TOMORROW'S ENVIRONMENTAL BENEFIT/COST ANALYSIS

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Paper to be presented May 17, 1973, at Oregon State University, Corvallis, Oregon.

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J. B. Burnham

In this country today, we are attempting to improve our environment, but we don't really know how to go about the job. On one hand, we suffer a shortage of energy; on the other hand, we need more energy for the environmental cleanup. As if this situation were not distracting enough, we are faced with a further dilemma. While utility and government planners are trying to meet the diverse demands of power and environment using the best techno-economic methods at hand, the community social values are seldom considered in any more than an intuitive fashion. This failure is due primarily to two causes: the lack of a method for measurement of these social values and no means of integrating these values with the techno-economic assessment of alternatives.

At Battelle-Northwest, we are working under the sponsorship of the U. S. Atomic Energy Commission on new techniques for measurement of social values, for analysis of environmental impacts, and for the integration of this information into a matrix which will be of value to decision makers. This paper will describe the methods under development for the measurement of environmental effects, methods for evaluating the community's value judgments on these criteria, and the means for combining them into a useful decision tool. Finally, an example will be given of how such techniques can be used to solve difficult socio-economic problems.

Since the implementation of NEPA,¹ it has been necessary for every major construction project to file an environmental statement. In the course of writing many of these statements for utilities wishing to build nuclear generating stations and of reviewing others for the Atomic Energy Commission, we at Battelle-Northwest have become vitally aware of the number and

diversity of societal values that must be considered in any of these construction projects. The analysis of these values and the effort to balance one against another have made it very obvious that some of the values may be accurately quantified. In other instances, however, the existing techniques preclude our making anything other than qualitative statements about the relative ranking of alternatives. The usefulness of these statements would be markedly enhanced if all the criteria could be quantified in an objective, accurate fashion.

In quantifying various design attributes, there is a temptation to reduce all criteria to a single denominator - the dollar is a favorite unit. This approach works to a point but is doomed to failure as one starts to rate the aesthetic pleasantness of a plant design on a dollar scale. It soon became apparent to us that a more realistic approach to quantification lay in the derivation of dimensionless indices for each criterion. ~~If each criterion can be compared with some~~ norm, the resulting dimensionless number is a measure of the relative excellence of a design or site for that particular attribute. This scale, if properly constructed, has the further advantage of being subject to most mathematical manipulations.

The selection of criteria to use in the analysis involved considerable research into the environmental statements already written, proposed guidelines for the preparation of statements, and the intervenors' actions filed against proposed plants. These last statements were considered because they are an indication of the items of social concern. Since the eventual goal of our project was the derivation of quantified technoeconomic criteria that could be weighted by social judgment factors, it was important to choose the criteria on compatible technical and social bases. There was a functional requirement that the criteria include all of the major design considerations and exclude (or consolidate) the trivia. It was considered desirable that the criteria be roughly of the same importance

magnitude. One could envision serious difficulties in using two such highly disparate criteria as "human safety" and "displacement of kangaroo rats". To all but kangaroo rat buffs, a more reasonable designation for the latter criterion would be "ecological impact". Finally, the criteria have to be mutually exclusive. If they cannot be designed and analyzed in such a way as to insure this quality, their mathematical significance will be seriously impaired. The criteria selected are as follows:

- Aesthetic Impact
- Land Use
- Economic
- Water Impact
- Air Impact
- Cultural
- Health and Safety
- Ecological Impact

It is obvious from this list that the goals of quantification and mutual exclusivity will be realized only through serious effort.

The two criteria, "aesthetic impact" and "land use", are the first to be quantified. A landscape architectural firm, Jones and Jones of Seattle, was engaged as a consultant to assist in the quantification of aesthetics. They have to perform a number of subtasks to reach this goal. These include: develop a method for describing a site in quantitative landscape terms, classify the physical appearance of the structures to be built, establish the visual absorptive capability of a site, determine the spatial limits of potential visual contact, determine and rate the degree of visual change caused, determine the total potential population/facility visual contact, and

combine these factors into an aesthetic rating value. Peer groups (architects and planners) will be utilized to establish internal weighting factors for the various evaluation criteria. The norm against which changes will be measured will probably be the "viewshed" as it exists before any construction has started. This technique is very similar to that used by Drobny² at Battelle-Columbus.

Land use is being quantified through a comparison with a real (or contrived) regional land-use plan. The "region" to be used in this analysis must be picked with some care. There are some obvious topological, economic, and visual considerations in the selection of the "region". It should include, but not be limited by, the area from which the plant can be readily seen. If it is part of a contiguous zone, all of that zone should probably be included. At this point in time, a region of some five miles' radius around the plant is being envisaged. Subtasks in this project include: the classification of important land usages by major use, definition of the region to be considered, identification of the physical characteristics to be used in evaluating land suitability, development of land suitability ratings for each land use, review of land-use plans for the region, and development of a land-use rating index.

When these two criteria have been successfully quantified, the remaining six will likewise be developed. In each case, a multidiscipline effort will be required to insure a comprehensive approach that reflects the best judgments of experts in the field.

The social psychologists at Battelle's Human Affairs Research Center in Seattle have been instrumental in the development of the societal measurement, using an indirect technique for determining the relative importance attributed by the public to the eight criteria discussed earlier. Present efforts are being concentrated on finding out what language will make each of these criteria clearly understandable to

laymen. They are also working with the landscape architects to develop visual aids that will help describe the site and design alternatives.

The results of the survey will be analyzed through regression analysis. This will produce "beta weights", which are measures of the weighting attributed to each criterion by the sampled populace. This factor, when multiplied by the techno-economic rating derived for that criterion, will yield a composite measure of each site (and design). The results can be used in this manner, or if all the criteria have been scaled properly, they may be added into a single composite score.

The evaluation matrix for the combined social and technical analyses would look like the one shown in Table I. In this scoring system, a high number is a large impact; hence undesirable. Although this example is purely hypothetical, one could imagine a decision being made on only ecological impact in favor of Design A. If the community valued this particular environmental effect far higher than any of the others, this would probably be a sound choice. Under the example conditions, though, the community weights such factors as "water impact", "air impact", and "health and safety" high on their scale of values. Under this set of circumstances, Design B would be preferred. Alternative sites as well as design options can be analyzed in the same manner.

In the measurement of any community, it will be necessary to understand the power structure of that group. A determination of the subgroups to be sampled must be made. Likewise, statistical sampling and analysis will be required to obtain the maximum information at minimum cost. Eventually, it is hoped that the technique can be tested in three situations. The first of these is a pristine site. This will be the real proof of the technique's ability to measure community social values and to integrate these into a technical design scheme. This composite approach should identify the best and most acceptable

TABLE I
EVALUATION MATRIX

	Societal Weighting Factor	Techno-economic Scoring		Weighted Scoring	
		Design A	Design B	Design A	Design B
Aesthetic Impact	0.2	90	60	18	12
Land Use	0.4	80	50	32	20
Economic	0.4	90	40	36	16
Water Impact	0.7	30	70	21	49
Air Impact	0.5	40	30	20	15
Cultural	0.3	50	40	15	12
Health and Safety	0.9	40	30	36	27
Ecological Impact	0.1	30	80	3	8
Composite Score				181	159

alternative. The second area that should be tested is one in which a nuclear plant is almost complete. While community positions will have already been polarized, this measurement will lead to the third measurement two or three years later in the same community. This will establish the time dependence of some values. Certain criteria are known to change with time. Aesthetic sensitivity, for example, is known to decrease with time. The change with time in the attitude of Chicagoans toward the Picasso statue in the Loop is an excellent example of this effect.

At present, the survey instrument is being tested for sensitivity with two highly selective populations that may be expected to have different value judgments. The differences and statistical variance of the responses from these two groups should be highly informative.

While the techniques described above will, hopefully, ease the task of designing and obtaining acceptances of new plants, there are still detailed socioeconomic problems in plant design that need solution. Although it is a commendable goal to protect the citizenry from all risks, no matter how small they may be, this is a hopelessly expensive proposition. A plant designer is constantly faced with the question of, "How safe is safe enough?"

The intelligent management of risks requires that they be analyzed in a logical, objective manner. The acceptability criterion of risk should be premised on the attendant benefits to be expected. Synthetic (or man-made) risks must first be regulated at a level such that society is protected from all hazards that are of the same magnitude as disease mortality (about 10,000 deaths per year per million people). If risks of this order are allowed, the populace will be subjected to a significant shortening of life. The limits of involuntary risk, no matter how small, should be set commensurate with the benefits of the causative operation. Decision makers should always be

encouraged to design and operate at levels even lower than those set by regulation. In fairness to the public that must pay the cost of this increased protection, however, the expenditures required to decrease risk below a regulated level must likewise be analyzed on a benefit/risk basis.

In the past, few of these decisions have been made on an objective basis. They are often determined under highly emotional adversarial conditions where rationality has little chance to function. There are now methods available for analyzing these difficult problems. The widespread recognition and utilization of these techniques would certainly decrease the chaos now facing most industry and government agencies involved with public health.

The science of analysis of public risk has been formalized in recent years. Figure 1 is taken from a recent publication by Starr³ and illustrates an envelope of risks that have historically proven to be acceptable by the populace. Those risks falling below and to the right of the curve are generally acceptable.

Although analysis of risk to human health can be analyzed on a scientific basis, there are still many anomalies that appear in the area of public risk. The public in the past has unknowingly accepted finite risks that have had almost no attendant benefits. For example, for many years, certain manufacturers of baby food have been adding monosodium glutamate even though this chemical is known to cause hypothalamic cell damage. If the babies had any sense of taste, one might rationalize the desirability of such an addition. However, since babies are several years old before they develop taste buds, this additive has essentially zero benefit. Such practices have helped produce a class of protesters so adamant about additives that they advocate a policy that forbids the addition of any new substances to the biosphere, regardless of potential benefits.

Figure 1. Benefit/Risk Pattern for Involuntary Exposure³

In considering public health risks, one must divide these risks into those of an involuntary nature and those of a voluntary type. The public has traditionally accepted of its own volition such activities as private flying, skiing, hunting, etc.; these demonstrate risks at least two orders of magnitude greater than those the public has been willing to accept on an involuntary basis. To quote Chauncey Starr: "...we are loathe to let other do unto us what we happily do to ourselves."⁴

A glaring example of a large population which is taking risks several orders of magnitude greater than most industry-created ones can be found in the Bay Area of California. A population of 4.7 million is living and working between two major faults - the San Andreas and the Hayward. The probability (based on rock strain measurements) of major movement on one or the other of these fault systems before the turn of the century approaches one. The United States Office of Emergency Preparedness has constructed a number of disaster scenarios on the basis of a magnitude 8.3 earthquake (equivalent to the 1906 San Francisco quake). The deaths in such an event are predicted to range from 3,000 to 100,000, depending upon the time of day, the failure or nonfailure of dams, etc. If we assume 10,000 deaths in this accident and a probability of one that it will occur within the next 27 years, we calculate a risk of 80 deaths per million people per year. This risk estimate could be high by a factor of about 3 or low by a factor of 10. There seems to be a willingness by the public to accept the danger of catastrophic natural events; whether this is based on an "act of God" philosophy or "it can't happen to me" reasoning is immaterial. The fact remains that a large, measurable risk is being essentially neglected by the populace and the regulatory bodies.

In contrast to this unconcern, the same populace was very aroused over the threat of nuclear reactors, lead from gasoline, and the use of other chemicals. They went so far as to propose that all nuclear plants, and even the manufacture of their components, be banned from the state.⁵ In June of 1972, one out of every three California voters was in favor of this proposition. When we consider the risk from a 1,000 MW_e nuclear plant, we find that Starr, Greenfield, and Hausknecht³ calculated it to be 0.1 death per year per million population. Since new reactors will tend to be distributed throughout the state for technical and economic reasons, the construction of additional reactors does not increase the population risk proportionately. This conclusion is borne out by a recent AEC study.⁶ The insouciance of the electorate over the earthquake risk is impossible to reconcile with the furor over the threat of nuclear reactors when the former is several orders of magnitude greater than the latter. We can only surmise that the voters have a grossly distorted understanding of risks in general and benefit/risk analysis in particular.

In the analysis of risks, it is important to recognize the difference between internalized and externalized risks. While in fossil-fueled generation plants, there are a number of risks which through tradition or oversight are externalized, the nuclear industry has from its inception internalized most of its risks. This means that nuclear power generation costs include essentially all the expenses of minimizing risk.

A specific example of how systems may be analyzed on the basis of benefit/risk can be seen in Figure 2. Figure 2 is a plot of radiation dosage to the surrounding populace within a 50-mile radius of the Calvert Cliffs nuclear plant.⁷ Also shown is the exposure to the populace that can be expected from natural radiation sources. The numbers shown represent various designs for the radiation waste (radwaste) treatment system. Number 1 represents the situation with no radioactive waste

Figure 2. Cost and Resultant Population Dose, Including Natural Background, of Present and Alternative Processing Systems

processing system. Number 2 represents a system without evaporators in the reactor coolant processing system or the miscellaneous waste processing system. Number 3 represents the plant system as it exists today. The other numbers are various combinations of extra evaporators, recycling systems, and a cryogenic system to condense the radioactive gases. When plotted on a scale such as this, it becomes evident how close to natural background radioactive wastes are controlled.

Table II shows some of the incremental population dosages caused by the radwaste systems and their associated costs. As can be seen, each additional level of treatment has a slight extra measure of protection inasmuch as the population exposure is slightly reduced. The capital costs for each additional system are also shown. The data in the table overstate integrated population exposure because the population figure for the year 2010 was used. In actuality, the annual population exposure will rise slowly up to the value used as the population builds up. By going through a very lengthy conversion of population exposure to fatalities and by factoring in a value of life, one can derive a range of values per unit of exposure (man-rem). The particular number to be used for the value of one unit of exposure is a rather argumentative one as a result of the multiple factors that go into its derivation. Various researchers have derived values from approximately \$10 per man-rem to about \$1,000 per man-rem. Otway has assembled these estimates; Table III is taken from his work.⁸

Sagan, in a 1972 article,⁹ derived a value of \$30 per man-rem on the basis of somatic effects. Lederberg has pointed out that the genetic burden of radiation is often underestimated.¹⁰ Using a technique based on the total national health costs, Lederberg derives a cost of \$100 per man-rem. Using Gofman's and Tamplin's estimates (which he does not particularly endorse) of radiation-caused cancer deaths, he deduces by the same logic an outside value of \$600 per man-rem. The most widely accepted

TABLE II

BENEFIT/COST ANALYSIS OF CALVERT CLIFFS' RADWASTE SYSTEM

<u>System Number</u>	<u>Population Annual Exposure (man-rem/yr)</u>	<u>Integrated 30-Year Exposure (man-rem)</u>	<u>Exposure Cost @ \$300/man-rem (\$ millions)</u>	<u>Total System Cost (\$ millions)</u>	<u>Benefit/Cost Ratio</u>
1	25,699	771,000	231	0	
2	289.4	8,680	2.61	7.82	29
3	30.76	923	0.277	8.60	3.0
10	29.76	893	0.268	9.13	0.017
11	11.78	353	0.106	14.5	0.030
12	10.82	325	0.0974	14.7	0.043

TABLE III
VALUE OF RADIATION RISK

	<u>\$/man-rem</u>
Cohen	250
Hedgran and Lindell	200
Dunster	~10
Lederberg	100-600
Otway	200*
Jury Awards	~250*
Future Earnings	~200*
Hazard Pay	135-980*
FAA Estimate	373*

*Inferred from life-value estimates.

estimates of the total cost of radiation risk seem to fall in the range of \$30-\$300 per man-rem; the higher, and admittedly conservative value, has been used in this analysis.

The last column of Table II shows the benefit/cost (or benefit/risk) ratio for the various alternative radwaste systems. With the values assumed, it is clear that the present radwaste system is conservatively designed. On the basis of the analysis, the addition of even more protective devices would have to be termed fiscally irresponsible.

A short-term financial argument has been presented at times for the addition of maximum protective devices. This rationale claims that the various intervenors around the country will be pacified by the installation of maximum protective systems. Since delaying a plant such as Calvert Cliffs can cost a utility at least \$90 million per year of delay, it is argued that the

expenditure of \$6 million for maximum protective devices is a sound investment. In the overall societal allocation of resources, this logic has no merit because it is based on short-term political expediency.

Such analyses may be called heartless and cold-blooded. This is a fatuous criticism because innumerable value judgments such as this are made every year both by corporations and individuals. Anyone who owns a life insurance policy has, consciously or not, made use of such reasoning. The significance of this logic is that it affords the decision makers, both corporate and governmental, the tools with which to measure their societal necessities. Likewise, it gives them and those who would audit them the means of differentiating between social responsibility and fiscal irresponsibility.

REFERENCES

1. National Environmental Policy Act of 1969. Public Law 91-190.
2. H. L. Drobny, "Social Accounting in Environmental Planning," Presented at Seminar on Corporate Social Accounts, Battelle Seattle Research Center, Seattle, Washington, November 10-11, 1972.
3. C. Starr, M. A. Greenfield, and D. F. Hausknecht, Public Health Risks of Thermal Power Plants, UCLA-ENG-7242, May 1972.
4. C. Starr, "Social Benefit Versus Technological Risk," Science, CLXV, September 1969.
5. State of California Ballot, Proposition 9, June 1972.
6. "The Potential Radiological Implication of Nuclear Facilities in the Upper Mississippi River Basin in the Year 2000," WASH 1209, U. S. Atomic Energy Commission, To Be Issued.
7. Baltimore Gas and Electric Co., Supplement to Environmental Report Calvert Cliffs Nuclear Power Plant, November 1971.
8. H. J. Otway, "The Quantification of Social Values," Presented at symposium entitled Risk Versus Benefit Analysis: Solution or Dream? Los Alamos Scientific Laboratory, Los Alamos, New Mexico, November 1971.
9. L. A. Sagan, "Human Costs of Nuclear Power," Science, CLXXVII, August 1972.
10. J. Lederberg, "Squaring an Infinite Circle," Bulletin of the Atomic Scientists, September 1971.