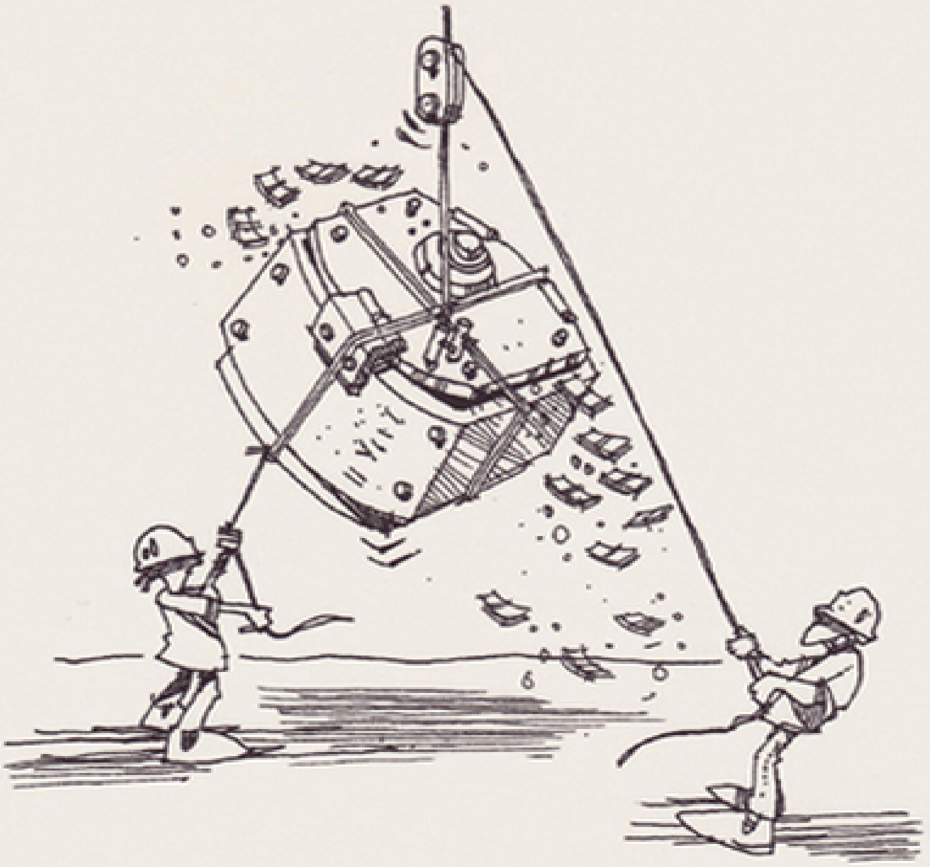
ENGINEERING MONEY

Financial Fundamentals for Engineers



RICHARD HILL & GEORGE SOLT

WILEY

Table of Contents

Index

Engineering Money
Financial Fundamentals for Engineers

Richard Hill
George Solt

WILEY

A John Wiley & Sons, Inc., Publication

Published by John Wiley & Sons, Inc., Hoboken, New Jersey

Published simultaneously in Canada

For general information on our other products and services or for technical support, please contact our Customer Care

Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit our web site at www.wiley.com.

Library of Congress Cataloging-in-Publication Data:

Hill, Richard (Richard William), 1947–

Engineering money : financial fundamentals for engineers / Richard Hill and George Solt.

p. cm.

Includes index.

ISBN 978-0-470-54601-7 (pbk.); ISBN 978-1-118-06308-8 (ebk.)

1. Engineering–Accounting. 2. Engineering–Finance. I. Solt, George S. II. Title.

TA185.H55 2010

658.15024′62—dc22

2010007985

Preface

There is a traditional gap in an engineer's education. Most academic courses around the world do little to explain that engineering projects depend as much on financial matters as they do on technology. Without money projects don't get built, and without profits there would be no incentive to build them.

In 1996 George Solt pioneered a course on this for senior-year civil engineering students at University College London, and Richard Hill took over the course in 2002. We now teach it to BEng, MEng, and MSc students in civil, mechanical, chemical, and biochemical engineering. When mature engineers hear about it, they all say "Gosh! I wish they'd taught me that when I was a student, I had to learn the hard way." This book is based on that course and aims to fill this gap in engineering education for both students and young engineers in industry. We must be doing something right because, since the first version of this book, our student numbers have grown so much that even though we run two parallel version of this course every year, we've had to move to a bigger lecture hall!

We both graduated in chemical engineering—George in 1950 from Battersea (now the University of Surrey) and Richard in 1970 from the University of Leeds. George spent 35 years in industry, in technical and R&D roles, and a short spell in a management consultant role before becoming a full-time academic. He was also engaged as technical expert for a number of major disputes before the High Court in London.

Richard worked for 25 years in design and proposals followed by 20 years as an independent consultant. We were both in the specialist field of water treatment plant contracting. The experience we gained and the lessons we learned are applicable to all branches of engineering, especially that of project engineering, where the interaction between money and engineering is more difficult and more important than others.

We two have worked together, first in process plant contracting and then as teachers, for so long that we can speak with one voice. When you read “I” in the text, it might be either one of us speaking, but it really makes no difference.

Our experience showed us that there is a need for teaching this subject to everyone who deals with projects. Of course, the need is greatest for engineers, all of whom will sooner or later find themselves acting as either contractor or client in some project.

There’s nothing difficult in the bits that make up this subject. So why does it have to be learned? Because in this field everything is interconnected—that’s why the book is full of cross references: The trick is to understand how the whole system works.

To make things easy, we have simplified definitions and explanations wherever we thought we could without actually misleading anyone. On the other hand, you’ll see boxes with interesting or entertaining bits that are only marginally relevant, so they’re easily skipped if you wish. We hope that they’ll help to explain why it’s so important for engineers to have a good understanding of financial matters.

Project engineering is, increasingly, an international business and, like most businesses these days it’s a 24/7 workplace. I do my consulting work from a small town near London. On a recent project the site team in Shanghai would send me questions by e-mail at 10 AM (which is 6 PM there) expecting to have an answer the following morning. So after 2 PM UK time I could talk to the plant contractors in the United States (who don’t get to work before then), and they might let me have the data I need at about 10 PM (5 PM their time) before leaving for home. I would then work through to respond to Shanghai by 1 AM UK time (that's when they start work in the morning): 24/7 is OK provided that you don't have to work all those hours yourself.

So we must be aware of different time zones, different customs, and different currencies. In this new edition we've used U.S. dollars, pounds sterling, and euros in our examples—it's as well to get to used to it.*

George Solt

Richard Hill

Note

* Exchange rates have varied a lot in recent years, but at the time of writing, the £ and € are roughly similar in value and worth about $1½ each.

Chapter 1

What's It All About?

IT'S ALL ABOUT MONEY

Engineers create wealth. It really is a simple as that. There's an old American tag that an engineer is a man who can do for half a dollar what any fool can do for a dollar. We create wealth by finding cost-effective solutions to problems. Railways, airplanes, atomic bombs, agricultural machines, generation of electricity, mass production of chemicals and pharmaceuticals, computers, and water supply: Engineers have made their mark in every area of human endeavor, and they have done it by reducing costs.

Engineers work in a variety of activities including design, construction, manufacturing, production, research and development, and maintenance—each of which is, ultimately, concerned with money.

ENGINEERING ACTIVITIES

Design is about devising some way of meeting an objective while making the best use of resources—*labor, materials, and energy*—all of which are measured in money. We also have to think of the environment and sustainability. These, too, have associated costs, but we are still learning how to measure them. That leads to difficulties that, to be honest, we haven't yet learned to resolve.

Construction and production are actually the ends of a wide spectrum of making things—a new airport at one end and churning out family saloon cars at the other. At the extremes, construction is a one-off, long-term endeavor that involves at least some novelty, whereas production is continuous and involves little novelty. In between, the two merge continuously into one another. Building a cruise ship is a construction project: Making motor boats is production. The difference is in the size, the novelty, the time scale, and the relationship between the buyer and the manufacturer of the product.

The importance of money matters also changes continuously along the spectrum. It is most difficult and important at the “construction” end. Money is, of course, important in production, but the engineer’s work is no more affected by it than if he were making baked beans, and the same goes for those working in maintenance. (So far I’ve said nothing about research and development, which is quite different, and there is a separate chapter on that subject.)

Construction work is classically undertaken by consultants and contractors. They are the people who are in the front line in the subject of this book—that is why much of it is addressed directly to them. However, most engineers will sooner or later be involved in building, upgrading, replacement, major refurbishment, and the like—all activities that involve consultants and contractors. Disputes can arise because clients don’t understand the money problems that contractors face, so there’s no excuse for production engineers to remain ignorant.

ECONOMIC ENGINEERING

The history of automotive engineering is littered with technological innovation. Henry Ford’s Model T, Vincenzo Lancia’s Lambda, Ferdinand Porsche’s Volkswagen Beetle, Pierre Boulanger’s Citroen 2CV, Alec Issigonis’s Mini, and many more. These innovations were driven by economics:

to make an automobile that was more affordable but without sacrificing quality and design.

> My colleague the keen sales director (see Chapter 7) had a Rolls Royce Phantom III (1937 model) of which he was immensely proud. It weighed 2.25 tons and got 7 miles to the gallon. People often asked whether they might look under the hood. There they would find a downsized version of the Merlin engine—the one that powered the Spitfire and other famous World War II aircraft: a 7-liter V12 engine, with 24 spark plugs and twin magneto ignition (see Chapter 24). "What a beautiful piece of engineering!" they would exclaim. But, of course, it was the exact reverse—it was a classical case of bad engineering. Ettore Bugatti (1882–1947), who knew a thing or two about motor car design, said of the Rolls Royce that it "represents the triumph of mechanics over engineers."

Which of theses innovative automobiles is the most important is a matter of opinion, but they were all far superior, in engineering terms, to contemporary Rolls Royces, which carry the same number of people in large and very expensive gas guzzlers. It's not hard to design and build anything if you can use the most expensive materials, take as much space as you like, and pay no attention to its running and maintenance costs—in short spend unlimited amounts of money.

While these technological innovations were made for commercial reasons, they also resulted in sociological change by bringing automobiles, which had been the preserve of the wealthy, within the reach of almost everyone. Indeed, the Mini became something of an icon of the 1960s, being driven by princesses, film stars, and factory workers. Engineers often underestimate the way they affect society both for good and bad (see Chapter 28).

WHO BENEFITS?

> There are many textbooks on “management.” Most, in my experience, are rubbish. I do, however, recommend *Up the Organization* by Robert Townsend. It was published decades ago, but it is still a classic. His answer to the question in the chapter title is “If you can’t do it excellently, don’t do it at all. Because if it’s not excellent, it won’t be profitable or fun, and if you’re not in business for fun or profit, what the hell are you doing here?”

Ultimately it’s society or “the public.” Unless there is a benefit to the general public, engineering innovations fail. Naturally, individuals and corporations make money along the way: Engineers are no more altruistic than other humans. But that is what provides the impetus for innovation. When Isambard Brunel built the pioneering Great Western Railway he did it for the benefit of the burghers of Bristol, who wanted to compete with the London docks for trans-Atlantic trade, and they paid him well for his efforts. But the benefit of lower cost travel between London and the west is still with us.

Businesses exist to make money—that is, a profit—for someone. So, ultimately, do engineers.

WHERE’S THE TECHNOLOGY?

> The word *engineer* comes from the same Latin word as *ingenious*, which implies that we have to use creative skills and inventiveness to solve problems.

We create wealth by innovations in technology or its application, but good engineers are not, primarily, technologists. We create wealth by using our ingenuity to solve problems, and that usually means using technology. What engineers do is to select and adapt the best technology to get the best fit to the problem, but the most difficult problems are often those of implementing the solution.

This is where social, political, and above all economic questions get mixed up with pure technology and very often become the controlling element. In my own field of water treatment, we currently have all the necessary technology to convert domestic wastewater (sewage) into drinking water, but persuading the public that the product is safe to drink—a sociopolitical problem—can only be achieved by education and persuasion.

Technological problems usually have a simple right answer—how thick does a 200 mm wide beam have to be to support a uniformly distributed load of 30 tons over a span of 10 m? Engineering problems, on the other hand, have answers that vary depending on the conditions of time and place.

Another example from wastewater treatment is wet-air oxidation. Capable of destroying a wide range of organic contaminants in wastewater, the process was developed in the 1950s by F. J. Zimmerman, a British engineer working in Wisconsin. In spite of continuing technological development, wet-air oxidation was always too expensive, in both capital and operating costs, to be attractive for wastewater treatment. In the last decade things have changed: Alternative disposal options such as chemical treatment and landfill, have become relatively more expensive as a result of environmental legislation and taxation. So, half a century after the technology was invented, the economic climate has changed and wet-air oxidation's time has finally arrived.

Geography also has a major influence, as the tale of L & C Steinmüller shows. The company started as a paper mill in Gummersbach, a remote village in the hills near Cologne, Germany, that took its product to the nearest railhead by oxcart. In the nineteenth century it replaced the oxen with an English steam locomotive. It had a multipass fire tube boiler. It failed miserably because, on steep uphill gradients, the boiler water drained back. The tubes at the front rose above the water level and, consequently, burned out. "Ach! We must put the water in the tubes," said Herr S, and had the boiler converted. The water tube design was such a success that boilermaking overtook the papermill as the company's main business. I was told this story when I visited the company works after the war and saw the original machine displayed at the front entrance.

> “Made in Thetford” I read. “Have any of you gentlemen ever been to Thetford? It’s in Norfolk, a completely flat part of the UK: this thing was never designed to go up and down hills!”

This is illustrated by the history of power generation. You might think that designing the most efficient power station is a fairly straightforward technological problem, but the developments of the last half-century show that this was not the case, and that economics, sociology, and politics all have an influence. By the 1940s, steam turbine generating sets were the main power generators in the world—coal fired in Europe and oil fired in the United States. Their technology had been refined for several decades. At the end of World War II, the nuclear research effort that had produced the atomic bomb was channeled into power generation, which promised unlimited cheap electricity. By the 1960s nuclear power stations were being built around the world.

In the 1980s, while large reservoirs of natural gas were being exploited, it became apparent that the high initial capital costs and massive decommissioning costs of nuclear power made it more expensive than the newly developed combined-cycle gas turbine technology. Moreover, high-profile nuclear accidents such as Three Mile Island and Chernobyl raised such antinuclear sentiment that governments around the world largely ceased construction of nuclear stations.

By the end of the twentieth century, wars in the Middle East raised the cost of oil, which in turn raised the cost of natural gas. In Europe, Russia’s manipulation of gas supplies added to concerns about the long-term economic security of fossil fuels. Nuclear power once more began to look cost effective. Meanwhile environmental concerns about carbon dioxide emissions, together with the threat of carbon taxes, led to a wave of enthusiasm for “renewable” power using wind, tide, and solar energy. Attractive though these technologies are, they cannot meet the ever-increasing demand for electricity. Many environmentalists, including James Lovelock the "father of the Gaia hypothesis," concluded that nuclear power's long-term sustainability outweighed the environmental problems of nuclear waste disposal, which had always been their main concern. Nuclear power seems to be back.

> It's like teaching musical composi-tion. The Juilliard School, the Paris Conservatoire, or the Royal College of Music are very good at teaching composition, but they can't turn their students into Bachs or Mozarts.

It's not easy to teach this sort of thing. In fact, engineering courses generally just teach technology, which is comparatively easy to teach and easy to assess in exams. But engineering projects live or die by money not technology, and most university courses don't tell you about that. That is why we pioneered this course at University College London and have written this book, which covers most of the outline of the course.

WHAT'S A PROJECT?

> It seems that when they started to build the famous Sidney Opera House it couldn't actually have been built to the original design. (Civil engineers on the whole are pretty critical of architects for occasionally landing them with this sort of situation.) It was only saved from oblivion by a radical redesign.

I've used the word *project*. The best definition I've come across for a project is "something that's never been done before," though we are here concerned only with engineering projects. Whether it's a tunnel under the Channel, a space station in orbit, a bacteria-driven computer chip, an oil refinery, or a bridge from Denmark to Sweden, every new engineering project is different. It needs to be designed and it needs to be built. And it needs to be designed and built economically.

The fact that a project is something new means that there must be more or less uncertainty about its outcome. Can we really build it for the budget and in the time proposed? Will it be profitable? Can we afford it? Can we do it at all? There are unknown ground conditions that can affect not only the foundation but the whole approach to construction. Marc Brunel, Isambard's father, had to invent a tunneling shield to construct the Rotherhithe tunnel under London's River Thames. It was innovative, completely untried, and had to be developed on the job. Although it's been updated, the same technology is still used for major tunneling projects such as the UK–France Channel Tunnel.

> The last time I saw one of the shields used to dig the Channel Tunnel, it was sitting on a mound near Dover, with a placard saying "FOR SALE—ONE CAREFUL OWNER."

HOW DO WE BUILD IT?

Most people who want something built don't themselves have the necessary skills or resources to build it. Building something such as an oil refinery requires a multidisciplinary team of engineers—chemical, mechanical, structural, electrical, and civil—to create the design. Then a vast team of skilled builders and fabricators are needed—scaffolders, pipe fitters, riggers, electricians, and so on. An organization is also needed to coordinate their efforts, no matter how small the project.

The construction industry provides these skills and the organization. It covers every scale of construction from the local builder who constructs house extensions to the international corporations that build power stations, chemical factories, and airports. Construction companies get paid to build projects for their clients. Often either the technology or the organization of such projects, or both, need additional skills that a consultant can provide. The agreement between the client and builder is called a contract and the builder is called a contractor. A consultant works somewhere in between them, and there is quite a variety of ways in which that can be organized.

THE CONTRACTING INDUSTRY

It’s not just engineers who work in the contracting industry who need to understand its needs. Sooner or later most other engineers (e.g., working in production) will also have dealings with the contracting industry, so they too need to understand how contracting operates as a business. It’s much like any other business in its structure and management, but it has many unique characteristics, particularly in the area of finance.

As we’ll see later, the contracting industry is very competitive. Only a few large contracts in any particular sector are placed every year, and it is important for a contracting company to win enough of them to survive. This means that profit margins on turnover are low—typically 1.5–5%—although the return on capital invested is quite good (see Chapter 5).

> I worked for a specialist process plant contracting company, and we had sold a water purification system to a large pharmaceutical company. The contract was successful, although there were several disputes during its execution. The following year I was approached by the pharmaceutical company’s project manager to see if we would bid for another water purification system at another factory because they were very pleased with the plant we had built. However, he told me that if we were to be given the opportunity to bid we’d have to nominate another contract manager!

The successful execution of an engineering contract depends greatly on technology and finance; but it also depends on the relationship between the project manager and the contract manager. The first is the purchaser's representative, who has to get the project completed and pays the contractor, and the second is the contractor's representative and manages the contract. We will see later how important this relationship is, but first we need to understand a bit more about money.

SUMMARY

- **Engineering is about money.**
- **Project engineering is about risk.**
- **Finance for routine production is similar to that for any other routine business.**
- **The time scale and novelty of project engineering creates different problems.**
- **Every engineer needs to understand about money.**