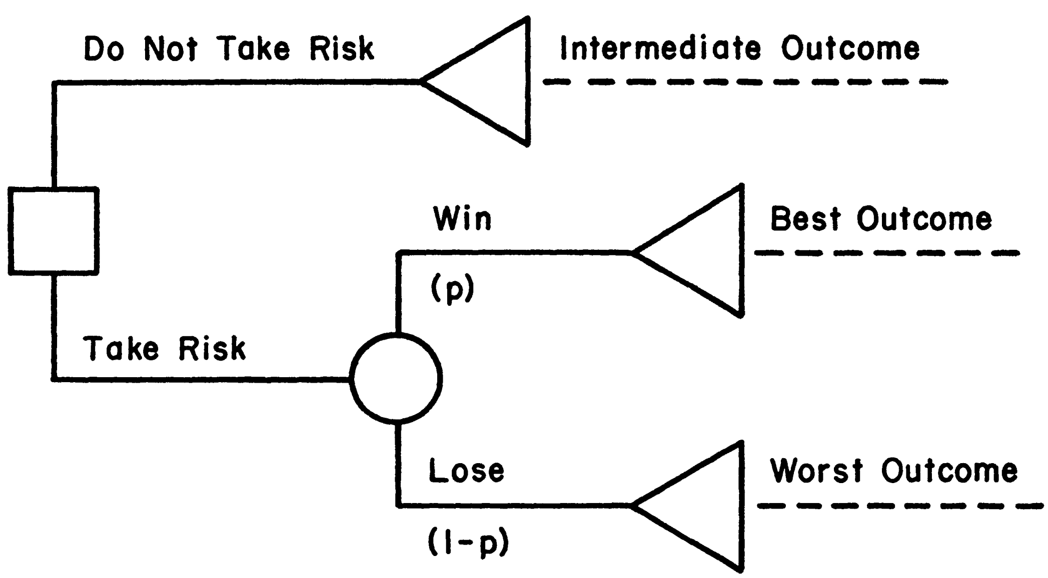

Figure 1. The Prototypal Decision Problem

Write a short memo—as brief as 2 or 3 pages—describing such a decision problem. The problem might be one involving you or someone you know; it might be taken from some newspaper or magazine story; it might be taken from a book—perhaps a history book, a biography, a public policy book, or a novel. In any case, the dilemma you choose should be interesting and the memo you write should be clear, concise, specific, and neat, preferably typed. While you may talk about this assignment with your classmates—indeed, we encourage such conversation—you should *not* write up the same decision dilemma that a classmate is working on. Be original and creative!

3. Mayor Holton's Dilemma

In the second week we go into the use of more elaborate decision diagrams. We also begin discussing the nature and logic of "preference-values," also known in the trade as "BRLTs" (Basic Reference Lottery Tickets) and "utilities." Here is one of the problems assigned during the second week.

It was two weeks before election day. Mayor Jack Holton was campaigning for reelection against a popular but, in Holton's view, incompetent opponent, Rodney ("Buddy") Richards. Holton's assistant, Tony Gabriel, had just given Holton a confidential report that contained a document and some supporting evidence indicating that Police Chief Pete Mack had taken a $10,000 bribe from the Mafia.

Mayor Holton was shocked. He had appointed Mack as police chief a year earlier, and Mack seemed to be doing a good job. Indeed, one of Holton's reelection campaign themes was that, under his and Mack's leadership, police efficiency and performance had dramatically improved.

Holton knew that, once the report became public, he would have to suspend Mack until Mack either cleared himself or was found guilty. If it weren't for the election, he would suspend Mack immediately. But he realized that doing so would decrease his election chances. He was tempted, therefore, to keep the report secret and to delay suspending Mack until after the election. But he knew that if he tried this and the report leaked to the press, his reelection chances would plummet. Since only his top aides knew about the report, Holton figured that there was only about one chance in five that the report would be leaked before the election. If it did leak, he would have to suspend Mack immediately.

If the report did not leak before the election, Holton would suspend Mack the day after the election. He would pretend the report had just been given to him. However, Holton was afraid that, if he did this, the press might subsequently learn of the earlier existence of the report. He figured that there was about a 40 percent chance of this happening if he were reelected and a 75 percent chance if he were defeated. If Holton lied in this way and the press found out about it, his future political effectiveness would be severely damaged.

Holton assessed the probability of being reelected as 30 percent if he immediately suspended Mack, 55 percent if he could successfully keep the report secret until after election day, and 15 percent if he tried to keep the report secret until then but the report was leaked to the press.

He thought that the best outcome would be to suspend Mack immediately and win reelection, and that the worst outcome would be to try to keep the report secret, have it leak before election day, and lose the election. In terms of preference-values, he rated the various outcomes as follows:

Outcome	*Preference-Value*
Suspend Mack now; lose the election.	0.20
Successfully keep the report secret until election day; win the election; successfully lie about date of report.	0.95
Successfully keep report secret until election day; win the election; get exposed about true date of report.	0.50
Successfully keep report secret until election day; lose the election; successfully lie about date of report.	0.15
Successfully keep report secret until election day; lose the election; get exposed about true date of report.	0.05
Try to keep report secret but report leaks before election day; nonetheless, win election.	0.45

Draw and resolve an appropriate decision tree for Mayor Holton's dilemma. Then comment on Holton's preference-values. What do these values indicate about him? What values would you use if you were Mayor Holton? Why?

4. Frank Clean, Narc

The second part of the course, which begins in the third week and lasts five weeks, focuses on probability and uncertainty (assessing probabilities and probability distributions, updating prior probability judgments on the basis of new information, approximating probability distributions by "event fans,"[29] and working with forecasting models). Here is one of the assignments, written by one of our colleagues, Professor Gregory Fischer:

Frank Clean, special narcotics agent, has received a tip that a big shipment of LSD is about to be received by a local distributor. Clean's problem is that if he makes the bust he will blow the cover of his informer. And he wants to save the informer for a really big case. The distributor himself is small time, and Clean can bust him whenever he chooses.

Clean's real goal is to catch the distributor's suppliers. He has three. Supplier X is really small time and would be easy to arrest. Supplier Y is a medium-scale operator, and Clean would like to be able to nail him. Supplier Z is really big time, and Clean would love to catch him. Unfortunately, Clean's informer is unaware of the source and knows only that the exchange of pills for money will occur in one week. He does know, however, that the distributor has received a sample of 100 pills from the supplier. Clean asks him if he can steal 5 of these, and the agent says he can.

Clean's plan is really clever. Based on his past experience, he estimates that 20 percent of supplier X's pills contain a dangerously high level of strychnine. (He uses this to "cut" the pills, producing a cheap but dangerous high.) Suppliers Y and Z, on the other hand, are more quality conscious. Only 10 percent of their pills have a dangerous level of strychnine.

Clean gets his sample of 5 pills and finds that 1 is defective. He turns to you, his decision analyst, and says, "What do I do?" You, in turn, ask him for two pieces of information. First, his prior probabilities are: P(X) = .5, (Y) = .3, P(Z) = .2. Second, his preference-values

29. To develop an event fan approximation for a continuous, uncertain quantity, select several (four, five, or ten) specific outcomes to represent a group of all the possible outcomes; assess the probability for each group of outcomes, taking this probability as the probability for the group's representative outcome; draw a probability branch for each (representative) outcome; and connect all the branches to a single event node. The result looks like a fan.

are: V(bust and get X) = 0, V(bust and get Y) = .8, V(bust and get Z) = 1, and V(hold off and preserve cover) = .4.

(A) Ignoring the sample of five pills, what should Clean do? (B) Assuming that the five pills have been randomly sampled from the true shipment, what should Clean do? For (A) and (B), neatly explain exactly how you arrived at your answers. (C) As an optional, additional assignment, suppose Clean's informer is nervous about trying to steal the sample of 5 pills. In particular, assume that if he does steal the sample, there is a 10 percent chance that his cover will be blown. Now suppose that Clean's preference-values are as follows:

Outcome	*Preference-Value*
Informer's cover blown	0
Bust and get X	0.5
Bust and get Y	0.9
Bust and get Z	1
Hold off; informer's cover preserved	0.7

Should Clean ask his informer to steal the sample of 5 pills?

5. College Choice

The third part of the course, which runs about four weeks, focuses on appraising the desirability of the possible outcomes of a decision. Topics covered include the logic of preference-values, risk-aversion, and trade-offs between competing objectives. The following problem is one of those we assign.

Imagine yourself back in high school again, trying to decide which college to attend among those that accepted you. Design an appropriate "attribute hierarchy." Then do a first-cut analysis of the decision problem, using the "sequential trade-off technique." Consider at least two colleges and at least three objectives. Your grade on this assignment will depend on the quality of your reasoning and on the clarity with which you present it. If possible, please type your report. If Duke was overwhelmingly better than the second-best college that accepted you, pretend that you were also accepted by some other college (Princeton? Swarthmore? U. of Michigan? Berkeley? M.I.T.?) that would make your choice between it and Duke a tough decision.

6. An Election Decision

In the fourth and final part of the course, which lasts about three weeks, we emphasize "analyzing your analysis." The main topics are sensitivity analysis and the value of information. Here is one of the problems we use:

Wooster Jeeves, the dynamic 32-year-old progressive Republican lieutenant governor of a middle-sized Midwestern state, is in a quandary. He could have the Republican nomination for the U.S. Senate for the asking, but he would face stiff opposition from the popular Democratic incumbent, Lionel ("Choo-Choo") McFeatherstone.

Jeeves could also run for governor, but he would have to fight for the GOP's gubernatorial nomination. Even if he won that nomination, however, he would face a tough race against John Johns, the almost certain Democratic candidate, although the Republicans' Watergate albatross would be partially balanced by Johns's lackluster record and colorless personality.

Considering these dreary election prospects, Jeeves is tempted to return to his old law firm and, while keeping up his political contacts, make some "good money." After all, if he were to lose an election this time, he might never get another chance. If he waits out this election, he will have a fighting chance of winning the governor's chair four years hence or even of ousting the state's other Democratic senator, Marlo Zettersen.

But Jeeves is reluctant to sit on the sidelines for four years. As he puts it, "Hell, I didn't get to where I am at 32 by idling in a rocking chair watching the cars drive by."

He is so perplexed that he calls in a decision analyst for advice. The analyst quizzes Jeeves, questions Jeeves's colleagues, ponders the polls, and so on; then he pushes some numbers around and produces the following guesstimates:

1. Jeeves has about a 25 percent chance of defeating Choo-Choo McFeatherstone.
2. The odds are roughly even that Jeeves can get the Republican gubernatorial nomination.
3. If Jeeves does get the gubernatorial nomination, he will have about one chance in three of defeating the Democratic nominee (who is virtually certain to be John Johns).
4. Jeeves thinks the best outcome would be his winning the gubernatorial

election and that the worst outcome would be winning the nomination but losing in November to John Johns.

5. In terms of preference-values, Jeeves thinks that winning McFeatherstone's senate seat would be worth .90; losing the senate race would be worth .05; fighting for, but not getting, the gubernatorial nomination would be worth .20; and withdrawing from both races to practice law would be worth .30.

(A) Write a memo to Jeeves advising him on what to do. If you made any important assumptions, state them. Do a complete sensitivity analysis to help Jeeves understand what the most critical numbers in his decision are. Be as neat, orderly, and helpful as you possibly can.

(B) In reading over your memo, Jeeves thinks to himself: "I can't quite seem to remember what that preference-value business is all about. What did I mean, for example, when I said that withdrawing from both races to practice law would be worth .30? And what does that preference-value attached to the decision to run for governor mean?" Jeeves asks you to write him a short memo answering these questions. Please do so.

(C) The Psephologists Polling Service, Inc., commonly known as "Psephologists," has proposed to Jeeves that he do a random survey of the state to better estimate his election chances. In particular, and for a hefty fee, Psephologists will poll 1,000 voters on what their preferences would be in a senate race between Jeeves and McFeatherstone. Jeeves asks the advice of a decision analyst who has taken some statistics courses. The analyst sits down with Psephologists and calculates the cumulative probability distribution (figure 2) of what Psephologists will tell Jeeves his chances are after they have taken the poll.

Now, (1) what is the probability that purchasing this information will lead Jeeves to change his decision (assuming Jeeves is following your advice)? (2) Calculate the expected value of this information. In answering both these questions, neatly show all your work.

(D) Entrails Augury Associates claims that, for a modest charge of only $5,000, they can give Jeeves "a very good idea" of whether or not he will be able to get the Republican gubernatorial nomination if he tries for it. Jeeves tells you that he is willing to pay up to $2,000 for every percentage point by which he can raise his expected preference-value. For example, Jeeves would be willing to

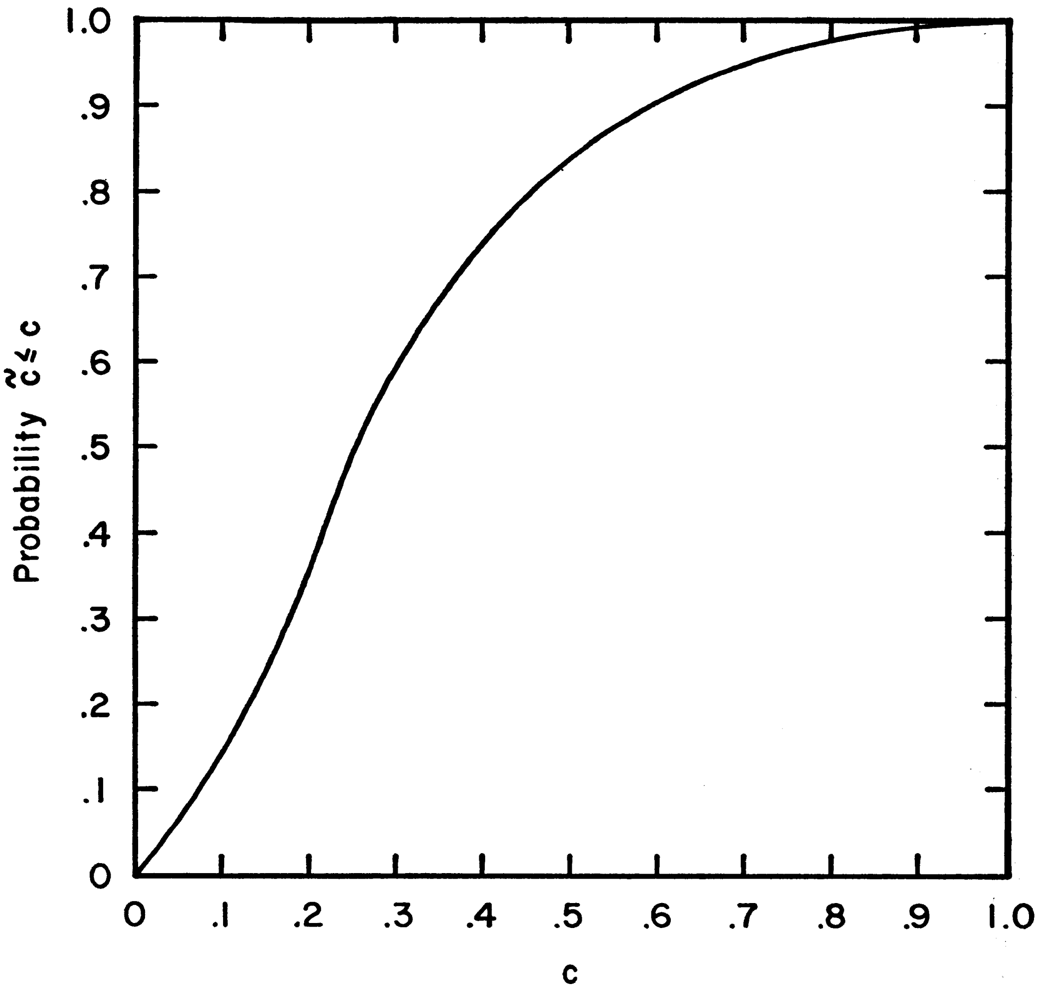

Figure 2. Jeeves's Chances, c, of Winning the U.S. Senate Seat, as Estimated by Psephologists after Taking the Poll

pay up to $6,000 to raise his expected preference-value from .36 to .39. Advise Jeeves about whether he should hire Entrails Augury Associates. Carefully explain your reasoning.

7. Term Project

A term project is due at the end of the semester. The following description of the project is handed out on the first day of class.

Not only are you going to be a decision maker in the future, but you are a decision maker right now and have been one in the past. You were probably accepted to more than one college, but you decided to come to Duke. You may have decided already what to major in; if not, you will have to decide soon. You have to decide what courses to take next semester. You may face a decision about what to do this coming summer. You may be a leader of some organization that must make an important decision. You may have been (or currently are) employed in a job requiring that you make a decision or give a decision maker some advice. Some friend or relative of yours may be faced with a decision problem about which you can contribute some advice.

Select some such decision problem, preferably one where a decision has yet to be made, and analyze it using the ideas you've mastered in this course. Write a memo summarizing your analysis.

Since the best way to learn decision analysis is to apply it to your own problems (and since this assignment will count for 10 percent of your grade), you will probably want to devote considerable mental exertion to the project.

Your memo should be very concise, but also very specific. It should clearly define the alternative choices of action and explain how the alternative selected is better than the others. Your memo should be accompanied by an appendix that clearly explains all your calculations and why you made them; this appendix should also explain how you made the probability and preference assessments that were required for your decision. Certainly, you will want to rewrite your memo several times so that it says precisely what you intend it to say, and you will want to redraw all your figures and recopy your calculations so that your appendix is neat and clear.

If the decision is one that you personally must make (or have made), write the memo to yourself.

CONCLUSION

The problems we assign can help the students develop their own decision-making skills. But it is impossible to formulate homework assignments that truly recreate all the complications and subtleties of an actual decision dilemma. The first step in resolving any problem is to determine what is important and to create a structure for the analysis. Implicitly, any homework problem does this important task for the student.

True talent for the art of decision making emerges only after hours of practice. We cannot force our students to undertake that practice, but our hope is that we can motivate them to do so and encourage them to think analytically.