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THE COST OF HUMAN ERROR INTERVENTION

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INTRODUCTION

DOE has directed that cost–benefit analyses be conducted as part of the review process for all new DOE orders. This new policy will have the effect of ensuring that DOE analysts can justify the implementation costs of the orders that they develop.

We would like to argue that a cost–benefit analysis is merely one phase of a complete risk management program—one that would more than likely start with a probabilistic risk assessment. The safety community defines risk as the probability of failure times the severity of consequence. An engineering definition of failure can be considered in terms of physical performance, as in mean-time-between-failure; or, it can be thought of in terms of human performance, as in probability of human error.

The severity of consequence of a failure can be measured along any one of a number of dimensions—economic, political, or social. Clearly, an analysis along one dimension cannot be directly compared to another but, a set of cost–benefit analyses, based on a series of cost-dimensions, can be extremely useful to managers who must prioritize their resources.

Over the last two years, DOE has been developing a series of human factors orders, directed a lowering the probability of human error—or at least changing the distribution of those errors. The following discussion presents a series of cost–benefit analyses using historical events in the nuclear industry. However, we would first like to discuss some of the analytic cautions that must be considered when we deal with human error.

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RADIOBIOLOGICAL COST-BENEFIT OPTIMIZATION

Approaches to Optimization

There have been sophisticated approaches to radiobiological, cost-benefit, analytic techniques developed for management guidance (Dunster, 1989; Gonzalez, 1983). One of the simplest forms of these techniques is shown in the following equation:

$$B=V-(P+X+Y) \quad (1)$$

where B is the net benefit of the introduction of a practice;
V is the gross benefit of the introduction of such practice;
P is the basic cost, excluding the radiation protection;
X is the cost of achieving a given level of radiation protection;
Y is the cost of the detriment of achieving the given level of protection.

There are several other more sophisticated variants of the equation presented above. However, the goal of all of these is to present information such as that shown in Figure 1.1.

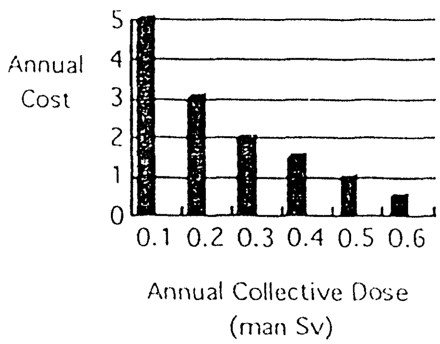

Figure 1.1. A representation of a cost-benefit profile of different design alternatives (indicated by each bar) providing different levels of radiation protection. Managers can choose cutoffs based on cost or annual collective dose. (Man Sv = radiation dose in sieverts.)

In Figure 1.1, data is provided concerning the cost of radiological protection of several hypothetical design alternatives. A management team could then make a decision based on either the cost of the different alternatives, or on the level of radiological protection that they believe should be achieved.

Level of Precision in Optimization

All the techniques discussed and alluded to in the previous section will provide exceedingly fine levels of analytic precision. There is, however, a more simplified procedure that we would like to present.

Using an extremely conservative technique, we will compare only the cost of a human error intervention program to that of constructing a facility and the revenues lost if that facility were to be destroyed by human error. In the examples that we will present, we will not factor into our equations the cost of human lives lost. We believe that because cost-estimates of human lives are arbitrary, such estimates would act merely as mathematical constants and would not provide additional information for high-level management decisions.

In the following section, we will present a brief background on how human error should be treated statistically and brief examples of cost-benefit analyses of human error intervention programs.

THE COSTS AND BENEFITS OF HUMAN ERROR INTERVENTION

Human Error as a Random Variable

Classical human risk analysis usually considers human error as a random variable. There are, at present, too many unknown variables influencing human behavior to determine accurately what a person might do in a given setting. This uncertainty forces us to consider human error in probabilistic terms.

The definition of a random event is one that can have, *a priori*, multiple outcomes. If a process can have only one outcome, it is thought of as deterministic. Taking this argument one step further because of the uncertainty associated with human error, analysts must regard it as a random event.

Once consensus is reached that human error is a random event, or more properly, a series of random events then the nature of this stochastic process must be described. That is, the probability density functions must be specified.

We are stating, in essence, that we do not know the cause of human error. In one sense, the assertion that human error is random will lower the "comfort level" of design teams and their program managers.

On the other hand, treating human error in a probabilistic sense allows us to bring to the problem powerful statistical tools if the probability density functions are known. These statistical tools are the same mathematical techniques used in standard engineering design to reduce the uncertainty associated with mechanical failure.

As scientists, we are not quite prepared to give up the notion that human behavior is deterministic. However, a probabilistic view of human behavior provides us with the most sound analytic basis for providing management guidance.

Human Error Intervention

There is ample scientific evidence showing that much can be done to decrease the probability of human error. A known set of influencing variables affect the probability of human error. Importantly, these variables can be brought under the control of design teams and program managers.

Figure 1.2 highlights the interactive affects of operator, equipment, training, procedural, management, and environmental variables. A slight shift in the value of any of these variables can produce dramatic behavioral changes that are followed by increased human error rates.

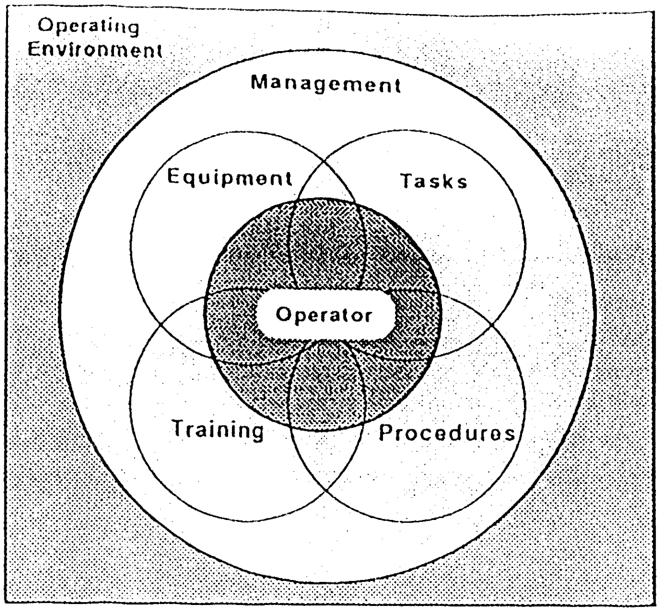

Figure 1.2. This Venn diagram shows the relationships among various factors that influence operator performance. Each must be considered during the design process.

From a probabilistic view, we can make reliable, predictive estimates of human error if the multivariate set of performance influences are well understood. This notion is supported by the following quotation:

> Some previous analyses of the Three Mile Island accident have been read to attribute it to "operator error." We reject this conclusion as being incomplete.
>
> While there is no question that operators erred... There were a number of important factors not within the operators' control... These include inadequate training, poor procedures, lack of management, misleading instrumentation, plant deficiencies, and poor control room design.
>
> (Rogovin and Frampton, 1980)

The High Cost of Human Error

The costs associated with finding and correcting human errors may be one of the largest hidden costs in the DOE budget. This has not been extensively studied by DOE yet, but an example from another industry demonstrates this point.

Prior to the forced corporate breakup, AT&T found that it was spending $100 million dollars a year locating and correcting human errors (Bailey, 1983). These costs were considered to be less than the costs that would have been incurred if these errors were allowed to be shipped to the public. Other industries have documented similar costs resulting from human error.

In the nuclear industry, we now know that the Chernobyl nuclear accident as well as the Three Mile Island incident were caused by interactive faults in equipment, procedures, training, and management. This interaction is what led directly to the series of human errors that in turn, propagated into events of severe economic, political, environmental, and social consequences.

THE COST OF FAILURE TO PROMOTE HUMAN ERROR INTERVENTION

The Three Mile Island Incident

It has been reported that Metropolitan Edison had rushed the Three Mile Island nuclear reactor into service by the end of 1978 in order to save $40 million dollars in taxes (Stephans, 1980; Medvedev, 1991). Three months later, a design-driven human error resulted in the worst commercial nuclear disaster in U.S. history.

In 1987, *US News & World Report* estimated that the direct costs of the Three Mile Island accident would exceed $3 billion. This estimate did not even consider the lost revenue which is approximately $365 million per year for every year TMI-2 does not produce power. The total loss, $3 billion plus $365 million over 40 years, will total approximately $15 billion.

DOE analysts have computed that the normal cost of a comprehensive human factors engineering design program would be no more than 1% of the total cost of a facility. If the Three Mile Island nuclear facility had cost $200,000,000 to build, the human error intervention program would have cost only $2 million.

The simple monetary cost benefit of such a human factors engineering program at Three Mile Island would have been 7,500:1.

Brookhaven National Laboratory

At BNL, a water purification system was operated by an individual who was misled by a control panel layout. In fact, the panel design violated several existing HFE standards.

In this event that occurred just a few years ago, an indicator light that correctly signaled the position of a valve control was uncorrelated with its function. During one shift, an operator observed what he thought was an overfill indication. In fact, the indication had nothing to do with an overflow condition. In an attempt to correct what he believed to be the problem, he allowed the tank to overflow. Due to its location on the roof, the overfilled tank caused the building to collapse partially. The repair costs totaled over $2 million.

It was estimated that a ten dollar label would have significantly reduced the probability of this two million dollar accident. By one simplistic analysis, the cost-benefit ratio of the human error intervention act to correct the problem would be 200,000:1.

The Chernobyl Accident

On April 26, 1989, after what turned out to be a series of miscalculations, an experiment on the graphite-moderated reactor went suddenly out of control. The result was the world's worst nuclear reactor disaster costing perhaps trillions of dollars around the world, and resulting in the evacuation of millions of people. The legacy of that experiment has been the documented increase in radiation-related illnesses.

There is little doubt that a chain of human errors—faulty procedures, followed by a series of misjudgments—was the cause of the accident (Medvedev, 1991). We will never really know what the costs of these errors will be but, if we take an extremely conservative estimate of $200 million for the cost of the facility, and $1 trillion for the aftermath, the cost-benefit ratio of a $2 million dollar human intervention program would be 50,000:1.

When the costs of such devastation are so great, it is clear that sophisticated, precise optimization algorithms are not needed to argue for human error intervention programs. We do not, however, want to leave the impression that we do not believe in the value of precision in cost-benefit optimization programs.

Such analytic tools are useful in ranking different radiological protection procedures once the decision to institute a program has been made. However, precision is not necessary in making the high-level, go-no-go decisions.

SUMMARY OF HUMAN ERROR INTERVENTION COST-BENEFIT ANALYSES

The two most costly nuclear reactor disasters were the result of human error. Almost seventy percent of the events documented in the Unusual Occurrence Report database have been traced to human error (Waters, 1993).

The analysis of human errors can be conducted using probabilistic-based methods. The error predictions that these analytic techniques produce are based on verified, empirically oriented, human factors engineering methods.

DOE analyses have shown that standard human error intervention programs could average 1% of the cost of the facility. Based on these estimates, even the most sophisticated of human error intervention programs would provide significant cost-reduction.

REFERENCES

Dunster, H. J., 1989, "Optimization and decision-making in radiological protection. A report of Committee 4 of the International Commission on Radiological Protection," *Annals of the ICRP*, Vol. 20, No. 1.

Gonzalez, A. J., Ilari, O., and Snihs, J. O., 1983, "Cost-benefit analysis in optimization of radiation protection. A report of Committee 4 of the International Commission on Radiological Protection," *Annals of the ICRP*, Vol. 10, Nos. 2/3.

Medvedev, G., 1991, *The Truth About Chernobyl*, Basic Books: New York.

Rogovin, M., and Frampton, G. R., 1980, "Three Mile Island. A report to the Commissioners Nuclear Regulatory Commission Special Inquiry Group."

Stephans, M., 1980, *Three Mile Island*, Random House: New York.

Waters, R. N., 1993, Personal communication to C. T. Bennett.

Webb, G.A.M., 1989, "Optimization and decision-making in radiological protection. A report of Committee 4 of the International Commission on Radiological Protection, *Annals of the ICRP*, Vol. 20, No. 1.

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