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Lloyd's Register Educational Trust

Carpe diem: the dangers of risk aversion

The 2007 Lloyd's Register Educational Trust Lecture

Professor Roderick Smith FREng
The Royal Academy of Engineering Research Professor
Imperial College London

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Introduction

I am privileged to have been given this opportunity to address this distinguished gathering tonight. I particularly thank the sponsors, Lloyd's Register Educational Trust, for inviting me. Lloyd's is a name known all over the world for its long history of insuring against risk. I am of course taking a great risk. If the lecture goes wrong, I will be seriously diminished in your eyes. My reputation is at stake. On the other hand, the potential rewards are high. I can test with you some of my ideas and use your feedback to refine them.

My lecture style is to speak without a script (also a risky activity). Hence this document is neither a formal written paper, nor an attempt to cover exactly what I may or may not say on the night. It is merely an informal and somewhat unstructured collection of ideas about risk, in which risk is interpreted very widely, much more broadly than the kinds of engineering risk with which I deal with professionally. It is deliberately provocative. It represents my personal views. It has proved to be a stimulating activity for me to explore, in a largely qualitative way, topics which are far removed from the usual papers I produce but are of deep concern to society as a whole.

The central message is conveyed by the title of the lecture. It is my opinion that as a society we are becoming increasingly risk averse and that this is a bad thing. I am "seizing the day" to share my ideas with you.

Risk:

On 2 May 2007, "risk" produced 355 million hits on Google.

Some background

Hazard is the potential to cause harm
Risk on the other hand is the likelihood of harm
Risk occurs in the future. We can use the past to extrapolate to the future; sometimes the statistical basis is strong. We can use experience, but the future is by definition hard to predict.

The only function of economic forecasting is to make astrology look respectable,
K J Galbraith.

Risk can be applied to the whole range of human experience. We tend to use the concepts frequently in, for example, financial exposure, accidents, safety, medical and health matters, food production and institutional reputation.

My concern, which is reflected in the title of my lecture, is that we have developed a culture of risk aversion. We are failing to recognise that risk must be balanced against the benefit that its acceptance produces. We cannot reduce risk to zero: we can manage it and reduce it to acceptable levels, commensurate with the benefits gained. It is worth noting that John F Kennedy pointed out that when written in Chinese the word *crisis* is composed of two characters. One represents danger, and the other represents *opportunity*, see Figure 1.

Figure 1. Crisis in Chinese characters

Hazard x exposure = risk

The edge of a cliff presents a clear and obvious hazard. If you never approach the edge of a cliff, then this particular hazard is not a source of risk to you.

An example may be useful. The average rate of death to rail passengers is about 0.2 per billons of kilometres travelled; to a pedestrian the rate is 37, 35 to a cyclist and to a motorcyclist is 105, all per billion km. If you never travel by any of these modes, you do not expose yourself to these risks. In each case the risk increase is proportional to the exposure that is, the distance travelled by each mode. The overall risk of a journey is the sum of the risks of each mode.

I cycle a total of 5½ km at either end of my 95 km commute from home in Oxford to Imperial College London. The total risk is (5½ x35) + (0.2 x 95), that is (192+19) x 10^{-9}. So the cycling part of the journey, although only 5% of the distance, generates 91% of the risk.

Now on the train, I am invited to read a glossy safety instruction sheet placed by every seat and there are notices everywhere warning me of this, that and the other: a possibility exists that in the future I may be forced to wear a seat belt. But the reality is that an accident is extremely unlikely: it is also a certainty that even if I had read any of the safety literature, it would not be recalled in the chaos of an accident.

If the public is told that cycling is 175 times more dangerous than travelling by train the majority would be surprised. The intense, often bordering on the hysterical, media publicity given to recent train accidents has created a perception that trains are "unsafe". The recent accident on the West Coast main Line caused one fatality but received blanket coverage for several days. During the recent May Bank Holiday, a single road accident on the M25 caused six deaths but was relegated to fourth item on the BBC news and received much less than one minute's coverage.

Perception of Risk

Perception is truth, because people believe it, Epictetus, Roman slave and philosopher 1st Century AD

Clearly there are differences in how risks are perceived by scientists, and by the lay public, all individuals interpret risk to different extents. Several factors can influence the different perceptions and interpretations of risk. These may include: personal experience of the adverse effect/event, social cultural background and beliefs, the ability to exercise control over a particular risk, the extent to which information is gained from different sources e.g. from the media and so on.

People have a tendency to overestimate very low risk and sometimes to underestimate very high ones. In general, they do not understand "power of ten notation": the relative risks calculated in the example given above will be appreciated, but the "1 in a billion", 10^{-9}, will not.

Entirely hypothetically, consider an aeroplane which is 10 times safer than others. Unfortunately the fare is also 10 times greater. The public are asked to choose to pay £100 for a holiday trip on the conventional plane, rising to £1,000 on the super safe version. On the bald figures of the relative risk alone, many people may be persuaded that the safer plane is well worth the extra fare. However, if the risk of death on the old plane is known to be 1 in a billion, there would probably be few takers. However, if the risk of death was 1 in 100 on the old plane and therefore 1 in 1000 on the "safe" version……
So both, relatively, and absolute safety comes at a price.

Tolerability and Acceptability of Risk

The scientific community can measure estimate risks and present this information as clearly as possible, with warnings about uncertainty. It is then up to society as a whole, to determine what is tolerable and acceptable based on a range of social, political, cultural and economic considerations. In some areas the risk is so high as to be clearly unacceptable and in others it is negligibly low and acceptable: but frequently the situation is in a grey area inbetween. The Health and Safety Executive, following on from the development of risk ideas in the nuclear industry, have developed the triangle of tolerability shown in Figure 2.

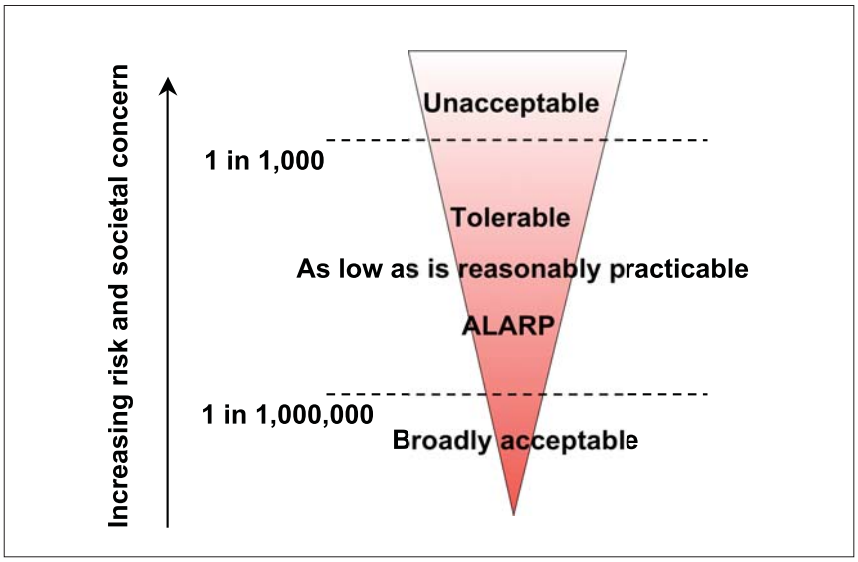

Figure 2. Regions of tolerability of risk.

Let us assume that a risk of less than 1 in a million is broadly acceptable, and a risk of 1 in a thousand is the upper limit of our acceptance, then the middle region represents the range for which risk is managed, in the jargon of the business, to be as low as reasonably practicable (ALARP), a concept now accepted in Health and Safety legislation. Clearly our tolerance of risk depends on the consequences. Some risks lead to inconvenience or financial loss, others result in the loss of life to a greater or lesser degree. The values chosen in the risk triangle would of course be adjusted to reflect these circumstances. Table 1 quantifies the risk of an individual dying in any one year from a wide variety of causes.

Risk of an individual dying per year from:	**1 in:**
Smoking 10 cigarettes per day	200
All natural causes age 40	850
Violence or poisoning	3,300
Influenza	5,000
Accident on road	8,000
Leukaemia	12,500
Playing soccer	25,000
Accident at home	26,000
Accident at work	43,500
Radiation at work	57,000
Homicide	100,000
Hit by lightning	10,000,000
Radiation from nuclear power station	10,000,000

Table 1. Individual risk, BMA, Living With Risk, Wiley, 1987.

Interestingly, "dying from all natural causes age 40" lies at the boundary of unacceptability. Most of the data points fall in the area of managed risk, whilst the risk of radiation from a nuclear power station, about which many people are greatly concerned, is an order of magnitude above the acceptable risk boundary, and is a risk similar to that of being hit by lightning. It is also worth noting again that the range of these risks is logarithmic, which is often a source of confusion to the linear mindset of the public. More recently calculated values suggest that the risk of death in one year's exposure to rail travel is in the order of 1 in 500,000, some five times less than homicide.

The Management of Risk

The term *risk assessment* has entered our language as we have become increasingly risk averse. Activities which were previously accepted as part of life, now need to be assessed and a paper trail laid as proof that has taken place. The burden of doing this can be sufficient to make the effort and formality outweigh the benefits of the activity.

I recently spent the night in a cottage of a mountaineering club of which I am a member. The noticeboard was filled with disclaimers to the effect that mountaineering can be dangerous and the Club and the Committee, having done all in their power to make it safer, wish members to know that they undertake the activity at their own risk. One of the reasons mountaineering is such a stimulating activity stems from the fact that it is potentially dangerous!

Of course, the fear which prompts these apparently ridiculous notices is not basically fear for the safety of one's colleagues, but fear that the club may be sued if anything goes wrong. In fact, these, and a myriad of similar notices, including these previously noted littering every train, are a kind of insurance policy against legal action.

Actually, the committee has probably spent more time, risk assessing the risk of possible legal action than debating how best to introduce new members to the joys of mountaineering. Adams (see bibliography) has given a wonderful example from a risk assessment document for field study trips from his university, in which students are advised, inter alia, to *"ensure you can see where you are putting your feet before walking."*

Who Foots the Bill?

The activities of no-win, no-fee lawyers are ubiquitous. There is some justification in feeling that, on occasions, they are unscrupulous. Thus we read of a lawyer acting in compensation claims for sick miners filing 90,000 such claims and making £45,000 a day from public funds, (*The Times,* 10 April 2007), and *"Teachers say greedy layers promote false abuse claims",* (*The Times*, 5 May 2007), in which it was claimed that local authorities settle claims of up to £12,000 to prevent frivolous claims reaching court, presumably to protect their reputation and to avoid costly legal bills. It is clear that the losers in this industry are the general public who, in the end, foot the bill. The sword of Damocles threatening legal action, coupled with the threat of professional ruin, clearly tends to make people cautious.

Eyes Wide Open

The railway industry is a good example of an industry in danger of missing the obvious because it is constipated by the paper mountains produced by the safety case. Some dangers are only visible to the operative being out on the track using his eyes, ears and common sense, rather than filling in forms. Missing bolts do not automatically declare themselves to the paperwork.

Accidents do not happen by accident Sir Herbert Ashcombe Walker, 1927, General Manager of the Southern Railway

There can be no difficulty in ascertaining almost day by day the state of the rails, sleepers, points and gauge of the permanent way. It is a simple matter of inspection and necessary repair, to neglect which is a direct breach of the company's contract with the public., The Safety of British Railways, H Raynar Wilson, P S King & Son, London, 1909

Contemplating the Impossible

As part of my duties as a Trustee of the Science Museum, I was part of the Audit Committee's annual deliberations on a risk register. Although, some of this activity is probably necessary, it was not particularly helpful to decide our greatest risk was from a terrorist attack in London. What could we do about this short of relocating? Nothing. When the attack happened, our visitor numbers dipped, but then recovered in an entirely predictable manner. I wonder if we might be better producing an opportunities register, and determining en-route what may prevent us from grasping opportunities.

Actually, the management of risk by extrapolating knowledge from the past usually fails to identify the next threat. The ideas of Nassim Taleb have recently been aired in a new book, *The Black Swan*. A Black Swan is an unpredictable and unexpected event, which nevertheless happens. It is then argued, with the benefit of hindsight, that the event was predictable. The terrorist attacks on the World Trade Centre on 9/11 had many Black Swan characteristics. Nassim argues that organisations should use creative thinkers who can imagine the impossible. A flaw is that if we worry too much about the "impossible" in the future, we will not have time to enjoy the fruit of the real and possible today. Nevertheless, unconstrained thinking is an attractive strategy, which lies beyond the routine activities of the risk assessment and the safety plan.

Risk and the Media

It is difficult to open a newspaper without some story about risk jumping out. Figure 3 illustrates a recent collection. Within the last few days before this was written, the following appeared in *The Times*:

Vale of Glamorgan Council has barred their call centre operators answering the phone in Welsh because it could "damage their vocal chords", 8 May 2007

Health & Safety Chiefs of Camden Council in North London have banned barbecues at community festivals in case people get killed and injured, 4 May 2007

Jurors at the fertiliser bomb trial had their request for a toaster turned down on health & safety grounds, 7 May 2007

These items were presented as little snippets presumably with the purpose of reinforcing the widely held view that some of the excessive zeal of health and safety officials is ridiculous and deserves to be ridiculed. Stories about health and child care are treated rather differently. Health research is guaranteed extensive coverage, even if it contradicts the finding reported a few months previously. Thus, on 20 April this year, the leading headline on the front page of *The Times* was, *Scientists prove that salty diet costs lives*. It went on, *The findings, from a 15 year study, offer the clearest evidence yet that cutting salt consumption saves lives by reducing the risks of cardiovascular disease. People who ate less salty food were found to have a 25% lower risk of cardiac arrest or stroke, and a 20% lower risk of premature death*. Beyond mentioning again that only the relative risk reduction is mentioned with no indication of the absolute risk, I leave readers to add their own criticism of the reporting. Predictably, *the Salt Manufacturers' Association questioned the quality and conclusions of the study*. Personally, I take such stories with a fair degree of scepticism and a pinch of salt.

Young children too are guaranteed prominent coverage. 19 April produced a major story: *Deadly toy danger grows as Chinese imports flood in*, with subtitles such as: *"Imitation food, Risk of choking as can be mistaken for real food, Stuffed toy, Risk of choking fur comes off easily, Book, Risk of choking, small parts liable to break off; Bib, Risk of poisoning, high lead content".* No evidence was given that any of these events had actually happened. I am sure most grown up readers will acknowledge that it is a miracle they have survived their own childhood.

In summary, I feel that the treatment of risk issues in our press is slight, alarmist and unsophisticated. It is generally sensational and certainly not aimed at educating the public to live with an intelligent acceptance of risk.

Figure 3. A selection of recent newspaper cuttings on risk and accidents. Other items include: *"Big Bang at the atomic lab after scientists get their maths wrong", "Are mobile phones wiping out our bees?", " Restaurant fined after fiery sausage explodes at the table"; "The £50,000 piano that fell off the back of a lorry".*

Risk in Sport

Sport provides an interesting example of voluntary exposure to risk. Some sports are called "high-risk", a fact reflected in insurance premiums for participating in them. Some sports are not obviously risky, but accident figures prove otherwise: for example, falls from horses cause a considerable number of deaths every year. The introduction of protective equipment provides an interesting example of the concept of risk compensation.

The cricketer on the right of Figure 4, is much better protected against the ball than his predecessor of a century before. When playing a fast bowler he is much more likely to adopt an aggressive stance because the consequences of a body/ball interaction are much reduced. Now the purpose of cricket is the interplay between the batsman and bowler, and the intention of the latter is not (in principle!) to injure the batsman. So the introduction of protective equipment changes the approach of both parties: it is arguable how the overall balance is changed, perhaps we accept we are playing a slightly different game.

Figure 4. Do advances in protection decrease risk?

Much of my own experience comes from mountaineering. At the advent of the sport in Victorian times, equipment was crude. The rope was weak and often broke. When it did not, the fall of one member of the party coupled with the lack of proper belaying measures, often resulted in the remainder being dragged from their holds.

Climb if you will, but remember that courage and strength are nought without prudence, and that a momentary negligence may destroy the happiness of a lifetime. Do nothing in haste; look well to each step; and from the beginning think what may be the end.
Edward Whymper, Scrambles Amongst the Alps, 1871.

Because of this risk, the cardinal rule, drummed into climbers from the outset, was, "The leader must not fall". However, in the last couple of decades, protection equipment has advanced to such a stage that the rock climber can fall with relative impunity. Risk compensation kicks in: we climb much more difficult climbs until we return to the same state of perceived risk. To some extent the same applies to general mountaineering, but here the risks are much wider than falling from the rock. Avalanches, crevasses, rock falls, altitude

sickness adds to the dangers. But we strive to climb more difficult mountains by more difficult routes. The internal ethics of climbing frown on the use of artificial aids, although the boundary between protection and direct assistance is blurred. The real purist may deplore the use of oxygen to climb Everest. He would deride the use of pitons and artificial aids to scale rock walls as mere steeple-jacking. The less principled just get on with determining their own levels of risk.

The Risk Thermostat

The concept of risk compensation, introduced by Wilde and subsequently modified by Adams, is outlined in Figure 5.

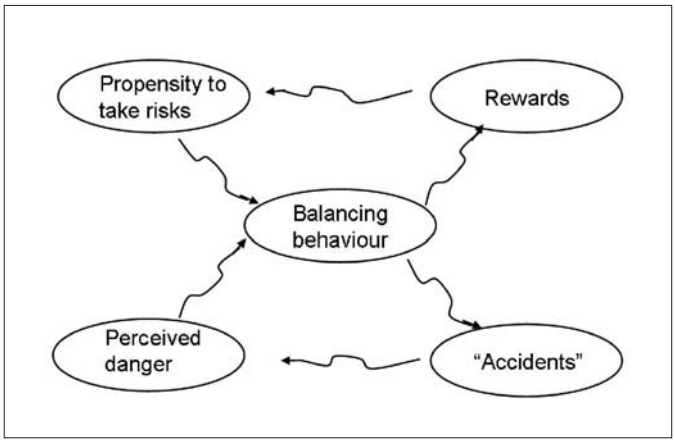

Figure 5. The risk thermostat as proposed by Adams

The model suggests everyone has a propensity to take risks and this propensity varies from person to person. This propensity is influenced by the potential rewards of risk taking. Perceptions of risk are influenced by experience of accident losses, by direct experience or from the reported experience of others. Individual risk taking is represented by a balancing act in which perceptions of risk are balanced against propensity to take risk. Losses are a consequence of taking risks, the more risks an individual takes, the greater, on average, will be both the rewards and losses.

Adams has discussed many interesting consequences of risk compensation particularly in the area of road safety. The idea goes like this: because the risk to me as a driver is reduced, I compensate (perhaps subconsciously) because I feel more secure and drive less safely. I therefore increase the risk to other road users, pedestrians, cyclists and people in other cars.

It should be pointed out that statistical analysis of accidents tends to support this idea. The question therefore becomes what is the overall effect of the introduction of airbags (and a host of other measures) on safety of the system overall? It has been suggested that the most effective safety device would be a large spike in the centre of the steering wheel!

Figure 6. Putting the Director on the front of the train to promote safety, cartoon by John Tenniel, Punch 18 July 1857.

Cost Benefit Analysis

It has become common to conduct a cost-benefit analysis to inform expenditure in many areas, including safety. There are several problems. The first is the definition of the system boundary, and therefore what benefits to include. For big infrastructure projects, it is easy to show that the economics do not add up as the boundary becomes smaller and tighter. This is frequently used to reject proposals which have a longer term and wider benefit. Most of the Victorian infrastructure on which we now depend, water supply, sewerage systems, the underground and railways, would never have been built if present cautious cost-benefit analyses had been used. This kind of risk aversion may well prove detrimental to our continuing economic progress.

If we evaluate safety proposals in terms of outputs of lives saved, we must define a value for a life. This is objectionable to many people (eg. life is so precious it cannot have a monetary value), but seems to me to be reasonable in principle. However, we must include all the other system benefits that may accrue from an improvement. For example, the introduction of a semi-automatic signal stop system following a series of railway accidents where signals were passed at danger, not only saves lives but was an essential step to modernising our railway.

It is interesting that in the history of our railways safety expenditure, in the form of brakes, signalling and the like, was often resisted by railway management, and it was often public opinion, exercised finally through the action of the Board of Trade, which forced them to adopt measures that were patently overdue: hence the appearance of cartoons such as that shown as Figure 6. Every proposed safety appliance was opposed on the grounds that a false sense of security would be imparted to the driver (or guard, or signalman) so that he would feel it less necessary to attend to his primary duty, which was to secure the safety of the train by his alertness and judgement.

The same kind of argument is echoed today with reference to many aspects of transport and industrial safety. The privatisation of our railway has led to claims of "profit before safety", claims which are not substantiated by the statistics (for example, see the 2005 Lloyd's Register Educational Trust lecture given by my colleague Andrew Evans). The basis of the statistics is that there has been a continuous improvement over many years and the privatisation has caused no unexpected discontinuity in the time series. What the statistics do not tell us is which, if any, of the post privatisation accidents would have occurred if the railway organisation had not been so changed.

Cutting Corners

A classic case of cost-benefit analysis leading to reputational damage, is that of the Ford Pinto, introduced in 1971. The car became the focus of a major scandal when it was alleged that the car's design allowed its fuel tank to be easily damaged in the event of a rear-end collision which sometimes resulted in deadly fires and explosions. Critics argued that the vehicle's lack of a true rear bumper as well as any reinforcing structure between the rear panel and the tank meant that in certain collisions, the tank would be thrust forward into the differential, which had a number of protruding bolts that could puncture the tank. This, and the fact that the doors could potentially jam during an accident (due to poor reinforcing) made the car a potential death-trap.

Ford was aware of this design flaw but allegedly refused to pay what was characterised as the minimal expense of a redesign. Instead, it was argued, Ford decided it would be cheaper to pay off possible lawsuits for resulting deaths. *Mother Jones* magazine obtained the cost-benefit analysis that it said Ford had used to compare the cost of an $11 repair against the cost of paying off potential law suits, in what became known as the Ford Pinto Memo.

The characterisation of Ford's design decision as gross disregard for human lives in favour of profits led to major lawsuits, criminal charges, and a costly recall of all affected Pintos. While Ford was acquitted of criminal charges, it lost several million dollars and gained a reputation for manufacturing "the barbecue that seats four."

Although many of my colleagues in the railway industry tell me they are very conscious of the possibility of being sent to prison if they make safety related mistakes. The reality is that the concept of "the controlling mind" has meant that it has proved to be impossible to secure convictions for manslaughter for employees of major companies in the United Kingdom.

National Risk: Privatisation of Public Services

The success of the early privatisations of public businesses led to a belief that all privatisations could succeed. The driving motivation of competition improving service and driving down costs works for many simple transactions. How it might work in more complex situations is not so clear.

It is worth discussing water supply, energy and transport in this context. These are services which are vital to the wellbeing of society, and, broadly speaking, are areas in which true and unfettered choice does not exist. They all depend on relatively expensive infrastructure, which has either a long payback period, which sometimes cannot be funded by the "fare-box".

I am just reading, as a shareholder of the Channel Tunnel, that the operating company is in danger of becoming bankrupt because of the debt mountain generated by the construction costs. But few would deny the need for a tunnel, or indeed, its operational success. I am deeply sceptical of the ability of the companies now running our water and power industries to coordinate and fund the massive infrastructure investments needed to secure our supply over the next 20 to 50 years. This period of time is clearly an order of magnitude longer than that required by private capital investment.

Back tracking

The privatisation of our railways is an interesting case study. One of the chief architects of the privatisation was Sir Stephen Robson, then Director of Finance, Regulation and Industry in the UK Treasury, who states; *"I think* (think? *If he does not know, who does!) the motivation for privatisation in the UK was to improve efficiency and also to improve services to the users of the railways... there is a lack of clarity about the objectives of state enterprises… there is interference by civil servants and politicians…The public sector is motivated by aversion to risk… the finances of state enterprises in the UK are often constrained by the states own fiscal position".*

Broadly speaking, ten years on, the railways now cost the taxpayer five times more than they did before privatisation, passengers are well aware that major shortcomings still exist, international comparisons place us in the third division, there are no plans for major enhancements, and the railway is back under the control of civil servants and the Treasury.

The political architects of rail privatisation have now acknowledged their mistakes, John Major, *"My instinct was to privatise it not as we did, with separation of train and track, it was to privatise it regionally".* I find it hard to understand why the comprehensive advice against the method used for privatisation, coming from the industry both at home and from abroad and in particular on the split of infrastructure and train operations, was unheeded. Despite all this, it is a pleasure to record that in recent years the railways have experienced a welcome if unexpected strong growth in both passengers and freight.

Very early in the development of railways, it was recognised that it was a mistake to regard railways as a means of transportation similar to the canal and turnpike road, to be used by individual vehicle owners upon the payment of a toll:

It was expected that the public should be admitted to exercise the business of carriers upon them {the rails}, subject to certain specified regulations and by-laws. It soon became apparent, however, that this new means of transport was attended by qualities which must exclude every indiscriminate exercise of carrying business. A railway, ***like a vast machine,*** *the wheels of which are connected with each other, and whose movement requires a certain harmony, can not be worked by a number of independent agents. Such a system would speedily be attended by self destruction. The organisation of a railway requires unity of direction and harmony of movement, which can only be attained by the combination of the entire carrying business with the general administration of the road.*
D Lardner, Railway Economics, London, 1851, pp 421-2

Effect of Privatisation on Research

When I started my PhD research at Cambridge, I was immediately seconded to the CEGB research laboratories at Berkeley nuclear power station on the Severn estuary. My immediate disappointment with not being in Cambridge was rapidly forgotten over the next few months as I was apprenticed to a team of highly trained scientists who introduced me to a subject then in its infancy, fracture mechanics and the techniques of the developing methods of finite element fatigue analysis. Within a couple of months I was filled with satisfaction when my first research paper was submitted to, and rapidly accepted by a journal.

I was sponsored for my PhD by the Gas Council. I exchanged ideas with colleagues in the Gas Research Station at Killingworth, the National Engineering Laboratory, National Physical Laboratory, British Rail Research, UKEA, British Steel and Royal Aircraft Establishment. None of these major laboratories now exist. The expertise has long been scattered.

The privatised industries have been particularly keen to associate research with short term economic gain. I dispute the view that the only purpose of a research effort is to produce an "invention every day which improves the

bottom line". Functions such as high level training and development of staff, with mobility into the production function, technical management of crisis and awareness of development elsewhere, particularly overseas, have been all but forgotten.

Expertise is Scattered

We are taking a huge risk by decimating our high level technical expertise. The incentive for UK students to pursue PhD studies in engineering subjects has largely disappeared: most of our research students come from overseas, particularly from rapidly developing countries such as China.

Before the railways were privatised, British Rail supported the Advanced Railway Research Centre which I led at the University of Sheffield. Our remit of training people in railway technology and conducting fundamental research was well regarded by our sponsor. Privatisation, brought an abrupt cut off of funding, and an appeal to Railtrack was met with the response, paraphrased, '*There are no problems left in railway research, there are no free lunches in the privatised industry, go away.*'

Of course, this hubris was met with nemesis, rather sooner than expected when the Hatfield accident occurred in late 2000. I was appointed by Railtrack to Chair their investigation in what was termed gauge corner cracking, actually a form of fatigue cracking from a stress concentrator, a topic which I had studied for my PhD. Because of the lack of a research department to assist in this crisis, a team of experts were called on from America (ironically, mostly trained at BR Research long ago!).

It became clear to me that the motivation of these outsiders was not to simplify and solve quickly, but, perhaps unconsciously, to complicate and extend their contract as long as possible. More immediately, because of lack of high level technical expertise within Railtrack, the company was risk averse to dealing with the many other cracked rails found on the UK network. The resultant disruption to the timetable was probably the worst perturbation in the long history of our railways. It was largely unnecessary and led to the downfall of Railtrack. Risk aversion proved to be a severe, and probably unanticipated reputation risk.

Short Termism in Research

Research is what I'm doing when I don't know what I'm doing.
Wernher Von Braun (1912-1977)

Now, even in academe, research is a managed activity. Typically a research proposal must come with targets, milestones, anticipated outputs and supposed benefits. Actually this kind of activity is well described by the term development, a vital activity in an industrial laboratory. However, the funders of university research should expect more for their support. They should anticipate the benefit of original thought, an outside view and they should accept the risk that the bottom line might not be improved tomorrow, but they just might benefit from an unexpected outcome, and they should definitely benefit from the output in trained people. The funding councils need to find ways of identifying original thinkers who can perform real research and

should concentrate less on routine managed development. In part this difficulty has arisen from the rapid expansion of competition for funds driven by research assessments. There is a fear that quantity may override quality. There is a danger that staff who are not natural researchers will be managed into research. This is both undesirable and fruitless.

Risk on a Global Scale: Climate Change

Global warming…. A far greater threat to the world than international terrorism UK Government Chief Scientist, Prof Sir David King

…alarming and simply unsustainable UK Prime Minister, Tony Blair

Our house is burning down and we are blind to it, French President Jacques Chirac

I stand before you as a representative of an endangered people…As a result of global warming and sea level rise, my country may disappear from the face of the Earth. President of the Republic of the Maldives.

I recall my feelings of skepticism when the first reports of anthropomorphic activity affecting global climate began to circulate. Surely, the earth is far too big to be affected by the actions of a few puny humans? Well, the "few" is of course rather a lot (and getting more all the time) and if we step back far enough, the earth is indeed fragile. The atmosphere surrounding the earth scales in thickness to the diameter of the earth as a sheet of brown paper wrapped round a football. It is in this tiny layer that the carbon dioxide emissions of our activities are accumulating and causing the *'greenhouse effect'* which is warming the planet.

The scientific consensus on measurements of the past is now very strong, see for example in the 2007 Report of the Intergovernmental Panel on Climate Change (IPCC). To summarise:

- It is almost certain the climate has changed in an unexpected way. It is most probable that these changes are caused by the accumulation of greenhouse gasses in the atmosphere.

- The science behind the greenhouse effect is well understood: it was established many years ago, by Fourier who asked, early in the nineteenth century, what determines the average temperature of the earth? , then refined by Tyndall (1859) who showed that carbon dioxide gas (CO_2) was relatively opaque to heat rays. Arrhenius tried in 1896 to calculate the effect of CO_2 concentration on the earth's surface temperature. We are rapidly getting more accurate answers to this last point.

- What is still being debated, but variations in predictions are narrowing as climate science matures, are the effects of the predicted temperature rises and the time scale over which the changes will happen. It is increasingly evident that most of the effects of temperature have positive feedback mechanisms (the change of albedo of white Arctic ice with dark water is a good example), so many researchers think that an unstable situation is likely in the near future, or indeed may already have been reached.

Exponential Growth

Concerns over global warming have meant that the threat of resources depletion has dropped down the agenda. I argue that the economy is actually driven by the physical processing of natural resources into materials than goods and services which are transported to consumers. When we have finished with the goods, we dispose of them, often with very little effort to recycle. This physical view of the economy is governed by the laws of thermodynamics and continuity. The question of how much natural resource we have to fuel the economy, and how much energy we have to extract, process and manufacture is central to our existence.

It has been calculated that if all the present population of the earth was consuming in the present style of the USA, we would need about three earths to sustain ourselves and about nine earths to absorb the wastes and toxins generated. But we have an economic model predicated on growth. Many features of our economic consumption can be described by the exponential growth function.

A key characteristic of any variable which multiplies proportional to its current size is its doubling period. It is elementary to show that relatively modest annual percentage growth rates lead to surprisingly short doubling times. Thus, a 3% growth rate, which is typical of the rate of a developed economy, leads to a doubling time of just over 23 years. The 10% rates of rapidly developing economies double the size of the economy in just under 7 years.

These figures come as a surprise to many people, but the real surprise is that each successive doubling period consumes as much resource as all the previous doubling periods combined. This little appreciated fact (outlined in detail as Appendix 1), lies at the heart of why our current economic model is unsustainable.

Concluding remarks

Whilst I argue that as individuals we need to accept that risk is part of life and we should be comfortable with the idea that we trade risk for benefit, it might appear that my criticisms of national policy in privatisation and international policy on global warming, are criticisms of events which have resulted from risk taking. I suggest that this apparent paradox might be squared by saying that in fact governments are risk averse to admitting their mistakes, are short term and very risk averse for proposing what might be unpopular policies. But, as far as global warming is concerned, we are all taking a huge risk by talking but not doing!

I have bemoaned the lack of public appreciation of risk, particularly of relative levels of risk and the trade-offs between risk and reward. It behoves us to explain our work in simple, yet accurate ways. Public engagement in the understanding of our activities is vital in this area. It would be a great advantage if we could enlist the help of the media in this task. One hopes the time will come when the consumers of media output will demand quality information and rather less sensationalism, personality, opinion and malicious destruction of individuals than regrettably makes up too much of media output today.

Bibliography

I have found the following useful in preparing this discussion:

Risk, John Adams, UCL Press, 1995. Adams has more claim to be regarded as a *'risk guru'* than anyone else. As well as his classic book on the topic, his website contains much additional material and discussion.
http://john-adams.co.uk/

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Appendix 1

Understanding the characteristics of exponential growth

Because the consequences of exponential growth over an extended period are so severe and these characteristics seem to be little discussed and appreciated, the basic theory is reproduced here.

Many activities and processes grow at a rate which is proportional to their current size,

ie. $\frac{dQ}{dt} = RQ$ where R is the constant of proportionality.

Integrating $Q = Q_0 e^{Rt}$

In which Q is the current activity level at time t after the initial level Q_0.

We define the doubling time, t_D, as the time taken to double the activity level, thus

$$2Q_0 = Q_0 e^{Rt_D}$$
$$2 = e^{Rt_D}$$

On taking (natural) logs

$$t_D = \frac{\ln 2}{R}$$

Hence we can construct the following table:

R	t_D (years)
0.01	69.3
0.03	23.1
0.05	13.9
0.10	6.9
0.15	4.6

Thus at an apparently low growth rate of 3%/year, about the rate at which the mature economies of the world wish to grow, the activity doubles in 23.1 years. For a rapidly developing economy, such as China's, the growth rate is approximately 10% /year, implying a doubling in only 6.9 years! A good approximation is t_D(years) = 70/ (% growth rate/year).

The total cumulative activity (a measure proportional to the total resource consumed in the particular example of economic growth), can be found by integrating the exponential growth curve between the time intervals under consideration. Thus between times t_1 and t_2 we obtain:

$$\int_{t_1}^{t_2} Q_0 e^{Rt} dt = \frac{Q_0}{R}\left[e^{Rt_2} - e^{Rt_1}\right]$$

For the particular case of the sum of all the consumption between t_1=0 and t_2=T, the above reduces to:

$$\frac{Q_0}{R}\left[e^{RT} - 1\right] = \frac{Q_0}{R}e^{RT}$$

after many doubling periods and when T becomes large.

Now consider what happens in the next doubling period, t_D:

We integrate from t_1= T to t_2= T + t_D to get the result

$$\frac{Q_0}{R}\left[e^{R(T+t_D)} - e^{RT}\right] = \frac{Q_0}{R}e^{RT}\left[e^{Rt_D} - 1\right]$$

But from the earlier definition of doubling time, hence the consumption in the next doubling period is

$$\frac{Q_0}{R}e^{RT}$$

that is, the really remarkable result, that the total consumed in the next doubling period is equal to the total consumed in all the previous doubling periods combined.

In this very important result lies the unsustainability of exponential growth. Put simply and alarmingly, it means that if an economy grows for example, at the modest at 3% /year in 23 years **the activity (the size of the economy) will have doubled and in that doubling period we will need to use resources equal to all the resources consumed in the history of the economy.** Note that these resources include the scarce resources of materials and energy.

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