Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987.

Assessing Subjective Preferences for Future Fire Research[1]

James B. Davis[2]

Abstract: Methods are described for making comparative valuations of future fire (or any other) research efforts when the benefits that result from some of the efforts cannot be described in dollars. The process helps research managers and scientists set priorities by using the values and beliefs of skilled fire specialists. The objective is to insure coherent decisions consistent with stated values. The process has application in decision problems faced by all executives and has been tested in a variety of forestry applications.

In terms of forestry and fire control, the year 2000 has already arrived. The near future is committed by today's decisions about how long-range research programs are proposed and how constraints are imposed. Just as forest management plans shape the size and timing of harvesting operations far into the future, so the networks of research paths, priorities, and long-term investments in fire research and allocation of resources among research areas determine the fire prevention and management technology of the early 21st century.

This paper describes methods to set priorities among research, development, and application efforts by using subjectively derived benefit scores and projected costs. The methods have been used several times in a variety of research priority evaluations (Davis and Shafer 1984, Shafer and others 1977, USDA Forest Service 1981). For example, the technique for determining benefit scores was used in the Forest Service's program analysis for the 1985 Resource Planning Act (RPA) and was also tested in the pilot study described in this paper. However, as far as I know, the methods have not been previously reported in the fire related literature. In the example described, these techniques are used to set priorities on several possible research and development efforts for dealing with the fire problem at the wildland/urban interface. The methods are a set of several possible techniques to analyze attribute values subjectively.

Although the loss of structures to wildfire is not new, the potential for fire loss is increasing dramatically as more people build their homes and live in proximity to flammable forests and woodlands. So rapid has been the build-up that, in some parts of this country, homes and other property exposed to wildland fire have increased fourfold during the past 5 years.

The problem is national in scope. Fire protection agencies, homeowners, builders, developers, and local planning agencies all share responsibility in finding ways to reduce this existing and potential loss of property and life (Davis and Marker 1987). Solutions range from effective application of what we already know, such as limitations on flammable building materials, to the need for new research in the many areas where our knowledge is limited.

THE PROBLEM OF SETTING PRIORITIES

Usually, there are never enough dollars or other resources to go around. Inevitably.

---

[1]Presented at the Symposium on Wildland Fire 2000, April 27-30. 1987. South Lake Tahoe, California.

[2]Research Forester. Pacific Southwest Forest and Range Experiment Station, Forest Service. U.S. Department of Agriculture, Riverside. California

research (and fire) managers must set priorities on projects or efforts that cannot be evaluated through conventional analysis. I want to emphasize that subjective techniques are not a substitute for measurement when it is possible. But, for example, fire commissioners may have to choose between alternate fire station locations, or a forest fire protection officer may need to find a balance between fire suppression and prevention when developing an annual budget. In such cases, precise measurement may not be obtainable, yet expert opinion is. In the pilot study discussed in this paper, the problem was where to concentrate scarce research and management dollars.

A DESIGN FOR SETTING PRIORITIES

The design described does not make decisions or portend what to decide. Rather, it helps managers to decide what the priorities should be by using, and making explicit, a consensus of values and beliefs. The objective is to ensure coherent decisions consistent with stated values (Kahn and others 1964, Richards and Greenlaw 1972).

The design involves seven steps:

1. List the items to be evaluated. The list should include all of the options available to the decision-maker, such as a list of the major equipment that might be purchased over the next few years.
2. Select a panel of objective evaluators who are expert on the subject.
3. Survey the panel to evaluate the items in terms of their overall benefits.
4. Compute benefit scores.
5. Estimate the costs.
6. Compare initial benefit scores and costs.
7. Adjust benefit scores to reflect management's values and beliefs.

Each step is described below, using data obtained in a pilot survey of fire managers and foresters familiar with the wildland/urban interface problem.

List the Items

In developing a problem analysis to define research needed on the wildland/urban fire problem, I needed to arrange the following nine research efforts--A through I--in order of their priority, based on each effort's overall benefits and estimated costs as perceived by fire experts:

A--Fundamental or basic knowledge about the physics of spotting and crowning in the urban/wildland interface and the development of fire behavior prediction models.

B--Effective ways to educate property owners, land developers, insurance carriers, and local planners about the problem.

C--Knowledge about relationships of building design, materials, and landscaping to fire hazard and behavior.

D--Aids for planning and budgeting, and training fire control personnel for increased involvement in both structural fire protection and wildland fire control. (How can local, state, and federal fire control forces be used more efficiently?)

E--Methods and systems to economically and efficiently measure and evaluate the risk and hazard over broad geographical areas.

F--Strategies to manage fuel hazard in the urban/wildland area such as mechanical clearing of vegetation, application of herbicides, and prescribed use of fire.

G--Methods to incorporate social, political, regulatory, and other factors in an overall economic understanding of fire protection investments. Fire protection investments are complex and considered "non-linear" by economists, who frequently don't get as much return on an investment at all investment levels. Research would include determining who pays. (Are insurance premiums and disaster loans inadvertently subsidizing high risk construction?)

H--Information on the selection of low growing or fire resistant vegetation for landscaping or greenbelt construction including maintenance and management strategies. (Who pays the cost?)

I--Information on the feasibility, costs. and benefits of engineered hazard reduction systems such as sprinklers (possibly using sewage effluent), road system design, and the possible use of flame or heat barriers and deflectors in critical areas.

We used a volunteer panel and consequently tried to make the task descriptions as succinct as possible in a short paragraph of text. The degree of generality or specificity in the item description was kept as uniform or as parallel as possible. This is essential in a full scale study, and a great deal of care must be taken in preparing the text. Obtaining professional editorial or copywriting help is probably essential.

An important limitation on the ratio-scaling method described in this paper is the practical limit on how many items can be compared. The equation is

$$f = \frac{n(n-1)}{2}$$

where "f" is the number of paired comparisons and "n" is the number of things to be compared. In this wildland/urban interface study, "n" equaled 9; consequently, there were 36 comparisons--about as many as one can expect from a panel of busy people.

Select a Panel

The second step is to select a panel of knowledgeable people to judge the importance of the items to be evaluated. The number to include in the panel depends on the variation in the subjects to be considered. There is always the question about how much time an expert panelist will spend in studying and understanding the issues to be compared. There is a tradeoff between a small group of "committed" panelists and a larger group, who can bring a wide range of insight to the analysis but who may not wish to spend much time on it.

The panel consisted mostly of foresters and fire managers attending the California-Nevada-Hawaii Fire Council meeting in Reno, Nevada, in fall 1986. The principle subject of the meeting was the wildland/urban interface fire problem and all panelists had 2 days of discussion about the subject prior to the survey.

Conduct a Survey

At the end of the conference, 75 participants were given a 10-page "ratio scaling" questionnaire to take home and fill out at their convenience. Forty-five returned them. The technique required each participant to divide 100 points according to personal preference over each of the 36 possible pairs of the nine research efforts being evaluated. In each pair, the 100 points were divided into a proportion of the greater to the lesser effort. For example, a participant might assign 60 points to effort A and 40 points to effort B if he or she believed that A was in the ratio of 60 to 40 or 3 to 2, with B. The average participant took about half an hour to complete the questionnaire.

Compute Benefit Scores

Table 1 shows the average number of points from 100 assigned to the research efforts listed from A to I across the top of the table in their comparisons with the efforts listed down the left side of the table (Torgerson 1958, Edwards 1957). For example, "Education of property owners, land developers, etc." (effort B) received an average of 51.98 points when it was compared with "Methods to incorporate social and other factors" (effort G). Methods to incorporate social and other factors, on the other hand, received 100 minus 51.98 or an average of 48.02 points in the same comparison.

Table 1--Average points assigned in comparative judgement (While the methodology does not yield accuracy to the second decimal place, serious rounding errors result if decimal places are reduced.)

Research effort	A	B	C	D	E	F	G	H	I
A	----	71.86	64.30	59.65	49.88	67.21	64.77	61.40	52.67
B	28.14	----	43.49	42.21	35.70	43.84	48.02	41.40	33.37
C	35.70	56.51	----	48.02	43.26	49.53	55.93	50.47	36.86
D	40.35	57.79	51.98	----	41.98	53.84	55.23	51.86	38.02
E	50.12	64.30	56.74	58.02	----	59.77	61.40	57.21	47.79
F	32.79	56.16	50.47	46.16	40.23	----	55.23	48.72	37.91
G	35.230	51.98	44.07	44.77	38.60	44.77	----	41.28	35.58
H	38.60	58.60	49.53	48.14	42.79	51.28	58.72	----	41.28
I	47.33	66.63	63.14	61.98	52.21	62.09	64.42	58.72	----

Table 2 shows the ratio of points between efforts B and G (i.e., 51.98/48.02=1.08) and has been rearranged so that the efforts are listed across the top in order of importance as judged by the number of points they received. Thus "Effective ways to educate property owners, land developers, etc." (B) received the most points and "Fundamental knowledge about the physics of crowning and spotting" (A), the least.

The next to the bottom row in table 2 shows the sums of the ratios in each of the columns (i.e., 13.80 is the sum of the ratios in the first column). If these sums are in turn summed across the next to bottom row the total amounts to 86.04 points for all of the research efforts.

In the last row of table 2, the benefit values have been normalized so that they sum to 1000 (i.e., the normalized value for B is 13.80/86.04 x 1000 = 160). These normalized benefit values are used in the tables and figures that follow.

The following overall results were obtained:

Research Effort	Score
B--Education of property owners, developers, etc.	160
G--Methods to incorporate social and other factors.	141
C--Knowledge about building design and materials.	122
F--Strategies to manage fuel hazard.	118
H--Low growing and fire resistant vegetation.	114
D--Aids for budgeting and training fire crews.	113
E--Methods to evaluate risk and hazard.	83
I--Information on engineered hazard reduction systems.	77
A--Basic knowledge about spotting and crowning.	72

As frequently happens, this pilot study raised more questions than it answered:

Would the scores have been the same in other parts of the nation?

Would the scores have been the same if the questionnaire had been taken prior to the meeting--were the judges unduly influenced by the presentations?

How would homeowners who had never been involved with forestry or fire departments have responded?

What would have been the scores of a statistically sufficient group of builders, planners, and insurance carriers?

Table 2--Example of how benefit scores were calculated for nine research efforts showing ratios of points assigned in comparative judgment (Judgement scores are reorganized in decreasing order). Diagonal cells are all 1.00 (X/X=1.00). Normalized scores sum to 1000.

Research effort	B	G	C	F	H	D	E	I	A
B	1.00	0.92	0.77	0.78	0.71	0.73	0.56	0.50	0.39
G	1.08	1.00	0.79	0.81	0.70	0.81	0.63	0.55	0.54
C	1.30	1.27	1.00	0.98	1.02	0.92	0.76	0.58	0.56
F	1.28	1.23	1.02	1.00	0.95	0.86	0.67	0.61	0.49
H	1.42	1.42	0.98	1.05	1.00	0.93	0.75	0.70	0.63
D	1.37	1.23	1.08.	1.17	1.08	1.00	0.72	0.61	0.68
E	1.80	1.59	1.31	1.49	1.34	1.38	1.00	0.92	1.00
I	2.00	1.61	1.71	1.64	1.42	1.63	1.09	1.00	0.90
A	2.55	1.84	1.80	2.05	1.59	1.48	1.00	1.11	1.00
Sum	13.80	12.11	10.46	10.17	9.81	9.74	7.18	6.58	6.19
Normal score	160	141	122	118	114	113	83	77	72

Estimate the Costs

Perceived benefits from research are only half of what is needed to set priorities (Sinden and Worrell 1979). One also needs to know what the research might cost. In the following example, I estimated costs covering a 5-year period as part of my preparation of a research problem analysis. In general practice, experienced persons should estimate the cost of the effort without being influenced by benefit scores. For example, in the RPA analysis, separate groups were used to determine costs and benefits.

The cost "stream" over the life of the effort is discounted to present worth--the money needed today to fund the research over its life span. The rate of interest should be based on current economic trends. Only efforts with similar time frames should be compared. An effort that will be quickly terminated, or one for which funding will be delayed, usually should not be compared with the others.

Compare Initial Benefit Scores and Costs

Each effort is then ranked and plotted according to benefit scores to form a benefit-only criterion curve (table 3, fig. 1). That is, the research effort with the highest benefit score (in this case B) is plotted first, against its cost. The research effort with the next highest benefit score (G) is plotted second, in a cumulative manner, etc., until all efforts are arranged along a curve (fig. 1).

Research efforts are also plotted by a benefit-cost criterion (benefit score/cost). In this case, C is plotted first because it has the the largest benefit-cost value (table 3). G is next, etc. (fig. 1). The two resulting curves provide data that can be used along with other considerations for making decisions under various cost constraints, about program content and the priorities within those programs. As figure 1 shows, the benefit-cost criterion curve always provides the same or more benefits for a fixed research investment. For example, if a

Table 3--Initial and final result, after fine tuning the benefit scores, of the nine research efforts

Research Effort	Initial Results			Final Results	
	Discounted Cost (Thousands)	Initial Benefit Score	Initial Benefit/ Cost Ratio	Final Benefit Score	Final Benefit/ Cost Ratio
B. Educate					
B. Educate Owners Etc.	200	160	0.80	217	1.09
G. Social and Political	150	141	0.94	117	0.78
C. Building Design	100	122	1.22	101	1.01
F. Fuel Hazard	500	118	0.24	187	0.37
H. Fire Resist. Vegetation	350	114	0.33	94	0.27
D. Planning Budgeting	200	113	0.57	93	0.47
E. Measure and Evaluate	300	83	0.28	68	0.23
I. Costs and Benefits	450	77	0.17	64	0.14
A. Spotting and Crowning	750	72	0.10	59	0.08
Totals	3000	1000		1000	

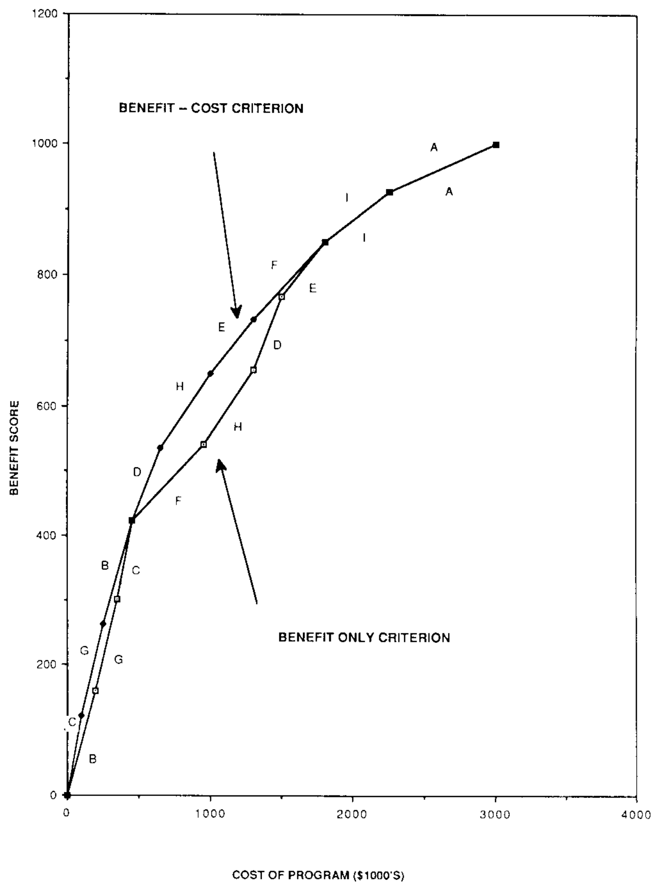

Figure 1--Initial comparison of benefit cost vs. benefit only criterion.

research program budget for urban/wildland research is set at $1,000,000 (discounted cost stream over 5 years), a program that contains research efforts C. G. B, D and part of H--with a total benefit score of 650--might be preferred over a program with research efforts B, G. C. and F--with a total benefit score of only 560 (fig. 1)--even though B was the highest priority research when only benefits were considered.

Adjust Benefit Scores For Management

The primary advantage of this method up to this point is that it provides an organizing framework for analyzing complex situations. However, since management is responsible for content and success of its research program, final decisions on content and benefits of that program is their responsibility. Management may wish to adjust initial results based on social, political, economic, or scientific information that may not have been evident or important to panel members.

The system permits a systematic method whereby management, if it wishes, can examine and may change benefit scores (and thus the location) of efforts along the benefit-cost criterion curve (Armstrong 1979). The only constraint is that regardless of the number of changes made, the sum of the benefit scores must equal 1000. For example, if management wants to increase the benefit scores of one effort, it must reduce the value of another or others, by an equal amount. Shafer and I have used the following adjustment process several times and believe that it should be adaptable to many research situations:

Management compares the program containing efforts C and G on the benefit-cost criterion curve with B on the benefit-only criterion curve. B costs almost as much as C and G together, but C and G have about 1 1/2 times the benefit score value as B. However, management may believe that B is more important than C and G, regardless of what the data suggests (table 3). So, B's benefit score is adjusted--let us say to 263 to make it equal in value to C and G. The reason for the change is documented, and the scores of all the other efforts along the curve are adjusted (that is normalized) so that their sum equals 1000.

Next, management observes that the group of effort including C. G. B, D and H on the benefit-cost criterion curve has a higher total benefit for the same cost, than the group including B, G, C and F on the benefit-only criterion curve. Since B, C, and G are common to both groups, and if there are no interdepences [sic] among the research efforts, F can be compared with D and H. Let us assume management wants F's score changed to 205 to match the value of D and H. The change is made, the data is renormalized, and the adjustment process continues until management is satisfied with the final benefit scores for all efforts. Final benefit-cost data are computed (table 3), and a final set of curves are determined (fig. 2).

Figure 2 shows the nearly optimal order of investment for a dissimilar mix of effort. Note in figure 2, that for any arbitrary limit on cost, the best mix is defined. For example, if the 5-year budget is $1,000,000 then the best investment strategy is B, C. G, D. and part of F.

Note that the benefit-only criterion curve has now been raised so that it more nearly follows the more optimal benefit-cost curve.

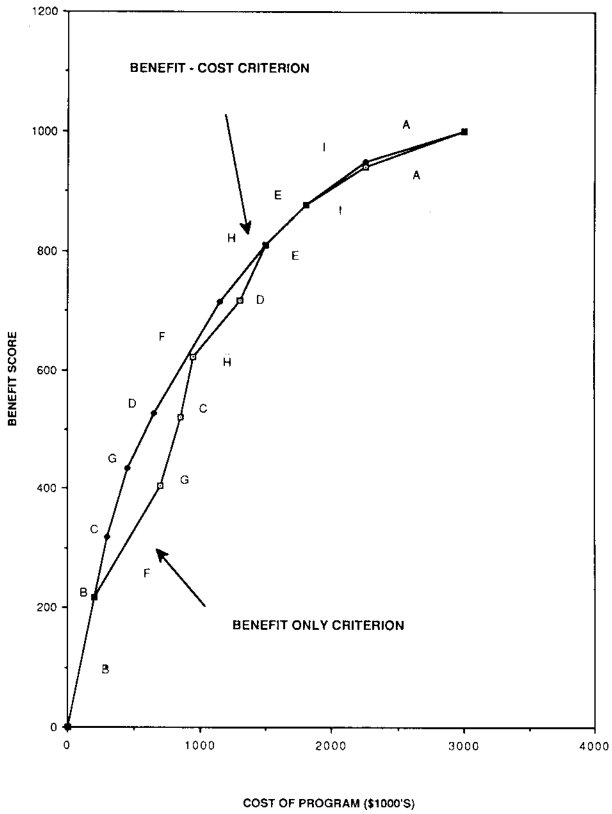

Figure 2--Final comparison of benefit cost vs. benefit only criterion.

This is the usual result of the management adjustment procedure.

In conclusion, the ratio-scaling and criterion adjustment system tied together worked well in evaluating intangible or at least incommensurable values in several studies including the RPA process.

However, a word of caution if you plan to use this methodology. Great care must be taken in preparing questionnaires and in analyzing results. In addition, the system will probably be unfamiliar to most of the participants so considerable effort must go into explaining and interpreting methodology and conclusions.

REFERENCES

Armstrong, Anne A. 1979. Decisions by design. Information World December: 24-25.

Davis, Jim; Marker, John. 1987. The wild land urban fire problem. Boston: National Fire Protection Association; Fire Command 54(1): 26-27.

Davis, J. B.; Shafer. E. L. 1984. The use of paired comparison techniques for evaluating forest research. Proceeding Soc. American Foresters. Portland, OR. 4 p.

Edwards, Allen L. 1957. Techniques of attitude scale construction. New York: Appleton-Century-Crofts, Inc.; 256 p.

Kahn, Robert; Wolf, Donald M.; Quinn. Robert P.; Snoek, J. Diedrick; Rosenthal. Robert A. 1964. Organizational stress: studies in role conflict and ambiguity. New York: John Wiley and Sons, Inc.; 470 p.

Richards, Max D.; Greenlaw. Paul S. 1972. Management decision and behavior. Homewood, IL: Richard D. Irving, Inc.; 655 p.

Shafer, Elwood L.; Moeller, George H.; Getty, Russel E. 1977. Future recreation environments. IS-316. Washington. DC: Forest Service. U.S. Department of Agriculture; 16 p.

Sinden, J. A.; Worrell, A. C. 1979. Unpriced values--decisions without market prices. New York: John Wiley and Sons. Inc.: 511 p.

Torgerson, W. S. 1958. Theory and methods of scaling. New York: John Wiley and Sons. Inc; 460 p.

USDA Forest Service. 1981. Criteria for deciding about forestry research programs. Washington, DC: General Technical Report WO-29. 52 p.