Engineering to shape a better world

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Each year the ICE President is invited to deliver his Presidential Address to members of the Institution of Engineers of Ireland (IEI) and the IEI President is invited to deliver his address to members of the ICE. This year, IEI President Peter Langford chose sustainable development as his theme. His address demonstrated the contribution of engineers to economic and social progress and showed how influential the engineering profession has been in developing the communication networks (infrastructure and electronic), the health and the very fabric of society. He followed up this analysis by identifying the challenges which lie ahead in the twenty-first century and by describing some of the solutions engineers in Ireland have found to help deliver a more sustainable future for us all.

I. INTRODUCTION

Ours is a great profession. There is the fascination of watching a figment of the imagination emerge through the aid of science to a plan on paper. Then it moves to realisation in stone or metal or energy. Then it brings jobs and homes to men. Then it elevates the standards of living and adds to the comforts of life. That is the engineer's high privilege.¹

These are the words of Herbert C. Hoover, engineer and 31st President of the United States of America (1929–1933). Hoover’s words capture the vision that has motivated many engineers, attracting them into the profession, sustaining them through the many challenges they face and providing fulfilment throughout their careers.

Inheriting this great privilege also requires us to accept a very serious obligation. We, in the Institution of Engineers of Ireland, have committed to deliver on that obligation by following our mission statement, which declares that

Our members serve society [and] seek to improve quality of life for all, creating prosperity and adding value through innovation and the promotion of health, safety and sustainable development.²

Increasingly, we find ourselves working with other professionals in collaborative teams when discharging our mission. As the range of engineering disciplines and specialisms has expanded, so too has the degree of overlap between engineering and other professions. This requires us to continually adapt and broaden our horizons into the social and economic areas, frequently taking leadership roles previously unfamiliar to engineers.

In this address, I will deal briefly with the historical context of engineering, sketch the current contribution of engineers to economic and social progress, assess the major challenges facing society and discuss the role of our profession in meeting those challenges.

2. CONTRIBUTION OF ENGINEERS TO SOCIETY

2.1. Historical context

It is difficult to pinpoint when and where engineering commenced. The answer probably resides in the Bible. We are all aware of the wondrous achievement of the engineers who built the pyramids and the great infrastructure developed by the Romans in transporting people and water over great distances.

In renaissance times we had the great inventions of da Vinci. As well as art, his range of interests varied from churches, fortresses and city planning to canals, armoured vehicles, flying machines and submarines. He surely qualifies for the title ‘engineer’.

We are more familiar with the exploits of great engineers during and since the Industrial Revolution. Isambard Kingdom Brunel stands out as a giant in this era. Even now, we marvel at the range of his work from railways to bridges, tunnels, buildings and shipping. His innovative engineering and the scale of Brunel’s projects were truly amazing. It was his vision, however, that really set him apart. He foresaw the tremendous benefits of long-distance travelling, and the possibility of connecting ordinary people readily, to promote economic and social development. When he was chief engineer of the Great Western Railway, he was chided at a board meeting over the proposed length of the line from London to Bristol and Plymouth. One member joked ‘Why not make it longer and have a steamboat go from Bristol to New York and call it the Great Western?’ Brunel seized on the idea and turned it into reality, steaming into New York in 1838. He had the skill and imagination to market his projects and the dedication to drive them relentlessly through to realisation, despite seemingly insurmountable obstacles.

Nearer to home in Ireland, we have some classic examples from the late nineteenth century in Charles Parsons and John...
Holland. Parsons was educated at home in Birr before attending Trinity College Dublin and Cambridge. Having served an apprenticeship in Newcastle-upon-Tyne, the hub of British engineering, at the age of 30 he invented the steam turbine. In this way, he managed to harness more energy from steam, using considerably less coal to generate the motive power.

While the steam turbine was ultimately one of the main contributors to global electrification, its initial impact was in revolutionising marine transport. Parsons’ initial attempts to interest the Royal Navy in turbine-powered vessels were rebuffed without much ceremony. Undeterred he built a demonstration boat, 30 m long and 2 m wide which he called Turbinia. In 1897, he arrived uninvited at the diamond jubilee review of the navy by Queen Victoria. Travelling at over 30 knots through the fleet, he showed up the existing technology of the navy. Orders for two turbine-powered destroyers soon followed! The pace of development after that is shown clearly by the commissioning of the Mauretania in 1907. This had 900 times the displacement of the Turbinia and could travel at 26 knots. Without the steam turbine, an ocean-going vessel of this scale would not have been possible.

John Phillip Holland was born in County Clare and worked as a teacher before emigrating to the USA. His enthusiasm for submarine design is reputed to have been motivated initially by nationalist ideals. Having failed to interest the US navy, he was funded by the Fenian Brotherhood until escalating costs ended the relationship. Subsequently, the US navy held three design competitions for submarines and Holland won all three. He then set up what was to become the Electric Boat Company, which produced the Holland VII in 1898. The US navy purchased this in 1900 and, with six more, it formed the first submarine fleet.

Two interesting factors were common to the experiences of Parsons and Holland which are still very relevant today

(a) the enormous dedication to translate their innovations into marketable products
(b) the power of defence budgets and their influence on technological developments.

A more recent example, of which the Institution of Engineers of Ireland (IEI) is rightly proud, is that of Thomas McLaughlin, a former Institution President, who almost single-handedly persuaded the fledgling Irish government in the 1920s to invest a huge percentage of its annual expenditure budget in developing the Shannon Scheme and, thus, the national electricity network. Despite very strong opposition, he managed to move the economic and social development of the country forward at least a decade ahead of where it otherwise would have been, were it not for his vision, persistence and persuasiveness.

2.2. Contribution of engineers to economic and social progress

We may sometimes wonder whether we have actually made progress and improved the lot of humankind in moving from one generation to the next. A few key facts, however, leave us in no doubt that we have moved significantly in a positive direction, despite some setbacks.

In 1900 average life expectancy worldwide was approximately 30 years, while today that figure has increased to 66 years. People now live, on average, 12 years more than they did in 1960. The really good news is that the difference in life expectancy between the industrialised world and the less-developed countries has narrowed dramatically from more than 25 years in the early 1950s to around 11 years today. This increase in life span has been accompanied by greater expectations in the quality of life to which we aspire and lower tolerance of human exploitation and unnecessary hardship. Very few would exchange living conditions now for those encountered 50 or 100 years ago.

The contribution of the engineering profession, for example through the provision of clean water and sanitation, has been an essential and intrinsic element in the development of the twenty-first century world. Without the input of engineers we simply would not survive. The greatest proof of this, and indeed the greatest compliment to the profession, is that so much is taken for granted. A simple illustration of this is the typical morning routine for a working adult

(a) awakened by radio alarm clock
(b) central heating already activated by timer
(c) wash or shower
(d) boil kettle
(e) make toast
(f) listen to, or watch, early morning news
(g) travel to work by road and/or rail
(h) take messages or make calls on mobile phone
(i) enter workplace (usually a building)
(j) use a lift
(k) switch on the computer.

Most people engage in at least ten significant activities, made possible by engineers, before commencing work each day. The engineering contribution is unacknowledged and indeed may only be highlighted in the event of an occasional malfunction such as the dramatic powercuts experienced in 2003 in New York, London and northern Italy. To what extent were these caused by over-reliance on market forces and insufficient attention to the engineering robustness of the transmission grid?

To ensure that normal life goes on each day, a huge number of engineers and technicians play the role of unsung heroes

(a) keeping our water and wastewater systems functioning properly
(b) collecting our waste and ensuring its proper disposal
(c) ensuring our transport systems operate satisfactorily
(d) providing the energy to meet working and domestic needs
(e) maintaining and improving communications services
(f) monitoring, controlling and improving environmental performance.

While keeping systems functioning is a daily necessity, constant planning and upgrading is also required to ensure future capacity needs are met.
It is arguable that the greatest achievements of engineering innovation are those that have led to the interconnection of people and nations throughout the world, either physically or through communications. Was the Cold War between East and West ended through brilliant political activity or through advancements in communications technology that no longer allowed authoritarian regimes to paint false pictures of ‘the enemy’? It is worth dwelling on some of the landmark engineering achievements that have forged better links between people.

The Channel Tunnel project, connecting Britain to mainland Europe, was first attempted in 1881 but was abandoned due to political difficulties encountered in Anglo–French relations. It was then commenced in earnest in the 1980s, with construction starting in 1987 and first traffic passing through in 1994. The partial completion of the high-speed rail-link to London in 2004 now means that the travel time from Waterloo to the centre of Paris is just 2 hours and 40 minutes. By 2006, this will be reduced by a further 20 minutes. The Channel Tunnel has greatly increased the movement of people between Britain and continental Europe, with the number of passengers per annum in 2002 rising to over 15 million. This would have been unthinkable 50 years ago, which makes us reconsider the viability of a tunnel connection between Ireland and Britain during this century.

A more recent European connection is the Øresund crossing between Denmark and Sweden, which effectively connects the cities of Copenhagen and Malmo. This is both a road and rail connection, comprising an 8 km bridge and 4 km of tunnel joined by a 4 km artificial island. An interesting knock-on benefit is the ability of the two countries to now jointly market Medicon Valley, a combination of the biotechnology expertise and resources of both regions, when competing for foreign direct investment.

It is the development of the jet engine, however, that has made the most dramatic impact on international and global travel. The innovation of engineers in the aviation industry gave us the Jumbo Jet, Concorde and the Airbus fleet, which have revolutionised long-haul travel. The vast numbers of Europeans visiting Australia as a matter of course for the Rugby World Cup illustrate this point very clearly.

It is also heartening to see the response of the rail industry. The superb developments in high-speed rail now make it competitive with short-haul flights for many journeys—frequently with major improvements in speed, comfort and cost.

While physical connections possess high visibility, it is in the area of communications that engineering innovation has been at its most effective in linking people globally. Although the telephone first came into being in 1876, courtesy of Alexander Graham Bell and his Italian–American contemporary Antonio Meucci, it was not until the last quarter of the twentieth century that long-distance telecommunications came into frequent and effective use for business and personal purposes. The pace of development in communications and information technology over the past 20 years has been extraordinary. In the 1980s, we wondered how we ever managed to survive without the fax machine. In the 1990s, email displaced the fax and exponentially increased the speed and capacity of communications. With the arrival of the internet we now have a highly competitive global communications system that provides widespread benefits and opportunities for rich and poor alike.

The wisdom of investing so much money in exploring space has often been questioned. However, if satellite technology had not been developed it would never have been possible to establish the communications network we now have. There are many useful downstream developments such as global positioning systems (GPS) which are only available due to the presence of satellites. These are increasingly becoming an essential part of everyday life.

Another area where engineering innovation has led to major improvements in quality of life is that of healthcare. We now take for granted the use of CAT scan and MRI technology, as well as artificial body parts such as knee and hip joints. These have all become readily available as a result of major engineering and scientific research. A notable feature has been the essential collaboration between engineers, scientists and the medical profession, spawning a new branch of the profession called biomedical engineering.

Increasingly, the more complex medical areas are generating exciting opportunities and innovations with new developments in micro-engineering technology. The provision of stents and artificial heart valves is now well-established medical technology. More recent developments include intervention through the arteries to treat conditions such as aneurysms using ‘balloon’ technology developed at micro level. An interesting innovation, developed by engineers at Boston Scientific, is the ‘Rotatralor’, which can grind out plaque from the walls of the artery without fear of damaging the walls themselves. A fascinating feature is that the equipment and techniques have been developed by refining and miniaturising established technology from the oil industry.

3. CHALLENGES FOR THE TWENTY-FIRST CENTURY

We have undoubtedly made progress over the centuries, and I believe that we can continue to improve our lot. Many challenges face us, however, and the scale and complexity of these make it clear that, while exciting times lie ahead for engineers, the future is not for the faint-hearted. As always when engaging in future-gazing, we encounter a very diverse range of opinions across the spectrum from the super-optimists to the peddlers of doom. There is ample evidence to show that, despite the intellectual resources applied by forecasters to date, neither extreme can claim to have been vindicated.

Much of our concern about the future revolves around ongoing threats to our environment, depletion of natural resources and the fight against poverty. All of these issues are embraced in the pursuit of sustainability. Sustainable development has been the subject of many definitions. The one proposed by the Forum for the Future is particularly appropriate, defining it as development that ‘enables all people to realise their potential and improve their quality of life in ways that simultaneously protect and enhance the Earth’s life support systems’.

Sustainability requires a balance between economic, social,
environmental and natural resource factors. The IEI has already acknowledged and accepted that challenge in its mission statement. This is reinforced by the IEI code of ethics which requires members to ‘promote the principles and practices of sustainable development and the needs of present and future generations’.4

3.1. Climate change
The most publicised issue to be addressed in seeking a sustainable future is that of global warming. The fact that it is a truly global challenge makes it difficult for individual countries and communities to comprehend and believe that their behaviour can make a difference.

The alternative view is that it creates a worldwide interdependence, so that we must be concerned about the performance of everyone else on the planet if we are to achieve long-term success in our own path. The fact that any action can only yield long-term results adds to the complexity.

So what do we know about global warming and its likely effects, and what can and should we be doing about it? Despite international arguments over the past decade, it is now accepted that global warming is happening and represents a major challenge for the future. To understand the likely implications, we might first consider some of the current predictions for Ireland.

An EPA report entitled *Climate Change—Scenarios and Impacts for Ireland*5 was published in 2003. Two of the key findings for engineers are as follows.

(a) Dramatic changes will occur in rainfall pattern. Winter rainfall will increase by up to 10% while summer rainfall will decrease by up to 40% on parts of the south and east coasts. Average run-off reductions of 30% are projected over large parts of eastern Ireland with serious implications for both the supply and quality of water.

(b) A sea level rise of approximately 0·5 m is projected by the end of the century.

On the other hand, water supply capacity problems and water quality concerns will become more acute, especially in the eastern half of Ireland, due to the increased frequency and duration of low flows.

The challenges for engineers are twofold.

(a) Actions are required to halt and, if possible, reverse climate change.

(b) Because of the long-term nature of corrective action, there is a need to plan for the inevitable changes that are already in train.

Ireland is committed, under the Kyoto Protocol, to achieving greenhouse gas emission levels in 2008–2012 that are no more than 13% higher than 1990 levels. Due to the phenomenal growth of our economy through the latter half of the 1990s, this target now seems unattainable, highlighting the difficulty in decoupling economic growth from environmental damage. The increase in primary energy requirements by mode of usage over this period is shown in Fig. 1. We are now required to look at enforcement methods such as carbon energy taxes and emissions trading.

The scale of the global challenge is best understood by reference to the comparative performance of different economies in their contributions to greenhouse gas emissions. Table 1 gives an approximate outline of the CO2 emissions on a per...
capita basis for the US, the EU, the rest of the world and Ireland in the year 2000. These figures exclude CO₂ from non-energy processes and other greenhouse gas emissions.

This points to perhaps the greatest challenge that we face in tackling the climate change problem. Wealthy countries constitute a minority of the world’s population but produce the lion’s share of emissions. Equity suggests that as the economies of the developing world grow, they are entitled to an equal share of the Earth’s carrying capacity for emissions. As we all aspire to a world in which a radical improvement in living standards is attained by developing countries, major inroads into the emission levels in the industrialised world will be required. The extent of this problem is shown in Fig. 2, which outlines the existing and predicted CO₂ emissions in both the industrialised and developing worlds, with the US and China highlighted separately.

### 3.2. Poverty

Bridging the gap between rich and poor in a sustainable manner is clearly one of the main tasks for the decade ahead. It is first necessary to understand that it is not just a matter of money transfers. Some of the principal causes of poverty and barriers to human development may be summarised as follows:

- (a) lack of access to safe water and sanitation
- (b) lack of facilities for adequate healthcare
- (c) lack of access to educational opportunities
- (d) shortage of adequate nutrition
- (e) lack of adequately paid employment
- (f) inadequate or expensive transport facilities
- (g) limited or expensive power supplies
- (h) poor government and leadership.

A few key statistics⁹ spell out the scale of the challenge:

(a) Population growth projections suggest that the world will be inhabited by 10–12 billion people by the end of the century, compared with 6 billion currently. Most of this growth will occur in developing countries.

(b) Some 20% of people live in the industrialised world and 80% in the developing world.

(c) The top 20% have a good standard of living while the bottom 20% have to survive on less than €1 a day.

(d) Every year more than 10 million children die of preventable illnesses.

(e) More than 20% of people lack access to safe water.

(f) More than 40% lack access to adequate sanitation.

(g) One third of people do not have access to electricity.

Recognising this, the Earth Summit in Johannesburg in 2002 set targets to:

(a) halve the number of people without access to safe drinking water by 2015

(b) provide access to modern energy services for 2 billion people who currently lack them

(c) halve the number of people without access to safe sanitation by 2015.

These are very ambitious targets that will require significant investment, skilful management and administration and a major commitment from the engineering profession worldwide.

Another issue that must be addressed is the ageing nature of our population, both nationally and internationally. While we constantly seek to increase life expectancy, all success brings challenges with it. Life expectancy worldwide has increased to
66 years and the equivalent figure in Ireland is now 77 years. Is it possible that with medical advances we will see this figure edging towards 100 by the end of the century? It is expected that the 60+ age group will reach one billion in 2020 and that three-quarters of these people will be in the industrialised world. In Ireland the number of over-65s will double from 400 000 to 850 000 over the next 30 years, with fewer adult offspring available to support them. This will have serious implications both for pensions policy and the funding of healthcare. Can we achieve major gains in the productivity of those in employment to maintain a satisfactory quality of life for all?

4. MEETING THE CHALLENGE

I have outlined some of the key issues to be tackled if we are to plot a successful course for humankind in the decades ahead. What should the role of the engineering profession be in meeting these challenges and how can we best contribute to shaping a better world?

Delivering sustainability is probably the greatest and overarching issue. This requires a holistic approach, dealing with the economic, social and environmental aspects of how we live, always maintaining a long-term perspective. It is worth reviewing some of the opportunities available for engineers in five key areas: energy, transportation, water resources, health-care and competitiveness.

4.1. Energy

Stabilising the increasing atmospheric greenhouse gas levels is likely to require emissions reduction of approximately 60% by 2050. The world population is likely to double, or at least reach 10 billion by the end of this century, and consumption levels will spread more evenly across the globe. This means that emissions reductions may need to approach 90% by 2100. The significant depletion of fossil fuel resources by mid-century requires us to address the issue as a matter of urgency, particularly in Ireland as we are ranked the seventh most oil-dependent country in the world. How can our profession best contribute? The three areas in which we can exert the most influence are

(a) innovative design of buildings, products and systems to minimise energy usage
(b) development of new energy sources, particularly renewables
(c) invention and development of new technologies that enable the efficient and equitable management of energy usage.

It is important to approach this issue in a positive frame of mind. We do have the capability to resolve our energy future while also improving our quality of life.

A classic example of what can be achieved from a building perspective is the recently completed Beddington Zero (fossil) Energy Development, known as BedZED. This was developed to show that in large-scale construction, a high level of sustainability can be practical and cost-effective. For success in such a venture, the project must satisfy economic and social objectives and benefit all stakeholders.

The development encompasses 83 mixed-tenure homes, 3000 m² of living/work spaces, retail and leisure uses, occupying a brownfield site in south London. It aims to eliminate fossil fuel usage through innovative design, passive solar energy and bio-fuelled combined heat and power. It also aims to halve water usage, treat effluent on site and recycle the treated water, disposing of surface water using the SUDS (sustainable urban drainage systems) principle. Feedback is monitored continuously so that future developments can benefit from the experience. To date the results show that, compared with current benchmarks

(a) space heating is 88% less
(b) hot water heating is 57% less
(c) electricity for lighting, cooking and all appliances is 25% less
(d) water consumption is about 50% less
(e) fossil fuel car usage is about 65% less.

On the commercial side, there is an exceptional demand for the properties and they fetch a premium over conventional dwellings in the marketplace.

Looking at product design, the most obvious target for reduced energy consumption is the motor vehicle, which is one of the major sources of greenhouse gases. Engineers in all of the world’s major motor corporations are working on innovative schemes to greatly reduce, and eventually eliminate, the use of fossil fuels. Currently there are hybrid (petrol/electric) vehicles available, such as the Toyota Prius, as an interim step. Longer-term plans envisage hydrogen-fuelled vehicles using fuel cell technology. There is much work yet to be carried out in relation to green hydrogen production, safety and commercial viability, and the need for alternative energy sources is paramount.

Indeed, the search for alternative energy sources is being pursued worldwide, with particular emphasis on wind, solar and wave power as well as biomass. The potential future use of nuclear power may also require consideration, particularly as some commentators do not believe that the necessary energy from renewable sources will be available in time to match the decline in fossil fuel sources. For this to happen however, major technological advances must be made and solutions found to assuage public concerns relating to risk and waste disposal.

Wind energy appears to be the best option for Europe and particularly for Ireland. It is predicted that Ireland can meet 16% (2.4% currently) of its electricity needs from wind sources by 2010, if the appropriate investment climate can be created and the planning issues, which inevitably arise, can be resolved satisfactorily.

The most spectacular example is the offshore wind farm planned by Airtricity on the Arklow Bank, some 10 km off the east coast of Ireland. The first 25 MW phase, being built by General Electric, consists of seven 3·6 MW turbines and is the first offshore application of GE’s new large-scale turbine technology (Parsons would be proud!). If this proves successful over the next two years, it is planned to expand the development to provide 520 MW. Clearly success on this project and feedback on the lessons learned is crucial to the timely development of a strong and viable renewable energy market in
Ireland. Currently, the largest offshore wind farm in the world is 160 MW and is located in Denmark.

Developments in solar energy have generally been on a different scale to those in the wind energy sector, but are no less exciting. They have tended to relate to specific project uses rather than producing major quantities of electricity for the national grids. Ongoing innovations allow more ready incorporation of photovoltaics into buildings and facilities, and commercial viability is constantly improving with advances in microelectronics and nanotechnology. Researchers anticipate that the use of solar cells to generate energy in houses will be viable within five to ten years.

4.2. Transportation

Despite economic peaks and troughs over time, the desire to travel and the interest in new travel experiences has grown constantly. People now believe that in the foreseeable future space travel will be an option for recreational travellers rather than something reserved for astronauts specially trained as part of major Government projects. A recent survey revealed that 70% of Japanese under the age of 70 want to visit space in their lifetime. It is expected that the first ‘standard’ customers will venture into space before the end of this decade.

Will the increase in world population and the improvement in living conditions in the developing world lead to an explosion in world travel in the first half of this century? Can we let this happen in an uncontrolled way without falling into chaos? Engineers will have a key role in predicting the likely scenario and in providing and managing the solutions.

In Ireland, we are faced with a situation where our car ownership levels have increased very significantly over the past decade and yet they are still below European levels. We also have a high level of car usage, in part at least, due to the underdeveloped state of our public transport network.

We are already at the stage where we have ever-lengthening peak times and a demand for road space that exceeds the capacity available, especially in urban areas. While we have network improvement plans in place as well as plans to improve public transport, we must also think in terms of 20, 30 or even 50 years hence. It is becoming accepted now however that we cannot continue to provide untrammelled freedom to car users. There is no doubt that we will have to actively manage the demand for car travel, which is more likely than not to involve fiscal measures.

Engineers can provide the technology for satellite-based, mileage-related charging schemes that charge more per mile for travel when ambient speeds are reduced. Allied to in-car real-time information on network congestion, this will allow for a more effective use of infrastructure. This will only be effective, however, if a high quality integrated public transport system, with real-time information, is available to complement private motoring.

The use of traffic modelling to predict how road networks and junctions will perform, for both private and public transport, has now advanced to the stage where anticipated performance can be demonstrated clearly to the policy makers and the public. An example of this is the recent issue of the M50/N7 interchange, which generated much public debate. Computer simulations are readily available to show whether road traffic and LUAS (Dublin’s new light rail transit system) movements affect each other and, if so, to what extent. They can also show the impact of potential longer-term solutions.

Sensors and GPS-type technology can be used to monitor vehicles throughout the network and provide major potential benefits that are currently not available. This has many advantages such as

(a) providing real-time information on traffic conditions and on public transport movements and availability
(b) monitoring traffic conditions over time as feedback for future management
(c) identifying the location and speed of any vehicle on the network.

Ongoing improvements in sensor technology and data management capacity will eventually enable us to establish many important characteristics of every vehicle on the network at any time.

The current scheme being operated by AXA Insurance for young drivers (males 19–25) is a great example of how existing technology can be used on a win–win basis. The essence of the Traksure scheme is that a young driver, committed to safe driving, can benefit from a reduced premium (up to 40% reduction) while being monitored with a specific GPS/GSM facility installed in the car. Speed and location are checked every 15 seconds and downloaded to the base server weekly. Based on performance, an errant driver receives up to three warnings before expulsion from the scheme. The experience to date is that many drivers are benefiting from the reduced insurance costs while the company is very pleased with the reduction in claims. It has to be assumed that loss of life and serious injuries are also being reduced to the benefit of both the public and the state.

A further development of this type, which is currently being piloted by Norwich Union in the UK, is a pay-as-you-drive approach. The principle is that the premium charged is based on the amount of travel as well as driver behaviour. Not only is this more equitable, but it will hopefully discourage unnecessary trips, yielding another benefit to society as a whole.

It is worth future-gazing to speculate on just some of the major opportunities that exist and those that engineers can deliver to society in further improving transportation. Can we capture sufficient data to monitor all speeding infringements remotely and thus ensure that virtually all breaches of speed limits are dealt with appropriately? It can surely be achieved and would improve driving performance dramatically, lead to a great saving in lives and serious injuries on the roads and free up Garda manpower. There are significant issues associated with the privacy of the individual, but these must be balanced fairly with the exigencies of the common good.

Further potential enhancements, available through electronic tagging and the use of biometrics, include security for vehicle owners and passengers. Voice, fingerprint, and other forms of
recognition allow the possibility to dispense with key-operated locks and, together with traceability, should reduce greatly the theft of vehicles and risk to travellers. Future technology will allow us to control the speed of all vehicles remotely. Should we seek to develop a road system where the maximum speed a vehicle can travel in any given zone is governed externally?

The potential for advancement in transportation through engineering innovation is indeed immense. The Irish Academy of Engineering has been reviewing the subject for some time, and, in a report to be published shortly, it paints a fascinating picture of what transportation might be like in Ireland in 2050. Can we travel by train from Belfast to Cork in less than 90 minutes? Will we have to book road space in advance if we wish to make an inter-city journey? Will we have a tunnel link to the UK?

4.3. Water

Water supply will pose major problems for us all over the next few decades. Water can no longer be treated as a free commodity with unlimited supply. The situation is best summed up in the opening words of the EC Water Framework Directive: ‘Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.’ Climate change and increasing demand for water in the developing world require us to examine closely our current patterns of water usage and to develop new management systems that will ensure that our behaviour reflects the spirit of the EC Directive.

Engineering innovation and action can lead the way by developing systems which harness and use our rainfall resources more effectively and also ensure that wastewater is reused or disposed of in a sustainable manner. Improving technology will also allow for greater monitoring of water usage so that appropriate incentives or charges can be put in place readily to minimise wastage of a precious resource.

For those in the developing world it is now a global priority to accelerate efforts to remedy their appalling water supply predicament. This will require a major effort from the wealthier nations as well as the governments and populations of the vulnerable countries. The engineering profession will play a key role in providing solutions based on appropriate technology, educating and training local communities to maintain and develop their systems and providing support until they attain self-sufficiency.

Many lessons have been learned from historical aid projects. Major national or regional schemes have often failed because of poor governance and grandiose schemes that did not provide the necessary resources to maintain and operate them. Community-based schemes that are easily operated and maintained have a much higher chance of success.

A simple example of such a scheme is the South African Roundabout HIV/AIDS Initiative. Safe water is provided based on ‘free’ energy generated by children playing on a roundabout, which pumps water from a borehole to an elevated storage tank. This is covered by a large billboard promoting HIV/AIDS awareness.

4.4. Healthcare

A further area where the engineering profession is becoming increasingly involved is in the provision of healthcare. Many of today’s advances in medical diagnostics and treatments are available through the collaboration of the engineering and medical professions. A typical example was featured in the Institution’s Chartered Engineer of the Year competition. One of the finalists described a biopsy forceps, which he developed in Cook Ireland’s R&D department in Limerick. The purpose of such an instrument is to access internal organs for testing without the use of surgery.

Advances are constantly being made in biomedical diagnostics and microsurgery, allowing intervention and resolution of situations previously deemed inoperable. These will continue to provide more certain and cost-effective treatment and lead to better quality of life and greater life expectancy. Further developments in miniaturisation will lead to remotely controlled cameras investigating most of the human body. The development of micro-instruments will also allow remote monitoring of patients and delivery of treatments.

Existing information and communications technology can be used to develop central databases containing a complete medical history of all participants. This will allow any GP, medical consultant or hospital department immediate access to records in the event of an emergency. A medium-term scenario envisages attachment of a small sensor device to a patient while going about his or her daily life. Online monitoring of blood pressure, heart rate or other parameters would then be possible, either at a GP’s surgery or in a hospital, with alarms activated as appropriate. By 2020 it is likely that remote medical monitoring will be as widespread as mobile phones are today.

In the next 30 to 50 years, some experts believe that nanomedicine—the combination of nanotechnology and ‘smart’ drugs—will completely revolutionise medical treatment. They anticipate the development of remotely controlled ‘nanoshells’ that will travel all over the body carrying treatments at nano level, while communicating with medical staff. They will target diseased and ageing cells to destroy or improve them, allowing cancer antidotes and other treatments to be delivered precisely at the locations required.

4.5. Competitiveness

Meeting future challenges successfully will rely heavily on innovation and technological development. Further exciting developments in communications and information technology will undoubtedly lead to major improvements in productivity and competitiveness. The amazing reduction in the size and cost of microprocessors shows no sign of abating. Ultimately a microprocessor may be as cheap as a sheet of paper, changing radically how we live our lives and carry out our business. For example, a laboratory for remote diagnostic or environmental monitoring may be so small that it can be housed on a chip.

We can only utilise these opportunities, however, with a plentiful supply of highly qualified engineers, scientists and technologists and increased investment in research and development. There is ongoing concern in the industrialised world at the reduction in students seeking a career in the science,
engineering and technology (SET) sector in recent years. A reversal of this trend is essential and will require a concerted effort from Government, the academic community and the profession.

It is the Irish Government's policy to increase our competitiveness internationally by upgrading our knowledge and skill levels, as we have moved away from being a low-cost economy. The only effective response to deal with our new position in the economic hierarchy, and still maintain our quality of life and our low level of unemployment, is to invest in our manpower, and in the SET area. The highest-quality education, research and innovation and an entrepreneurial environment are essential if we are to become a strong and competitive knowledge-based economy.

5. RESPONSE OF THE ENGINEERING PROFESSION
The engineering profession plays a central role in industrial development, in the provision of infrastructure, in education and in innovation, which brings with it a particular responsibility in meeting the challenges ahead. These challenges must, however, be approached in a positive manner and viewed by us as an opportunity to use our unique skills and expertise to shape a better world. In doing so, and in delivering on the Institution's mission statement, it behoves us to think globally as well as locally.

5.1. Sustainability
Kofi Annan, Secretary General of the United Nations, declared that the biggest challenge of this century is to turn the seemingly abstract concept of sustainable development into a reality for all the world’s people. The engineering profession is ideally placed to take on this challenge. In our daily lives we must create awareness and promote sustainability among those with whom we are engaged and also in the public arena. The 2003 annual conference on Delivering Sustainability highlighted a number of actions required and the Institution has made submissions to Government, both in the Republic of Ireland and in Northern Ireland, summarising the recommendations arising from the conference.

One key issue to be addressed by engineers is the need to ensure that plans and designs for projects in the future will cater for the inevitable consequences of climate change. A case in point is the predicted change in rainfall patterns which will directly affect Ireland's water supply regime. To respond to this, the Institution has set up a high-level task force to prepare a submission to Government on delivering sustainable water services for the twenty-first century.

While future water supply is a concern for this country, it is also the single greatest issue facing large parts of the developing world. Irish engineers and aid agencies make a significant contribution to improving water supply and living conditions in poorer countries. Through the revolution that has taken place in communications and information technology, this contribution can now be supported by the good will and expertise of the engineering profession in Ireland through virtual volunteering and e-mentoring. The Institution held discussions with the main aid agencies and with a range of companies and public-sector organisations, with the objective of turning this potential into reality. A pilot scheme to assist the developing world in this way has recently (2004) been launched by the Institution.

5.2. Education
We can only deliver on our aim to forge a better future for society if we have a plentiful supply of suitably qualified engineers and technicians. This is now a major problem globally as well as nationally. It is vital, therefore, that we convey to students the excitement and opportunities offered by our profession, when they are considering career choices. The IEI's science, technology and engineers programme for schools (STEPS) programme has made an excellent start on this journey, but it needs to be expanded to reach more schools and promote the SET sector at junior and primary level. The recent introduction of science at primary level and the Discover Science and Engineering Programme are very welcome initiatives from Government.

Radical changes in engineering education are required if we are to attract more students onto engineering courses. The structure and curriculum must reflect the emergence of new specialisms such as biomedical engineering. Greater flexibility must also be provided to allow students to explore alternative career paths as they progress from general engineering initially, through to specialisation at graduation. The Institution, which continually assesses and accredits third-level engineering courses through its Accreditation Board, encourages innovation in curriculum development. In this context, IEI believes that implementation of the Bologna Declaration, which seeks agreement on a common European approach to third-level education by 2010, is the ideal platform for Ireland to make a significant step forward in providing the supply of high-quality engineers and technologists required for the twenty-first century.

5.3. Competitiveness
Ireland has attracted many of the world’s major players in the high-technology pharmaceutical, biotechnology and ICT sectors over the past 25 years. They have located here because of the competitiveness of our business environment and the skilled manpower available. This development has contributed hugely to our economic and social progress during that period. A cornerstone of this success has been the ability of Irish engineers to adapt and grow in meeting the needs of the new enterprises. Without exception, they have matched, and frequently outshone, their equivalents in the home bases of these companies.

The next stage of our growth will not be achieved merely by seeking to repeat our past success. It will require us to foster a greater entrepreneurial culture in our engineering graduates and to develop a vibrant research community, backed by a supportive business and financial framework. The IEI must play its part in translating Ireland's recently acquired high-technology skills and manpower into a new engine of economic growth by promoting RTD and innovation between industry, third-level colleges and research organisations. The Institution made a detailed submission to the Enterprise Strategy Group established by An Tánaiste Mary Harney, TD, and we collaborated with the Irish Academy of Engineering and ICT Ireland in making a submission to Government on the development and commercialisation of intellectual property in Ireland.
In tandem with this, engineers must be to the forefront in implementing Government and EU policy of promoting lifelong learning as an essential requirement for a knowledge-based economy. The Institution has a key role in ensuring the profession meets the highest international standards, both as individuals and in their organisations. Early progress in the Continuing Professional Development Accreditation Programme, developed by the IEI for this purpose, has been very satisfactory. It has received considerable support and funding from the Department of Enterprise, Trade and Employment. To deliver its full potential it needs sustained commitment so that it becomes the norm for organisations in both the public and private sectors.

As well as our skills needs, all commentaries and reports on our competitiveness highlight the urgent need to improve our physical infrastructure as a driver of economic and social progress, particularly in the transportation, energy and communications sectors. Delivery of this infrastructure will be effected mainly by the engineering profession, once political and financial commitments are in place. The Institution has been particularly active in this area, making submissions to Government on the implementation of the National Development Plan, on cost estimation and control and on the proposed Strategic Infrastructure Bill. We must continue to use our wide range of expertise to advise Government and seek the necessary commitment and prioritisation to ensure Irish society can achieve its full potential.

6. CONCLUSION
In the course of this address, I have provided a brief historical context to the engineering profession. I have detailed some of our more recent contributions to society and highlighted some of the key challenges facing us in the century ahead. I have suggested some of the great benefits that we in the engineering profession can bring to society, both locally and globally, based on existing and emerging technologies.

We are rightly proud of our heritage as a profession and have learned much from the past achievements of engineers. If we are to meet the challenges awaiting us we must continue to learn, we must have courage and we must be prepared to lead. The challenges awaiting us may seem daunting, but the future for engineers in meeting them will surely be both exciting and fulfilling. We might usefully draw our inspiration from George Bernard Shaw: ‘Other people see things and say: “Why?” . . . But I dream things that never were—and I say: “Why not?”’

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1. HOOVER, H. C. Inaugural address. 1929.
3. www.forumforthefuture.org.uk

Please email, fax or post your discussion contributions to the secretary by 1 December 2004: email: emma.holder@ice.org.uk; fax: +44 (0)20 7665 2294; or post to Emma Holder, Journals Department, Institution of Civil Engineers, 1–7 Great George Street, London SW1P 3AA.