# SOLVING FOR PROJECT RISK MANAGEMENT

## UNDERSTANDING THE CRITICAL ROLE OF UNCERTAINTY IN PROJECT MANAGEMENT

CHRISTIAN B. SMART

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McGraw Hill Education

New York Chicago San Francisco Athens London Madrid
Mexico City Milan New Delhi Singapore Sydney Toronto

1 2 3 4 5 6 7 8 9 LCR 25 24 23 22 21 20

ISBN 978-1-260-47383-4
MHID 1-260-47383-X

e-ISBN 978-1-260-47384-1
e-MHID 1-260-47384-8

**Library of Congress Cataloging-in-Publication Data**

Names: Smart, Christian, author.
Title: Solving for project risk management : understanding the critical role of uncertainty in project management / Christian Smart, Ph.D.
Description: New York City : McGraw Hill, 2020. | Includes bibliographical references and index.
Identifiers: LCCN 2020026092 (print) | LCCN 2020026093 (ebook) | ISBN 9781260473834 (hardback) | ISBN 9781260473841 (ebook)
Subjects: LCSH: Project management. | Risk management.
Classification: LCC HD69.P75 S563 2020 (print) | LCC HD69.P75 (ebook) | DDC 658.4/04—dc23
LC record available at https://lccn.loc.gov/2020026092
LC ebook record available at https://lccn.loc.gov/2020026093

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CHAPTER 1

# Show Me the Data

## The Enduring Problems of Cost Growth and Schedule Delays

Gottfried von Leibniz was a German polymath who lived in the seventeenth and early eighteenth centuries. Two of his most well-known contributions include coinventing differential and integral calculus and his philosophy of optimism. Leibniz believed that we live in the "best of all possible worlds."[1] This was lampooned by the French writer, historian, and philosopher Voltaire, who caricatured him as Professor Pangloss in his novel *Candide*. Throughout the novel Pangloss suffers from a series of misfortunes. Among other calamities, he is enslaved on a Turkish ship and almost executed by the Inquisition. Despite this, Pangloss remains optimistic. This gave rise to the term *Panglossian*, which means extreme optimism, especially when faced with misfortune.[2] One of the chief sources of cost and schedule risk, as we shall discuss in this chapter, is a Panglossian outlook on the part of project managers. Just like the professor with an always sunny outlook even when storm clouds threaten, project management as a profession has refused to face the reality that we live in a hazardous world. The evidence for this is the abundance of cost growth and schedule delays for a wide variety of projects.

Cost and schedule growth reflect changes in dollars and time from one point to a later point. A program budgets for $100 million, but the final actual cost doubles to $200 million by completion. A program plans for a three-year schedule, but it takes nine years instead. Growth is calculated based on the increase in cost or amount of time divided by the earlier cost or amount of time, respectively. To express a number in percentage terms, it is multiplied by 100. For example, in the case of the increase from three years to nine years, the increase is 6/3 = 2, or 200%.

Cost growth and schedule delays are systemic and enduring issues. Many projects in a wide variety of industries regularly experience them. Depending on the application, average cost growth ranges from 30% to 50%, and it is much higher in many cases. For most endeavors, at least one in every seven projects more than doubles in cost from initial projections during the development phase. In accordance with the adage that time is money, schedule delays are also significant. Depending on the type of project, in percentage terms schedule delays can average just as much and sometimes more than cost increases. These two interrelated problems have been consistently high for decades with little change over time.

When you see the word *average*, you probably think about a likely or expected outcome. An average represents the central tendency of a data set. In statistics, three different kinds of averages are commonly used: the mean, median, and mode. These values have a significant impact on our treatment of risk, so they are the most meaningful measures for our purposes. For a discrete set of points, the *mean* is the sum of data points divided by the size of the data set. Just like the center line on a road, the *median* is the 50/50 point. Half the outcomes are greater than the median, and half are less. That is, there is a 50% chance of a result less than the median, and a 50% chance of a result greater than the median. The *mode* is the most likely occurrence. When data points are evenly spread in a symmetric pattern around the average, these three measures are all the same. For example, given the five data points 1, 2, 3, 4, 5, the mean, median, and mode are all 3. This is because the data points are symmetric about 3. Given the seven data points 1, 1, 2, 3, 5, 10, 20, the mean is (1 + 1 + 2 + 3 + 5 + 10 + 20)/7 = 6. The median is 3 since there are three data points {1,1,2} that are less than 3 and there are three data points {5,10,20} greater than 3. The mode is 1, since there are two occurrences of 1 in the set, while all the other numbers occur only once. When we refer to the word *average* in this chapter, we will be referring to the mean because it considers the large cost and schedule risks. The second set of data points {1,1,2,3,4,10,20} is *skewed*. That is, the largest numbers are farther away from the average than the smallest numbers. We see this often in practice in projects, since there are more ways for events to go wrong than there are ways for programs to go right. Also, the cost of a project can never be less than zero; it cannot be cheaper than free. Schedules cannot be negative, as time travel is impossible. However, both cost and schedule can increase significantly, as there is no true upper bound. Also, while it is possible that in some cases a project will discover an opportunity for savings, there is a built-in asymmetry. More can go wrong than can go "right." As a result, cost is more likely to grow than shrink. Even if a program manager finds savings, he or she will likely not turn in the savings but rather find ways to spend the money on the project. It is typically the case that, once money is allocated, it will be spent. This is often referred to as the "money allocated is money spent" (MAIMS) principle.[3]

Note that the problems of growth and delay are distinct from the issues that some projects cost too much and take too long to develop. For example, the government is infamous for overpaying for simple items, such as $10,000 for a toilet seat cover.[4] The subject of this chapter is increases in cost and schedule from one point in time to another. For development projects, the beginning point is typically the beginning of detailed design. Some organizations, such as NASA, start tracking cost and schedule before that point. The earlier the point in time a project starts tracking growth and delays, the greater the uncertainty and the greater the likelihood of growth and delays, but a fair starting point for a baseline is when preliminary designs are in place so that a project has a good sense of scope. Figure 1.1 displays a general timeline that applies to all projects.

**Figure 1.1** Timeline of Project Phases

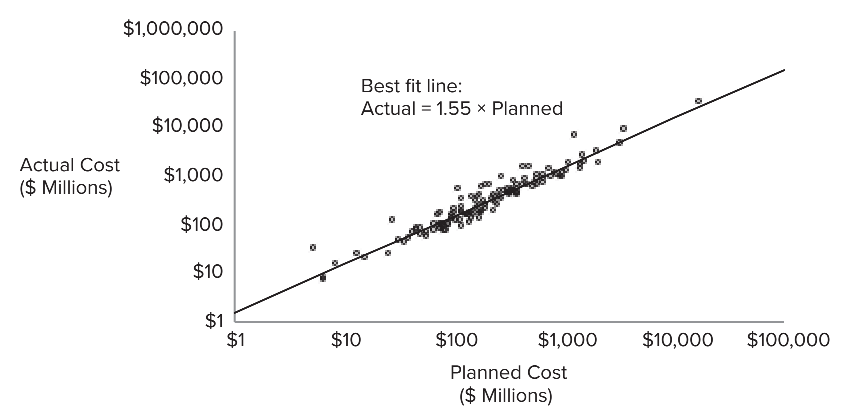

Some organizations have their own names for these phases, but the phases in Figure 1.1 apply to all projects. Initial planning is the start. Depending on complexity, this could be a short period or a long period affected by factors such as the use of advanced technologies, as some of the time for initial planning could be used for necessary technology development. Once initial planning is complete, the development process begins. This involves engineering work, along with building prototypes and conducting tests. At some point during development, production begins. Production does not apply equally to all endeavors, and to some, it does not apply at all. Weapon systems typically produce in quantities numbered in the hundreds and thousands. NASA satellites typically involve the production of one unit, as do infrastructure projects such as a bridge, tunnel, road, or dam. Software projects do not produce a tangible product at all. Endeavors that do not result in a physical product or those that produce one unit may consider any production to be part of the development phase. Once a product has been developed and produced, it needs to be operated and maintained. This can occur over a long period such as years or even decades. This is typically the longest phase and often consumes the largest amount of cost and time in the life cycle of project. At the end of their useful life, a tangible, non-software product will need to be disposed of or destroyed.

When measured from the beginning of development, the phase with the greatest amount of cost uncertainty is often development, so many studies of cost growth focus on this phase. However, it is not always the case that development has the greatest amount of risk for cost increase. If the product is a new configuration that is not like anything in the past, the operation and production phases can be risky as well. For example, the Space Shuttle was a radical departure from previous launch vehicles, such as the Saturn V that preceded it. The initial plans called for the Shuttle to operate much like a conventional airplane with one flight per week. However, this was wildly optimistic as it never flew more than nine times in one year. This low flight rate, combined with the complexity of the system itself, caused operations costs per flight to be much higher than initial projections. Production cost increases can be driven by errors in forecasting production quantities. When multiple units are to be produced and it takes years to develop a design, it is hard to accurately forecast quantities to be produced. The number of units produced is an important driver for production costs, as it is inversely correlated with the average unit cost. In most cases, there is a large fixed cost associated with manufacturing. When more units are produced, this cost can be spread over more units, which results in lower average unit cost. When fewer units are produced, this fixed cost is allocated across fewer units, thus raising the average unit cost.

## IT ALWAYS COSTS MORE AND TAKES LONGER THAN YOU THINK

Cost increases and schedule stretches are commonplace for many different types of projects. Megaprojects—those that cost billions of dollars—are often the focus of growth studies.[5] However, most projects, regardless of size, experience cost and schedule increases. A recent NASA study showed average cost growth for 133 development programs was equal to more than 50% across a wide range of small to large projects, from those that cost tens of millions of dollars to those that cost billions.[6] See Figure 1.2.

**Figure 1.2** Actual Cost of NASA Missions Compared to Initial Estimates




The equation in Figure 1.2 is simple. Take the planned cost and multiply it by 1.55 to get the best estimate of actual cost. This simple line explains more than 95% of the relationship between the planned and actual costs. Note that the scale of the graph in Figure 1.2 is on a log scale, which means that orders of magnitude—1, 10, 100, etc.—are equally spaced. This is necessary to properly visualize data that varies over a wide range. This simple analysis is not intended as a Band-Aid to fix cost growth, as there is a significant amount of variation around the line that is diminished by the log scale. It is intended as an illustration that both small and large projects experience significant cost growth. The variations like those in Figure 1.2 have consistently been at this level for not only NASA but also Department of Defense missions since the 1960s. I have also analyzed schedule growth for these types of missions, and the average schedule delay ranges from 27% to more than 50%. Norman Augustine, former Army official and former CEO of Lockheed Martin, one of the largest defense contractors in the United States, noted that the cost for development programs grows on average by 52%, which he called the "Las Vegas Factor of Development Program Planning"[7] as this is the amount estimates would need to increase in order to ensure that the project (akin to a casino in this analogy) will break even.

Cost overruns get much attention, but schedule delays are important as well, because time is a valuable resource. Augustine also noted that in his experience schedules for development projects grew by 33% on average, which he termed the "Universal Fantasy Factor."[8] Douglas Hofstadter, a cognitive scientist, noted that there were predictions in the early days of computer chess that it would only be 10 years before computers could play chess as well as the world champion. Claude Shannon, a mathematician who developed information theory, was an early pioneer in the field. He published a paper on a programming a computer to play chess in 1950. Hofstadter noted that 10 years after that there was an update to the prediction, which was that in another 10 years computers would surpass the best human chess players. The point in time at which computers became superior to the best humans in chess always seemed to be 10 years away. This example led Hofstadter to coin the eponymous Hofstadter's Law: "It always takes longer than you expect, even when you take into account Hofstadter's Law."[9]

However, there are often exceptions to such laws. Garry Kasparov, world chess champion from 1985 to 2000, predicted in 1990 that it would be at least 10 years before a computer could beat the best human chess player in a match. Kasparov would make a good project manager, as he was optimistic. His forecast was off by three years. In 1997, the IBM computer program Deep Blue defeated Kasparov in a six-game chess match.[10]

To understand why Hofstadter's Law holds (with the occasional exception for overconfident chess grandmasters), consider a thought experiment that most everyone can relate to—the daily commute to work. At one time, my daily commute by car to work ranged anywhere from 25 minutes to more than an hour. The typical, or most likely, commute time was around 35 minutes. Two factors that drove this time were the time I left my house and the amount of school traffic. If I left my house early enough, I would avoid school traffic and many other commuters. When I left early enough, I could make it to work in 25 minutes. Also, during the summer and school holidays, like Christmas and spring break, my commute was also about 25 minutes regardless of when I left home. However, there were other events that would slow me down. For example, road construction along my route to work happened occasionally and would slow my commute. I also crossed a train track going to work, and sometimes would have to wait on the train. A significant part of my route was along an interstate, and occasionally there were wrecks that slowed my commute. My longest commute was over an hour—a car had crossed the median at a high speed, hitting another car head-on, and caused two deaths. My commute was typically 35 minutes. Occasionally, I could make it to work in 25 minutes, but it could also take much longer to get to work. Only so many things could speed up my commute, but there were many events that could slow me down. The things that could go right were lack of school traffic and leaving for work earlier or later than usual. The things that could and did sometimes go wrong included waiting for a train crossing, a stalled car along the route, a car wreck along the route, someone stopped by a police officer for speeding, me being stopped by a police officer for speeding, road construction along the route, and school traffic, including bus traffic, being heavier than usual for some reason. It is much harder to overestimate the amount of time it takes to get to work than it is to underestimate because there are so many more things that can happen to increase the time than to decrease it. As a result, schedule growth, like cost growth, is highly skewed to the right (or upside).

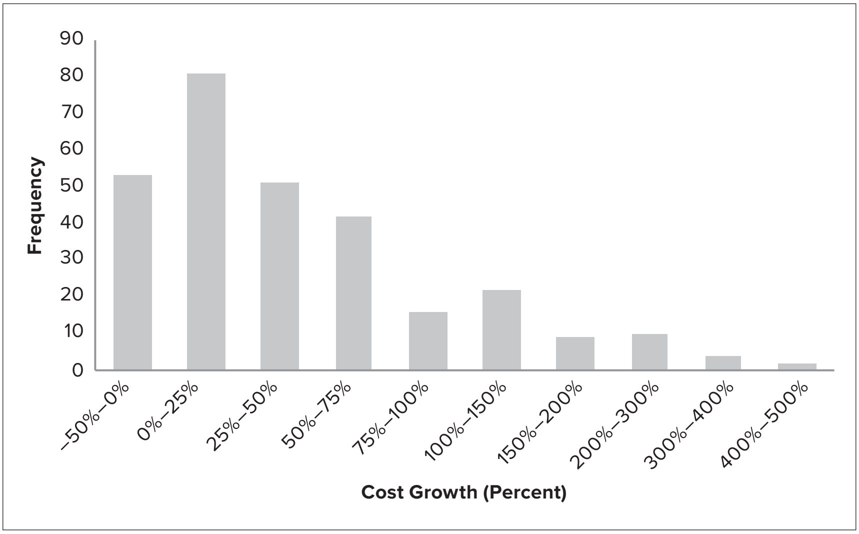
Not only do development endeavors take longer than planned on average, they are rarely completed on time. I have discovered in my experience that schedule underruns are rare, and schedule slips are even more likely to occur than cost growth. C. Northcote Parkinson was a twentieth-century British naval historian and author of 60 books. Today, he is best remembered for Parkinson's Law, which states that work expands to fill the time available.[11] Rather than complete a project early, projects typically use any spare time to continue system development such as doing additional testing to ensure that the system works correctly.

## SHOW ME THE DATA

A few years ago, I compiled a data set of development cost growth for 289 NASA and Department of Defense programs and projects.[12] The minimum cost growth was –25.2% for a super lightweight version of the Shuttle external tank. The negative number means that cost underran the initial budget by approximately one-quarter of the initial budget. One in six missions reported actual costs that were lower than the initial plan. The maximum cost growth among the missions studied was 475% for the Comanche helicopter program, which was eventually cancelled before development was completed. The average cost growth for all missions was 52.0%.

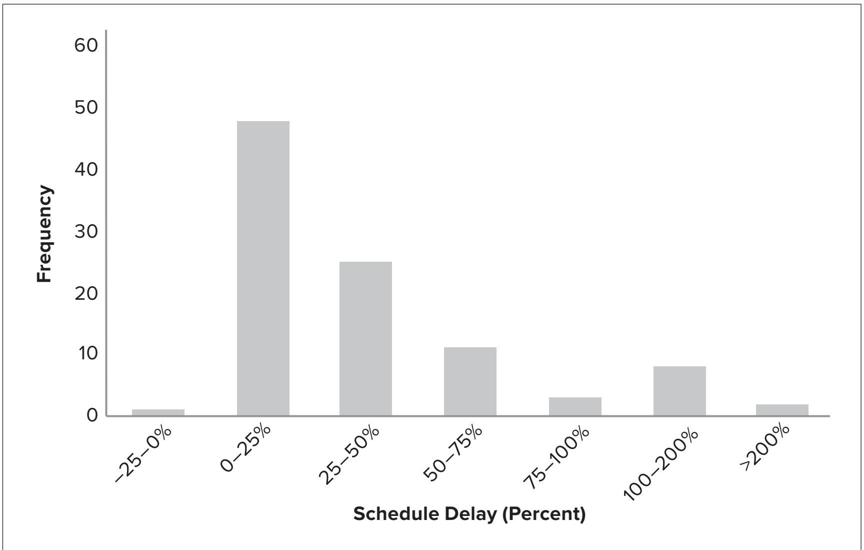
This value is the same as Augustine's Las Vegas Factor that we discussed earlier. Most missions experienced relatively small amounts of cost growth—half experienced growth less than 30%, with some missions experiencing extreme amounts of cost growth. One in six missions had cost growth equal to or in excess of 100%, which means cost at least doubled. See Figure 1.3 for a graphical summary.

**Figure 1.3** Summary of Cost Growth Data for 289 NASA and Department of Defense Development Programs




Several years ago, I collected data on development schedule delays for 98 NASA missions.[13] There was only one schedule underrun. This was for a well-managed in-house effort. It was an earth-orbiting spacecraft that observed the time variation of a variety of X-ray sources, including black holes. Eight other missions were completed on time, which means more than 90% of the schedules had some amount of delay. The average delay was 38%. Ten percent of missions doubled or more in length of time. The longest delay was for the Ulysses program, a joint NASA and European Space Agency mission to study the Sun. Figure 1.4 displays a summary of this data as a histogram.

**Figure 1.4** Summary of Schedule Delay Data for 98 NASA Missions




Schedule delays are common in defense projects as well. A study of tactical aircraft (*tactical* means that it does not carry or is not itself a nuclear weapon) found an average 7% delay in length of development and 25% in production. A study of tactical missiles found an average 52% increase in development schedules and a 53% increase in production schedules.[14] Another study of a variety of weapons systems found an average development schedule delay equal to 27.5%, with 9 of out 10 missions experiencing increases in schedules.[15]

Cost overruns and schedule delays are not limited to aerospace and weapons systems development projects. Bent Flyvbjerg, a professor at Oxford, has been studying the issue of cost growth for large infrastructure projects for many years. He calls these large endeavors megaprojects. He has studied a variety of different types—rails, bridges, roads, and tunnels, including the tunnel under the English Channel that connects England and France. In a large study of 258 transportation infrastructure projects, approximately 90% experienced cost growth. The average cost growth, depending on type, ranged from 20% to 45%. The average increase in schedule ranged from 23% to 45%. Flyvbjerg found that this pattern of growth has been remarkably stable over a 70-year period. Among the more spectacular examples of cost underestimation are the Sydney Opera House, with actual costs approximately 15 times higher than those projected, and the Concorde supersonic airplane, with cost 12 times higher than predicted. When the Suez Canal was completed in 1869, actual construction costs were 20 times higher than the earliest estimated costs and three times higher than the cost estimate in the year before construction began.[16]

Software and information technology projects are notorious for extreme cost and schedule growth. The average change in software requirements during development has been reported to average 1% to 2% each month and can be much higher.[17] This means that the longer the project, the more requirements will change. For a 5-year project, on average, requirements will increase by 80% to 220%. For a 10-year project, this range is 230% to 980%. The primary metric for measuring the scope of a software project is called equivalent software lines of code (ESLOC). The number of lines of code is a count of the lines in the text that make up the instructions in a computer program. ESLOC represents new software lines of code to be developed plus some fraction for integrating those previously developed. This metric is closely correlated with the cost of a software project. For military applications, a study of 131 data points found 51% average growth in ESLOC during development and that 16% more than doubled.[18] Another, smaller study for military missions showed similar programs averaged 49% ESLOC growth, with approximately 20% at least doubling in cost.[19] A large survey of thousands of software and information technology development projects has tracked cost growth and delays from 2000 to 2008, finding that average cost growth ranged from 43% to 56%, average schedule delays ranged from 63% to 84%, and 24% of these kinds of projects failed.[20] New oilfield projects experience significant cost growth as well, with 30% experiencing overruns in excess of 50%.[21]

Hydroelectric power generation from dams often experiences significant cost growth and schedule delays. Dams require complex engineering and geological studies, as the amount of water contained can impact fault lines and cause seismic activity. Cost growth for these systems ranges on average from 24% to 96%, and schedule delays average 27% to 44%.[22]

The Olympics may have the worst record of all for cost growth of any project type. From 1968 to 2016, the average cost overrun was 156%. Almost half reported cost overruns in excess of 100%. The largest overrun was for the Montreal Olympics in Summer 1976—the final cost was more than eight times the initial plan.[23] The date for an Olympics is set well in advanced. Unlike most other projects, there have been no schedule delays in the past. This could be a factor in why the cost overruns are much higher than for other types of endeavors. However, the 2020 Summer Olympics planned for Tokyo was postponed in March of that year due to the COVID-19 pandemic. A schedule delay for an Olympics is unprecedented, and a risk no one could foresee—just as it always costs more and takes longer than you think, it is always riskier than you think.

Table 1.1 summarizes cost and schedule growth across several industries.

The averages for cost and schedule growth among industries varies from 20% for roads to 156% for the Olympics. Average schedule delays range from 0% for Olympics prior to 2020 to 84% for information technology and software projects. All projects experience regular, recurring cost and schedule growth. Cost overruns occur

**Table 1.1** Comparison of Cost and Schedule Growth Across Several Industries

| | Olympics | Software/ IT | Dams | NASA/ DoD | Rail | Bridges/ Tunnels | Roads |
|---|---|---|---|---|---|---|---|
| Average Cost Growth | 156% | 43–56% | 24–96% | 52% | 45% | 34% | 20% |
| Frequency of Occurrence | 10/10 | 8/10 | 8/10 | 8/10 | 9/10 | 9/10 | 9/10 |
| Frequency of Doubling | 1 in 2 | 1 in 4 | 1 in 5 | 1 in 6 | 1 in 12 | 1 in 12 | 1 in 50 |
| Average Schedule Delay | 0% | 63–84% | 27–44% | 27–52% | 45% | 23% | 38% |
| Frequency of Schedule Delay | 0/10 | 9/10 | 7/10 | 9/10 | 8/10 | 7/10 | 7/10 |

in 80% or more of projects, and schedule delays occur in 70% or more of projects, regardless of industry, as shown in the table by frequency of occurrence. The frequency of doubling is an important statistic.[24] This indicates how often projects have more than doubled in cost from the initial plan. For every industry, except roads, this is a relatively common occurrence, ranging from one in every 2 projects to one in every 12. These wide ranges make it difficult to grasp the true magnitude of risk and make basic statistics not useful for its analysis. I gave a presentation on risk at a workshop. When I discussed that the average cost growth for military and aerospace projects has historically been in excess of 50%, someone in the audience said that if you look at how many projects experience that much growth, it is much lower. That is true, as we mentioned earlier due to skewness, 50% of military and space projects experience cost growth less than 30%. He considered this latter figure as evidence that, most of the time, projects "get it right." I do not consider 30% cost growth to be getting "it" right, especially for billion-dollar programs, but that is not the point. Risk has two dimensions—likelihood of occurrence and consequence. Consequence is the more important of the two, but less appreciated, due to our innate need to be "right." What causes trouble is the programs that more than double in cost. While they are not the majority, their growth is large enough to make a difference. We can be right 90% of the time, or even more frequently, but get wiped out by a blowout program that doubles, triples, or quadruples in cost. We will expound on this idea in later chapters.

## IT'S EVEN WORSE THAN IT APPEARS

Ideally, growth in cost and schedule should be measured holding everything else constant, or what economists call other things being equal. However, that is impossible to do as performance is not fixed. When project managers find that their costs are growing and it is taking longer to accomplish work than planned, they may not always have the luxury of getting more money or more time. In such cases, the project either must stop work, which could mean cancellation, or it must cut scope to live within its means. In a canceled project, most if not all the work done is wasted. In some cases, technology development or part of a project can be transferred to another. Regardless, much time and effort is wasted when projects are cancelled. For example, hundreds of millions of dollars were spent on developing the cancelled Ares I launch vehicle, part of NASA's Constellation program to replace the Space Shuttle. Cutting scope happens frequently and is one way that projects often cope with cost and schedule growth. A program may have originally planned to fly five scientific instruments on a satellite but, when faced with pressure to keep costs reined in, may instead fly only three. Thus, the true risk is under accounted for in the actual cost and schedule growth data as the scope is not held constant. Without this option, programs would experience even greater cost overruns and even longer schedule delays. A satellite can remove a scientific instrument and still conduct at least part of its mission. Software can cut out features and still be worthwhile. A road project may plan to widen two lanes to six, but due to overruns may only be able to expand to four. In my experience with NASA and military projects, I have firsthand anecdotal evidence that development projects frequently cut scope to try to deal with overruns in money and time. The impact of this is that the risk management problem is even worse than is indicated by the numerous studies on cost and schedule growth. That is because the value of the delivered project is less than planned. Projects often end up paying more but getting less. This problem is not limited to aerospace and weapons systems: large infrastructure projects that cost billions of dollars, often referred to as megaprojects, are criticized for frequent poor performance.[25]

The Ulysses space mission is a prime example of such a project. It was named after the Latin for Odysseus, the hero of Homer's Odyssey. The Ulysses spacecraft took a long voyage to study the Sun. This was a joint project between NASA and the European Space Agency (ESA). The initial plan was to use two spacecrafts. One spacecraft was to be developed by each of the two agencies. Development started in October 1978, with a planned launch of both spacecraft on the Space Shuttle in February 1983. This was only 52 months. While four years and four months seems like a long time, the average development schedule for a NASA mission is 60 months.[26] This average includes both earth-orbiting and planetary spacecraft. Simple earth-orbiting spacecraft can be developed, built, and launched in a few years, but deep space missions typically take much longer—a decade or more. Cassini, a mission to Saturn, took 110 months to develop, build, and launch, and Galileo, a mission to Jupiter, required 135 months. This latter mission, like Ulysses, was originally planned to be much shorter in terms or development time, only 43 months. Galileo's schedule tripled in length during development.

The original plan for Ulysses was for NASA and ESA to each pay for the development of their respective spacecraft. NASA was to pay for the launch aboard the Shuttle. To save money in fiscal year 1982, NASA delayed the planned launch. Congress cut the budget for the program. This caused NASA to cancel the development of its spacecraft. The result was a loss of half the instruments planned for the mission. However, NASA paid for the launch and for a radioisotopic thermal generator, a type of power source that uses a radioactive material often used on long duration planetary missions. The launch was again delayed by the Space Shuttle Challenger incident. The overall costs, excluding the mission operations costs, decreased slightly from the initial plan, but this is hardly a good deal, as the mission lost half its scope as a result![27]

Another case of a (potentially) successful project that has significantly cut scope is the California High-Speed Rail (CHSR). The initial goal of this state government-funded project was to provide bullet train transportation with 520 miles of track from San Francisco to Los Angeles, with several stops. In 2008, planning began. Initial projections for cost were $40 billion, with completion planned for 2028. A one-way fare for one ticket from Los Angeles to San Francisco was expected to be priced at $55. One year later, the project was expected to cost $98.5 billion with a completion date in 2033, and a one-way ticket from the City of Angels to the City by the Bay was expected to cost $95. The section of the project where construction began, a 119-mile path in California's Central Valley between Madera and Bakersfield, was initially expected to cost $6 billion. Estimates for that rose to $7.8 billion in 2016. It increased again in 2018 to $10.8 billion. Of this latter $3 billion increase, $600 million was for reserves, so at least some attention was paid to risk.[28] Estimates for the total project continued to go and up down over the period from 2009 to 2019. The latest estimate published in early 2019 was $77 billion, almost double the initial forecast.[29] On February 12, 2019, the governor of California

Gavin Newsom announced a significant scope reduction in his state-of-the-state address. Governor Newsom said the new scope of the project was restricted to a 171-mile stretch from Merced to Bakersfield. This includes the initial 119-mile track from Bakersfield to Madera, plus a 52-mile track from Madera to Merced.[30] This smaller scope endeavor is projected to cost $12.4 billion. Plans also include the use of low-speed Amtrak trains rather than bullet trains.[31] California Highway 99 travels directly between Merced and Bakersfield. The distance is 165 miles, and the drive time is projected as two hours and 26 minutes. A high-speed train could make the trip in about an hour, saving about one-and-a-half hours compared to a car trip. A $12.4 billion investment is a lot of money to provide fast trips between Bakersfield (population 380,000) to Merced (population 80,000). Unless this is eventually followed by completion of the original scope, this mega project will be a mega waste of time and money. This is a good example of the sunk cost fallacy. The California government has already spent a large sum of money, but it is never rational to continue with a project simply because a lot of money and time has already been devoted to it. Despite the irrationality of making decisions based on sunk cost, behavioral economists have noted its frequent occurrence.[32]

The pharmaceutical wholesaler FoxMeyer's attempt in the mid-1990s to implement a new enterprise resource planning system is an example of a project that suffered cost overruns, schedule delays, and not only failed to perform up to expectations, it drove the company to bankruptcy! At the time it started the project, FoxMeyer was an established, large enterprise with annual sales in excess of $5 billion. FoxMeyer's mainframe system needed replacement. The company decided to replace this with a (then) newly emerging business software product called enterprise resource planning (ERP). This type of product unifies all processes with a company into one system. It replaces separate products for different departments such as logistics, sales, and production with one single software product.

The company was also expected to receive additional business from a major new client, so it needed to be able to handle this additional business. The company expected to save $40 million in annual operating costs once the new system was in place.[33] The project began in 1993. The company invested $65 million in the project and planned to complete implementation in 18 months. While initial testing of the system indicated that it could handle the increased workflow, it turned out it could only process 10,000 orders a day compared to the legacy mainframe system's capacity of 420,000. Despite the new product's limitations, FoxMeyer's leadership refused to abandon the new product and continued to try to make the new system work. The cost rose to $100 million and the schedule slipped. In 1996, the company filed for bankruptcy.[34] This information technology endeavor not only suffered from cost growth and schedule delays, but the technical performance was so abysmal that management's refusal to abandon it took down the company.

## SUMMARY

We have shown that cost and schedule growth are consistently high across a wide range of projects. This has been the case for a long time and shows no signs of slowing. Not only is the track record bad, it is even worse than the historical data indicates. That is because in many cases technical performance is reduced in order to mitigate cost and schedule problems. Projects spend more, take longer, and achieve less than planned. The next chapter discusses the key reasons for cost and schedule growth.

# ABOUT THE AUTHOR

**Christian Smart** is the Chief Data Scientist with Galorath Federal, a leading international supplier of parametric cost models and data analytics consulting services. He supports NASA and the Department of Defense in the application of analytics for cutting-edge programs, including nuclear thermal propulsion for crewed space transportation and hypersonic weapon systems.

Dr. Smart's professional career has focused on parametric cost analysis and cost risk analysis of space flight and weapon system programs and related areas, such as machine learning, regression analysis, cost and schedule risk analysis, probabilistic risk assessment, and the project management policies that support best-in-class cost and schedule analysis. He led the development of a quantitative cost risk analysis capability for the NASA/Air Force Cost Model. Dr. Smart participated in the development of a probabilistic risk analysis for the Space Shuttle. He led and edited the publication of a cost estimating handbook for the Missile Defense Agency. Dr. Smart developed a joint cost and schedule quantitative risk analysis for the Ares I launch vehicle and served on the Review of United States Human Space Flight Plans Committee (also known as The Augustine Commission), for which he was awarded an Exceptional Public Service Medal by NASA in 2010.

Dr. Smart served as the Cost Director for the Missile Defense Agency for several years, leading a team of more than 100 estimators. He is a longtime member of, and is certified by, the International Cost Estimating and Analysis Association (ICEAA). Dr. Smart currently serves as the Vice President for Professional Development for ICEAA. He has written extensively about cost modeling, parametric cost estimating, and cost risk analysis. Dr. Smart has won numerous best paper awards at cost estimating conferences. He has been an American Society for Quality Certified Reliability Engineer.

Dr. Smart has BS and BA degrees in mathematics and economics from Jacksonville State University, and a PhD in Applied Mathematics from the University of Alabama in Huntsville. He, his wife, and their young son live near Nashville, Tennessee.