

# Chapter 1

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## What's It All About?

### **IT'S ALL ABOUT MONEY**

Engineers create wealth. It really is as 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.

Which of these 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

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.”

often underestimate the way they affect society both for good and bad (see Chapter 28).

## WHO BENEFITS?

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.

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?"

## WHERE'S THE TECHNOLOGY?

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.

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.

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

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 boiler-making 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!"

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 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.

It’s like teaching musical composition. 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.

## WHAT’S A PROJECT?

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.

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.

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).

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

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!

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.**