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Title: Balancing Safety vs. Costs to Efficiently Produce Nuclear Electricity.

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Abstract: The evolution of safety standards and criteria in the industry that supports the commercial generation of electricity from nuclear power stations is a continuing process that rest on a broad basis of scientific investigation and risk assessment. This paper is not another debate about whether a person is pro- or anti-nuclear. The intention of the author in this paper is to clarify the risks taken in nuclear plant and estimate the risks taken in a nuclear plant and estimate the amount of money spent to reduce those risks. It is very important nowadays to be able to strike a balance between the benefits foreseen from new technical development and the resources that have to deployed to achieve or to prove an acceptable level of safety.

# Balancing Safety vs. Costs to Efficiently Produce Nuclear Electricity

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TERM PAPER

# Balancing safety versus costs to efficiently produce nuclear electricity.

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# INTRODUCTION

The evolution of safety standards and criteria in the industry that supports the commercial generation of electricity from nuclear power stations is a continuing process that rest on a broad basis of scientific investigation and risk assessment.

This paper is not another debate about whether a person is pro- or antinuclear. My intention in this paper is too clarify the risks taken in a nuclear plant and estimate the amount of money spent to reduce those risks.

It is very important nowadays to be able to strike a balance between the benefits foreseen from new technical development and the ressources that have to be deployed to achieve or to prove an acceptable level of safety.

# I ESTIMATION OF THE RISKS

## 11 How radiation exposure causes Human deaths

Human deaths result of an exposure to radiation. Radiation consists of particles that can easily penetrate deep inside the human body and dammage biological cells, and thereby cause cancer or genetic defects in later generations. Each of us who lives on this earth is stuck by about 15,000 particles of radiation-from natural sources- every second in life.

In addition, we are stuck by about a hundred billion of them when we get a medical X-ray or when we watch TV. No level of radiation is perfectly safe. Any single of these particles can cause a fatal cancer, but the probability that it will do so is only one chance in 30 quadrillion( 30 million billion)!

A radiation of one millirem (this corresponds to being stuck by approximately seven billion particles of radiation) has about one chance in eight million of causing a fatal cancer, and about an equal chance of causing a genetic defect in later generation (estimated by the U.S. National Academy of Sciences BEIR Committee).

In quoting a value for the risk per millirem, a highly convinient assumption is to imply that the risk increases linearly with the dose. There is some question as to whether this simple proportionality with dose can be extented to low levels. There is abundant evidence that nature provides mechanisms of radiation damage: The great majority of animal experiments indicate that cancer incidence at low doses is substancially less than predicted by linear extrapolation of high dose.

Since 1 millirem is a typical radiation exposure in highly publicized incidents(for example, the average exposure recieved by nearby citizens in the area of the Three Mile Island accident in Harrisburg, Pennsylvania, was 1.2 millirem), let us pause to give some perspective on the dangers of 1 millirem exposure(e.g.,[4]).

| Activity | Shortened life span (in minutes) |
| --- | --- |
| Drinking a diet soft drink | 0.15 |
| Crossing the street | 0.4 |
| Being exposed to 1 millirem of radiation | 1.5 |
| Smoking a cigarette | 10 |
| Drinking a non diet soft drink | 15 |
| Eating a calorie-rich desert | 50 |
| Flying coast to coast | 100 |
| Driving coast to coast | 1000 |
| Skipping annual PAP test | 6000 |

## 12 Weighing the risks.

The probability of accidents depends on the design of the reactor and associated safety systems. The consequences depend on other factors:

Amount of radioactivity released.
Proximity of people to the plant.
Weather.

Reactors are usually built in relatively remote areas as precautionary measure.

Both the probability of the accident and their consequences are equally important in determining the actuel risk from accidents. For example, if an accident of a particular type could be expected to kill one thousand people, but the probability of occurence was only once per million years in reactor operation, then the average risk is one one - thousandth of a death per year of reactor operation. That is, the average risk from a particular accident is obtained by multiplying the consequences of the accident by the probability of recurrence.

This average risk is small compared with other risks that we accept routinely. For example, airline accidents can also kill hundred of people, and these occur with notable frequency.

The basic notions of risk have long been understood by those who examine the liability of energie technologies. But a nuclear power plant is so complex that it has been difficult to understand the risk from reactor accident quantitatively (e.g.,[1]).

## II ESTIMATION OF THE COSTS

### 21 The costs of savety in different areas

It is a question of the use of ressources: How much effort can be spared to extend one person's life?
Table II.1. shows some estimates of the money spent on saving one life(e.g.,[3]).

Table II.1.: Expenditure to save a life

| | $ per life saved |
|---|---|
| Food for third world starvation relief | 12 000 |
| Medical | |
| Cervical smear | 6 000 |
| Intensive care | 25 000 |
| Heart pacemaker | 120 000 |
| Accident prevention | |
| Traffic | 300 000 |
| Smoke alarms in houses | 400 000 |
| Stell industry | 900 000 |
| Chemical industry | 1 600 000 |

### 22 The cost of savety in a nuclear plant

The basic design of a nuclear reactor is aimed at the safe control of nuclear power; no-one design a reactor that will works and then adds features to achieve some level of safety. So one can look only at comparisons and at the cost of marginal improvements. Siddall (e.g.,[7]) has argued that the increased above general inflation of nuclear power plant costs is largely due to the escalation of every aspect of regulatory intervention and the assiociated time-consuming procedures.

He estimates the additional cost over the life time of the reactor, and arrives at a figure of $188 million per statistical life saved, assuming a nominal 10% per annum interest on capital.

Other studdies have estimated that as much as one half of the capital costs of a nuclear power station built after 1978 are due to increased regulatory requirements introduced over the previous ten years.

## III RELATIONSHIP BETWEEN COST AND RISK

All level of risk impose costs upon society due to deaths caused among the risk receivers. In addition, costs are incured by risk imposers in response to whatever standars of safety are introduced by the government agency.
These risk-reducing response normally involve changing methods of production or reducing output.
The extra costs incurred are real costs to society, not just transfers from one group to another.

The two sets of cost are shown in figure III.1.

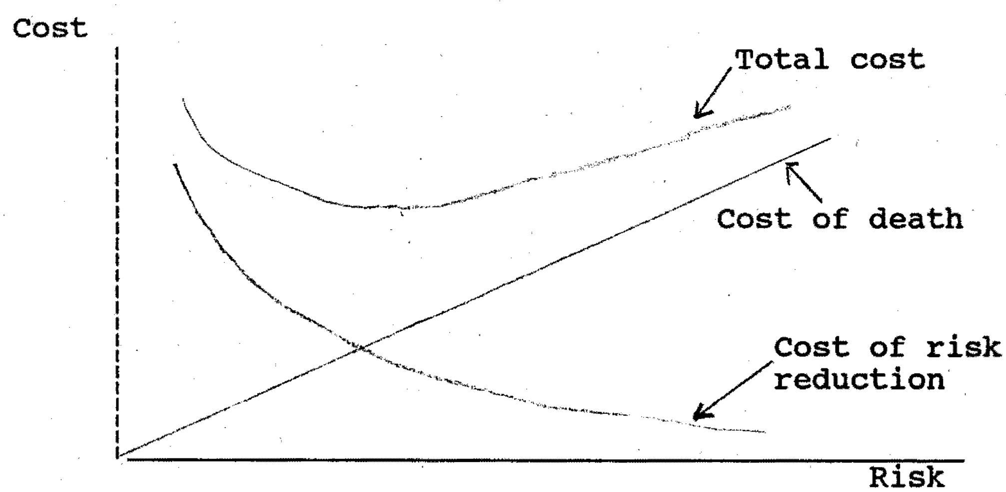


fig.III.1.

The level of risk that the government permits an industry to impose is shown along the horizontal axis. The lower this level, the lower the costs due to deaths amongst he risk receivers, and the higher the costs due to risk reduction response amongst the risk imposers, and vice versa. The total cost to society is the sum of these two sets of costs (e.g.,[4]).

## IV ESTIMATION OF THE OPTIMUM LEVEL OF RISK, GIVEN THE COST OF THEIR AVOIDANCE.

In free market economics, interpersonal trade in a commodity will only occur if it bring benefits to both sides and therefore society as a whole. Unfortunately, the lack of compensation mean that this reassuring conclusion does not hold for risk. Without outside intervention, the imposition of risk can increase far beyond the stage where net benefits to society are obtained. If there is an absolute lack of compensation and choice, risks will continue to increase until the risk imposers would get no extra benefit from a higher level of risk. Since the risk receivers will be incurring substancial extra disbenefits ( death being the ultimate disbenefit) from some of those risks, so too will society as a whole.

### 41 The optimum level of risk

Getting back to the model establish in part II, there is a level of risk where the total cost will go through a minimum. This level of risk is optimal for society as a whole. The government agency should design its safety standards or tax structure with the aim of ending up at this optimum level of risk(e.g.,[2]).

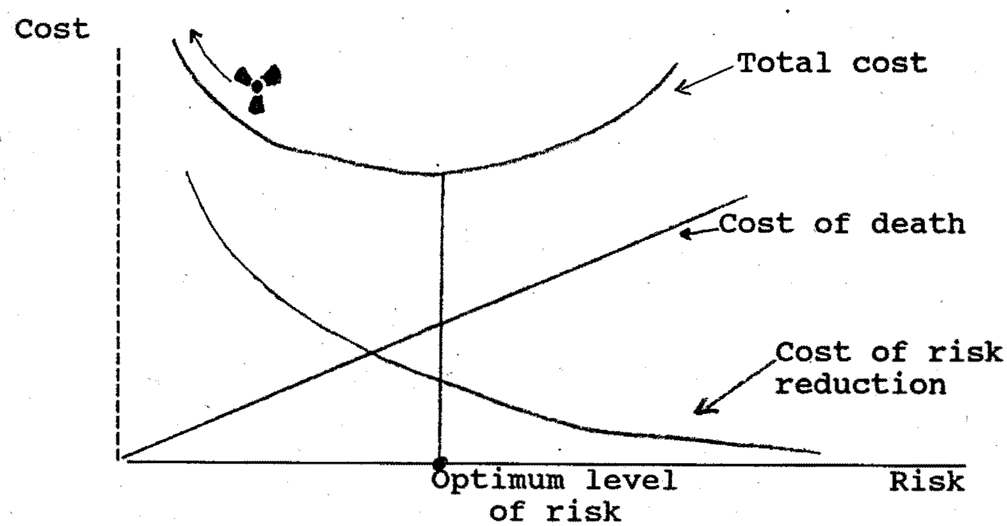


fig.IV.1.

This method of balancing conflicting objectives to achieve an overall optimum has great merit in many fields.
What happens if we try to fit nuclear power risks into this scheme?

On any sensible valuation, the safety standards presently achieved by operators of a nuclear plant, locate nuclear power on the rising part of the total cost curve as shown in figure IV.1.

For example, the valuation of each life saved would need to be somewhere between $18 million and $1000 million to justify present plans for burying high level waste in stable geological formations rather than continuing to dispose of it in deep ocean area.

The inexorable pressure from public and government is pushing nuclear power toward ever more stringent safety standards as shown by the arrow in figure IV.1. This pressure will continue to lead nuclear power further away from the optimum suggested by the economic theory of external costs, in exact contradiction to the prediction of the theory.

# V A CASE STUDY: HIDDEN COSTS OF THE ACCIDENT OF THREE MILES ISLAND

One of the worse accident to have occured to date at a civil nuclear power station took place on 28 March 1979 at the Three Mile Island Unit 2 reactor in Pennsylvania, USA.
Coming as it did at a time when nuclear capital cost were continuing to show significant increases in real terms, and lead times were lengthening beyond the planning horizons employed by most utilities, the timing of the accident was particularly inopportune.

The accident itself is fully documented in the report of the President's Commission(e.g.,[5]). That the accident can seriously be regarded as major when no directly attribuable loss of life is ever likely to be apparent may be explained by considering the costs of the accident, both direct and indirect, some of which are listed below:

The direct cost of the clean-up operation at TMI-2 is estimated to be between $975 and 1034 million, figures which do not include provision for further decommissioning or reconstructing the stricken reactor. This is an unavoidable cost which was met in order to bring the reactor into a safe a stable condition.

The cost of writing off what was essentially a new reactor ( the total cumulative gross generation figure of 2126 GWh for TMI-2 is equivallent to 3 months full power operation, the accident taking place just one year after initial criticality). Current estimates of nuclear capital costs would put the figure involved somewhere in the range of $1000-3000 million. For the full cost to be attributed to the accident, it is necessary to assume that TMI-2 will never again be operated as a commercial nuclear power station and that no scrap or recovery value should be assigned to the plant. While the former is almost certain to be true, given the extent of damage to the plant, the second assuption is probably over pessimistic and some reduction to the capital cost figure should be made.

Marginal costs of replacement generation were met by the owners of TMI-2. These costs were significant, particularly as it was considered necessary to shut down TMI-1 immediatly following the accident. The undamaged TMI-1 plant remained non-operational four years after the accident.

The effect of the TMI accident has been to lower confidence generally in the nuclear industry, costs being associated with such an erosion of confidence for a number a reasons. For example, additional post-TMI regulatory requirements have led to increased construction times for stations currently being built. Such delays lead to increased costs.

There is another cost which may conceivably be laid at the door of TMI. If, in the period immediately after the accident, nuclear utilities world wide adopted a cautious approach and either shut down or de-rated reactors while investigations were made as to whether a similar accident might occur at their plant, then the costs of such action in term of replacement generation costs may be appreciable when summed over a large number of reactors.