Introduction 1

Complex decisions

Imagine you are facing the following problem. You have been employed as a manager by a major industrial company for several years, but recently, you have become dissatisfied with the job. You are still interested in the nature of the work, and most of your colleagues have a high regard for you. However, company politics are getting you down, and there appears to be little prospect of promotion in the foreseeable future. Moreover, the amount of work you are being asked to do seems to be increasing relentlessly, and you often have to work late in the evenings and at weekends.

You mentioned this to an old friend at a dinner party. 'There's an obvious solution,' he says. 'Why don't you set up on your own as a consultant? Hundreds of companies could use your experience and skills, and they would pay well. I'm certain that you'd experience a significant increase in your income and there would be other advantages as well. You'd be your own boss, you could choose to work or take vacations at a time that suited you rather than the company, and you'd gain an enormous amount of satisfaction from solving a variety of challenging problems.'

Initially, you reject your friend's advice as being out of the question, but the idea becomes more attractive as the days pass. Over the years, you have made a large number of contacts through your existing job, and you feel reasonably confident that you could use them to build a client base. Moreover, besides your specialist knowledge and analytical ability, you have a good feel for the way organizations tick, you are a good communicator, and colleagues have often complimented you on your selling skills. Surely, you would succeed.

However, when you mention all this to your spouse, they express concern and point out the advantages of your current job. It pays well – enough for you to live in a

Decision Analysis for Management Judgment, Sixth Edition. Paul Goodwin and George Wright.

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large house in a pleasant neighborhood and send your children to a good private school – and there are many other benefits, such as health insurance and a company car. Above all, the job is secure. Setting up your own consultancy would be risky. Your contacts might indicate now that they could offer you plenty of work, but when it comes to paying you good money, would they really be interested? Even if you were to succeed eventually, it might take a while to build up a reputation, so would you be able to maintain your current lifestyle or would short-term sacrifices have to be made for long-term gains? Indeed, have you thought the idea through? Would you work from home or rent an office? After all, an office might give a more professional image to your business and increase your chances of success, but what would it cost? Would you employ secretarial staff or attempt to do this work yourself? You are no typist, and clerical work would leave less time for marketing your services and consultancy. Of course, if you failed as a consultant, you might still get another job, but it is unlikely that it would be as well paid as your current post, and the loss of self-esteem would be hard to take.

A colleague further discourages you when you mention the idea during a coffee break. 'To be honest,' he says, 'I would think that you have less than a fifty–fifty chance of success. In our department, I know of two people who have done what you're suggesting and given up after a year. Why don't you apply for a job elsewhere if you're fed up here? In a new job, you might even find time to do a bit of consultancy on the side if that's what you want. Who knows? If you built up a big enough list of clients, you might be able to become a full-time consultant in a few years, but I would certainly counsel you against doing it now'.

By now, you are finding it difficult to think clearly about the decision; there seem to be too many different aspects to consider. You feel tempted to make a choice purely on emotional grounds – why not simply 'jump in' and take the risk? But you realize that this would be unfair to your family. You need a method that will enable you to address the complexities of the problem so that you can approach the decision in a considered and dispassionate manner.

This is a personal decision problem, but it highlights many of the interrelated features of decision problems in general. Ideally, you would like to maximize your income, maximize your job security, maximize your job satisfaction, maximize your freedom and so on, so that the problem involves *multiple objectives*. No course of action achieves all these objectives, so you need to consider the trade-offs between the benefits offered by the various alternatives. For example, would the increased freedom of being your own boss be worth more than the possible short-term loss of income?

Second, the problem involves *risk*. You are uncertain about the income your consultancy business might generate, the sort of work you could get (would it be as satisfying as your friend suggests?), the prospects you would face if the business failed and so on. Associated with this will be your *attitude to risk*. Are you a person

who naturally prefers to select the least risky alternative when taking a decision, or are you prepared to tolerate some level of risk?

Much of your frustration in attempting to understand your decision problem arises from its *complex structure*. This reflects, in part, the number of alternative courses of action from which you can choose (should you stay with your present job, change jobs, change jobs and become a part-time consultant, become a full-time consultant, etc.?) and the fact that some of the decisions are *sequential*. For example, if you decide to set up your own business, should you open an office, and if you open an office, should you employ a secretary? Equally important, have you considered all the possible options, or is it possible to create new alternatives that may be more attractive than the ones you are currently considering? Perhaps your company might allow you to work for them part-time, enabling you to use your remaining time to develop your consultancy practice.

Finally, this problem is not yours alone; it also concerns your spouse, so the decision involves *multiple stakeholders*. Your spouse may view the problem in a very different way. For example, they may have an alternative set of objectives from yours or different views on the chances that you will make a success of your business and may be more or less willing than you to take a risk.

The role of decision analysis

In the face of this complexity, how can decision analysis be of assistance? The key word is *analysis*, which refers to the process of breaking something down into its constituent parts. Decision analysis, therefore, involves decomposing a decision problem into a set of smaller (and, hopefully, easier to handle) problems. After each smaller problem has been dealt with separately, decision analysis provides a formal mechanism for integrating the results so that a course of action can be provisionally selected. This is referred to as the 'divide and conquer orientation' of decision analysis.[1]

Because decision analysis requires the decision-maker to be clear and explicit about their judgments, it is possible to trace back through the analysis to discover why a particular course of action was preferred. This ability of decision analysis to provide an 'audit trail' means that it is possible to use the analysis to produce a *defensible rationale* for choosing a particular option. This can be important when decisions have to be justified to senior staff, colleagues, outside agencies, the general public or even oneself.

When there are disagreements between a group of decision-makers, decision analysis can lead to a greater understanding of each person's position so that there is a *raised consciousness* about the issues involved and the root of any conflict. This enhanced communication and understanding can be particularly valuable when a group of specialists from different fields has to meet to make a decision. Sometimes, the analysis

can reveal that a disputed issue is not worth debating because a given course of action should still be chosen, whatever stance is taken concerning that particular issue. Moreover, because decision analysis allows the different stakeholders to participate in the decision process and develop a shared perception of the problem, it is more likely that there will be a *commitment* to the course of action which is eventually chosen.

The insights engendered by the decision-analysis approach can also have other benefits. They may lead to creative thinking and new, and possibly superior, courses of action. The analysis can also provide guidance on what new information should be gathered before a decision is made. For example, is it worth undertaking more market research if this would cost $100 000? Should more extensive geological testing be carried out in a potential mineral field?

It should be stressed, however, that the role of decision analysis has changed over the years. No longer is it seen as a method for producing optimal solutions to decision problems. As Keeney[1] points out:

> Decision analysis will not solve a decision problem, nor is it intended to. Its purpose is to produce insight and promote creativity to help decision-makers make better decisions.

Phillips[2] also emphasizes this changing perception of decision analysis:

> …decision theory has now evolved from a somewhat abstract mathematical discipline which when applied was used to help individual decision-makers arrive at optimal decisions, to a framework for thinking that enables different perspectives on a problem to be brought together with the result that new intuitions and higher-level perspectives are generated.

Indeed, in many applications, decision analysis may be deliberately used to address only part of the problem. This *partial decision analysis* can concentrate on those elements of the problem where insight will be most valuable.

While we should not expect decision analysis to produce an optimal solution to a problem, we can regard the results of an analysis as 'conditionally prescriptive.' By this, we mean that the analysis will show the decision-maker what they should do, given the judgments they have put forward during the analysis. The basic assumption is that of *rationality*. If the decision-maker accepts a set of rules (or axioms) that most people would regard as sensible, then, to be rational, they should prefer the indicated course of action to its alternatives. Of course, the course of action prescribed by the analysis may well conflict with the decision-maker's intuitive feelings. This conflict between the analysis and intuition can then be explored. Perhaps the judgments put forward by the decision-maker represented only partially formed or inconsistent preferences, or maybe the analysis failed to capture some aspect of the problem.

Alternatively, the analysis may enable the decision-maker to comprehend the problem better, so their preference changes toward that prescribed by the analysis. These attempts to explain why the rational option prescribed by the analysis differs from the decision-maker's intuitive choice can lead to insight and understanding, which, as we emphasized earlier, are the main motivation for decision analysis.

Good and bad decisions and outcomes

Consider the following two decisions based on those used in an experiment by Baron and Hershey.[3]

A. A 55-year-old man had a heart condition, and a physician had to decide whether to perform an operation which, if successful, would relieve the man's pain and extend his life expectancy by 5 years. The risk of the man dying as a result of the operation was 8%. The operation was performed and had a successful outcome.
B. A 55-year-old man had a heart condition, and a physician had to decide whether to perform an operation which, if successful, would relieve the man's pain and extend his life expectancy by 5 years. The risk of the man dying as a result of the operation was 2%. The operation was performed and, unfortunately, the man died.

Which was the better decision? In the experiment, people who saw decision A typically rated it more highly than those who saw B because it resulted in a better outcome. But, objectively, decision B carried much lower risks and offered the same potential benefits as A. This suggests that we need to distinguish between good and bad decisions and good and bad outcomes. A rash decision may, through luck, lead to a brilliant outcome. You may gamble your house on a 100-to-1 outsider in a horse race and win. In contrast, a carefully considered decision, made using the best available decision-analysis technique and based on the most reliable information available at the time, may lead to disaster. This means that when we consider a single decision, the outcome usually provides, at best, only limited information about the quality of the decision.[4]

Outcomes across many decisions provide a better guide. If you are a newspaper seller and every day have to decide how many newspapers to have available for sale, your average profit over (say) the last 100 days will be a good guide to the quality of your decision-making. You might be lucky and get away with a bad decision on a single day, but this is unlikely to be the case over a large number of days.

If decision analysis is used to support a decision, how should we assess its effectiveness? Schilling *et al*.[5] suggest three main criteria: the quality of the process used

to arrive at the decision, output effectiveness, and outcome effectiveness. The *quality of the process* reflects factors such as the extent to which people in the organization participated in the decision-making process and exchanged information, the extent to which the process was transparent and comprehensible and how much it yielded insights into the problem. *Output effectiveness* embraces 'hard' factors like increased profit and 'softer' benefits like providing a common language that enables different specialists and stakeholders to communicate and develop a sense of common purpose. *Outcome effectiveness*, which is usually more challenging to measure, relates to the long-term consequences of the analysis. Did the use of decision analysis help the decision-makers to achieve their final objectives?

Applications of decision analysis

The following examples illustrate areas where decision analysis has been applied.[6, 7]

Selecting best management practices to reduce river pollution in South Africa[8]

River pollution poses a threat to the environment, water resources and human health. Watershed managers in South Africa used the Simple Multi-Attribute Rating Technique (SMART) (Chapter 3) to prioritize practices for reducing pollution and its risk to river users. SMART enabled the decision process to consider a broad range of environmental, economic and social criteria, such as capital costs, job creation opportunities, level of community support, impacts on local scenery, and resulting pollution levels. It also permitted a variety of stakeholders to be involved, including those using the river for recreational purposes, municipal representatives, scientists, NGOs, and engineers. In addition to identifying the most appropriate pollution mitigation strategies, the findings provided valuable insights to all those participating in the process.

Assessing the profitability of blueberry production in Georgia[9]

Blueberry production carries risks that result from the possibility of poor crop yields and variable market prices. Monte-Carlo risk analysis (Chapter 8) helped farmers in the US state of Georgia to assess the likely returns of planting blueberries and the risks of negative returns. The method allowed the effect on the profitability of a wide range of possible yields and prices to be assessed so the chances of a negative return could be evaluated for both average farmers and those of different types (e.g., those achieving

above or below average yields). By revealing these risks, the approach offered benefits not available to traditional investment appraisal methods that ignore the variability of crop yields and prices and estimate a potential return based only on average yields and prices.

Deciding whether to modify computer-based forecasts of the demand for products[10]

Managers often adjust computer-based forecasts of the demand for products, such as those sold in supermarkets, based on their judgment of likely future demand. However, many of these adjustments serve only to reduce forecast accuracy because managers suffer from some of the psychological biases discussed in Chapter 10. When supplied with a computer-based forecast, managers must decide whether an increase or reduction is required and how big a change they need to make. Researchers analyzed over 146 000 forecasts produced by companies. They then used a decision tree (Chapter 7) to depict the choices managers faced and the probability that their actions would improve or reduce forecast accuracy. Amongst other findings, the analysis revealed that adjustments that increase forecast size carry a very high risk of lowering accuracy. In contrast, those that lead to lower forecasts tend to lead to moderate improvements.

Prioritizing infrastructure-renewal projects at MIT[11]

The buildings and grounds of the Massachusetts Institute of Technology (MIT) need to be maintained and renewed constantly, but the resources available for carrying out this work were limited. The department responsible for the work therefore needed a systematic method for prioritizing projects such as the maintenance of heating, ventilating, air conditioning, plumbing, and electrical systems, and the refurbishment and replacement of roofs. This prioritization needed to reflect the risk of not carrying out a particular project. A series of workshops involving members of the infrastructure renewal team took place. At these workshops, they used a value tree (Chapter 3) to identify and agree on the objectives against which they could assess the projects. Typical objectives were minimizing impact on the environment, minimizing disruption to academic activities and minimizing impact on the public image of MIT. They then used the analytic hierarchy process (AHP) (Chapter 4) to assess the relative weights that should be attached to these objectives. Utility functions (Chapter 6) allowed them to obtain a score for the consequences of not carrying out a given project in relation to each objective. By combining the weights and scores, they obtained an overall 'performance index' for each project to prioritize them. The application of

these decision-analysis tools led to several benefits. It allowed people from different professional backgrounds to apply their expertise to the process and reach a consensus. It also provided a consistent and defensible rationale for the prioritization. Most notably, the workshops led to a change of culture in the department so that people were more willing to address risks, objectives and priorities in an explicit and structured way.

Supporting the systems-acquisition process for the US military[12]

In the past, people have criticized the acquisition process for major military systems in the United States because it did not produce defensible decisions underpinned by sound analyses and a clear rationale. As a result, decision-analysis techniques like SMART (Chapter 3) have been increasingly used to structure decision-making at the various stages of the process. For example, when the US Army air defense community needed to establish the most cost-effective mix of low-altitude air defense weapons, decision analysis was used to help a group of technical experts and senior officers rank alternative weapon mixes. The process enabled a large number of criteria to be identified (e.g., flexibility at night, refueling capability, capability of defeating an enemy fixed-wing aircraft). It allowed options to be evaluated explicitly by considering all these criteria. Where decisions involved several organizations, the decision model had a valuable role in depoliticizing issues.

Selecting software in a Portuguese energy company[13]

The MACBETH (Measuring Attractiveness by a Categorical-Based Evaluation Technique) method (Chapter 4) was combined with decision conferencing (Chapter 13) and the Delphi method (Chapter 13) to assist a Portuguese energy company in selecting an Enterprise Management System (EMS). To reflect the preferences of people who would be using the system, the MACBETH method required weights to be attached to attributes, such as an EMS's security and its ease of integration with other systems operated by the company. The Delphi method allowed the weights to be obtained from a broad group of people anonymously and free from the influence of others. A steering committee meeting in a decision conference then used the weights from Delphi as a basis for their own assessments. The MACBETH method allowed the committee to evaluate the performance of the different systems across the attributes and select one of the candidate systems. The participants regarded the decision process positively as a result of their involvement.

Deciding on hospital locations in Taiwan[14]

The provision of health services in Taiwan is highly competitive, and selecting the wrong location for a hospital can be costly. AHP (Chapter 4) was used to develop a method for determining the optimal location of hospitals, considering a wide range of factors. The AHP enables broad issues, such as the cost of land, competing local facilities, the demand for services, and risk, to be broken down into more specific considerations. For example, risk involves the possibility of changes in production costs, changes in demand and changes in the financial market. Local demand can be divided into the size of the population, its age structure, and density. This allowed decision-makers to make comparisons of the importance of these issues and how well alternative locations performed in relation to them. The output of the method is the recommendation of the best location.

Our own consultancy-based case examples of scenario planning

Anticipating the need for doctors and dentists in the English National Health Service[15]

Doctors and dentists take many years to train in their various specialisms. But what will the future demand be for these health service professionals? A scenario exercise (Chapter 16) was conducted in England to identify four alternative scenarios. Factors that were predetermined, or 'in the pipeline,' were identified – such as an aging, internet-savvy population – together with uncertainties such as the economy's future strength and the linked ability to provide healthcare. These views of alternative futures were used to advise the UK government on student intake numbers in the health professions.

Anticipating the fueling supply and demand for military ships

A scenario exercise guided thinking about the design of the future propulsion systems of military ships, whose hulls will be in the water for about 25 years. Military ships make up about 1% of the world's ships. Almost all ships are currently fueled by marine diesel, but the type of fueling may change. The exercise allowed participants

to consider a range of questions. Which replacement fuel will propel such ships in the future? Where in the world will this fuel be readily available, especially at 'friendly' refueling ports? Will the autonomous ships of the future need as much fuel? Can small onboard nuclear reactors be adopted to enable military ships to be independent of conventional fueling needs as they patrol the world?

Anticipating the impact of COVID-19 on city living

At the time of the outbreak of the coronavirus disease 2019 (COVID-19) pandemic, the Glasgow City Council used scenario planning to consider the future of the city center. This involved contemplating a range of uncertainties. For example, would the pandemic effect be maintained for an extended period, or would it soon be alleviated? At the time, many citizens with the disease, or those in close contact with those infected, were supported financially by the UK government since they could not work. However, this financial support was very costly to the government and increased its international borrowing – borrowing that would eventually have to be repaid by higher taxation on those working. If COVID-19 lingered and the government raised taxes, then anxious, less affluent citizens would be unlikely to return to the previously busy streets of Glasgow City Centre. In all scenarios, Glasgow city footfall was anticipated to reduce, with the wealthy middle classes now working more from their homes in the outer suburbs and shopping remotely. Current priorities for improving inner-city transportation therefore appeared to be less important, while the provision of enhanced digital services across the Glasgow city region appeared to be a much more important priority.

Anticipating the energy transition from fossil fuels to renewables

A multinational oil- and gas-operations-focused company was considering the future for itself and its approximately 50 000 employees – most of whom were blue-collar workers. Many saw the energy transition to renewables as something happening to others outside of the company's focus on its day-to-day tasks. Would the company's skills and know-how be less in demand and less valuable in the future? The company's leadership wanted to explore the energy future and, importantly, communicate a vision of a changing world to the workforce. All the scenarios that were developed included the coming energy transition, but one, entitled 'Tailwind,' anticipated that the change would come more quickly than many currently thought. This new understanding was communicated to the workforce in the form of easily readable scenario storylines, with the aim of changing mindsets. The scenarios provided the basis of a 'jolt' to the organization and its current priorities. As a side benefit, the wide distribution of the company's scenario reports would, it was hoped, attract now-needed specialist energy workers to a changing organization.

Overview of the book

The book is organized as follows. Chapter 2 discusses the biases that can arise when *unaided* decision-makers face decisions involving multiple objectives. Chapter 3 then shows how decision analysis can be applied to these sorts of problems. The focus here is on decisions where there is little or no risk or uncertainty about the outcomes of the different courses of action. Chapter 4 presents some alternative methods for handling decisions involving multiple objectives. Risk is addressed in Chapter 5, where we show how probability theory can be used to measure it, and in Chapter 6, where we apply probability to decision problems and show how to incorporate the decision-maker's attitude to risk into the analysis.

As we saw at the start of this chapter, many decisions are difficult to handle because of their size and complex structure. Chapters 7 and 8 illustrate methods that can help clarify this complexity, namely decision trees, influence diagrams, and simulation models.

Of course, all decisions depend primarily on judgment. Decision analysis does not aim to replace these judgments but provides a framework to help decision-makers clarify and articulate them. In Chapter 9, we look at how a decision-maker should revise judgments in light of new information. Chapter 10 reviews psychological evidence on how good people are at using judgment to estimate probabilities. We consider the implications of this research in Chapter 11, where we demonstrate techniques for eliciting probabilities from decision-makers. Evidence shows that most managers see their role as trying to reduce and manage risks where possible. In Chapter 12, we show how decision-analysis models can provide a structure for risk management so that managers can identify the aspects of the decision that have the greatest potential for reducing risks or exploiting opportunities.

Although, in general, decisions made in organizations are ultimately an individual's responsibility, often a group of people will participate in the decision-making process. Chapters 13 and 14 describe problems associated with group decision-making and discuss the role of decision analysis in this context. We place special emphasis on decision conferencing and problems involving the allocation of resources between competing areas of an organization.

Significant decision-making errors can arise because the original problem has been incorrectly framed. In particular, in strategic decision-making, the decision can be perceived in a way that fails to consider fundamental changes in the organization's environment. The result can be overconfident decisions based on outdated assumptions. We discuss framing problems and the cognitive inertia often associated with them in Chapter 15. Here, we also introduce prospect theory, which explains why changes in framing a problem can lead to different decisions. Chapter 16 shows how scenario planning, an alternative way of dealing with uncertainty, can help alert decision-makers to possible environmental changes when formulating future

strategies. However, formal processes for evaluating and comparing strategies have been a neglected area of scenario planning, so in Chapter 17, we show how to combine decision analysis with scenario planning to help planners choose between alternative strategies.

Finally, in Chapter 18, an alternative form of decision support, known as bootstrapping, is contrasted with the decision-aiding methods we have covered in the book. We also ask whether snap decisions, based on intuitive judgments, should have any role in management decision-making and discuss how decisions can be designed so that people are encouraged to choose the 'best' option. Artificial intelligence (AI) is playing an increasing role in management, and we discuss its potential role in supporting decisions and its limitations. In addition, this last chapter looks at the key questions a decision-maker should consider to maximize the effectiveness of decision-aiding methods. It concludes with a summary of the types of problems that the different methods are designed to address.

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