Praise for Bulletproof Problem Solving

"The Bulletproof Problem Solving approach acknowledges the reality many environmentalists face today: this is hard work. Conn and McLean's guide makes it a little bit easier."

-Mark R. Tercek, CEO of The Nature Conservancy and author of *Nature's Fortune*

"Conn and McLean have distilled their matchless experience in attacking challenges of every scale and level of complexity into this virtual war-room of a book, creating an indispensable resource for the 21st century problem-solvers upon whom our future depends. A must-read for all aspiring change agents!"

-Sally Osberg, retired CEO of the Skoll Foundation, co-author of *Getting Beyond Better: How Social Entrepreneurship Works*

"Navigating ambiguity and solving complex problems creatively is the truth test for humans to complement rather than substitute the artificial intelligence of computers. Without much better approaches to teach those skills, our schools risk preparing second class robots rather than first class humans. Rob McLean and Charles Conn show that this can be done and provide an intuitive roadmap for how to do this, with lots of real-world examples that make it fun."

-Andreas Schleicher, Director for the Directorate of Education and Skills, OECD

"Great strategic problem solving is an essential tool, one whose value is only going up. *Bulletproof* provides the secret sauce behind the McKinsey framework to help structure and guide the problem-solving process. I want to hire people who understand this approach."

-Barry Nalebuff, Milton Steinbach Professor, Yale School of Management and cofounder, Honest Tea

"The old paradigm of strategy departments and planning cycles has been overthrown by agile and rapid team-based problem solving, providing better solutions and better organization alignment to implement. This book, written by two of the smartest people I know, provides the needed blueprint for how build these world-beating problem solving teams."

-Mehrdad Baghai, Chair of Alchemy Growth and author of *As One*

Bulletproof Problem Solving

Charles Conn and Robert McLean

WILEY

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Foreword

Bulletproof. At McKinsey there is no greater compliment than to have your reputation as a problem solver described as "bulletproof." While it takes many skills and types of intelligence to make a modern consulting firm work, the cornerstone capability is always creative problem solving.

The importance of great problem solving has only grown as the pace of economic and technological change has accelerated in recent years—and the scope and complexity of the problems we need to address increases alongside it. Today we are just as likely to be hired to help a country public health system prepare for the next Ebola outbreak as to develop a digital marketing strategy for a new consumer product. As ever more data becomes available, the bar on the quality of thinking rises. We need bulletproof problem solvers.

Whether you work in industry, the nonprofit sector, or government, there is no way to anticipate and plan for the new structures and operating rules that are unfolding. Nor is simply accelerating and adapting traditional, domain-oriented, training approaches sufficient. The only way to successfully navigate this level of change is to be a fluid and creative problem solver. That's why the World Economic Forum labeled complex problem solving its number one skill for the twenty-first century. Organizations everywhere are looking for this capability in their talent recruiting above all else.

What is perhaps surprising is that a disciplined, comprehensive approach to problem solving isn't taught in schools or universities. It is absent from most curricula even in many business schools. You can see elements in things like root-cause analysis or the current vogue for agile teams and design thinking, but they don't go far enough. This book introduces the systematic process for problem solving that has been missing, a version of the time-tested methodology we have used for many years in McKinsey.

The seven-step method Charles and Rob demonstrate here is transparent and straightforward. It doesn't require specialist skills or fancy mathematical talent—though the authors do show when more sophisticated analytic techniques can be valuable, and why they are often more accessible than you think. It is iterative and flexible; it can be applied quickly to get rough-cut answers, and more slowly to fine-tune nuanced answers. It shows how to fight the human biases in decision making that we have learned so much about in recent years. And it works on nearly any kind of problem, from personal life decisions, to business and nonprofit questions, to the biggest policy challenges facing society.

As a longtime runner, I was especially drawn to Rob's analysis of whether or not to have knee surgery. I was also impressed by the straightforward analysis that can help voters consider their response to complicated policy decisions in areas like fisheries and educational funding. I naturally enjoyed reading the cases covering business strategy or enhancing profitability. And while there are some genuinely intractable social and environmental problems, this methodology can still shine light on solution paths to even the trickiest challenges, including fighting climate change and obesity.

You couldn't ask for more qualified authors to write a book of this kind. Charles drafted the original internal McKinsey presentation on problem solving, *7 Easy Steps to Bulletproof Problem Solving*, one of our most requested professional development documents ever, when we were young consultants in Toronto. I have known Rob for more than 35 years, starting with a project we did together on how to leverage the time of the CEO of Australia's largest company.

During their time at McKinsey, Rob and Charles collaborated with other colleagues to develop the horizons approach to growth strategy that we still use today. After they left the firm, I enjoyed watching them both continue to apply their problem solving method as entrepreneurs and as change makers in the nonprofit sector. In recent years I have had a front-row seat as Charles brought this distinctive mindset to strategy development and transformation at the Rhodes Trust.

Problem solving is the core skill for the twenty-first century. Now, finally, we have a guide to doing it right that any of us can follow.

Dominic Barton

Managing Director (Retired),
McKinsey & Company

The 70s and 80s were characterized by intense interest in strategy development. That was displaced by an era from the 90s onward that focused on execution, including deep attention to getting things done, as exemplified by the book *Execution* by Ram Charan and Larry Bossidy, and a number of books on business process redesign.[1] However, a ruthless focus on execution assumes you have strategic direction right and can adapt to new competition, frequently from outside your industry. This can no longer be assumed.

MANAGERIAL SKILLS EVOLUTION

ERA	Strategy	Execution	Complex Problem Solving
TIME PERIOD	70s – 80s	90s – 2015	2015 onward
CHALLENGES	Where and how to compete	Getting things done	Agile and creative problem solving

As this new era of the problem solving organization takes hold, we expect it will trigger even more interest in how teams go about sharpening complex problem solving and critical thinking skills—what is called *mental muscle* by the authors of *The Mathematical Corporation*.[2] The other side of the equation is the increasing importance of machine learning and artificial intelligence in addressing fast-changing systems. Problem solving will increasingly utilize advances in machine learning to predict patterns in consumer behavior, disease, credit risk, and other complex phenomena, termed *machine muscle*.

To meet the challenges of the twenty-first century, mental muscle and machine muscle have to work together. Machine learning frees

[1] Larry Bossidy and Ram Charan, *Execution: The Discipline of Getting Things Done* (Random House, 2008).

[2] Josh Sullivan and Angela Zutavern, *The Mathematical Corporation: Where Machine Intelligence and Human Ingenuity Achieve the Impossible* (Public Affairs, 2017).

human problem solvers from computational drudgery and amplifies the pattern recognition required for faster organizational response to external challenges. For this partnership to work, twenty-first century organizations need staff who are quick on their feet, who learn new skills quickly, and who attack emerging problems with confidence. The World Economic Forum in its *Future of Jobs Report*[3] placed complex problem solving at #1 in its top 10 skills for jobs in 2020. Here is their list of important skills that employers are seeking:

TOP 10 SKILLS IN 2020

1. Complex Problem Solving
2. Critical Thinking
3. Creativity
4. People Management
5. Coordinating with Others
6. Emotional Intelligence
7. Judgment and Decision Making
8. Service Orientation
9. Negotiation
10. Cognitive Flexibility

It is becoming very clear that job growth is focused in areas where tasks are *nonroutine* and *cognitive*, versus *routine* and *manual*. The intersection of nonroutine tasks and cognitive ability is the heartland of complex problem solving. The authors of a recent *McKinsey Quarterly* article made the point that "more and more positions

[3] *Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution* (World Economic Forum, 2016).

require employees with deeper expertise, more independent judgment, and better problem solving skills."[4] We are already seeing that many organizations place a premium on analytic skills and problem solving and make it the essential criterion to be hired. Commentator David Brooks of the *New York Times* takes this conclusion even further when he says, "It doesn't matter if you are working in the cafeteria or the inspection line of a plant, companies will only hire people who can see problems and organize responses."[5]

Education Gaps

If creative problem solving is the critical twenty-first century skill, what are schools and universities doing to develop these skills in students? Not enough. It remains early days in codifying and disseminating problem solving best practices in educational institutions. Andreas Schleicher, Director of Education and Skills and Special Advisor to the Secretary General of the OECD, explains the need for developing problem solving skills in students this way: "Put simply, the world no longer rewards people just for what they know—Google knows everything—but for what they can do with what they know. Problem solving is at the heart of this, the capacity of an individual to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious."[6]

The OECD Program for International Student Assessment (PISA) started testing individual problem solving skills in 2012 and added collaborative problem solving skills in the 2015 assessments. One of the interesting early findings is that to teach students to become better problem solvers involves other capabilities than simply teaching reading, mathematics, and science literacy well. Capabilities such as creativity, logic, and reasoning are essential contributors to students becoming better problem solvers. That is what this book is about.

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[4] Boris Ewenstein, Bryan Hancock, and Asmus Komm, "Ahead of the Curve: The Future of Performance Management," *McKinsey Quarterly*, May 2016.

[5] David Brooks, "Everyone a Changemaker," *New York Times*, February 18, 2018.

[6] Beno Csapo and Joachim Funke (eds.), *The Nature of Problem Solving: Using Research to Inspire 21st Century Learning.* (OECD Publishing, 2017).

Universities and colleges are being challenged to demonstrate that their graduates have developed problem solving skills to prepare them for the demands of the workplace. One method of evaluating whether over a college degree there is improvement in critical thinking is the CLA+ test (Collegiate Learning Assessment plus) developed by the nonprofit Council for Aid to Education (CAE). The *Wall Street Journal* reported in 2017 that of the 200 colleges that apply the test "a majority of colleges that took the CLA+ made measurable progress in critical thinking"—although some well-respected colleges didn't show much difference between incoming freshmen scores and those of seniors.[7] Effective university approaches to develop critical thinking and problem solving range from analyzing classic poems like *Beowulf*, to teaching logic structures, and setting practical group projects that require demonstration of problem solving abilities. What we glean from the article and college practices generally is an awakening of interest in student problem solving, and expectations that problem solving will be enhanced over the course of a degree program. But we have not seen a common framework or process emerge yet.

The Seven-Steps Process

The heart of the book is a seven-step framework for creative problem solving, *Bulletproof Problem Solving*, starting with these critical questions:

1. How do you define a problem in a precise way to meet the decision maker's needs?
2. How do you disaggregate the issues and develop hypotheses to be explored?
3. How do you prioritize what to do and what not to do?
4. How do you develop a workplan and assign analytical tasks?
5. How do you decide on the fact gathering and analysis to resolve the issues, while avoiding cognitive biases?

[7] Douglas Belkin, "Exclusive Test Data: Many Colleges Fail to Improve Critical-Thinking Skills," *Wall Street Journal*, June 5, 2017.

6. How do you go about synthesizing the findings to highlight insights?
7. How do you communicate them in a compelling way?

In the book we take you through the seven steps in a way that builds understanding and mastery through examples. We highlight a variety of analytic tools available to aid this process, from clever heuristics, analytic short cuts, and back-of-the-envelope calculations, to sophisticated tools such as game theory, regression analysis, and machine learning. We also show how common cognitive biases can be addressed as part of the problem solving process.

The final two chapters explicitly deal with how you solve problems when uncertainty is high and interdependencies or systems effects are significant. We believe that even the so-called "wicked

3. *Failure to disaggregate the problem*. We see few problems that can ever be solved without disaggregation into component parts. A team looking at the burden of asthma in Sydney got the critical insight into the problem only when they broke it down along the lines of incidence and severity. In Western Sydney the incidence of asthma was only 10% higher than Northern Sydney, but deaths and hospitalization were 54–65% greater. The team was familiar with research that linked asthma with socioeconomic status and tree cover. It turns out that socioeconomic status is significantly lower in Western Sydney, tree cover is about half Northern Sydney, and daily maximum particulate matter (PM 2.5) is 50% higher. By finding the right cleaving point to disaggregate the problem, the team was able to focus on the crux of the issue. This led to them proposing an innovative approach to address respiratory health through natural solutions, such as increasing tree cover to absorb particulate matter.

4. *Neglecting team structure and norms*. Our experiences in team problem solving in McKinsey and other organizations highlight the importance of a diversity of experience and divergent views in the group, having people who are open-minded, a group dynamic that can be either competitive or collaborative, and training and team processes to reduce the impact of biases. This has been underscored by recent work on forecasting.[8] Executives rank reducing decision bias as their number one aspiration for improving performance.[9] For example, a food products company Rob was serving was trying to exit a loss-making business. They could have drawn a line under the losses if they took an offer to exit when they had lost $125 million. But they would only accept offers to recover accounting book value (a measure of the original cost). Their loss aversion, a form of sunk-cost bias,

[8] Philip Tetlock and Dan Gardner, *Superforecasting: The Art and Science of Prediction* (Random House, 2015).

[9] Tobias Baer, Sven Hellistag, and Hamid Samandari, "The Business Logic in Debiasing," *McKinsey Latest Thinking*, May 2017.

meant that several years later they finally exited with losses in excess of $500 million! Groupthink amongst a team of managers with similar backgrounds and traditional hierarchy made it hard for them see the real alternatives clearly; this is a common problem in business.

5. *Incomplete analytic tool set*. Some issues can be resolved with back of the envelope calculations. Others demand time and sophisticated techniques. For example, sometimes no amount of regression analysis is a substitute for a well-designed, real-world experiment that allows variables to be controlled and a valid counterfactual examined. Other times analysis fails because teams don't have the right tools. We often see overbidding for assets where teams use past earnings multiples rather than the present value of future cash flows. We also see underbidding for assets where development options and abandonment options, concepts akin to financial options, are not explicitly valued. How BHP, an Australian resource company, addressed these issues is developed in Chapter 8.

6. *Failing to link conclusions with a storyline for action.* Analytically oriented teams often say, "We're done" when the analysis is complete, but without thinking about how to synthesize and communicate complex concepts to diverse audiences. For example, ecologists have pointed to the aspects of nature and urban green spaces that promote human well-being. The message has frequently been lost in the technical language of ecosystem services—that is, in describing the important role that bees play in pollination, that trees play in absorbing particulate matter, or water catchments play in providing drinking water. The story becomes so much more compelling when, in the case of air pollution, it has been linked to human respiratory health improvements in asthma and cardiovascular disease.[10] In this case, by completing the circle and finding a way to develop a compelling

[10] *Planting Healthy Air* (The Nature Conservancy, 2016).

storyline that links back to the "hook" of human health makes all the difference in capturing an audience and compelling action.

7. *Treating the problem solving process as one-off rather than an iterative one.* Rarely is a problem solved once and for all. Problems we will discuss often have a messiness about them that takes you back and forth between hypotheses, analysis, and conclusions, each time deepening your understanding. We provide examples to show it is okay and worthwhile to have second and third iterations of issue trees as your understanding of a problem changes.

What's in Store?

This is a how-to book. We work through 30 real-world examples, employing a highly visual logic-tree approach, with more than 90 graphics. These are drawn from our experience and honed over an intensive summer of research with a team of Rhodes Scholars in Oxford. They include problems as diverse as the supply of nurses in the San Francisco Bay Area, to capital investment decisions in an Australian mining company, to reduction of the spread of HIV in India, to air pollution and public health in London, to competitive dynamics in the hardware home-center industry, and even to approaches to address climate change. The insights in some cases are novel, in other cases counterintuitive. The real-world examples behind the cases have created value amounting to billions of dollars, saved hundreds of thousands of lives, and improved the future for endangered species like salmon.

If you want to become a better problem solver, we show how you can do so with only a modest amount of structure and numeric ability. Individuals make decisions that have lifetime consequences—such as career choice, where to live, their savings plan, or elective surgery—often without due consideration. These are among the examples we walk you through in the book to illustrate the value of a structured process to improve your prospects of better outcomes in your own life.

PROBLEM SOLVING CASES

INDIVIDUAL

- Should I put solar panels on my roof?
- Should I support the school bond?
- Where to live
- Is where I live affecting my health?
- Should I have a knee arthroscopy?
- How to judge contested characters in history
- Will I outlive my savings?
- What career should I choose?
- Where to serve in tennis

ORGANIZATIONS

- Pricing decision at Truckgear
- Competitor analysis-Home Depot vs. Hechinger
- Drones to the rescue/shark spotting with machine learning
- Airport capacity
- Growth strategy at J&J
- Drone company staircase
- Should we defend our IP in court?
- Bias in mineral exploration
- Predicting sleep apnea with machine learning
- Bus routing with machine learning
- Classifying heart attack risks in hospitals
- Oil refinery strategy communication
- Electronic Arts: A/B testing
- Crowdsourcing problem solving in organizations
- Supply of quality nurses in Bay Area
- How to make long-term resource investments
- Root cause of market share loss

CITIZEN / POLICY

- Protecting salmon in the Pacific Northwest
- HIV in India
- How to tackle climate change
- Can obesity be reduced?
- *Challenger* Space Shuttle disaster
- How to reduce overfishing

As citizens we have a desire to understand issues of the day more clearly and to be able to make a contribution to resolving them. There is a temptation to say, "That issue is way too complex or political for me to add a perspective." We hope to change your mind about that. There are few bigger problems on the planet than climate change, obesity, reducing the spread of infectious disease, and the protection of species, and we demonstrate how to tackle problems also at this societal scale.

For college students and graduates in analytical roles we hope this book will become an important resource for you—a comprehensive suite of tools and approaches that can make you a better problem solver, one you will return to again and again. For managers we set out how to evaluate your competitor's performance, decide where and how to compete, and develop a strategy in uncertain and complex settings.

Our aim is simple: to enable readers to become better problem solvers in all aspects of their lives. You don't need post-graduate training to be an effective problem solver. You do need to be prepared to work through a process and develop cases of your own where you can try-test-learn the framework. This quote from Nobel Laureate Herb Simon captures much of what we set out to do in the book: "Solving a problem simply means representing it so as to make the solution transparent."[11]

[11] Herbert Simon, *The Sciences of the Artificial* (MIT Press, 1968).

Chapter One

Learn the Bulletproof Problem Solving Approach

In the 1980s, when Charles was at business school, he wanted to understand the then-ascendant Japanese business practices better. He wrote to dozens of Japanese companies to see if they would host him for a summer internship. Most never replied, but just as he was thinking he might be unemployed for the summer, Charles received a letter from a Dr. Utsumi at Canon, the camera and printer company. Canon was prepared to hire Charles as its first western intern, and soon he was winging his way to Japan.

It sounds like a fun adventure, and it was, but it was also a huge shock. Charles was seconded to the production planning division in a distant Tokyo suburb, and assigned to a Canon men's dormitory, three train lines and 90 minutes away. He couldn't speak or read Japanese. He was assigned what seemed at first an impossible task: develop a model for how to site factories. He despaired—what did he know about where to put factories? It seemed like a specialist problem.

But, with the help of a translating colleague, he began to interview the team about their experiences in different factory location decisions around the world. Patterns began to emerge in his findings. He learned which variables were involved, from local authorities' incentives, to local taxation rates, wage levels, raw materials transportation cost, and so on, and eventually he figured out which were more or less important. Finally he built a logic tree that captured the variables, the direction or sign of impact, and the weight of the factors. He tested the model with data from past factory decisions and honed its accuracy with the senior team. In the end, this little model became the core tool used by the department to make complex factory siting decisions! The secret was that it was a single-page way of seeing complicated trade-offs that had previously been buried in dense reports. It made the logic of the criteria clear, and opened weighting of variables up to discussion.

It saved what might have been a disastrous internship, but more importantly, it convinced Charles of the decision-making power of relatively simple logical structures and processes in problem solving. That is the core focus of this book.

Problem solving means different things to different people. When Rob asked his seven-year-old granddaughter how school was going, she said to him, "Papa, I'm very good at problem solving." This of course was music to Rob's ears! Of course, she was really talking about doing math and logic problems in a school setting. Unfortunately, these essential problem solving building blocks are seldom taught as a systematic process and rarely in a way that addresses problems of everyday relevance and consequence. For us, problem solving means the process of making better decisions on the complicated challenges of personal life, our workplaces, and the policy sphere.

The magic of the *Bulletproof Problem Solving* approach we introduce here is in following the same systematic process to solve nearly every type of problem, from linear ones to problems with complex interdependencies. It sets out a simple but rigorous approach to defining problems, disaggregating them into manageable pieces, focusing good analytic tools on the most important parts, and then synthesizing findings to tell a powerful story. While the process has a beginning and end, we encourage you to think of problem solving as an iterative process rather than a linear one. At each stage we improve our understanding of the problem and use those greater insights to refine our early answers.

In this chapter we outline the overall *Bulletproof Problem Solving Process,* introducing you to the seven steps that later chapters will address in more detail. We demonstrate the use of logic trees to uncover the structure of problems and focus on solution paths. We provide several straightforward cases to get readers started. Later chapters will introduce advanced techniques for more complicated and uncertain problems.

The Bulletproof Problem Solving Cycle

The bulletproof problem solving process is both a complete process and an iterative cycle. This cycle can be completed over any timeframe with the information at hand. Once you reach a preliminary end point, you can repeat the process to draw out more insight for deeper understanding.

We often use the expression, "What's the one-day answer?" This means we ask our team to have a coherent summary of our best understanding of the problem and a solution path at any point in the project, not just at the end. This process of creating active hypotheses is at the heart of *Bulletproof Problem Solving*. It can even help you face the dreaded "elevator test." The elevator test is when you, as a junior team member, find yourself in an elevator with the most senior person in your organization and they ask, "How is your project going?" We have all had this happen. You panic, your mind goes blank, and you stammer out a nonsensical dog's breakfast of an answer. The bulletproof problem solving process in the following pages can help you beat this situation and turn the elevator test into an opportunity for promotion.

The kind of problem solving we describe can be done alone or in teams. If you're tackling a problem by yourself, we suggest building in review processes that you can use with family and colleagues to get the higher objectivity and other bias-fighting benefits of a team.

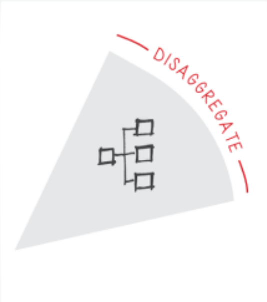
The seven steps are introduced in Exhibit 1.1.

EXHIBIT 1.1 The bulletproof problem solving cycle

STEP 1: DEFINE THE PROBLEM

When a problem's context and boundaries aren't fully described, there is a lot of room for error. The first step in our process is to arrive at a problem definition that is agreed upon by those involved in making a decision. We test the problem definition against several criteria: that it is specific, not general, that we can clearly measure success, that the definition is bounded both in time frame and by the values of the decision maker, and that it involves definitive action being taken. This step may appear constraining, but it leads to the clarity of purpose essential for good problem solving.

STEP 2: DISAGGREGATE THE ISSUES



Once the problem is defined, it must be disaggregated (or broken down) into component parts or issues. We employ logic trees of various types to elegantly disassemble problems into parts for analysis, driving from alternative hypotheses of the answer. There is both an art and science to "cleaving" problems—revealing their fault lines—that drives better solutions. This is the stage at which theoretical frameworks from economics and science provide useful guides to better understanding the drivers of your problem solution. We usually try several different cuts at disaggregation to see which yields the most insight.

STEP 3: PRIORITIZE THE ISSUES, PRUNE THE TREE

The next step is to identify which branches of the logic tree have the biggest impact on the problem, including which you can most affect, and focus your initial attention on these. We employ a simple matrix of size of impact of each lever and ability to move the lever as a way to prune our logic trees. Prioritizing analyses helps us find the critical path to the answer efficiently, making the best use of team time and resources.

our readers will face, and that exhibit the power and utility of the process described in detail over the next several chapters.

1. Is Sydney airport capacity adequate for the future?
2. Should I install solar panels on my roof now?
3. Where should I move?
4. Should a start-up raise its prices?
5. Should I support a K–12 school education levy in my town?

These relatively simple cases will outline each of the seven problem solving steps, but with a focus on the use of logic trees to help you represent the problem and break it into manageable parts. Later chapters will go into the fine points of the other steps in more detail and for more complicated problems.

Case 1: Does Sydney Airport Have Adequate Capacity?

When Rob was the lead partner in recruiting for the Australian and New Zealand practice of McKinsey, the consulting firm made the decision to look beyond traditional hires with MBAs to try to attract clever physicists, scientists, lawyers, engineers, and liberal arts graduates. Discussing business cases in interviews put many of the potential hires at a disadvantage. So his recruiting team came up with a non-business case that they called the Sydney Airport case. It is pretty simple, but it is a good way to show the seven-steps method.

All of the candidates had flown into Sydney Airport and were aware of discussions in the newspapers about whether another airport was needed at that time. Sydney Airport has two of the 10 busiest air routes in the world, so this is a real-world example. At the interviews the candidates were given a simple problem definition (step 1 problem definition): "Will Sydney Airport capacity be adequate in the future?" and asked how they would think about that question. The problem statement was bounded around passenger airport capacity, so the candidates didn't have to spend a lot of time on policy factors that might warrant a second airport, such as greater accessibility, safety, or environmental factors like noise, or even alternatives like a very fast train link between major cities. As we'll see later, the boundaries on problem definition are really important to agree on up front.

Candidates would often ask a clarifying question or two and then outline their approach to addressing the issue. So what was Rob's team looking for? They wanted to see if the candidates used a logical structure to help them solve the problem. It's much easier to show the parts of the problem in written form, so we encouraged candidates to use a whiteboard or pad of paper. It is usually a trial and error process to get the breakdown right to solve the problem. This is step 2, problem disaggregation, and Exhibit 1.2 shows a simple first cut.

EXHIBIT 1.2

In this case, the simplest possible way to cleave the problem is to define airport capacity as supply (of landing slots) less demand. You could have a more complicated tree with competition from other ways to get to Sydney (and you might get extra credit for showing how those affect demand), but it probably isn't necessary in this relatively simple case.

A good candidate would dig a little deeper of course. Exhibit 1.3 shows one way of defining airport supply capacity (number of runways, capacity of each runway, and utilization) and demand (Sydney's share of regional demand). In the short term, the number of runways is fixed, and so is runway capacity (defined mostly by aircraft type).

EXHIBIT 1.3

Candidates would typically explain their approach to modeling demand growth by making different assumptions about gross domestic product (GDP) growth, fuel costs, and relative location attractiveness of Sydney relative to other destinations (see Exhibit 1.4).

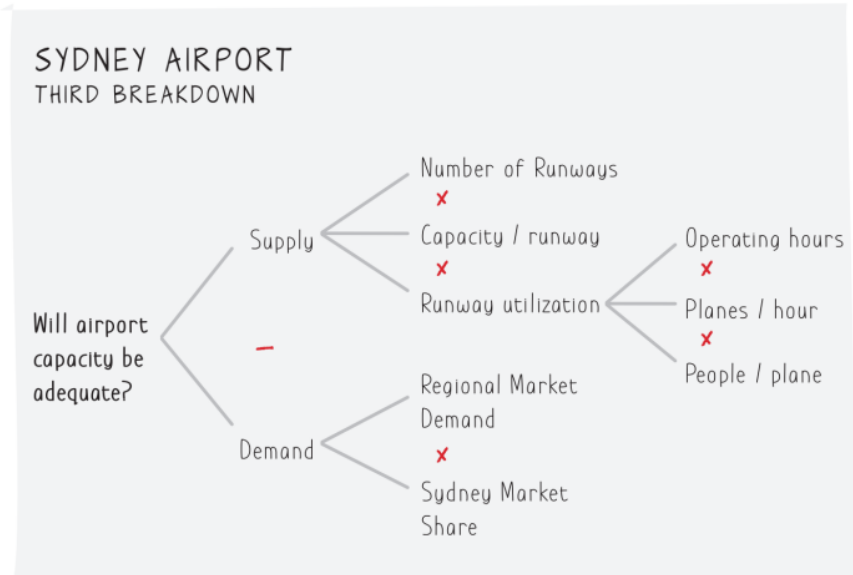


EXHIBIT 1.4

But the most productive approach to this problem is to go deeper into runway utilization, as it is one of the few variables that can be actively managed by transportation planners. Runway utilization is determined by hours of operation, spacing between aircraft movements, and the number of people per airplane. Hours of operation are limited by curfew periods, weather, and maintenance. Thinking about how you could vary these is the heart of steps 4 (workplanning) and 5 (analysis).

The answers Rob most liked were the ones where candidates would say something along these lines:

> Runway utilization is the key so I'd be looking at operating hours, planes per hour, and the people per plane. You probably can't do much with operating hours because there are curfew restrictions

between midnight and 6 a.m. because of the residents nearby. With planes per hour—a core variable for utilization—I'd want to see if they could safely reduce further the time between take-offs and landings. The third factor is the people per plane and that comes down to slot pricing favoring larger planes and policy about light aircraft use at peak hours (steps 6 and 7 synthesis and storytelling)

Good candidates might also propose to raise prices to curtail demand, a tool for airport capacity management, though one that could result in Sydney market share loss, which city economic planners might not embrace.

The branches on this kind of simple logic tree are joined together mathematically, so it is possible to model simple scenarios and show different alternatives by modifying the variables that planners could affect. A really outstanding candidate might show the impact of increasing utilization by 20% on passenger numbers, or employing larger planes.

What actually happened at Sydney Airport? Sydney got a third runway some years later and has managed the impact of significant traffic growth by working on the key variables identified in the case. Despite the current airport authority's opposition, Sydney is to get a second airport in the next decade.

Case 2: Should Rob Install Solar Panels on His Roof Now?

A few years ago Rob thought it might be time to install solar panels at their house in the Australian countryside. Rob and his wife Paula wanted to do something to offset their carbon footprint for some time, but were struggling to make a decision with reducing (and now eliminated) subsidies available from the power company, declining costs of installing solar PV, and questions over the future level of feed-in tariffs (the price at which the electricity company buys *from* you when you generate excess power at home). Was now the right time? He decided to approach it in the way he had learned electricity to the grid via feed-in tariffs. Most of this analysis can be done by online calculators that solar installers offer, once you know the size of the system, roof orientation, solar electric potential, and the efficiency in power generation. Rob simplified the analysis by leaving out battery storage options that add to cost but provide the opportunity to replace peak power charges. With an annual cost savings of around $1,500 and investment costs of just over $6,000, payback was attractive at about four years (step 5).

The next question was whether he should make the investment now, or wait, hoping for lower solar panel costs later. Rob was aware that the cost of a watt of PV had fallen almost 30% from 2012 to 2016, and almost 90% from the early days of solar PV. He wasn't sure whether this would continue in the future. With some simple Internet research, Rob learned that declining costs of equipment was still uncertain, but the cost per watt was unlikely to fall by more than 30% for at least the next three years. There is also uncertainty about future feed-in tariffs that have been set to encourage sales of solar PV. This has to be considered against rising retail prices for electricity customers.

At $1,500 per year, the cost savings lost by waiting would be $4,500 over three years, so the up-front cost of the solar PV installation would have to fall by 75% to make waiting worthwhile. Rob could have used a net present value analysis where the time value of money is considered rather than a simple payback. But in this case the simple method is fine: He felt comfortable with the four-year payback providing an implied rate of return of 25%. It was worth doing now.

Finally, he wanted to estimate how much of his CO_2 footprint he would reduce by going ahead. This depends on two things—one is what fuel source he is displacing (coal or gas in this case), and the second is the kilowatt hours (kWh) he is generating compared to his electricity use, which he knew from the first step. Rob simplified the analysis by looking at the carbon footprint of the average Australian citizen, and found that the avoided carbon from his little solar project could reduce his footprint by more than 20%. Since the payback as an investment is very solid in this case, Rob really could have pruned off this branch of the tree (step 3) and saved some time—but he and Paula had multiple objectives with this investment.

Whenever you do this kind of analysis, it is worth asking what could go wrong, what are the risks around each part of the thinking?

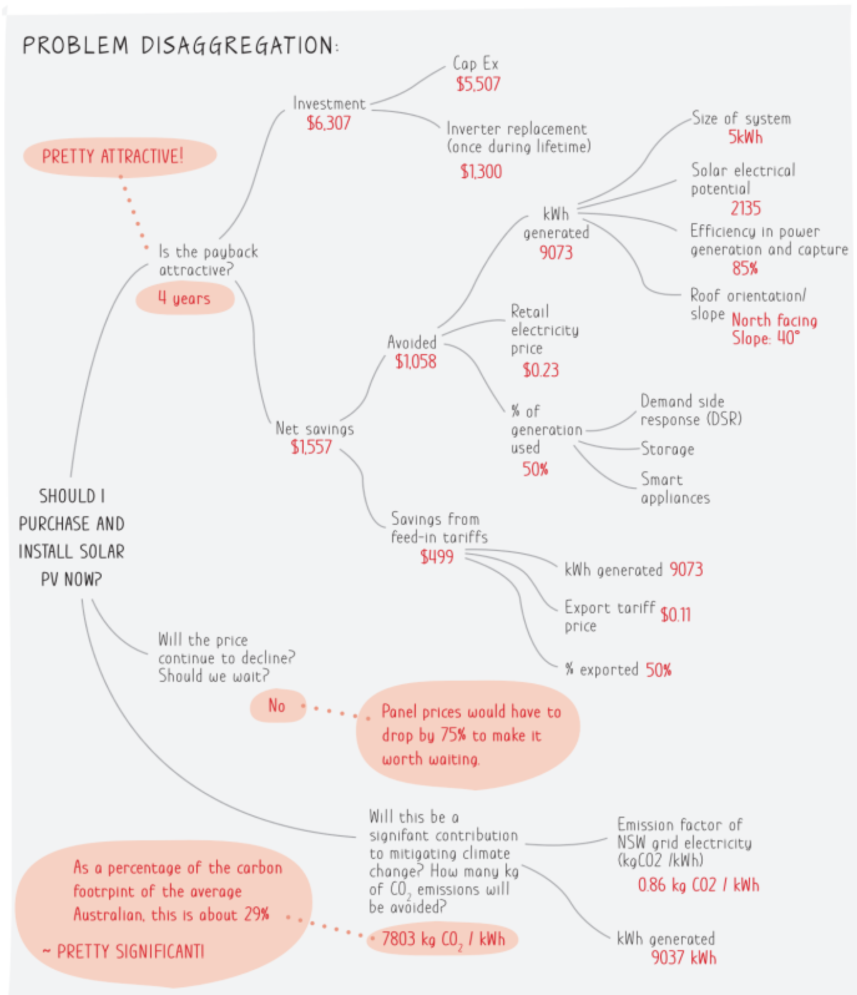


Exhibit 1.6
Assumptions: House type: detached bungalow, Roof orientation: north, Slope: 40°, Suitable roof area: 40m2, Installation size: 5kWh, Shading: none, Numbers for calculations are from 2017, Australia.

In this case there is a chance that the power company would reduce the subsidies for installing solar PV. This can be mitigated by acting quickly. The power company could also reduce the feed-in tariff rate at which it purchased any excess power produced by Rob—and in fact they did that later. But with a four-year payback the exposure is reasonably limited.

The result of Rob's analyses is shown in the more complicated tree shown in Exhibit 1.6.

With only a bit of online research, Rob was able to crack a relatively complicated problem. Rob should install solar panels now. The payback is attractive, and likely cost declines to install later are not enough to offset the savings he could earn now. As a bonus, Rob and Paula were able to reduce their carbon footprint by nearly 30% (steps 6 and 7).

The core of this good result was asking the right questions and disaggregating the problem into straightforward chunks.

Case 3: Where Should I Move?

In the early 2000s Charles was living in Los Angeles. Having recently sold the company he cofounded, his family wanted to move to a small-town environment where there would be more opportunities for recreation and really good schools. They liked the ski towns they had visited, and they had always enjoyed college towns. But how to choose? There are so many variables involved, and it is easy to get it wrong with only impressions from brief visits. Then Charles remembered the factory siting problem he worked on back at Canon in Japan and set up the decision-making effort in a similar way.

The whole family got involved in the problem solving brainstorming, kids included. They started by listing out what mattered to each of them, so their personal factors defined what it meant to be a good place to live. The family agreed on a weighting that favored the school system first, then the natural environment and recreation, and finally characteristics that made for

FAMILY BRAINSTORMING SESSION: WHERE TO LIVE?

ELEMENTS OF A GOOD LIFE	WHAT DOES THAT LOOK LIKE?
Really good schools for the kids	Great teachers Small class sizes Good taxpayer support for education School choices: public, charter, private Graduates get into good colleges
A clean environment and lots to do outside	Water and air quality high A four season climate Lots of sunny days, but sufficient rain Rivers to fish in Great hikes nearby Skiing and mountain biking
A cool, friendly town	A walkable town center Arts, theatre, libraries Not too much traffic Fun coffee shops and good restaurants Do any friends live there? Is it a university town? Is crime a problem?
Can you earn a living?	Cool, small companies Diverse local economy Not too far to West Coast work for Charles

EXHIBIT 1.7

a cool, in-town experience. Charles then added the elements of the ability to earn an income! These were agreed after lively debate with everyone involved (step 1). They planned to use the list to develop a set of towns to visit during family vacations (see Exhibit 1.7).

Charles began the analysis by breaking down the problem into the major elements the family said they valued, then identifying subelements, and finally measurable indicators or variables that captured each subfeature, such as sunny days or a comfort index (defined by temperature and humidity) for climate variables (step 4). It was a little work, but he discovered that most of the data was available online. With the family's input, he put a relative weight next to each variable, to reflect the importance of each element to their final decision.

He developed a tree of around 20 variables and gathered data for about a dozen towns (step 2). The tree he developed is shown in Exhibit 1.8, with the weightings shown in red.

EXHIBIT 1.8

The where-to-live case illustrates how you can start with a simple list of issues or elements that are related to your problem statement, disaggregate the elements further into indicator variables, then finally add concrete measures and weights. The rest is straightforward arithmetic based on a considered ranking of features. This type of tree and analysis approach has applicability to many choice problems. Charles and Rob have used it to assess what apartment to buy, what employer to join—and, of course, where to put your factory.

Case 4: Making Pricing Decisions in a Start-up Company

In the past few years, one of Charles's friends started a company that makes an accessory for pick-up trucks that has a unique and clever design. The company, which we'll call Truckgear, sells around 10,000 units a year, a number that is growing quickly. It is at breakeven on a cash basis (cash basis means not taking into account the accounting charge for depreciating assets). Charles invested in the company and helps devise its strategy.

Start-up companies face big and complex problems early on in the process and, compared to larger companies, they have limited cash resources and team members to address them. Truckgear had to make decisions on whether it should own its own manufacturing plant, which market segments to compete in (there are new and used truck segments and several sales channels to each), whether it should have its own sales force, how much to spend on marketing, and most fundamentally, how fast to grow given limited cash? No wonder start-up teams hardly sleep!

Recently the company had a big decision to make: Should it raise its prices (step 1)? It had held its initial pricing of around $550 for three years. Materials and manufacturing costs had increased as the product features were improved, crimping its margins and lowering the cash generated per unit. Obviously in young companies cash is even more critical than in established ones, as the sources of external financing are significantly fewer. The dilemma Truckgear faced was this—if the marketplace reacts negatively to the price increase, Truckgear growth would slow and perhaps even drop in unit sales.

There is no perfect answer to this kind of question, but we employed a particular kind of logic structure to assess it, a profit lever tree (step 2). We wanted to hone in on the key factors around the decision, and this kind of tree is mathematically complete, so we could use it to model different assumptions.

Exhibit 1.10 is a simple version of this kind of tree.

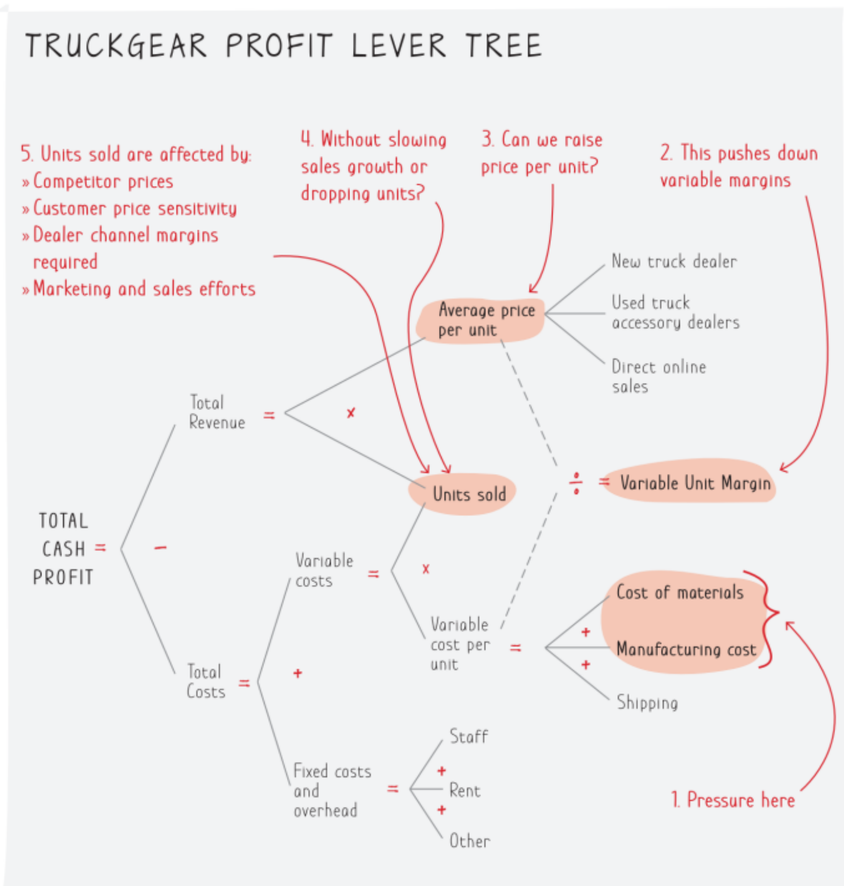


EXHIBIT 1.10