# THE ECONOMICS OF RADIOLOGICAL PROTECTION

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(The following is a transcript of Mr. Lochard's presentation.)

The objective of my presentation this morning is to give you an overview of the status of economic thinking in radiological protection. I will not say anything new about this topic, but I will try to put everything into perspective and give you a flavor about the state of the art in this field.

I would like to remind you of the key reason why economics is at the heart of ALARA thinking. If we are dealing with the stochastic risk related to radiation, the basic problem is that we don't know anything about the real shape of the dose-risk relationship -- is there a threshold or no threshold. The attitude of the ICRP, and I would say the entire radiological protection community, was to adopt a prudent attitude and to assume that there was no threshold. The result of this basic assumption is to enter into a risk reduction approach. As a first step, you could imagine that the zero risk objective is the good one, but you have to be careful. This is where the economical aspects enter into the system. Looking for zero risk is not the right way, because on one side this leads to a misallocation of protection resources in society, and secondly, you can have transfers of risk from one group to another. This is an important topic. When you try to reduce a risk to zero, you generally generate some risk for other groups. For these two basic reasons, efficient allocation of resources and avoidance of risk transfers between groups in the society, ALARA is the proper route for dealing with radiological risk (Figure 1). I mentioned this point yesterday during the panel. The result of this attitude is that a residual risk always remains. Whatever you do, if you don't go to the zero risk level, you will leave some residual level of risk. This residual level of risk is a question to be looked at carefully.

In terms of economic models, the story began with ICRP Publication 22 and the introduction of the so-called cost-benefit model, which is, in fact, an adaptation of the famous optimal pollution control model developed by economists in the framework of welfare economics to deal with externalities related to environmental pollution. The cost-benefit model in radiological protection is just an adaptation of this classical model which all economists learn in their first year of school. The key feature of this model is to try to find the minimum total cost including, on one side, the cost of detriment, i.e., the economic evaluation of the detriment related to radiological risk, and on the other side, the cost of protection (Figure 2). The whole system is driven by the fact that the cost of protection is following the law of diminishing marginal returns, which is also a key law in the economic thinking. This is not a physical law, but an empirical law. In many situations, the more money you spend, the less efficient it is to reduce the risk. This is the basic model on which the whole economics of radiological protection is based.

I will now develop two sides of this model, i.e., the cost of detriment and the cost of protection. As far as the detriment cost is concerned, there has been an important evolution since ICRP 22. At the beginning, people were focused on the reduction of collective exposure using a single monetary value of the man-Sv. There was a slow evolution towards taking more into account individual levels of exposure. To say that in a condensed way, if we want to integrate the most recent developments from ICRP, the main objective when looking for the reduction of exposures is, of course, to reduce collective exposures, but at the same time, to reduce the dispersion in individual exposures as well as the highest individual exposures. This is clearly mentioned in ICRP 60 through all the developments related to the concept of dose constraints. The challenge now, in terms of monetary valuation of the man-Sv, is to find a way of dealing with these three objectives at the same time. One solution is to use models for the valuation of the man-Sv like the one described on Figure 4.

Referring to this figure, you have on the ordinate the monetary value of the unit of collective exposure, and on the abscissa is the individual level of exposure expressed as annual dose. For doses under $d_0$ you don't take care about the level of individual exposure because the differences are not meaningful. You can imagine for $d_0$ something like 1 mSv, for example. However, when you are dealing with higher individual doses, the "alpha value" is increasing with the level of individual dose according to an aversion factor, which is noted here in the formula as "a." Note that "a" must be greater than 1 to cope with the three objectives: reducing at the same time the collective exposure, the dispersion of individual doses, and the highest individual doses.

There is another important issue in terms of economics within the valuation of detriment, which is the problem of how to deal with future detriment. Many times we are faced with a situation of choosing to spend money today for avoiding doses in the future. The traditional way of dealing with this situation is to use a discount factor, and engineers tend to use the classical interest rate approach. This is an important point. It was demonstrated recently by economists that the interest rate is not applicable to nonmarket goods, and obviously with the radiological detriment we are dealing with a nonmarket good. It was also demonstrated that the tradeoff between costs and exposures distributed in time relates on some sort of willingness to pay from individuals. The market cannot give us any good numbers. We have to refer to the so-called social values, and we need to develop contingent valuation approaches in this matter. In this perspective, it seems that using a discount rate in the range of 1-5% is appropriate to deal with future detriment. This is an area which needs to be investigated further, especially in the field of radiological wastes where we deal with very long time frame.

To finish the first part of this presentation on the value of the detriment, I would like to emphasize the need to differentiate values of man-Sv according to risk situations. If we take, for example, occupational exposure, we can assume that workers are informed in advance about the risk in the industry, and they are willing to join the industry because of the benefit that they obtain. This is totally different from the public that is living around an installation for which the risk can be seen as imposed. We can also think about the medical exposures where you get a direct benefit from the exposure you receive voluntarily. All these types of exposures have a clear impact on the risk perception and should be translated in one way or another into different alpha values according to the risk situation. This is an area we need to develop further in the future. There is, however, a consensus among those who are dealing with these types of problems to consider the willingness to pay approach developed by economists as a means to establish alpha values related to risk perception.

The next part of my presentation is related to the cost of protection. The cost-benefit model proposed by ICRP in Publication 22 and repeated in all successive publications is based on the assumption that protection and production costs are independents. In other terms, it means that if you improve the protection, this does not affect operation and maintenance costs. This assumption is misleading. We have many empirical analyses, especially in the nuclear industry, suggesting that there is a clear correlation between the improvement of protection and the reduction of operational costs. Traditionally, we have thought that improving radiation protection is spending more money and reducing the benefit of the activity or the practice. In fact, there are some possible synergies between improving radiation protection and also reducing operational costs. This is clearly shown on Figure 8. In the ordinate we have the outage collective dose related to the 1300 MWe French PWRs for the last outages in 1993, and in abscissa we have the cost of these outages. We can see a clear correlation between the collective dose associated with outages and the cost. This needs to be further analyzed to see how it relates to the lengths of outage, but it is a very encouraging curve showing that there is probably a very good correlation between good protection and a reduction of total cost of operation.

The last point I would like to make is related to the compensation of residual risk. It is clear that the cost-benefit model proposed by ICRP is a way to internalize the radiological detriment up to the point where the marginal cost of protection equals the marginal cost of detriment. But there is always a residual risk. When you are ALARA, you have reached the acceptable level of residual risk, but a residual risk still remains, and one way to spend more money if a radioinduced disease appears after exposition. This compensation can be based on the attributable risk approach, which is another facet where the economists have something to say about radiological risk management.

To conclude, I would like to come back to the curve that was produced by CEPN some years ago when the research group was working on the use of robotics in nuclear power stations (Figure 10). Classically, economists have always presented cost-effectiveness where the reduction of exposures is just more costly. In fact, because of the correlation that I have mentioned between protection and production costs, there is a large potential for reducing exposure and saving costs at the same time before entering into the situation where reducing risk is spending more money. Our experience so far demonstrates that further improvements in dose reduction within or outside nuclear industry can still be achieved without significant increases in costs.

## Author Biography

**Jacques Lochard** is currently the Director of the Nuclear Protection Evaluation Center (CEPN). CEPN is a nonprofit organization, founded in 1976, for research and consulting in the area of optimization of radiological protection and comparative assessment of health and environmental risks associated with energy system. Mr. Lochard's main contribution in radiation protection has been the development of methodologies and implementation tools in the field of optimization of radiological protection. Mr. Lochard is currently the Secretary of the French Society of Radiation Protection (SFRP). He is also widely involved in the international radiation protection scene. He is a member of the Executive Council of the International Radiation Protection Association (IRPA); a member of the Committee on Radiation Protection and Public Health (CRPPH) for the Nuclear Energy Agency of the OECD, and Secretary of Committee 3 of the International Commission on Radiological Protection.

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