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TECHNOLOGY – Saviour or Servant?

TURNING NEW IDEAS INTO USEFUL THINGS

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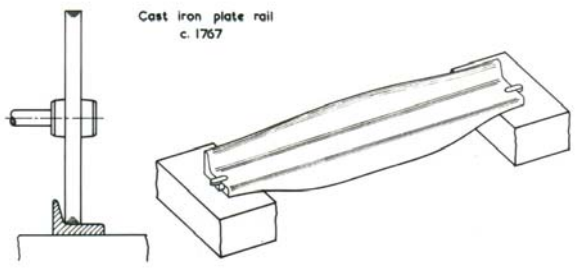
The subject of this talk is the process of innovation that delivers technology to society. Without innovation the good ideas and inventions of science cannot be put to use. But innovation is often not an orderly process and it may have unpredicted and sometimes undesirable results.

When Victorian Britain became the "workshop of the world" there were many bad consequences for those who worked in industry or lived in industrial cities. Today, the advance of information technology can depersonalise human relationships. Try talking to an automated answering machine to fix a telephone fault! And what about genetic engineering? As well as its huge potential to do good, the biotechnology revolution can clearly do great harm if wrongly applied.

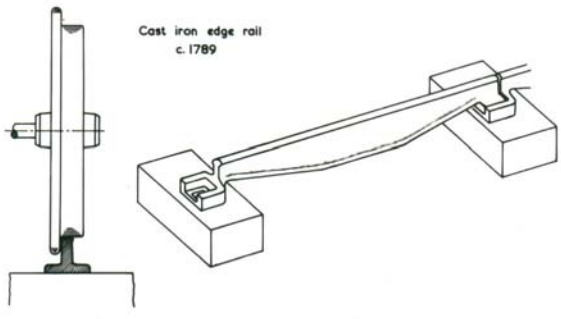
I shall begin with a brief history of railways because we can see why railways were designed in the way that they were, and how unexpected and undesirable consequences eventually followed from their design.

Starting the railways

We take for granted that a railway train has steel wheels that run on steel rails. The rails are clipped to sleepers which are carried on a bed of ballast. This is a system that has evolved over 250 years and Britain led the world in its invention and development, a development that has been copied all over the world. How did this happen?



Original plate rails had vertical flanges to hold the wheels central



New edge rails rely on flanges on the wheels to hold the wheels central

When William Jessop had the task of building a new wagonway from Loughborough to Nanpanton in the 1780s, for horses to haul coal wagons, he would have thought first of laying down a bed of rails with upstanding flanges to stop the wheels of the wagons falling off the rails. But it occurred to him that a cheaper, and perhaps better system, would be to take the flanges off the rails and put them onto the wagons' wheels. This would use less iron and the result would be the same. At first he put flanges on the outside of his wheels, but this proved unsatisfactory as the forces involved tended to push the flanges off their wheels and then derailments occurred. Instead he rebuilt his wagons with flanges on the inside of the wheels. Then cornering forces pushed the flanges further onto their axles and derailments did not occur, or at least not so frequently.

This led to the flanged railway wheel that has been adopted ever since. It is a feature of railways everywhere in the world. And it is a system that worked very well – up to a point. To make the wagons run smoothly, it was found that the wheels' tread should be smooth with a gradual transition from horizontal tread to vertical flange. However as speeds increased, instead of running steadily on straight track, the wheels had a tendency to move from side to side of the track at high speeds. A motion called hunting occurred, which you may have noticed sometimes when travelling fast on a train. There is a rhythmical movement from side-to-side which shakes the book you are reading or slops the coffee in your cup. This hunting motion is damaging to the track and the rolling stock, as well as being uncomfortable, and a great deal of effort has gone into designing railway trains and track which minimise this undesirable feature of Jessop's innovation.

Even the very fastest railways in the world use flanged steel wheels on steel rails, when a better system could now be designed which overcomes the drawbacks that spring from Jessop's original design. But the investment in infrastructure and know-how is so great that a fundamental re-think is ruled out except perhaps for a completely new and separate railway that would not have to share traffic with the existing railway system.

The railway revolution has brought huge benefits to the world but now serious disadvantages are becoming apparent when an old system is having to be used in modern conditions that were never contemplated 250 years ago. Recent catastrophic accidents have been caused by the unexpected consequences of steel rails being unable to cope with much faster and heavier trains than was ever contemplated all those years ago. Now huge quantities of money have to be spent to upgrade and maintain what is essentially an old and unsuitable system for modern requirements.

Technology revolutions

This example is not atypical of the process of innovation. Two centuries ago the Industrial Revolution had seen the widespread adoption of steam power following James Watt's invention of the condensing steam engine. Watt claims to have had his idea in a pub in Glasgow. By his friendship with his business partner Boulton, Watt was able to lead the change from water and horse power to steam power, which altered the way of life of millions of people and of course made steam trains possible.

The consequences were astonishingly far-reaching. Agriculture lost its importance as people moved to the cities. By the time of the Great Exhibition of 1851, Britain claimed to be the workshop of the world. But there were great disadvantages: enormous industrial and environmental pollution, dreadful working conditions, the gross exploitation of human resources, the dark satanic mills of Victorian Britain.

So often this is the case. The good exists alongside the bad. It is almost as though you cannot have one without the other. Has it not always been so when the enabling function of technology is exploited by innovation? Advantages that are perceived by some are not recognised by others.

The information technology revolution, a much more recent example, has changed how people work – changed how we interact with each other in a fundamental way. Now we buy books, cars and holidays on the internet – probably talking to no-one in the process, existing in our own private cocoon, isolated from our neighbours and self-sufficient within the technology. At present the internet is slow for many people who have no access to a broadband connection. As well as isolation, this can cause a good deal of frustration and waste a great deal of time. How well have you found that "Help lines" work? It is hard to make contact with another human being. And what about internet banking? The whole pattern of working and employment is changing as local branches close, the banks employ more computer engineers and fewer cashiers, and establish call centres thousands of miles away in another continent.

Now we are in the throes of a biotechnology revolution. There are huge opportunities to understand and conquer disease. At the same time there is the real danger that human life will be cheapened as replacement parts can be produced artificially and, quite soon, there is the possibility that life may be started in the laboratory without egg or sperm. Most people will oppose such a development, but will it always be bad? Can good outcomes justify the bad?

I think it would be wrong to draw sweeping conclusions about anything as general as a technology revolution and to consider only bad consequences. Change comes gradually as new ideas become established and new working methods and procedures are introduced. Literally thousands of useful "things" emerge as new ideas take hold. Most will be "good" in some sense or other, otherwise people will not want them, and they will have no market. A small proportion may be "bad" because intentionally or unintentionally they may harm people or our environment.

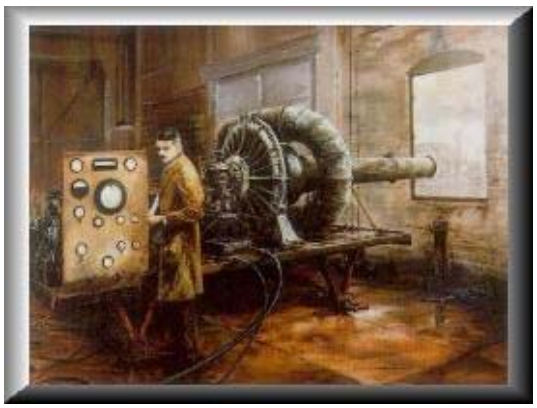
How does the creative process of innovation work? Can good and bad outcomes be anticipated? Are bad consequences foreseeable?

Making innovation happen

When I began my career in the engineering industry in the 1960s, there was a clear pattern. I worked for a large engineering company, English Electric, which made power station equipment and electrical goods from aircraft systems to domestic appliances. When there was a call for a new power station, or when the company's marketing department found that a rival washing machine was outselling the company's product, a specification was drawn up to say what was required. The Design Department then had the job of using available technology to create the

necessary drawings and specification, and the Production Department got on with making whatever it was. Finally the Sales Department had the job of distributing the product and satisfying the customer. All this activity was supported by a Research and Development Department who monitored what rival companies were doing and tried to keep product development ahead of the game.

This process works well in an established industry, but it has been found that large companies are often not responsive to truly new ideas. The inflexibility of a large organisation makes it an infertile environment for genuinely new things. To disrupt established manufacturing methods or processes for a new product of uncertain future is usually too hard for even the most enthusiastic entrepreneur to achieve.



Whittle's experimental jet engine, painted by Rod Lovesey

First test flight of the Gloster E38/39 with Whittle's engine, May 1941

As an example, the greatest invention to spring from 125 years engineering at Cambridge University is probably Whittle's invention of the jet engine. Whittle was an RAF officer studying engineering as an undergraduate when he developed his basic ideas for jet propulsion. Without the help and encouragement of two members of staff, nothing would have happened. As it was, patent cover expired before any progress had been made, and it was only when the Ministry of Defence reluctantly provided funding that slow progress became possible. A world war and the suspicion that Germany had a similar invention provided the impetus that eventually led to success. But the role of Whittle's two friends was pivotal to what happened. And a new company Power Jets Ltd had to be set up to do the first development work and trials. Existing aircraft engine companies did not have the resources or the inspiration or the foresight to foster this work, until it had already been proved successful.

To turn a really new idea into something useful is extremely difficult and it is often a hazardous financial undertaking. Some years ago, one of my former students became R&D director of a new firm which had been formed to develop a new method of needle-less injection. This appeared to offer big advantages over existing methods, but it was costly to develop. Also an extensive programme of clinical trials had to be completed before the product could be put on the open market. Unfortunately the expenditure required ran ahead of predictions as results took longer to come in than expected and design changes had to be made. The upshot was that the company's

financial backers lost patience and the share price plummeted from 275p in 2000 to 2.5p and liquidation in 2003.

Sadly that story has become commonplace in high-technology industry.

Perhaps surprisingly, developments in biotechnology may not need the scale of financial and entrepreneurial support that characterise engineering innovation. A relatively small laboratory can achieve profound results without necessarily having the huge infrastructure backup that is needed for successful engineering innovation. For example, to change the design of railway wheels is practically impossible for existing railways. The only option is to change the design for a completely new railway – at huge cost and with high risk. But to grow artificial tissue for "spare-part" surgery and see this used is a practicable proposition which may bring great benefit to many people relatively quickly.

So in technology, as in other fields, the process of innovation is variable. It may be a long, hard route characterised by repeated failures and disappointments and only successful after years of commitment and determination, or it may be a short, simple process to turn someone's brainwave into a useful thing.

Trying to do good innovation

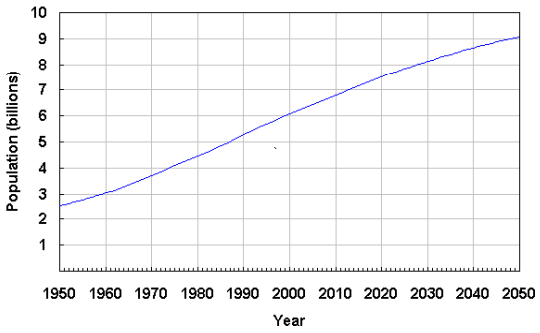
How should we judge whether innovation has a good or a bad outcome? For those of us working in universities, our job is to advance knowledge and educate students so that these things can happen. The outcome will not always be what we expect, but we strive to achieve a good and useful outcome.

What can we do to try to ensure that good things come from innovation? There has been extensive legislation on Health and Safety issues. The process of risk assessment was introduced by the chemical industry in the aftermath of major disasters like the Flixborough explosion of 1974 and is now used widely before new products are introduced. People independent of the designers are required to follow an ordered procedure to try to identify what might go wrong and what its consequences would be. This often leads to design changes before a plant is built or a product is put into production and is definitely a contributor to a safer world.

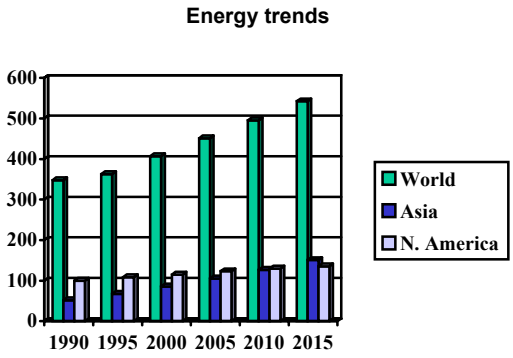
Environmental risk assessment was also led by the chemical industry and is now widely practised. Of course there is not always agreement on realistic environmental standards to aim for. For example, when leaded petrol was still being used, diesel engines were advocated as more environmentally friendly. Now there is concern about the very small soot particles generated in the exhaust of diesel vehicles.

An interesting example is the support for wind turbines to generate clean energy. They will help us to meet national targets for reducing the use of hydrocarbons. But they have disadvantages. They depend on the wind blowing, they are costly to make and run, and they are visually intrusive. A negative factor that is often overlooked is that, unfortunately, they will not make much impact on the global problem of greenhouse gases which are emitted when fossil fuels are burnt and which will get steadily worse in the next 50 years.

This is because pollution from energy generation is a world problem. When you consider that the world's population will increase from about 6 billion now to about 9 billion people in 2050 and that the two biggest countries, China and India, have 2.25 billion people now, the UK is a very small player on the world's stage. Our population now is about 60 million, or 0.06 billion.



Source: US Census Bureau, 2002



Source: Annual Energy Outlook
DOE, Washington

Because both China and India have huge untapped reserves of coal, they will burn increasing amounts of coal to provide the extra energy they need. The generation of electricity from those vast untapped energy sources will bring enormous benefits to developing Asia, but it will come at a cost. The resulting release of huge quantities of greenhouse gases may have very serious bad consequences for the world.

How will we cope? We should encourage research and development to improve technology so that Asia's fossil fuels can be burnt without emitting so much carbon dioxide. Perhaps new technology for carbon sequestration will enable atmospheric carbon dioxide to be absorbed and returned to earth and sea. But, whether this happens or not, the improvement and extension of electrical power systems throughout developing Asia is undoubtedly a good thing while the resulting global warming is a bad thing. How do we reconcile those two opposites?

Probably the best long-term source of clean energy is nuclear energy, yet we have set our faces against nuclear energy in this country, while apparently being perfectly happy to buy nuclear-generated electricity from France to use here. Has the nuclear alternative been dismissed too lightly? There are already over 400 nuclear reactors generating power around the world. And it has been reported that 35 new nuclear power stations are currently under construction, 17 of them in Asia. Is British policy for nuclear power the correct one or are we burying our heads in the sand?

Future dilemmas

So there are ethical and moral issues for innovation for which there are no agreed protocols and there is no accepted route. People are wary of new technology. There have been well-publicised mistakes – the BSE disaster is a recent example. Inevitably new technology brings new risks and, initially, there are mistakes. But old technology

can go wrong too. The Hatfield and Potters Bar railway accidents show the consequences of pushing old technology too far.

In the end our response to innovation depends on the majority view of members of the public – there are no absolutes (perhaps you will disagree with this) – politicians make laws, and politicians have to keep people happy if they are to be re-elected. Generally innovation is driven by commercial forces, but it is controlled by legislation which in turn depends on the public will. And the legislative process can be a slow one. The slow progress of genetically-modified crops is an example. People are cautious – sometimes more cautious than their elected representatives in Parliament.

Recently I attended a performance of Haydn's Creation, which many of you will know. Beginning with the representation of chaos, God created the heavens and the earth. As the oratorio progresses, so the process of divine innovation unfolds, until Adam and Eve extol "*This world so great, so wonderful, Thy mighty hand has framed.*" But the oratorio ends with the foreboding of the angel Uriel: "*O happy pair! and ever happy still unless, by false conceit misled, ye strive at more than granted is; and more would than know ye should*."

Is technology a Saviour or a Servant, or possibly a Serpent? Isn't the answer that it is all three? Sometimes more of one than another, but always with the prospect of making things better and the danger of making them worse. Perhaps I can put it in the words of psalm 127: "*Except the Lord builds the house, their labour is but lost that build it*."

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