Engineering: Rising to the Modern Challenge

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Some years ago I read a 1970s study of professional education. It contained the following assertion: 'society wants, and needs, what the professions of medicine, law and engineering can confer – health, justice and comfort.' I was shocked. I had never thought of my profession in that way. Why was that? I've realised since that I, and most engineers, get engrossed in what they are actually doing, rather than thinking about what it is for.

When I think of what I have done as an engineer, I remember the sites I worked on, or the time spent subsequently in the research laboratory, or on full-scale tests of actual structures. Times spent on sites like Luichart Dam, for example, in the Highlands of Scotland: the calculations using seven-figure logarithms, surveying out in the sun – and the rain – ensuring the dam was being built 'to line and level', of concrete beams being bent to failure and then the feeling of achievement, on returning years later, to see the completed dam, and that thrill, when experiments turned out to fit the theory, or computer predictions fitted with experimental results. Such thoughts and feelings are sometimes shared with a fellow-engineer but very rarely with anyone else.

This failure to describe first what we do, and more importantly, what we do it for, is a major reason why very few people, even in our sophisticated and technological Western society, under-

stand our role. It's also why engineers, unlike doctors and lawyers, are virtually never the stuff of drama on screen or stage. Doctors and lawyers nearly always relate directly to people one-to-one – and often about intimate and personal problems. Not many engineers are in this position.

A key result of this 'invisibility' is that society appreciates very little of the comfort we provide. That's not too serious (although it does mean that we lose some good recruits). What is serious is that we are beginning to be seen in a negative way, especially by the ecological and environmental movements. This is a key challenge.

To trace the development of this challenge, we need to go back some way into history. We need to probe why it is that this negative image has developed and then to examine how we might begin to meet the challenge. But first some history.

History

Engineering has a long and proud history, much of which remains to be discovered, recorded, and assessed. We will start in 1802, when there were already significant numbers of professional mining engineers, civil engineers and military engineers. Mining engineers made decisions about where shafts were to be sunk, and tunnels extended. They devised drainage, and later, pumping systems to remove water. Their main interest were in the coal and ores from which metals could be smelted. Civil engineers designed, and supervised the construction and maintenance of bridges, roads, canals and harbour works, to facilitate travel and trade (the provision of reservoirs for piped water supplies and of sewage treatment systems hadn't really started at this time). Military engineers, as they had been doing for millennia, were devising fortifications for defence and war engines for attack. For example, the foundries in the Carron valley in Scotland were busy casting carronades (as they had been for many years prior to 1802), for use in both navy and merchant shipping, helping to

assure British supremacy in both sea warfare and trade.

What sort of physical comfort was being supplied? The aristocracy and other wealthy townspeople of Glasgow had certainly become much better housed and clothed. Coal fires provided warmth, and lots of hot water, improving hygiene and health for them (although improvements in the training of doctors, where Scotland was leading the world, take credit too). While it must be accepted that many people in Glasgow were living in less healthy environments than if they had stayed in the country, a trend to a general increase in comfort for everyone had been established.

As far as professional education and training for engineers was concerned, the first civil engineering school had been founded in 1750, in pre-revolutionary France, and the first mining engineering school in 1765 in Saxony. Military engineering had been organised well before this; for example the Corps of Engineers of the British Army was created in 1716, with some formal training involved, but falling well short of a full degree or diploma course.

An Early Engineer: John W. Macquorn Rankine (1820-1872)

The first engineering school in Scotland was set up at Glasgow University under Professor Lewis Gordon in 1842. It had limited success, mainly due to severe opposition from professors in other faculties. Only when John William Macquorn Rankine was promoted to professor in place of Gordon in 1855 could the course be described as properly established. Rankine went on to develop both a local and an international reputation (his text-books were translated into French, German and Italian, and English versions were widely used in American colleges). He also served as president of the Glasgow Philosophical Society (GPS) and was a prime mover in the setting up of the Institution of Engineers and Shipbuilders in Scotland in 1857 which continues today as the only Scottish professional engineering institution.

Rankine had exceptional abilities. At the age of 14, he was given a copy of Newton's *Principia* in the original Latin and he

recorded later that he 'had read it carefully'. During his two years at Edinburgh University (he left early because of straitened family circumstances), he studied metaphysics and the theory and practice of music, alongside the scientific subjects of chemistry and natural philosophy (the equivalent to our present-day physics). In his career and public life, these initial wide interests served him well and he was prolific in both the scientific and engineering worlds. He was instrumental in the appointment of a Glasgow graduate to head the first college of engineering in Japan in the 1870s (which was before Oxford or Cambridge had accepted engineering as a subject for study).

Alongside this he continued an active life in Glasgow society, not least through his musical talent – he was in frequent demand at social functions to sing songs of his own composition. It is clear that he was a well-known and well-loved figure in the Glasgow of his time and there were other engineers of calibre who were similarly known, and as active in local affairs and society. There were, for example, many papers related to engineering presented to the GPS in the first 50 years of its existence and we can conclude that in Rankine's day, engineers had an assured place in Scottish society: that society knew what they did, and appreciated it.

Moving Forward to Today

In the course of the 20th century, engineers became more specialised, and began to concentrate more and more on engineering. That specialisation has been encouraged by the development in both the UK and the USA of at least twenty separate professional institutions, each devoted to a particular type of engineer (mechanical, electrical, and so on), and within these types there is further specialisation. Each institution, with its own official charter or constitution, has tended to guard jealously its independence and in such circumstances, no clear unified voice emerged to speak for the profession as a whole. UK

engineers who prospered in the period around 1900 tended to buy country estates, and their sons were not encouraged to continue in their father's profession. Few engineers have ever gone into politics, and of those that have, none have made any serious mark.

Nevertheless, throughout the 19th century and up until the 1940s, the work of engineers continued to be known to society at large, and appreciated. The profession was portrayed as attractive (but only, of course, for boys). I recently presented a volume from the early 20th century entitled *Victories of the Engineers* to Paisley University library. It deals with projects ranging from the construction of the Panama Canal to the building of battleships, and communicates something of the sense of excitement and achievement that can be achieved from careers in engineering.

However, since the 1940s, engineering has steadily lost its appeal. Surveys of school-leaver opinion about career choice has shown a steady increase in a negative attitude to the subject. At least one writer traces this back to Hiroshima and Nagasaki while others attribute it to the rise of the environment and ecology lobbies, identifying Rachel Carson's *Silent Spring* as a major influence. I agree with those influences, but think it probably has as much to do with the seemingly unstoppable and uncontrollable growth in technology, and its growing influence on more and more of our lives. It appears out of control and we feel uneasy as a result.

Furthermore, the word 'sustainability' has entered the language. It is not a reassuring word. It makes us think of things running out, with potentially catastrophic effects and in so far as global capitalism is seen to be the cause, engineers are seen as willing accomplices by the environmental and ecological lobbies.

Engineering Reactions to Sustainability

What are engineers doing about sustainability? To make an assessment of this, I made a review of material (as of December

2002) on the Internet websites of the US National Academy of Engineering (NAE), the UK Royal Academy of Engineering (RAE), and the Verein Deutscher Ingenieure (VDI Association of German Engineers). Part of the remit of these three senior engineering organisations is to advise their respective governments.

I looked at recent papers, articles, or substantial news stories and classified them under three headings: firstly, items simply describing engineering projects; secondly, items describing engineering projects where sustainability was at least mentioned; finally, articles with a substantial element on sustainability.

A report satisfying the last category was about establishing a 'hydrogen economy.' It was stated that the technology had now been developed, all that was now needed was 'the political will to get it going.' Another example was the RAE's response to the UK government's 2002 statement on the future of UK energy supply.

Altogether a total of some 50 items were reviewed. A total of five were in my final category, indicating a significant effort to look not just at what to do and how to do it (our usual pre-occupation), but also giving arguments as to necessity, with discussion of alternatives.

But with regard to the specific engineering projects from all three national organisations, I found nothing that was really radical, and serious issues were often avoided. For example, there was virtually nothing in the RAE's recommendation to the government on nuclear power about how engineers might help in allaying the strong public concern about disposal of nuclear waste.

What do I mean by radical? Scientist Theodore von Karman said, 'Scientists find out what is: engineers dream of what never was before.' Here are three of my engineering dreams.

Ocean Farming

At the moment, we simply hunt food from the oceans, taking a proportion each year of fish and other creatures, leaving nature itself to replenish the stock. We gave up this grossly inefficient

principle on land over 10,000 years ago. Switching from hunting to farming in the sea will, as on land, increase the yield by a factor of more than a hundred. It's not a new idea. Already in the 1970s, it was being argued that unless we developed ocean farming, there would be widespread famine throughout the world in the year 2000. Developments in agriculture up till now have meant that hasn't happened, but with our still rising population ocean farming should now be receiving serious study.

The engineering problems are considerable. To control cattle on the range in the American West the only technology needed was barbed wire, although it should be noted that the engineering of its production called for real talent. The floating structures to 'fence in' growing fish will be several orders more complex. They will need to cope with severe storms. But these same structures will offer further opportunities. They could carry wave and wind power installations which in turn could support significant industrial production. The experience of the offshore oil industry will be invaluable.

Controlling the Climate

All but a few people accept that the increase in the percentage of carbon dioxide recorded over the last 150 years in the Earth's atmosphere has come from the coal we have burnt over that same 150 years in our fires at home, and in power stations to produce electricity. It's also agreed that this has at least contributed to an overall increase in Earth temperature, and that there is more of this to come – the so-called greenhouse effect. Thus, say many people, we must control carbon dioxide release to keep down this temperature increase. But what about going even further and accepting control of the climate, via an International Climate Control Commission?

American scientists and engineers have looked at the idea of controlling global warming by adjusting the amount of sunlight reflected back out into space by introducing quantities of fine white dust into the stratosphere. The reaction of many people to

this suggestion will be one of 'shock-horror' with a fear of what might happen if it gets out of control? I don't actually think it would be a serious problem; there would be ways of getting the white dust back down again and there would be trials in any event with larger dust particles which would settle to a lower level and be finally brought to earth again by rain.

But what about organising reflection of the Sun's energy at ground (or sea) level? Many of us do this already during the summer by adding a mild whitewash to the outside surface of our greenhouses to prevent overheating. I have a vision of a billion of us volunteering to put out 1 m^2 panels on our garden paths, or on our roofs, white side up or black side up as instructed for that day and/or night via the internet from 'International Climate Control HQ.' It could be organised on a voluntary basis – many of us in Western Europe already put out waste for collection once a week, having spent a considerable time and effort sorting it. Yes, a number of us keen volunteers would make mistakes, putting out black instead of white, as well as forgetting to tell Climate Control that we are going to be on holiday and can't find anybody to take over our responsibilities, but satellites will be checking us out, issuing reminders about our responsibilities, and more important, adjusting for 'no-shows' in exactly the same way that airlines currently do.

The engineering here is not rocket science, and will be much more about organisation, planning and control. But that's just what engineers who direct large projects do, ensuring all the bits and pieces are brought together in proper order and in due time.

Dealing with Sea-level Rise

This is linked to the previous problem. What we do about the climate will affect the degree of sea-level rise. My dream here is that we engineers emphasise that we can deal with sea-level rise directly. To highlight what could be done, I first take an extreme hypothetical example.

Let's assume all the ice in West Antartica melts in the next 50

years, which will produce a sea-level rise of 5 metres (an extremely unlikely scenario: it's estimated that by 2050 the sea-level rise from global warming will be around half a metre at the very most). But let's assume that we knew it definitely was going to happen. A third of Florida would face flooding – what would the people there do?

A large portion could be surrounded by dykes, designed by Dutch engineers and life there would continue as before. The city of Miami would be a bit of a challenge. But over the next 50 years, large areas of it are going to be rebuilt in any event and buildings could easily be built either with a flood-resistant first storey, or on raised ground. As for the high-rise structures on the waterfront, they could be temporarily evacuated, and jacked up 5 metres, using the same technique applied to a North Sea oil production platform that subsided far more than expected after installation. And there would even be a benefit, since the massive investment currently planned to re-establish large parts of the Everglades Swamp area would not be needed.

Quite simply, investment would be forthcoming to conserve the capital value of that area of Miami, in exactly the same way that investment has been forthcoming over the last six centuries to preserve and extend the productive land area in Holland. The Dutch could easily, had they wished, emigrated en masse to America in the 1900s and abandoned their land (as many in Ireland and Scotland were forced to do in the previous century). But they chose to stay. I think Miami people would want to stay too.

Other areas in the world do not have the investment potential of Miami. But over the next 50 years the accuracy of short- and even medium-term weather forecasting will become much higher. Rather than provide expensive fixed protection like dykes, it may be sufficient to organise emergency evacuation procedures of both people and their more valuable belongings, combined with high-level flood refuge structures at suitable intervals for those who refuse initially to leave their homes or businesses. Such

refuges installed in Bangladesh have already significantly reduced loss of human life in floods.

Discussion

There are serious global, political and legal issues with the first two of the proposals just outlined. For example, how much of the ocean might the USA get to farm, and how much would Iraq get? Does land-locked Switzerland get any at all? And how much of the ocean are we going to leave as marine reserves, to preserve existing marine species for future generations (whether as a genetic bank, for contemplation, or as a source of wonder to our great-grandchildren)? The idea of climate control will be scary to many, but is it scarier than the prospects offered by genetic engineering? The third proposal is hypothetical but even the modest sea-level rises which are foreseen are going to affect countries all around the world.

It is quite clear that these issues cannot be tackled by engineers alone. But somehow or another we must ensure our voices go in to the debate. In recent discussions about the impact of flooding due to expected sea-level rise, many scenarios suggested by the Inter-governmental Panel for Climate Change specifically exclude any consideration of increased coastal protection. Even a minimal engineering voice would have shown the stupidity of this.

However, it is not that the voices of engineers are deliberately excluded. I discovered in the websearch mentioned earlier that the US National Academy of Engineering had only recently amended their constitution to allow them to take a pro-active role in advising government. Their previous constitution allowed them only to respond to requests from the US government. The current NAE president, William Wulf, in his explanation of this expanded role to the newly elected members for 2002 took pains to point out that it could be controversial. But he was equally emphatic that the rough and tumble of debate had to be accepted. He himself, along with the NAE chairman, have taken a

lead in speeches following 9/11. For example, alongside a pledge to support research into improving national security, there was the observation that the roots of terrorism had to be tackled as well. There was also a quiet observation about the role humanitarian aid might have played in an Afghanistan which the US had abandoned after the withdrawal of the Soviet Union. We are learning to speak up.

Concluding remarks

Engineers need to be seen in society not just as people who 'do technology', but as serious joiners in the debates about what should be done. We should be pro-active in our advice to society and more international in our thinking. The 21st century needs our advice. I am confident it will get it.

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