ON BEING AN ENGINEER


Pipeline route crossing the landscape, Turkey, June 2004 © BP plc

On May 15 2008, the Lord Browne of Madingley presented the Lubbock Lecture, marking the centenary of the founding of Engineering Science at Oxford. In the lecture, on which this article is based, the President of The Royal Academy of Engineering spoke on what it is to be an engineer. Drawing on his own experiences at BP, he put forward the view that a successful engineer requires not only technical know-how but also an awareness of the political, social and business concerns central to any significant engineering challenge.

I want to demonstrate that engineering is at the centre of society – that engineers have a unique set of skills and perspectives which should be used to create a better future for all of us. In order to do that, I would like to talk about a major engineering project that I was involved with and then about the challenges facing young engineers now and the skills that they need to meet them.

VARIED SKILLSETS

The bedrock of engineering will always be the application of mathematical and physical theory to create wealth and to improve our quality of life. But engineering is far more than just applied science. The essence of engineering is in its *practice*. The particular skills of engineers are developed by solving real world problems rather than becoming conversant in physical theory.

The complex nature of these practical engineering challenges means that engineers need to engage with communities, with politics, with economic realities and with environmental considerations. The bigger the engineering challenge, the greater the need for judgement and, just as importantly, empathy.

In order to demonstrate these points, I'm going to describe a major engineering project from my own experience as CEO of BP. This is the story of the Baku-Tbilisi-Ceyhan pipeline. The BTC pipeline, as it is called, was an enormous undertaking from a technical perspective. But the success of this project was predicated on the ability of the engineers to manage a host of social, economic, political and environmental issues.

TECHNICAL CHALLENGES

The oil reserves of the Caspian Sea have been known about for a long time. By 1900 there were more than 3,000 oil wells in Baku, the capital of Azerbaijan. As the Caspian is an inland sea, transporting the crude oil from there to world markets has been a longstanding challenge.

The BTC project met that challenge by building a pipeline of more than 1,000 miles in length. The pipeline runs from a modern offshore platform in the Caspian Sea, through Azerbaijan and Georgia, reaching a terminal on the Mediterranean coast of Turkey. The oil completes its journey end-to-end in just 10 days, flowing at a rate of one million barrels a day. The first oil reached its destination in May 2006.

The technical challenges in designing and building the pipeline were immense, not least because of the sheer scale of the project. The BTC is the second longest oil pipeline in the world and it cost over US$4 billion to build. The pipeline climbs severe gradients, up to 3,000 metres in places. It crosses 1,500 rivers and roads and is buried along its entire route. The construction of the pipeline was complicated by the fact that it was only possible to work during certain months of the year because of inclement weather.

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Route of the BTC pipeline © **BP Frontiers magazine**

Of course the all-important consideration in the construction of any pipeline is its route. Looking at gradient, waterways, roads and other communication networks is a routine task for an engineer constructing a pipeline of this size. But if these factors alone were taken into consideration, the pipeline would have taken a very different route to that which it eventually followed.

POLITICAL OBSTACLES

In seeking the best route, BP's engineers had major political obstacles to contend with. Azerbaijan is flanked on one side by Armenia. The relationship between these two countries has for several decades been hostile, dating back to the Armenian-Azerbaijani conflict which broke out during the final years of the Soviet Union.

In the 1990s, when plans were being laid for the pipeline, the situation between the two countries was far from stable. I experienced this first-hand during one of my visits, which coincided with Armenia invading Azerbaijan. It was clear that laying the pipeline between these two countries would entail too much political risk.

Azerbaijan's other neighbour on the shores of the Caspian is Iran. Political relations between Iran and the US were tense and the number of US companies involved in the BTC partnership ruled out laying the pipe in that direction too. So the route out of Azerbaijan *had* to be through Georgia. The Georgian authorities were willing to do business with us, but the then President, Edvard Shevardnadze, placed many restrictions on the project, making it plain that technical considerations were not his main concern. The planning of the pipeline route was thus fraught with political obstacles that had a fundamental impact on the engineering of the line.

FAIR TO ALL

Building a line that crosses three countries means dealing with different laws, cultures and languages. But transparency dictated that there had to be a parity of treatment across all borders based on a single legal relationship that was acceptable to all of the governments involved. Legal agreements had to be published in several languages – setting a new standard of disclosure for infrastructure projects.

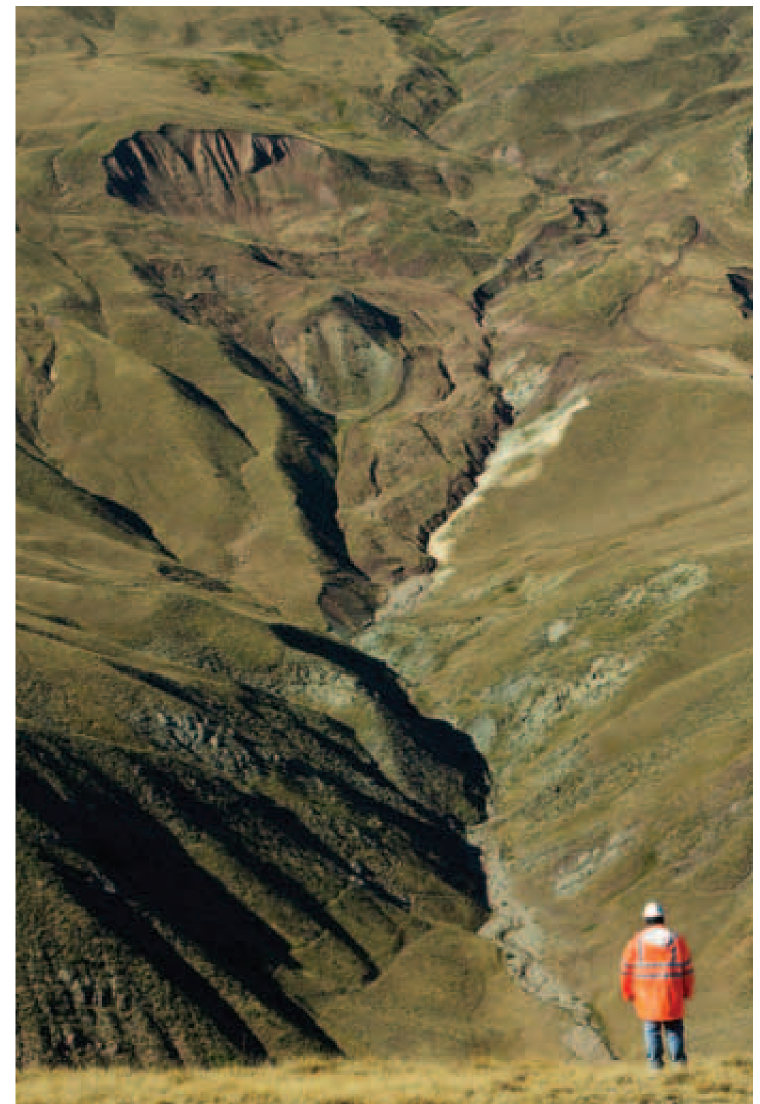
Despite the complexity, the BTC pipeline was the first project to meet the Equator Principles, which set a benchmark for the financial industry in managing social and environmental issues in project financing. Achieving such standards was by no means simple. There was a balance to be struck between transparency and the requirements of the different laws and standards of each state. These matters required our team of engineering managers to exercise a good deal of diplomacy and sensitivity in their negotiations.

High-level negotiating skills were also needed in dealing with the multiple business partners involved – 11 companies, representing eight different countries; six commercial banks; and 13 credit export agencies. Managing the huge and diverse team of staff on the project was also a challenge as the BTC partnership was run by a 500-strong management team located in 17 different project offices.

ENVIRONMENTAL RISKS

And business risks were by no means the greatest of the risks to be managed. The very fact this was an oil pipeline meant the project involved inherent environmental risks. There was a constant risk of a leak or spill that could devastate the natural environment – in the midst of some extraordinarily attractive scenery. It is of paramount concern to the engineer that environmental risks are kept as low as reasonably possible and that, should accidents happen, the consequences can be controlled.

In this case, the risk was heightened by the route that we were forced to take. The pipeline crossed several seismic



The Northern Anatolian Fault, Turkey, September 2004 © BP plc

Pipeline construction on severe gradients, Georgia, August 2004 © BP plc

This is the 34th Maurice Lubbock Memorial Lecture, commemorating the Hon Maurice Fox Pitt Lubbock. The lecture is intended for scientific and lay audiences, and is on engineering in relation to its environment – its industrial application, its place in society, its significance for managers, sociologists, economists and others, and its significance for education. The first lecture was given by Sir Harold Hartley in 1964.

faults – such as the Northern Anatolian Fault – presenting the risk of earthquake and consequent rupture of the pipeline and leakage.

A number of engineering solutions were put in place to manage these risks. The pipeline was laid in a trapezoidal trench filled with granular material to allow it to move if an earthquake occurred. Contingency was made for the most serious seismic event envisioned over a 10,000 year period.

Despite the inherent risks, an overarching aim of the project was to have a positive net environmental impact. A key objective was to reduce the number of tankers carrying oil through the Bosporus and the narrow Turkish straits, reducing the risk of pollution on the banks of Istanbul, one of the world's great cultural treasures. Preserving wildlife habitats was another important objective. The fact that the pipeline was buried meant that it was possible in most cases to reinstate the land to its original condition.

SOCIAL CHALLENGES

As well as technical, political and environmental challenges there were also great social challenges. The BTC project set particularly impressive standards in this area. Some 450 communities and approximately 750,000 people were affected by the construction of the pipeline. But it was our aim that no person would be displaced. And we were successful in meeting this aim – no person had to leave their home as a result of the project. Landowners were able to return to their land and to use it as before with only minimal disruption.

That is no small feat, considering we had to deal with 1,000 landowners, owning 30,000 parcels of land in three different countries. The land had to be procured ethically, through a fair and transparent system of compensation. Construction couldn't take place without agreements on land, and therefore settling and paying compensation had to be factored into the project schedule. Land procurement was a rate determining step for the entire project.

The positive social impacts of the pipeline were considerable. At peak levels, 22,000 people were employed, between 70% and 80% of whom were local people and all of whom received training and education as well as wages.

So technical, political, environmental and social complexities were an inherent part of the engineering challenge.

INTERDISCIPLINARY SKILLS

Of course no engineer can be expert enough to deal with these issues on her or his own. An essential engineering skill is being able to recognise the limits of one's competencies and to procure expertise where necessary, working with people from different sectors and cultures. The BTC project drew on a wide range of experts: specialists in biodiversity, who alerted us to threats to wildlife; NGOs and human rights organisations, who scrutinised and advised us on environmental and social impacts; and archaeologists, who helped us navigate around historical sites along the route.

These groups were by no means passive observers. There were inevitably objections and debates. A project of this level of complexity and political sensitivity will never leave everyone happy. But it is a central feature of engineering projects that choices involve tradeoffs. Engineers must work in imperfect circumstances with competing demands.

All of this demonstrates that engineers must be able face in many different directions. Engineering is not just understanding and applying scientific theory. I believe it's time to redefine the package that makes up the term 'engineering skills'.

We must all work to ensure that the public – especially young people – understand the dynamic role of the professional engineer in making a difference and shaping the future of society. And engineering students need to be alert to the broader impacts of what they do.

We must teach our engineers to understand the workings of the worlds of business, politics and public policy. We must prepare students for real world problems in all their complexity. I firmly believe that opening minds to wider issues will help engineering departments, like our hosts here this evening, to continue to attract the very best students. Opening engineers' minds to these wider issues will also be of benefit to society.

ENGINEERING THE FUTURE

To a great extent the need for oil results from our reliance on the motor car. However, events might have developed differently. The BTC pipeline might never have been needed. It was a hundred years ago that Oxford University began teaching engineering science. It was also one hundred years ago that the Model T Ford went into mass production. When the Model T was created, it could have run on either gasoline or ethanol. Gasoline prevailed because of 'Prohibition' in the United States, which restricted the production of alcohols, and because of the low price of oil.

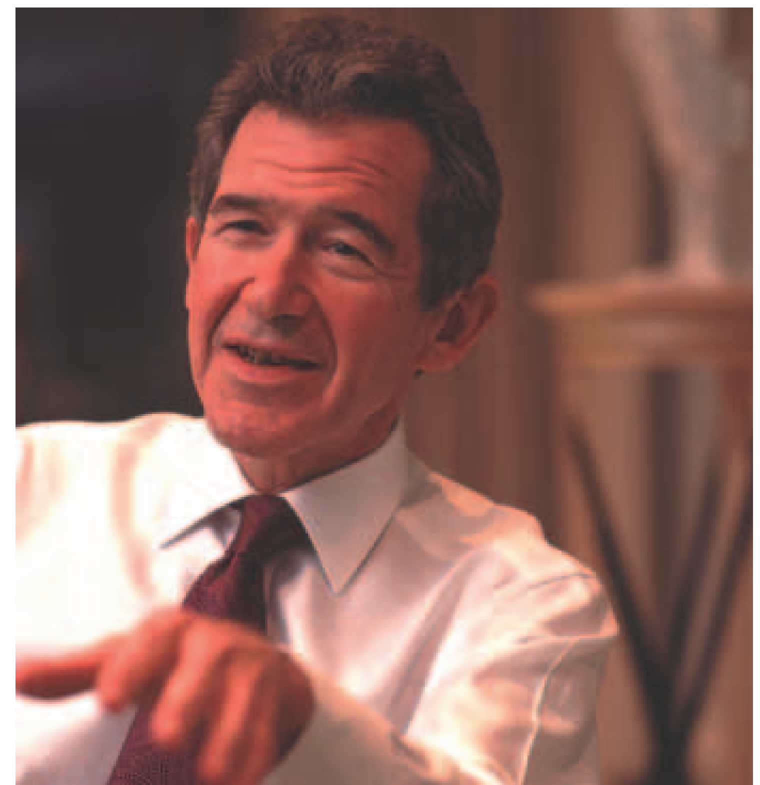
The impacts of that development have been as significant as the advent of the motor car itself. Gasoline is a high-carbon fuel. Burning it releases greenhouse gases, the consequences of which we are only now beginning to understand. Gasoline's predominance, the reasons for which had little to do with pure engineering, has had profound consequences for mankind. It has helped create what I believe is today's greatest engineering challenge: combating climate change. Perhaps we could now be running cars on renewable, low-carbon fuels if things had developed differently.

My view is that engineers must be more involved in thinking through the relationship between their work and broader society. The motor car example shows how political and economic concerns outside engineering have had a profound impact on engineering. The BTC pipeline example shows that engineers can have an equally profound impact on politics and economics.

Engineers cannot predict the future. But we *can* use our expertise to have a positive influence on that future.

Dr Natasha McCarthy helped draft this version of Lord Browne's lecture for Ingenia *magazine*

A transcript and recorded footage of the lecture is available at
www.eng.ox.ac.uk/events/centenary/programme.html



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