TRAINING ACTORS ON INDUSTRIAL RISKS AND RESPONSIBILITY

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I/ RISK AND RESPONSIBILITY

1/ Managing risk has always been an important aspect of business management, but with the increasing rate of change and the growing uncertainty in the future world, risk management will become increasingly important. Formerly, risk management functions were carried out by specialists in several separate parts of an organisation. Managing risk is now part of every manager’s role and specialist risk managers are expected to manage broader areas of risks.

2/ In the design of a process or a product it is usual to apply a factor of safety. All engineering structures incorporate factors of safety implying uncertainty plus a bit more. But this factor of safety changes with time and circumstance. Due to the power of computers and the apparent better knowledge of scientific and technological phenomena, the tendency is to cut safety margins to reduce costs and this is true in all engineering disciplines. More confidence and reduced safety factors can lead to disasters. Unfortunately, as we are not going to completely abandon innovation, many hazards will occur in the future.

If engineering is based on incomplete models, judgement and experimentation, who should be held responsible when engineering projects fail causing loss of life and property, and damage to the environment? We see everyday that the issue of who should take responsibility when things go wrong is becoming a central concern for the engineering profession. More and more often prosecutions against engineers and managers set a precedent that have important ramifications on the way engineering is practised.

3/ In fostering new and ever more complex technology, engineers have created a dynamic environment in which the number of problems is constantly expanding. Most engineers today work on problems unimaginable to earlier generations. Now our environment is man-made. The instruments created to understand and control the environment is also responsible for complicating it.

4/ Most real-world problems are ill structured, in the sense that system-boundaries are unpredictable and environments are heterogeneous. Generally they resist codification and modelling. As you know there are two types of knowledge management: tacit and explicit.
Tacit knowledge or implicit or procedural knowledge in opposition to explicit or codified knowledge is the ability to perform an activity in a new context. Knowledge that we employ to reduce complexity is largely tacit; tacit knowledge is summed up by Michael Polanyi as: “We can do more than we can tell” or “we cannot tell everything we can do or know”.

So, how do we develop the tacit knowledge which is a strategic tool to promote and control technological progress and to successfully reduce complexity?

5/ Problem-solving takes place under time constraints. What can be done in the real world is quite different from what can be imagined in “theory”. The solutions of engineering problems are always time critical. This is evident for the design of new products and also crucial when it comes to risk management and protection from hazards. A solution based on codified knowledge is no solution when it comes too late. For engineers, like for all other professionals, the further they proceed in their careers, the more important proven tacit knowledge becomes. So, in learning and employing codified knowledge, students acquire tacit knowledge. It will require a thorough scientific education to develop a feeling for technologies. It is the one-sided engineer who fails the real world test.

II/ RISKS IN THE ENTERPRISE

What are the risks in the enterprise? Every enterprise is confronted with risks:

- **Speculative risks** that are the very essence of the enterprise: investing capital in a new factory, entering new markets, launching a new product, etc. For example, among the most promising of the new drugs filling the pipe lines of pharmaceutical and biotechnological compounds are compounds produced by live, genetically modified microbial or animal cells. Over the next 5 years, the revenues generated by protein-based therapeutics are expected to grow 15% a year (according to MacKinsey Company), about twice the rate of the rest of the pharmaceutical industry. More than 200 drugs derived from cell cultures are in clinical trials and about 70 of these drugs are expected to come to market by 2006. Thus a lack of manufacturing capacity will cost the company several million dollars in lost revenue.

- **Pure risk**, being the result of coincidences. These are the events (such as fires, explosions, damage to environment, defective products) produced by the activity of the enterprises (example the SEVESO factory). It was above all for this kind of event that a risk manager used to be appointed. Any enterprise has to face the risk that it runs, but also the risks that a third party runs: financial risk, increase in interest rates, price variation on raw materials, exchange risks, etc.
• **Risks bound to the production of goods and services**: 
  - risks linked to suppliers (security and quality)
  - damage to goods
  - damage to persons
  - damage to the environment.

• **Risks linked with the sale**: business and political risks, credit risks, risks linked with the products, quality defect, wrong use of the products.

• **Risks bound to the worldwide dimension**: these last few years, the strategy of the enterprises has faced a geographic extension of their activities. In this domain, risk analysis has to be adapted to the local context and for example to take into account the regulations and the laws.

  Globalization also requires a more important coordination of the different local entities in order to maintain the coherence of a trade policy and to preserve the image of the trademarks of the enterprise.

• **Other risks** exist like risks linked with transportation, risk of illegality, risks linked with loss of image, hazards emanating from the environment, be they political like wars or terrorism or natural like earthquakes.

So, it is impossible for the policies of the risk management not to consider the regulation environment, social environment, natural environment, political environment, economic and competitive environment.

Another of the most important challenges for a company is to manage information. Attacks on corporate information systems by hackers, viruses, worms are increasing dramatically and costing companies a fortune. In 2001 US business reported 53 000 system break-ins, a 150% increase over 2000. Indeed the true number of security breaches is likely to have been much higher because concerns about negative advertising means that almost two-thirds of all incidents actually go unreported (as reported by Carnegie Mellon University). Many companies have appointed a chief security officer, who works with business leaders and IT managers.

The digital history of a company or a nation is emperilled by the very technology that is used to create it. The Internet search engine Google claims access to just over 3 billion Web pages, a massive collection of information in a constant state of change. The average WEB page has a life-span of just 2 months. Half of all the WEB content made in 1998 had disappeared by 1999 (Washington Post 15 February 2003). This is an event similar to when the Romans burned the Alexandrian library several times between 100 BC and 391 AD, and its complete destruction in 642 AD.

There appears to be a growing interest in risk ranking and before that in grouping risks into categories. If an agency wants to use the results of a risk ranking project as input to risk management, explicit analysis for choosing a risk categorisation scheme is needed.
The choice of categories should reflect risk management objectives. Engineers must understand the role of risk information in management decision and risk communication, identify current and emerging methods for quantifying risk, and rank risks to human health and environment.

III/ TRAINING OF ACTORS

In this context how should we train engineers for tomorrow?

1/ Modelling and reality

With the development of information transmission storage processing and management new questions have arisen among them: what kind of information must be conveyed and what type of media must be used (text, sound, still or moving pictures, video, images). Engineers must also be aware of the limitation and the pitfalls of the media they choose to develop.

Representation and more generally interfacing are very important and must be understood and mastered. Engineers need to be made more aware of the problems of representation, simulation and modelling or else they will run the risk of being cut off from reality.

We can quote examples of the problems that can arise when advanced computers cannot interface with the factory floor and all the difficulties there are in communicating between different branches of advanced engineering.

We must develop interfaces between the different branches of engineering at large and must also educate our students to question, using traditional back-of-the-envelope “approaches”, which such interface gives them access to.

We must link advanced modelling with reality without losing sight of reality. For example, earth sciences and biology are a good training ground for engineers who will have to perform accurate observation and select significant factors in an industrial environment.

2/ Polyvalence and pluridisciplinarity

As our technical culture is increasing, new problems and new technologies such as new materials, new processes, waste recycling, high capacity network, bioengineering and so on, appear constantly. The rapidity of changing biotechnology alone often exceeds our ability to adjust ethical and legal norms. So, the frontier between various disciplines needs to be re-examined in order to develop hybrid technological curricula. Genuine polyvalence and pluridisciplinarity need to be achieved. That is the reason why some Grandes Ecoles provide the students with multiple perspectives on complex problems and across majors and departments. This is one way to develop tacit knowledge.
This cross-disciplinary collaboration is difficult to carry out. It is funny to see that disciplines often separate more than nationalities; it is easier to have different people from different countries working together but in the same speciality than to have people from the same school but learning different subjects. We have been trying since last years to prepare the students to cope with all the dimensions of a project: technical, economic, sociological, etc.

3/ Communication

Technological systems are designed as though organisations could operate with perfect communication, as though people were not prone to distraction or illogic. How long does it take for people to process information and how do people behave under stress? So it is also important to learn how to diffuse knowledge and expertise: not only to establish a dialogue with scientists, technicians, politicians and managers, but also to explain and popularise engineering. Communication is crucial to narrow the gap between public acceptance and technological projects. Engineers have to learn various roles during their career: experts, coaches or teachers.

4/ Humanities

At the same time, there is a growing importance of the humanities in engineering education. While this need has been recognized since the early twentieth century, it continues to be the privilege of a limited number of high level institutions. Some of the Grandes Ecoles d’Ingénieurs in France have introduced and permanently reinforced economics, management and sociology and the contributions made by engineers to these fields are substantial in France and Europe. If an engineer does not possess this cultural dimension, he may be ill prepared to tackle the organizational and managerial opportunities of companies. He has to be familiar with economics, accounting, sociology, finance, marketing, operational research, epistemology, to name but a few. There is no technology without management requirements and management purpose.

This cultural basis is at the same time expanding and will continue to do so.

a/ Socio-economics and technical training need to be integrated: such cultural training should not be merely an enclave within technological training, but curricula need to be redesigned. We must also create hybrid areas of study such as manufacturing and production systems (including plant modelling, management of component flow, plant technologies, strategies used in making an inventory of the available evaluation tools), or environmental engineering. We can add design, maintenance, communication

b/ The historical dimension of engineering culture should be highlighted: the history of society, of industrial systems, of techniques, of engineers, of sciences and epistemology can develop a critical mind and reveal in some cases what has become of former certitudes which were claimed to be scientific.

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c/ It is important that engineers understand the relationship between art and technology, between intuition and logic. This will be increasingly important in designing products, in communication and representation (symbolic codes and languages)

5/ Social responsibility of the engineer

The social responsibility of the engineer is growing, which requires increasing knowledge of standards, rules, regulations, laws and national and international political institutions. Courses dealing with these topics are already offered in some engineering schools in Europe but need to be developed. Attention has to be focused on respect for the environment, rigor, quality (total quality management and continual quality improvement), safety, security, and on defining the frontiers between what is permissible and what is not.

6/ Critical mind and crisis management

One of our major challenges is to train people who can constantly adapt to change while at the same time being suitably critical of such change and, at times, to resist it. In a world in perpetual evolution, we also have to prepare our students to derive an advantage from the controversy induced by conflicts generated around products and processes, by the art of negotiation and lateral thinking. Moreover they have to learn to manage crises. Curricula and continuing education can beneficially include courses on risk prevention and crisis management including simulation and games. Modern societies are faced with the problems of how to control major technological hazards. It is of the utmost important that future executives should be prepared to deal with this type of crisis.

Facing uncertainty will have several positive aspects:
• accepting the variety of needs felt by different people and communities
• establishing interesting exchanges between countries having different types of technological developments.

That is the reason why for example at Ecole des Mines de Paris (EMP) all the students have to explore different controversial subjects under all their aspects, technical, social, environmental, economic, etc. Underlining the evidence of controversies about services and techniques is an interesting way to develop a critical turn of mind and negotiation ability.
7/ Developing international and multicultural perspectives

So it is obvious that the engineering profession is a global, international profession. At the same time, it remains true that many specifications in the education and the general culture of engineers remain deeply rooted to their national specificity. We need therefore not only to teach engineers how to communicate across national boarders, using English in particular, but must make them aware of these cultural differences in order to break down barriers and to learn from one another. At EMP, 10 foreign languages are taught. But this is not enough. The knowledge of other cultures and other civilisations is also needed in order to encourage working in collaboration and to reconcile technology and society.

Many programmes in Europe now are multidisciplinary, intercultural and inter institutional and involve courses and degrees between different universities.

For example, the Athens programme is organised by 10 engineering schools of Paris and 8 European Universities (Aachen in Germany, Louvain and Leuwen in Belgium, Lisbon in Portugal, Trondheim in Norway, Madrid in Spain, Delft in the Netherlands and Budapest in Hungary). Twice a year, the institutions offer at the same period about eighty different courses attended by more than two thousand students, among whom 800 move from one institution to another one, in the context of SOCRATES European programme. During these exchanges, we also offer the students cultural visits and make them understand better the policies of each country.

It is also compulsory in many engineering schools to have an industrial training period in a foreign country. At Ecole des Mines de Paris all the students spend at least four months in industry outside of France.

In some schools, courses compare the social evolutions, labour laws, relations between categories through different countries to show that the social rules are not unique.

8/ Identification of problems

Traditionally engineers have seen their role as being that of problem-solvers. Engineers have to spend more time developing the art of defining problems and mastering the skills of problem analysis. They have to ascertain what the problem is and which technology is most appropriate for solving it, rather than to try to look only for problems to which their own skills can be applied. There is much that can be done with regard to ways and means of monitoring projects either individually or as a part of a team or as a part of a network.

Engineers must learn to work in teams cutting across disciplines, the departments of a company, and across the companies themselves, between a company and its environment either locally or across countries.
In conclusion, to develop skills in risk management and responsibility in contemporary engineering, it appears clearly that engineering is every day something more than just engineering and this creates a major challenge: in a few years we have to teach an engineer to be familiar with a wide range of relevant technologies and expertise, familiar as well with management, financial skills, sociology and humanities, knowing different national cultures, aware of his responsibility as a key player of industry and as the educator of his teams, capable of mastering research and innovation programmes.

In fact engineering education has to meet three kinds of mobilities: geographical mobility, intellectual mobility and cultural mobility. The engineer will be the manager of change.

Furthermore multimedia networks, “benchmarking”, internet surfing, a number of variable electronic forums identify some main ideas. These ideas are used by the media, journalists, politicians, and sometimes without any verification and unfortunately without enough critical thinking by the educators and the decision makers. They become universal truths, but imperialistic for the mind. If we do not take care, they become “politically correct” which is bound up with a lack of imagination. It has to be remembered that diversity has to be preserved and it is this diversity that permits us to accept the other and to enhance collaboration.

It is also necessary to explain the innovation process, the place of technologies in society. We have to underline the social aspect at the origin of technological choices. Engineers must be not just technicians but also real politicians in the “noble meaning” of this word.

Finally, to develop individual initiative, autonomy, risk-taking and personal responsibility we have to train our engineers how to become entrepreneurs.

As you know, this is a major challenge of our universities today and as John Hennessy from Stanford said: “it is the way to give to students some real world experience on the kinds of changes that they will face in the real world”. Many engineering schools are developing such a programme in France and in Europe.