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Regulating safety in a disaggregated private sector: a challenge for new build

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A new build of nuclear power stations?

Global warming is recognised as the most important long-term issue facing UK policy makers and is reflected in Government targets to cut CO_2 emissions by 60% by 2050. The scale of this challenge is put into perspective by data from the past 20 years showing steady or increasing trends in emissions in the domestic, services and transport sectors of the economy. The overall trend has only been prevented from rising more steeply by a 50% reduction in energy consumption by industry – caused largely by manufacturing's move offshore over that period.

In the transport sector, innovative solutions, such as hydrogen-fuelled cars, have been proposed to maintain rising levels of transport for people and goods while cutting emissions. However these contribute to the reduction in CO_2 only if there are adequate supplies of "zero-carbon electricity", as the overall efficiency of the hydrogen route, if supplied from fossil fuels, is significantly lower than of current technology. This will place even greater demands on the electricity supply industry.

Last November the Government announced a series of studies into energy policy, including reopening the question of a new build of nuclear power stations. It is recognised that there are a number of hurdles to large scale nuclear construction including economics, long-term (>50 years) fuel availability, waste disposal, public acceptability and safety regulation. This paper is restricted to the last of these topics. It does not attempt to justify the construction of new capacity but discusses some of the issues that will have to be addressed if such construction is to go ahead.

In many ways, the break-up of the CEGB was very similar to the break-up of British Rail. What had been a state-owned, vertically integrated corporation was converted into a number of competing service providers. The distribution infrastructure was separated from operators (National Grid or Railtrack). Central research facilities (Central Electricity Research Laboratories or Railway Technical Centre) were closed or sold and the design competence was dispersed to consultancy organisations. It is now recognised that the arrangements put in place for the rail industry were not ideal – particularly in regard to the large-scale introduction of new equipment. The structure of the electricity supply industry has not yet been tested in this way as there has been no significant construction activity of large nuclear or fossil-fuelled stations but it is relevant to draw parallels with the rail sector, to avoid similar pitfalls.

The structure of a future nuclear industry

The current nuclear stations were built for a public sector customer by large UK contractors working to customer-approved drawings. Government policy appears to be that any future build will be managed within the private sector. Because of the lack of a major reactor engineering company in the UK, it seems inevitable that construction would be by a joint venture of several constructors, some not domiciled in the UK, drawing expertise from various parts of the fragmented nuclear and engineering industry. It is also inevitable, given the structure of the industry, that the contractors would be working to functional specifications or performance contracts rather than building to operator-approved drawings.

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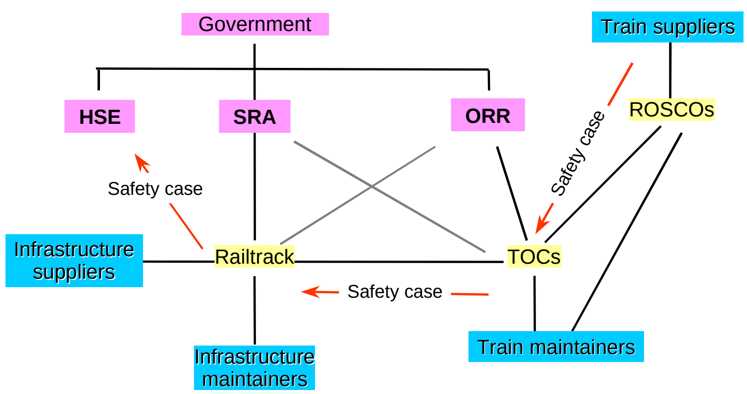
The extent to which a plant promoter is or is not an "informed customer" in respect of nuclear power plant operation is likely to be important for safety regulation. Whether the operator is also the owner of the assets or whether the plant is leased from a financial institution will affect the industry structure as will the decision on whether maintenance is handled by the operator or bought-in from the suppliers.

The situation is made more complicated by the number of different Government agencies involved in power station construction and operation (the economic regulator, safety regulator and planning authorities) and by the ownership structure of the nuclear sites – a situation closely parallel the rail industry. It is likely that some new reactors would be built at the same sites as the stations presently being decommissioned. Parts of these sites are owned by the Government through the Nuclear Decommissioning Agency (NDA), which has a primary role to close down the existing facilities, not to build new ones.

A comparison with rail

Previous experience, in the rail industry, of migrating regulation from a monolithic public-sector organisation to a complicated and disaggregated private-sector has not been a good role model. Although different in detail, the complexity of the possible contract structure for a nuclear new build is comparable to that of the UK rail industry from 1994 to 2000.[2]



In the latter case, there were three Government bodies involved – the Health and Safety Executive (HSE), the Strategic Rail Authority (SRA) and the Office of the Rail Regulator (ORR). The HSE was the regulatory authority for health and safety on the railway and enforced H&SW legislation (comparable with the NNI). The SRA's key role was to manage passenger franchises with train operating companies (TOCs) and the ORR's principal function was to regulate Railtrack's stewardship of the national rail network. Apart from the statutory regulators, the legislation required several cross-approval processes, so that, for example, Railtrack had to certify that a new fleet of trains would not introduce unacceptable risk onto the network.

Trains were supplied by manufacturers to Rolling Stock Companies (ROSCOs) who leased them to TOCs. ROSCOs usually retained responsibility for periodic heavy maintenance (typically every 2 to 5 years) while the TOCs were responsible for daily inspections and light maintenance. Neither ROSCOs, nor most TOCs, had in-house maintenance facilities so most of this work was subcontracted to train maintenance contractors, many owned by the manufacturers and the safety of both new build and maintenance processes were monitored by a network of safety audits supported by Independent Safety Assessors (ISAs).

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[2] Since 2000 there have been a number of changes to the structure of the UK rail industry: the *Railways (Safety Case) Regulations 2000* changed responsibilities for acceptance of safety cases and the replacement of Railtrack by Network Rail significantly changed the relative responsibilities of the different players in the industry. The 2003 Regulations implementing the European Directives 96/48/EC and 2001/16/EC on European interoperability have changed some safety responsibilities and will have much wider implications over time. The *Transport Act 2000* and the *Railways and Transport Safety Act 2003* have made further changes to responsibilities and to the safety regulatory structure. To avoid comparisons with a moving target or with regulations that are not yet fully implemented, this paper describes the situation that existed from 1994 to 2000, when most of the current new build fleets were ordered.

Design Authorities

The term Design Authority is well known in both the rail and the nuclear industry. A review of the design authority role in the rail industry[3] identified the need for the following five competencies:

1. **The "know why" of a system** For any system or equipment, there is a need for a body that understands the technical and operational requirements and that retains records indicating how these influenced the design of the system. It is not simply a question of knowing how to manufacture or maintain equipment, someone has to know why it is how it is. Whereas other bodies, such as licensees, maintenance organisations, users or overseas manufacturing units may have the "know how" to build or maintain a component or system, they are unlikely to have the "know why" of the design.
2. **Confirmation of suitability for safe use** There is a need for a body that has the authority, competence and responsibility for confirming that a train and its constituent systems meet the technical requirements and that it is safe for use.
3. **Retention of information** There is a need for a body to retain design information so that, if 20 years after a train enters service there is an accident or modifications are needed to meet changing requirements, the original design calculations can be recalled.
4. **Validation of technical change** In an evolving railway, there is a need for a body capable of making an informed judgement on the suitability of a train or its systems for a particular route or application and for assessing the technical, operational and safety implications of any proposed modifications to an existing vehicle.
5. **Management of configuration levels** There is a need for a body to establish different configuration levels of any particular design as it evolves throughout its life and that has the competence to certify that any particular modification is compatible, not only with the original design, but also with any subsequent approved modifications.

These five competencies are common to all contracts for significant engineering projects but different industries have approached them in different ways.

Model 1 - aerospace

The model used in the civil aerospace industry is that the original equipment manufacturer (OEM) carries the responsibilities listed above. The civil aviation industry in the UK has one regulatory body, the Civil Aviation Authority (CAA) connected to the European JAA and with close links with the American FAA. Before an aeroplane may fly, the CAA must certify it. There are two main components which are certified, the airframe and the engine. All parts that are fitted to one of these components are certified with the component. Thus the design authority lies either with the engine manufacturer or with the airframe manufacturer. (The engine/airframe interface is treated as part of the airframe certification.)

Under this system, Rolls Royce maintains the design authority role for all engines it has built until the planes stop flying and is thus responsible for configuration control. Any incident to any RR engine regardless of age is notified to RR. Apparently they still receive incident reports on Spitfires! These reports are considered and the action taken is a balance between commercial risk, customer expectation and safety. No work may be carried out on the engine without the authority of Rolls-Royce. This includes routine maintenance which must be notified to RR and the local certifying agency (CAA in UK) before it is started.

The model described is broadly similar to that used in the road vehicle industry where the vehicle manufacturer retains design information and the results of safety testing, defines the conditions under which the vehicle is expected to operate, is responsible for the recommended maintenance schedule, scrutinises accident data and, where necessary, issues recall notices.

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[3] A Railway Industries Association (RIA) working group consisting of 10 industry representatives met during the spring of 2003 to prepared a Guidance Note on Design Authorities. The Railway Safety and Standards Board (RSSB) were represented on the group.

Model 2 – the CDM regulations

The alternative model is that used by the construction industry, in a modified form the chemical and nuclear sectors and, since privatisation, the rail industry. It can be typified by the requirements of the Construction (Design and Management) Regulations 1994. The regulations assume that a building may be commissioned by a client who is not expert in the design and construction of buildings. The client is required to appoint a competent engineer to plan and design the building and who produces a "safety file" that is handed to the client when the building is complete. This file includes the necessary calculations and data so that, if the client commissions modifications, the new designer can pick up were the original engineer left off.

Under the Railways (Safety Case) Regulations 1994 the rail industry adopted a broadly similar model to the CDM Regulations for infrastructure but a rather different model for trains. In the latter case, the train operating company (TOC) was required to produce a safety case describing how the rolling stock would be operated and the features of the trains that supported this operation. Inevitably, as the TOC had not designed the trains, they relied on the leasing company (ROSCO) to provide the information that was, in turn, requested from the manufacturer.

One result of this safety process is that similar vehicles sold to different TOCs have significantly different safety documentation – partly because they are used on different routes. Perhaps more significantly, the safety cases differ because they are prepared by different operators and, almost inevitably, the projects are managed by different people in the regulatory authority, supported by different Independent Safety Assessors (ISAs) having different preferred methods of demonstrating the mitigation of risks. Apart from the cost of duplicating this effort (a safety case usually consisting several hundred pages of text supported by many filing cabinets full of calculations, test results and other documents), uncertainty in the process means that it is difficult for a manufacturer to price the cost of demonstrating safety.

For these reasons, UK rail vehicle manufacturers look in envy at the European motor industry or the aviation sector where, once a plane has achieved (admittedly expensive) approval from the JAA, it may be sold freely throughout the world. In 1996, the European Interoperability Directives started a process to establish the concept of Europe-wide design approval for rail vehicles but so far Britain has made little progress in this direction. Much of the UK rail infrastructure differs from one route to another and no lines are fully compatible with European standards, so local rules continue to dominate. An equally challenging problem however exists in the safety regulatory framework, requiring a demonstration that risks are reduced to a level *as low as reasonably practicable* (ALARP) discussed in following sections.

If it is decided to construct a new fleet of new nuclear stations, the industry will be faced with the situation where the design authority for the reactor is the (overseas) contractor, not the plant operator, as was the case with most of the present stations. Current safety regulation of both the UK rail and energy industries places the main burden of demonstrating the safety of the plant on the operator, not on the designer, as is the case in the civil aircraft and road vehicle industries. The likely ownership structure risks creating a situation, similar to that on UK railways, where there is not a single body responsible for the overall safety of the activities on a site and where the operator of an asset who, under current legislation, "owns" the safety case is not the body which understands the technical risks.

Criteria for risk assessment

Since 1974, the safety of employees has been covered by the Health and Safety at Work Act. Reading the 1972 Robens Committee report, on which this act was based, it is clear that their deliberations were primarily concerned with the direct risks to employees in a factory environment and members of the public who were directly affected by industrial operations. The report did not cover the transport industry or state enterprises having Crown Immunity.

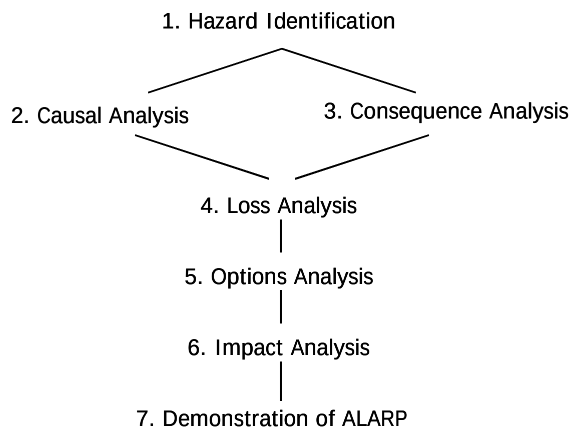
During the 1980s, the use of the Act was extended to cover risks, such as low level radiation, where there is a statistical, rather than a direct, relationship between cause and effects and this allowed the Act to be used to evaluate proposals for the construction of new nuclear power stations.

Introducing ALARP on the railways

The Transport Act 1993 included a change in responsibility for safety regulation of the railways from the DfT to the HSE. This introduced the principle of ALARP into the industry which, until then, had been regulated by prescriptive regulations and "sound common sense" from Her Majesty's Railway Inspectorate.

The change was dramatic and suddenly the industry was required to assess all risks and demonstrate that everything reasonably practicable had been done to reduce each. It was no longer good enough to produce a train that met the public's expectations for safety, we had to demonstrate that we had assessed the risks of, say, the brake system, had brainstormed all possible ways of making it safer, costed and evaluated each and adopted those that met the target for VPF (value of prevented fatality).

The process that was adopted is set out in what is colloquially known as *The Yellow Book* [4]. This identified the 7-stage process, shown on the right, starting with hazard identification and looking at the causes and consequences of each hazard. Stage 4 calculated the potential loss, taking into account the possible consequences of a hazard and the likelihood of it occurring. Stages 5 and 6 considered options for eliminating or mitigating the hazard and what impact each would have on the project, both in terms of safety and cost. Finally stage 7 demonstrated that the risk had been reduced to an ALARP level, taking into account the possible risk reduction that could be obtained by each of the options and the cost of each.



Shortage of data

The change in the regulations created two problems for the industry: the first was a dearth of quantitative data about the safety performance of many components, particularly new and largely unproven designs. Like the nuclear industry, the rail industry had been subject to a hiatus when few new trains had been ordered. One result of this was that there were data about rates of hazardous failures of 30-year old trains but these were not typical of what was being designed in the 1990s and, in any case, most of the problems were due to specific design faults not generic properties of that type of equipment.

Like nuclear stations, there are relatively few trains of any particular type from which to collect experimental data. In any day, hundreds of cars throughout Europe suffer burst tyres and, if one could collect the data, it would not take long for a pattern to emerge. However, world-wide, only a handful of high-speed trains suffer a serious brake failure each decade. Many of these can be linked to particular design decisions, not repeated on other vehicles, so there were no reference data for the mean time between failure (MTBF) of many systems. In the absence of measured data, there was a temptation for the regulators – and particularly the ISAs – to ask for calculations based on worst-case combinations of pessimistic assumptions using techniques such as Failure Mode and Effect Analysis (FEMA). This was particularly the case when considering more erudite risks, such as the possibility of inverter-fed traction systems interfering with safety signalling. There has never been an accident in the UK attributed to such a cause and a rational analysis shows the risks as vanishingly small, but it is still one of the largest costs in safety case preparation.

How safe is safe enough?

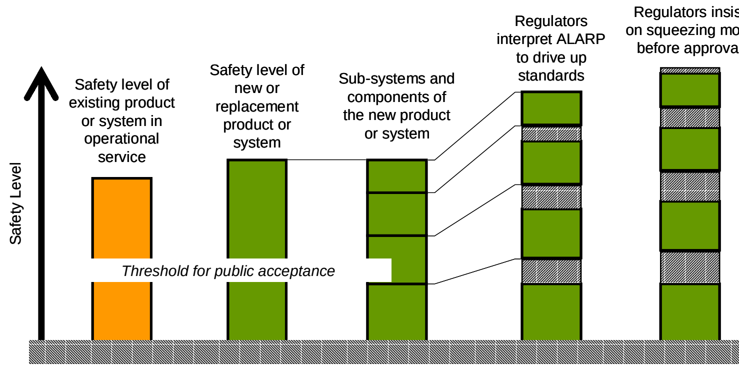
The second problem was that human ingenuity can come up with a thousand and one ways of improving something. The Robens Committee probably envisaged a conversation about what is practicable along the lines of "Could you design a guard for that hydraulic press that still allowed the operator to adjust the tool when necessary?" "Yeah – cost about £200." "OK, lets do it." With more complicated systems, it was not uncommon for ISAs, many of whom had previously been in BR design departments, to identify possible design solutions that might improve the safety of particular systems and it was very difficult to freeze a design and say "we have reduced the risks to ALARP".

PA Consulting[5] have argued that the UK regulatory requirements place a huge burden on the industry and have described the rail safety process, using the diagram on the following page. At the left is a bar

[4] Engineering Safety Management, Volumes 1 and 2, Published by Railtrack PLC 2000, ISBN 0 9537595 0 4

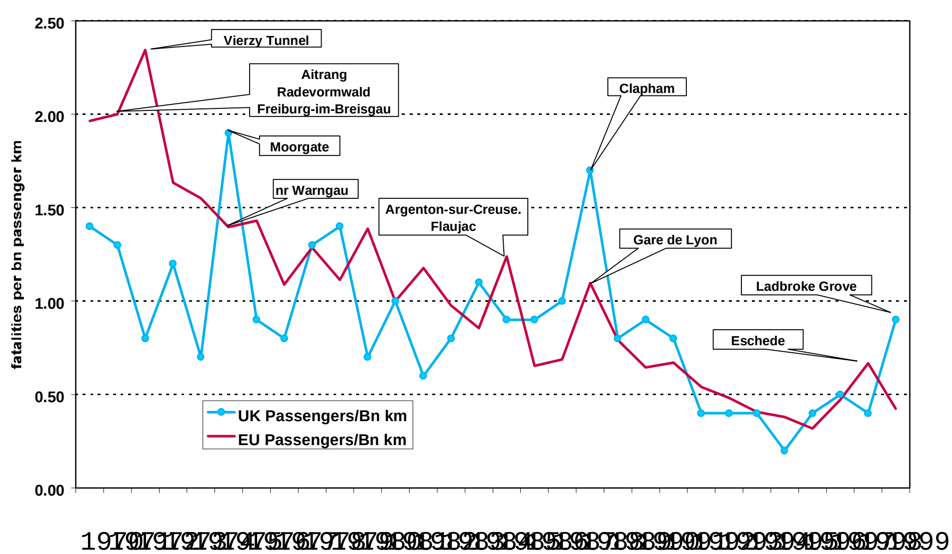
[5] PA Consulting, ALARP versus GAME: How UK's rail industry can cut the regulatory burden and save costs, March 2004

representing the safety of existing trains, which are generally well above the threshold of public acceptability. A manufacturer then produces a new design of train that has a safety level better than the older design where the risk is divided between different subsystems (shown in the third bar). The regulator requires each subsystem to be optimised to reduce the level of risk to ALARP and then requires additional safety improvements after the main design period and up to system commissioning as shown in the right hand bar below.



It is argued that, by applying ALARP for each component of the system, and applying it at the time of commissioning, the overall effect is to add more delay, cost and uncertainty than would result from a *globalement au moins équivalent* (GAME) approach, as used in France, applied at the overall system level and mainly at the design stage. ALARP is appropriate for improving safety performance that is near the intolerable level, but GAME is more appropriate where the risk is at least in the middle of the tolerable range, (as it is for rail and also for nuclear power).

These two factors created an environment where the manufacturers felt they had no control over the outcome of the safety regulatory process. There were no longer prescriptive rules about what was and was not allowed and they were required to justify the safety of individual systems against ill-defined criteria using non-existent data. Throughout most of the EU, rail regulation bears more similarity to the pre-privatisation situation in the UK,[6] but overall safety performance is similar. Aidan Nelson, Director, Policy & Standards at RSSB has produced the following comparison of performance:

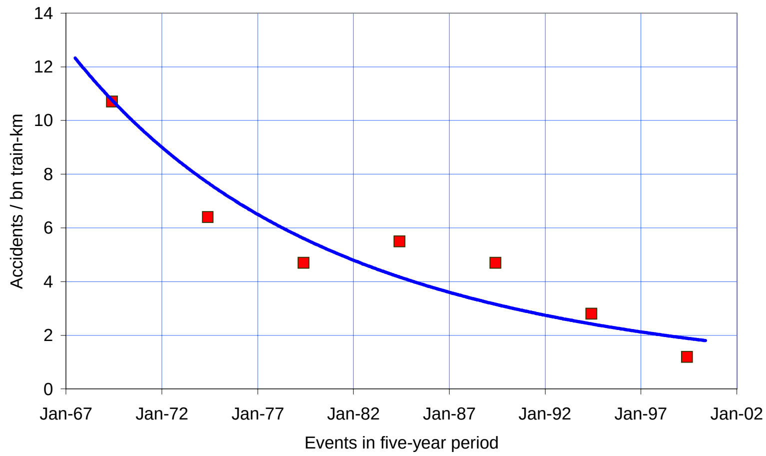


Sources: UIC for EU figures, TSGB for UK Railways, Semmens P. (1994) Railway disasters of the world

It can be seen that, in terms of passenger safety, there is little difference between the UK and the European average. More recently, Prof. Andrew Evans at Imperial College has shown (see graph below) that

[6] Dr Chris Elliott, Pitchill Consulting; Rail safety regulation in other European countries, 10 February 2004

privatisation had little impact on the trend of safety of UK railways – neither better, as presumably the proponents of the 1993 Act might have hoped, nor worse, as long-term opponents of privatisation had feared.



In written evidence to the Ladbroke Grove Inquiry (Part 2) the Railway Industry Association wrote: "Safety regulation in the UK is the most complicated and expensive in Europe but our safety record is no better than average. The cost of these provisions and the delays they engender are a disincentive to the growth of rail travel and promote the use of less safe transport modes. We consider that the complexity of the present arrangements is detrimental to a clear allocation of safety responsibilities and that a fundamental overhaul of the system is needed to reduce the number of bodies and simplify their relationships. This is essential for the development of a safe and cost-effective railway."

Societal concern

Since the construction of Sizewell B, the criteria against which safety are judged have changed. The 1987 document *The tolerability of risk from nuclear power stations* was largely based on "hard science" and probabilistic risk assessment. 14 years later, the document *Reducing Risks, Protecting People* (R2P2) 2001 contained 50 occurrences of the phrase "societal concern" which justified the regulatory body imposing regulations based on how the public (or more often their surrogate, the press) reacts to a risk, irrespective of the scientific basis for regulation.

A factor that makes societal concern even more difficult for a contractor to assess is the use of *The Precautionary Principle* in assessing risks for which there is little or no scientific or statistical evidence demonstrating how the supposed "risk" affects the victim. The Precautionary Principle was established to deal with risks, such as the level of CO_2 in the atmosphere, where it is clear that there is an upper limit above which the world will suffer serious problems but no-one can be certain as to whether this limit should be 350 or 550 ppm. Against this background, it makes sense to assume the lower (precautionary) limit. Adam Burgess of the University of Kent, has written about the risks of mobile phone masts[7] and how there is neither epidemiological evidence nor a plausible theory of causation of how these might be detrimental to human health. Nevertheless the Stewart Inquiry concluded that "there is sufficient anecdotal evidence to justify further research and taking a precautionary approach to the use of mobile phones".

From the point of view of a private sector constructor, and more especially the financial institutions funding the construction, the official recognition of societal concern as a reason for regulation, coupled with an open-ended risk assessment process that finds it difficult to give credit for a history of safe operation in other countries, creates greater financial uncertainty than exists under a prescriptive regime, such as exists in the USA, or under the GAME (*globalement au moins équivalent*) philosophy used in France. The uncertainty is further exacerbated if the safety regulator is prepared to use unproven anecdotes as justification for regulatory intervention. Overseas companies entering the UK railway equipment market have lost considerable sums of money adapting to the UK regulatory regime and it seems likely that the proportionately greater risk and societal concern surrounding a new build of nuclear power stations may

[7] Burgess A., *Cellular phones, public fears and a culture of precaution*. Cambridge, ISBN 0 521 81759 5

encourage companies to provision for regulatory risk to an extent that jeopardises private sector involvement in the project.

How is the railway experience relevant to the nuclear industry?

If it is decided to replace the current fleet of nuclear power stations, it is inevitable that the replacements will be built by the private sector. To avoid the liability on the Public Sector Borrowing Requirement (PSBR), the risks will be passed to the private sector – presumably shared between the operators, constructors and financial institutions.

In assessing any major DBO (Design Build Operate) project, investors will look at the risks, which can be subdivide into four main areas:

- ◊ **Delivery risk** – what is the likelihood that the design will prove more difficult than expected, that the build will take longer or be more expensive or there will be delays in commissioning that will delay the date the project earns money?
- ◊ **Revenue risk** – what is the likelihood that the money earned by the project per unit of output (kWh delivered or train-km operated) will be less than calculated when the tender was written?
- ◊ **Regulatory risk** – what is the likelihood that the approval process will increase the costs, delay the start-up of the project or otherwise reduce the profitability of the venture?
- ◊ **Financial risk** – exchange rates, interest rates, etc.

Some UK nuclear power stations suffered long delays in their construction because each station was unique and the British gas-graphite reactors were not designed for mass-production, as are most PWRs. However, if a nuclear operator decides to buy a proven design from an established constructor, such as Framatome or GE, the ***delivery risk*** should be reasonably low – other power stations of that type will be running and most of the serious causes for delay should have come to light and been resolved.

In a world where prices of oil can vary between $40 and $80 / barrel over a few weeks and where the UK energy trading regime (NETA) involves a daily auction of available capacity, it is risky to predict revenue streams for a technology that has a uniquely high up-front cost but low running costs. This is a characteristic shared with many renewable technologies and the Government has recognised that a change in economic regime is needed to mitigate ***revenue risk*** if the private sector is to be persuaded to accept them.

The fourth category, ***financial risk***, is one that can be managed, at a price, by normal financial engineering techniques.

It is the third category above, ***regulatory risk***, where investors have little control and where it will be difficult for the Government to take action. The need to demonstrate the risks from each subsystem had been reduced to ALARP, when there were no reliable data and a plethora of possible options that could be described as “practicable”, left many train-building companies facing long delays in delivery and commissioning and with losses measured in tens of millions of pounds per contract. The situation was exacerbated by the complexity of the network of different approval bodies discussed earlier in this paper.

For a major train builder, such as Siemens, Alstom or Bombardier, each of which had built thousands of trains in mainland Europe, constructing a few hundred for the UK should have been a low risk venture and had the benefit that there was no public opposition or societal concern: the public were keen for the UK networks to be provided with new trains and there was some recent history of the introduction of new rolling-stock. Experience showed that all three incurred high costs of regulatory risk to a greater or lesser extent.

If a nuclear new build goes ahead, the regulatory risk will be vastly greater than was seen in the privatised rail industry for five main reasons:

1. A nuclear power station is significantly more complicated than even a very sophisticated train (such as Eurostar). There is far more scope for creeping modifications to different subsystems in the name of safety.
2. However unlikely, a serious incident in a nuclear power station has greater repercussions than a serious train crash and therefore one would expect greater regulatory attention.

3. A power station is less self-contained than a train and the design has to be customised for the local environment (cooling water, disposition of different buildings, foundations, etc.)
4. There is less recent UK experience of building – and regulating – power stations than trains.
5. There will be significant groups in the population opposed to a nuclear new build and thus one can expect the regulator to take more notice of societal concern – something a contractor would find very difficult to take into account at the bid stage.

How is a contractor likely to respond to these risks? One choice would be to ask the Government to underwrite them, as with economic risks. However, as the regulatory structure is enshrined in law, it is inconceivable that the Government would consider it appropriate to offer indemnity to a contractor against the costs of complying with pre-existent legislation. Another would be to ask that some of the regulations be modified or waived but one only has to consider the public outcry in response to a headline "Government tears up safety law to help big business" to realise this is unlikely.

The contractor is thus left with little alternative but to provision for the regulatory risk – in other words, to base the tender price on the most pessimistic assumption of what might be demanded by the regulator and the implications on the contract delivery and performance. Apart from the risk to the viability of the project, such a strategy can hardly be said to offer good value to UK energy consumers.

A way forward

The 1974 Health and Safety at Work Act has had positive influences on most industrial operations. However it was not originally intended to be used for the rail industry or for nuclear power stations. Recent additions to the regulations, such as R2P2 and the use of the *precautionary principle* against anecdotal risks with no scientific basis, make the regulatory process unbounded. When this regulatory structure is teamed with a financial model where the private sector is expected to underwrite regulatory risks, contractors are unlikely to be prepared to accept the risk without a significant price increase.

Five actions would help to break this impasse:

1. There is a need to revisit the concept of "the informed customer", the responsibility for the demonstration of safety and the concept of design authority when an operator purchases an asset (either a power station or a train) from a constructor, rather than being involved in the design process.
2. Industry needs clarity in how the ALARP criterion is applied to complex multidisciplinary projects where there may be a multiplicity of ways in which risks can be reduced.
3. There is a need to establish a mechanism to enable safety justifications produced in countries that do not use the ALARP principle to be incorporated into a UK safety case.
4. Society has to address the way in which it attempts to apply a scientific and numerate risk management process to perceived risks that have negligible physical or statistical basis.
5. Industry and the regulators should consider how best to close-out risks before companies are required to submit a fixed-price tender for a project.

Even if one cannot go as far as the equivalent of internationally-recognised JAA approval for particular reactor types, the ability to pre-licence designs or for short-listed bidders to be able to freeze the main parameters of the safety case before a BAFO (best and final offer) has to be submitted would reduce the regulatory risk to constructors and thus improve value for money to the UK electricity consumer.