Decision Support Methods for Prescribed Fire

Final Report
Joint Fire Science Program
RFP 2001-1, Task 7

Project # 01-1-7-14

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December 15, 2005

RMRS Agreement No. 02-JV-1122131-012

INTRODUCTION AND OVERVIEW

As federal land management agencies move into the 21st Century, one of the most challenging issues they face is the management of fuels to achieve ecological objectives and to influence the potential for catastrophic and uncharacteristic wildfires. At a broad policy level, a number of frameworks exist that provide guidance to local units about the desired future condition of forest ecologies as well as the potential role that fire can play in achieving and maintaining these conditions. However, local units often have to consider other objectives in the design of fuel management programs. For example, local community social values and economic objectives often need to be considered as part of program design. Likewise, fuel management must also take account of the escape risk associated with fuel management programs that incorporate prescribed fire as a fuel management tool.

Many of the difficulties associated with implementing fuel management are attributable to "upstream" difficulties that local units face in the early stages of program design. This can come about from a variety of causes. First, too much weight may be given to ecological or fire-related criteria (e.g., internal agency priorities) in choosing which of several programs to develop, and insufficient weight may be given to social or non-agency priorities. Projects that suffer from these difficulties are more likely to do poorly in terms of social response.

From a cost efficiency standpoint, projects that are part of a fuel management program should be submitted to the NEPA process only if they have a relatively high likelihood of success, where success includes implementation. Projects that have a high potential to meet, for example, ecological criteria but that cannot be executed or implemented because of a failure to meet social criteria represent an opportunity loss with respect to other projects that may have done less well in terms of ecological objectives, but have had a higher likelihood of being implemented. Also to be considered is the cost of the NEPA process itself: although these costs are not typically considered as part of the direct cost of fuel management projects, NEPA planning costs can be considerable and the use of NEPA planning resources needs to be considered carefully and in light of their effectiveness. In many cases, it is of value to design and implement fuel management programs based on small and early successes from a social perspective that can lead to a greater likelihood of implementing large and more ambitious projects later in the program sequence.

Improving the process of fuel management program design requires methods that can help structure complex problems, including those that involve multiple stewardship objectives and that may span ownership boundaries. In addition, fuel management itself benefits from improved documentation that substantiates not only the legal requirements of a project, but also its broader rationale, which may include social and economic objectives that extend beyond the boundaries of the administrative unit. Methods for *visualizing* and *communicating* the rationale for a fuel management program increases its potential for implementation. The tendency for programs to define projects in unidimensional terms (e.g., acres treated, targets) is avoided by developing multi-attribute representations that better characterize the complex mix of objectives inherent in fuels management.

The goal of this project is to bring greater structure to the process of fuel management program development and to make the process of fuel management program design more efficient from the perspective of the agency resources required to move a program through the NEPA process. To meet this goal, the project proceeded along the following lines:

- Develop a pre-NEPA framework for evaluating alternative fuel management programs,
- Improve the scope, visualization and communication of the rationale supporting a fuel management program,
- Provide a strategic logic for fuels management programs.

These objectives were pursued in three project phases: (a) development of a conceptual approach based on methods from the decision and risk science, (b) a software prototype that demonstrates the conceptual approach and serves as a proof of concept, and (c) a set of technology transfer activities that both inform conceptual and software development and serve to identify opportunities for and barriers to integration of the approach into the field. Although the various phases of the project can be viewed as distinct, in reality they overlapped considerably and were mutually informed by what we achieved as we progressed.

CONCEPTUAL APPROACH

This project conceptualizes the development of a fuel management program as a set of *design decisions* that address a range of objectives expressed as evaluation criteria. These criteria include ecological, economic (including cost), social, and risk-related criteria (such as risk of prescribed fire escape). In this conceptualization, a particular fuel management program is one of several alternative program designs that each meet design criteria to a differing degree. The best program from a multi-attribute perspective is the one that reflects the best mix of value tradeoffs associated with the various evaluation criteria or attributes.

Although fuels management is often viewed from the plan or project perspective, our approach is programmatic. By programmatic we mean an ensemble or sequence of projects and activities that are distributed geographically and temporally, and that constitute a *portfolio of projects* that define the program. Alternative portfolios each constitute a possible fuel management program. The process of portfolio evaluation involves choosing the portfolio that best meets the objectives of the portfolio while at the same time minimizing risk.[1,2] By casting fuel management as a portfolio problem, the focus is placed on a collection or portfolio of projects that yield a return over time and that take into consideration the risks associated with the individual projects as well as the overall portfolio.

Representation of Portfolio Objectives. The objectives associated with the portfolio are represented in terms of a multi-attribute framework in which a set of measurement criteria are established for each attribute and the entire framework is used to scale or score each of a number of alternative portfolios. Multi-attribute decision modeling is a prescriptive approach for managing complex decision problems.[3] Its structure and logic has been applied in the context of wildland fire. For example, Wildland Fire Situation Analysis (WFSA), a process used by the wildland fire community to structure and evaluate alternative fire management strategies as part of fire management decision making, uses a multi-attribute approach that takes into consideration a range of evaluation criteria, including safety, economic, environmental and social. Objectives are developed for each relevant value category and assigned a priority rating. Alternative fire management strategies are scored in terms of the multi-attribute

[1] Markowitz, H. M. (1970). *Portfolio selection: Efficient diversification of investments.* New Haven, CT: Yale University Press.
[2] Bernstein, P. L. (2005). *Capital ideas: The improbable origins of modern wall street.* Hoboken, NJ: John Wiley & Sons.
[3] von Winterfeldt, D., & Edwards, W. (1986). *Decision analysis and behavioral research*. New York: Cambridge University Press.

model to produce a multi-attribute score (probability weighted) that reflects the relative “goodness” or quality of each alternative with respect to achieving the objectives in the multi-attribute model.

Representation of Portfolio Risks. The risks of the portfolio are represented in terms of uncertainty or variance associated with each of the attributes in the multi-attribute framework. Two types of risk can be represented as variances: risk associated with “means,” and risk associated with “outcomes.” Means-related risk refers to the variance or uncertainty in how a given program (or project) will be applied. Means-related risk is associated with means-related objectives. For example, a program may involve a prescribed fire treatment that has as an objective the treatment of a given volume or amount of fuel. How much fuel is treated depends, for example, on the conditions of the fuels at the time the treatment is implemented and constitutes a source of uncertainty and, therefore, is means-related risk. Outcome-related risk refers to the variance or uncertainty with regard to outcome-related objectives, such as the ultimate impact of a fuel treatment on, for example, the FRCC condition class of a vegetative area. Both types of risk are related to one another; the less variance there is in means or treatments, the less variance there will be outcomes. However, the two are not necessarily related for all types of means and outcomes objectives. For example, for fuel management programs that extend out over a number of years, the *amount of a treatment applied* may be known to a high level of confidence (i.e., low means-related risk) but the ultimate effect of the treatment(s) on the environment may be much less known due to sources of uncertainty beyond management control (e.g., climate change, imperfect information, ecosystem change). In the conceptual approach developed here, risk is represented in terms of probability distributions over both means (or treatments) and outcomes (or effects).

Process Model. The approach to accomplish the objectives involves the development of a model for evaluating alternative fuel management project designs based on a multi-attribute framework that represents design criteria in terms of an attribute structure. The attribute structure represents a *decomposition* of design criteria into *measurable objectives* that provide a basis for evaluating alternative program designs. The structural features of the framework permit the representation and visual display of projects that includes prioritization of objectives and tradeoffs. The framework provides the basis for development of a software decision support tool to aid in fuels management program design. The conceptual model of the aid is shown in Figure 1.

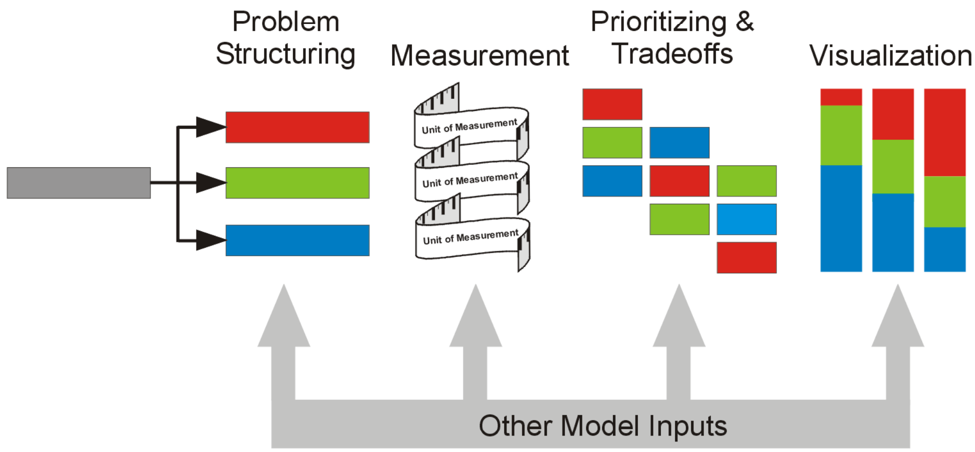


Figure 1. Process model

The figure shows four distinct elements:

- Problem Structuring: This aspect of the model uses a multi-attribute value structuring approach to represent fuel program objectives in terms of a Multi-attribute Decision Problem Topology. The Topology consists of a fundamental and subordinate objective hierarchy. Each objective is named and defined in the structure to promote clarity and to improve communication.
- Measurement: Each subordinate objective is linked to a measurement scale expressed in terms of an appropriate unit of measurement.
- Prioritizing & Tradeoffs: Objectives are prioritized in terms of their relative importance within the context of the multi-attribute objective hierarchy (i.e., problem structure)
- Visualization: Problem visualization is accomplished by using graphic methods to portray the relationship between problem elements (e.g., objectives, measurement)

Each of these elements has the potential to receive input from other models, such as models of fire threat or ecosystem change, through a consultation process that will be discussed below. The present project placed particular emphasis on the first two elements of the process model: Problem Structuring and Measurement.

“Fuels Program Strategic Analysis (FPSA)” – A Software Demonstration Prototype for Multi-attribute Evaluation of Alternative Fuel Management Program Designs

FPSA and what it does

FPSA is a software prototype that demonstrates the application of decision and risk science principles to fuels management program decision making. The prototype runs on a standard PC and provides a framework for comparative evaluation of alternative fuels program designs in terms of a set of multi-attribute criteria specified by the user. The program utilizes a graphic user interface (GUI) to represent the decision problem in terms of a multi-attribute tree structure with up to three levels of an objective hierarchy. The hierarchy is dynamically reconfigurable by “dragging and dropping” screen icons that represent objectives in the problem structure.

Interacting With the User – A Consultation Process.

Many projects that have as their goal the development of a decision aid or support tool generally conceptualize their product in terms of a stand-alone application intended for a single-user environment such as a personal computer. Many such products have limited use not because they are poorly conceptualized or lack relevance to the field, but rather because their sophistication is not matched by user capabilities and the depth of field training. This project took the approach that the development and fielding of software-type tools should take place in consultation or facilitated environment where users are supported and developed by computer-based tools that function in a shared communications context.

This approach focused effort on developing a software prototype that:

- Demonstrates the application of decision and risk science principles in the context of fuel management program design and evaluation:
- Provides a software platform and context for teaching and training in the decision and risk science principles embedded in the software;
- Integrates software conceptual development, technology transfer and field training by developing a tool that can be used in a facilitated group work context.

Developing the Multi-attribute Decision Problem Topology.

The fundamental framework that drives FPSA is the Multi-attribute Decision Problem Topology. This is a mult-attribute value tree representation of the decision problem. An objective hierarchy is created by identifying a set of fundamental objectives and then specifying subordinate objectives at up to three levels deep. A fourth level is the specification of a measurement scale by which decision alternatives are evaluated. Figure 2 shows an example for a problem based on fieldwork with the prototype done on the Coos Bay District, BLM.

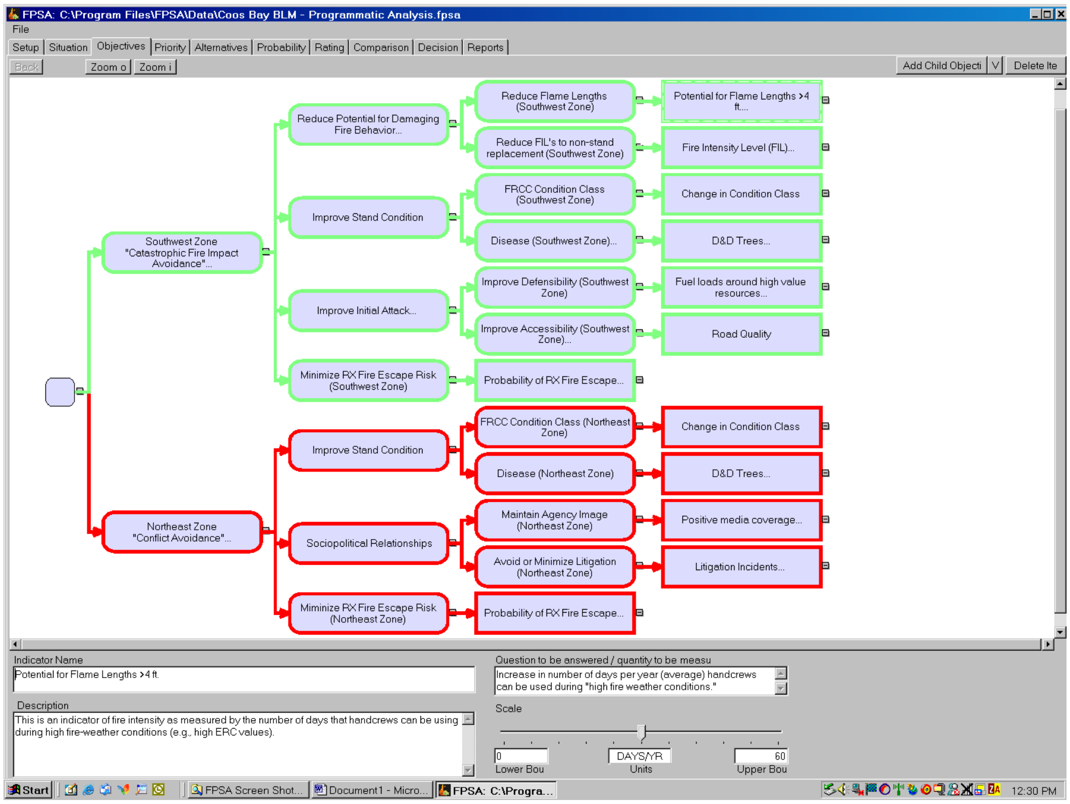


Figure 2. Multi-attribute Decision Problem Topology.

A user-defined, on-screen color scheme is used to distinguish between multiple fundamental objectives. In this example, two fundamental objectives have been identified, each representing a separate management zone for the administrative unit as a whole. Objectives are represented on-screen by rounded rectangles while measurement scales are represented by regular rectangles. Text boxes for naming and describing objectives and measurement scales are provided. In addition, the upper and lower boundaries and the unit of measurement for each objective is specified. These values are used to populate the remainder of the analysis and are carried forward in the problem.

Prioritizing Values and Objectives.

Values and objectives are prioritized in FPSA using a rating scale approach. Figure 3 shows a set of priorities in terms of rating scale values for each of the objectives in the example shown in Figure 2.

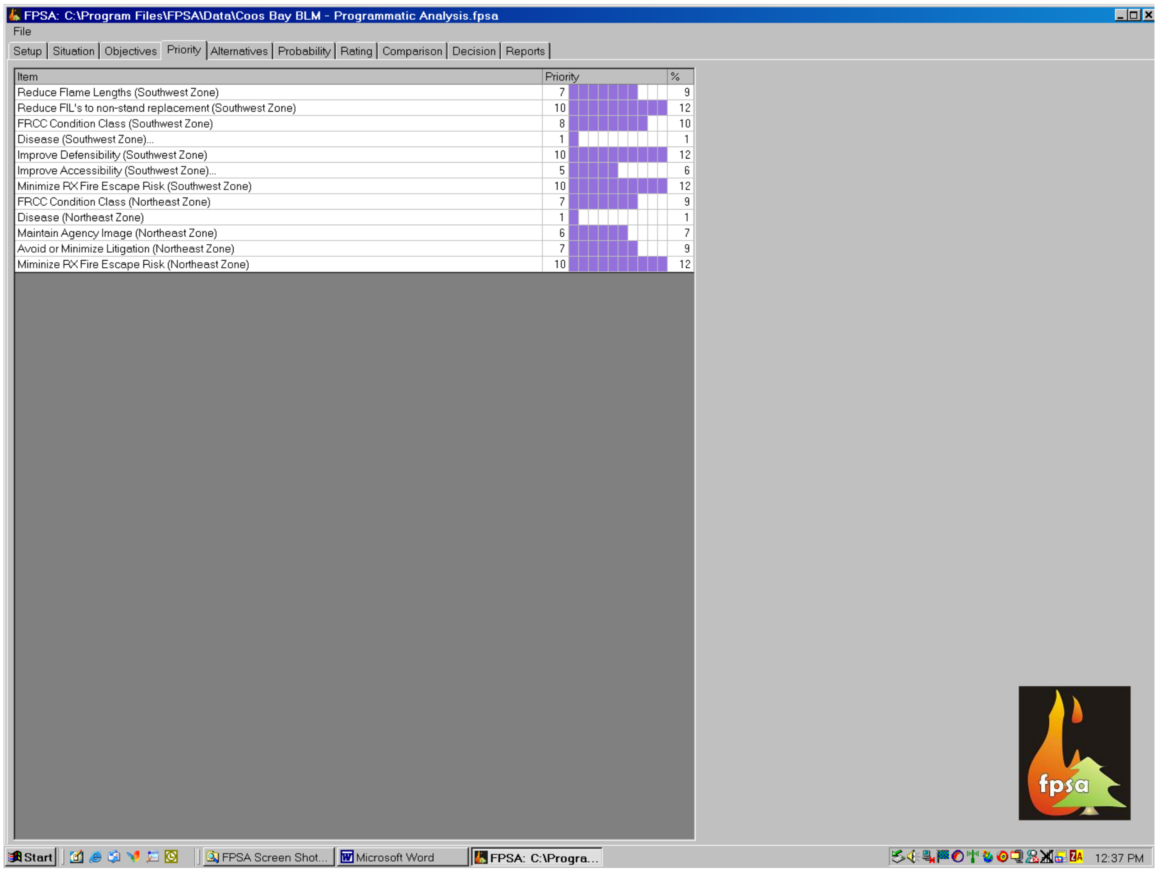


Figure 3. Prioritizing of objectives using a rating-scale approach.

Rating scale values in the prototype are allowed to range between a low of "1" and a high of "10." In addition to the "raw" priority values, the normalized weighted priority is shown as a percentage. The quality of these ratings can be further enhanced by off-line work that involves using techniques such as swing weighting[4] or Saaty's AHP approach[5] to explore alternative weighting methods. The approach incorporated in the prototype reflects a simplified approach that makes minimum demands on the background and skills of users.

[4] von Winterfeldt, D., & Edwards, W. (1986). *Decision analysis and behavioral research*. New York: Cambridge University Press.
[5] Saaty, T.L. (1980). *The analytic hierarchy process*. New York: MacGraw-Hill.

Describing Alternatives for Analysis.

Alternative fuel management programs are described in terms of (a) their features and/or other characteristics, and (b) the distribution of outcomes associated with each alternative program. Figure 4 shows an example of four alternative program designs described in terms of the type of fuel treatment planned for each program.

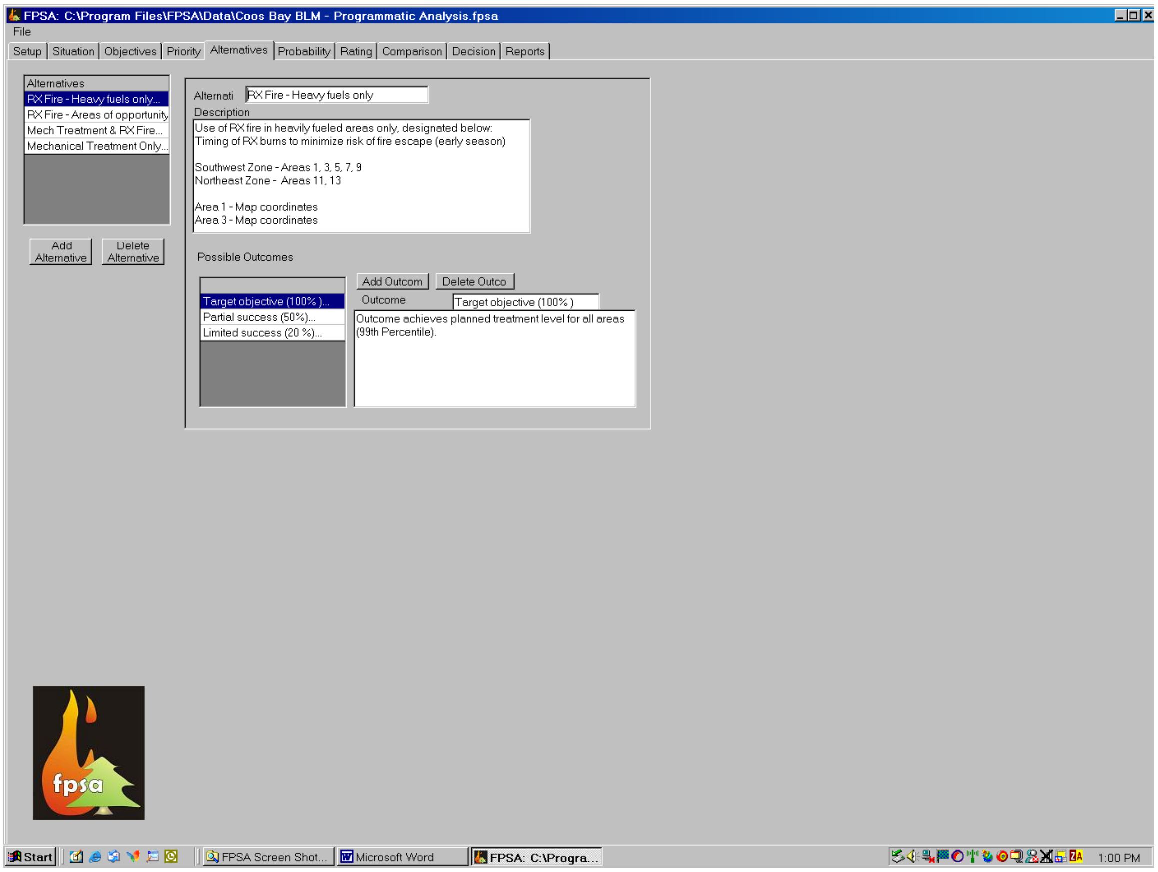


Figure 4. Description of alternative fuel management programs for analysis.

Three outcome possibilities are shown for each program alternative. The outcome possibilities correspond to means-related risk and represent the distribution of potential treatments. In the example the three outcomes levels are 100% success (treatment levels achieved as planned), 50% success and 20% success. The prototype provides for many more levels of outcome distribution.

Assignment of Probabilities to Outcome Distributions.

The prototype provides for the assignment of probabilities to the outcomes distributions for each of the program alternatives (Figure 5).

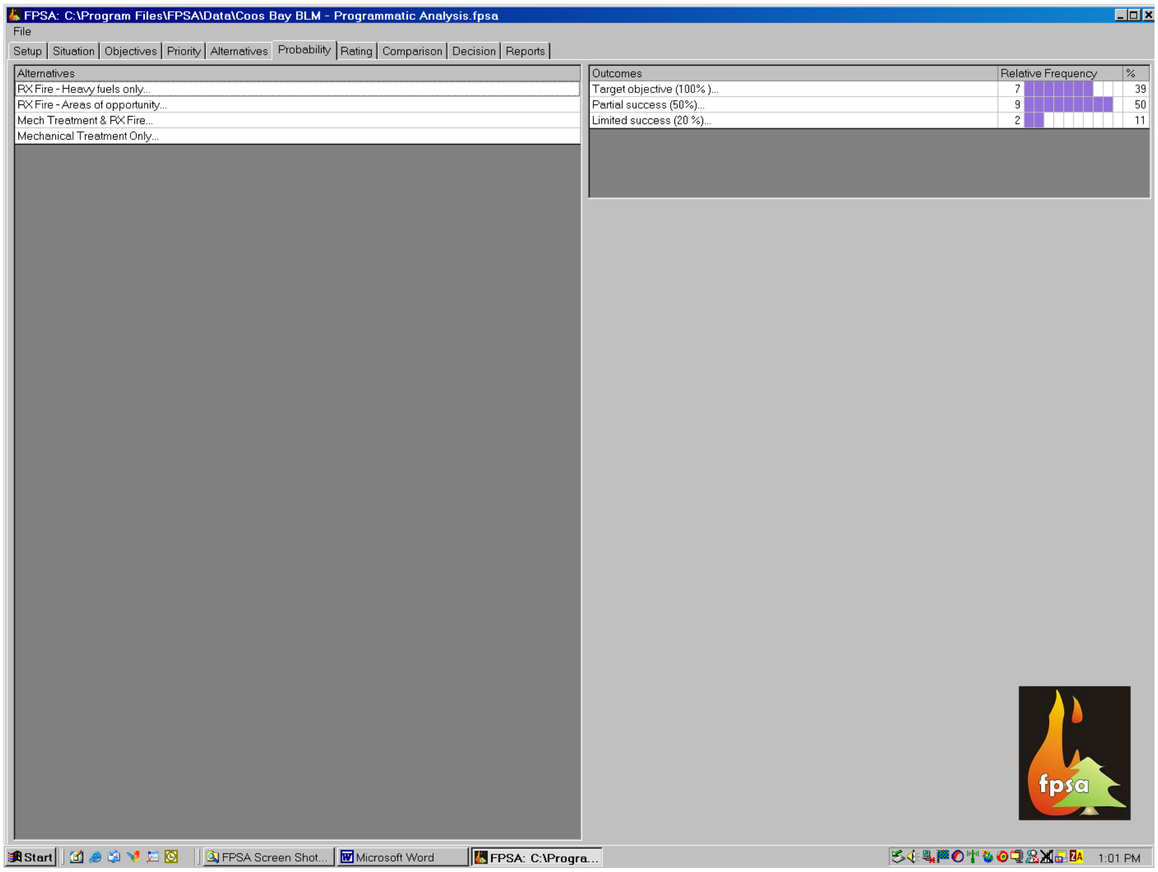


Figure 5. Assignment of probabilities to each outcome for each program alternative.

Scale values ranging from “1” to “10” are assigned to each outcome on the distribution of outcomes for each program alternative. These are translated into a percentages as a number of points on a probability distribution to give a simplified probability distribution function (pdf).

Rating Outcomes on Measurement Scales.

Each objective in the Multi-attribute Decision Problem Topology is rated on each of the evaluation scales for each of the means-related outcomes. This produces a correspondence between the level of treatment and the ultimate impact of the amount of treatment on the objectives in the evaluation framework (Figure 6).

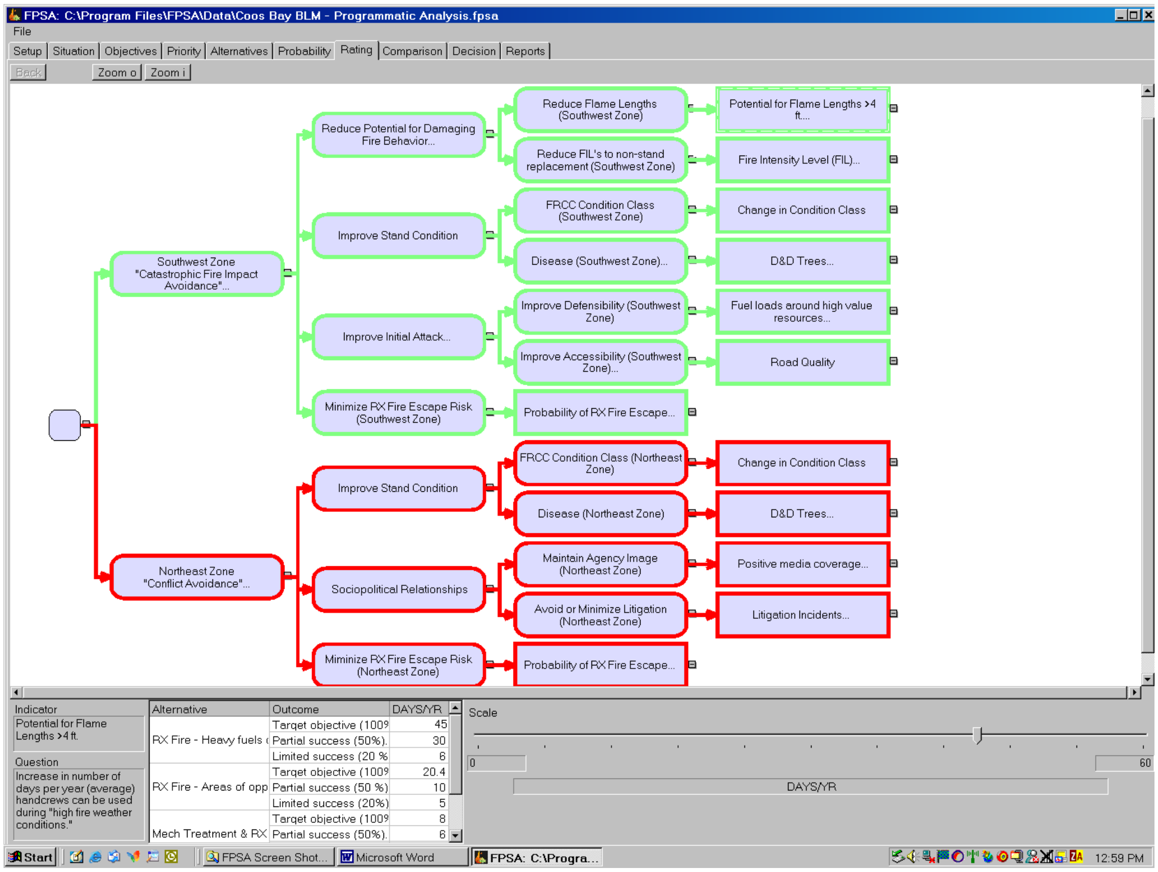


Figure 6. Rating outcomes on measurement scales in the Multi-attribute Decision Problem Topology.

In this screen, the rating scale definitions are brought forward and applied to each of the alternative programs in the analysis according to the means-related outcome distributions. For example, in Figure 6 the measurement scale is "Potential for flame lengths > 4 ft." which is an indicator for the objective "Reduce Flame Lengths." The scale ranges from a low of "0 days" to a high of "60 days." Each of the alternatives are rated in terms of the measurement scale for each of the means-related outcome levels in the analysis. In the example, the alternative "RX Fire – Heavy fuels" will result in 45 days change on the measurement scale if the treatment is implemented to its full planned level

(100%); 30 days if implemented at 50% of the planned level; and 8 days if implemented at 20% of the planned level.

Comparative Evaluation of Alternatives.

Alternative fuel management programs in the analysis each receive a multi-attribute criteria score based on the ratings received on the multi-attribute scales in the Decision Problem Topology combined in an additive model that is weighted by the risk distribution associated with the means-related outcomes for each program (Figure 6a). The weights in the additive model are derived from the priority values associated with each of the subordinate objectives in the Multi-attribute Decision Problem Topology. The scores are a direct reflection of the quality or “goodness” of each of the problems with respect to the objectives they are anticipated to achieve and how much of each objective is achieved given the potential for variance in how much actual treatment each program might accomplish.

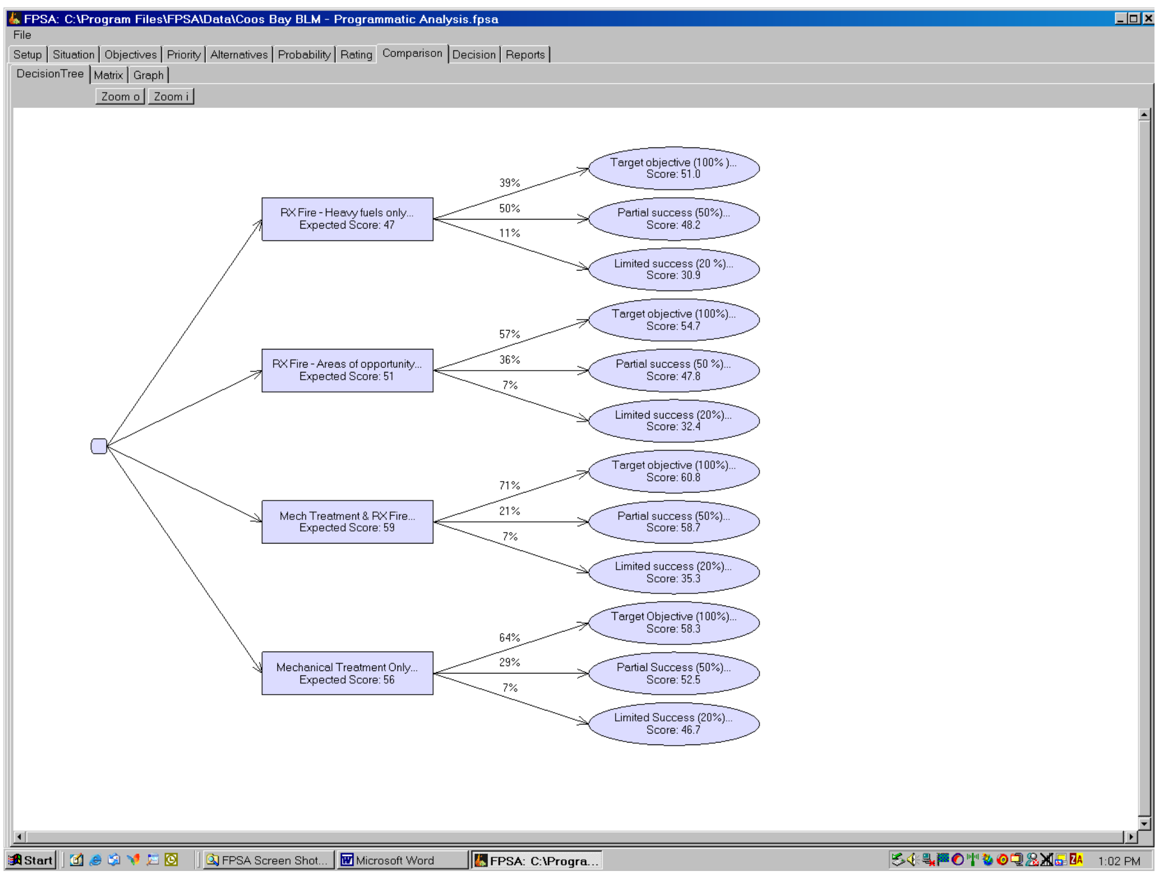


Figure 6a. Comparison of alternative fuel programs scored according to a multi-attribute additive model with probability weighting.

The basic additive scoring model for the multi-attribute evaluation of a set of decision alternatives is given by:

$Y_i = W_1X_1 + W_2X_2 + W_3X_3 + \ldots W_nX_n$ where,

$Y_j \ldots Y_k$ is the set of k multi-attribute decision alternatives;

$X_i \ldots X_n$ are the outcome ratings on the set of n attributes or evaluation criteria; and

$W_i \ldots W_n$ are the n normalized attribute weights (based on priority ratings) associated with each of the $X_i \ldots X_n$ attributes.

The basic additive scoring model is enhanced to include risk by incorporating the uncertainty associated with the various fuel treatment (or decision) alternatives. This uncertainty derives from the variance in the amount of treatment applied (means-related risk) and from variance in the effect of the treatment applied on the outcome variables or attributes (outcome-related risk).

For each of the X_i attributes in the problem, a value of $E(X_i|Y_j)$ is specified as the expected value of the joint probability distribution over attribute X_i given a treatment level Y_j.

The score Y_j given to each multi-attribute decision alternative in the set of k decision alternatives is an expected value score. The full scoring model is given as:

Score $Y_j = E(Y_j) = W_1(E(X_i|Y_j)) + W_2(E(X_2|Y_j)) + W_3(E(X_3|Y_j)) + \ldots W_n(E(X_n|Y_j))$.

A graphic visualization of the scoring shown in Figure 6a is shown in Figure 6b. In this screen the four fuels management program alternatives are shown on the horizontal (X) and the multi-attribute model scores are shown on the vertical (Y) axis.

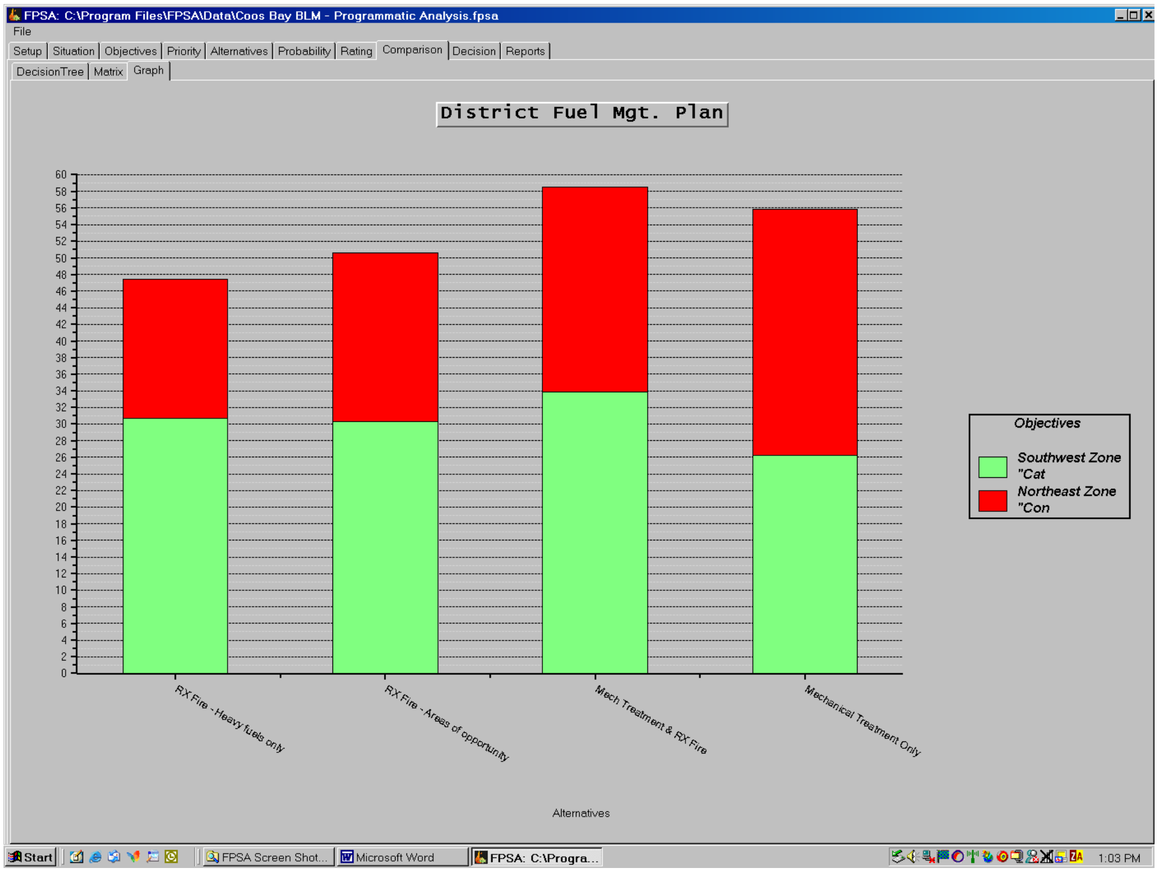
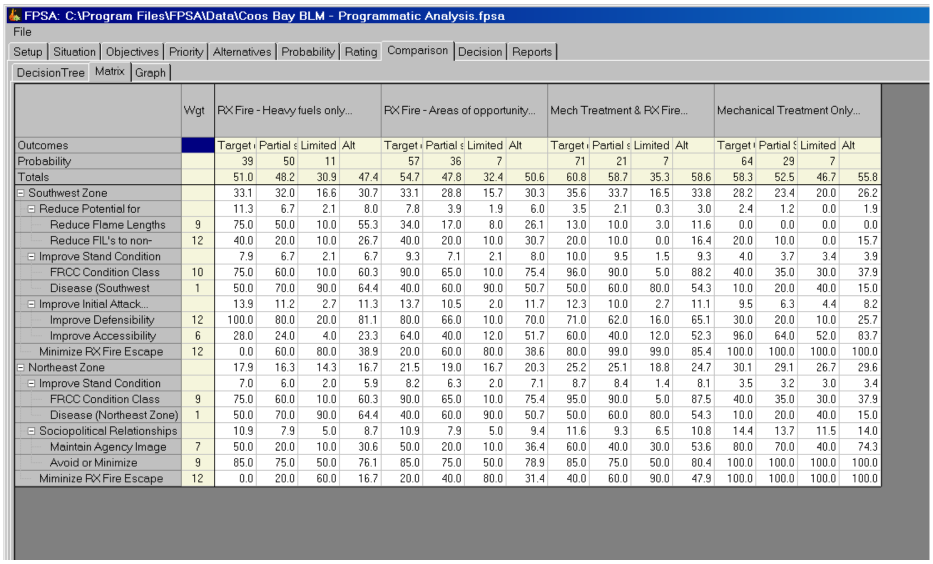


Figure 6b. Graphic visualization of multi-attribute scoring of decision alternatives.

The scores for the two fundamental objectives are represented separately on each vertical bar and distinguished by the same color scheme as used in the objective hierarchy originally developed at the beginning of the program.

A matrix representation of the scoring components can be accessed directly and the numerical values for all variables can be changed to conduct a sensitivity analysis. The matrix is shown in Figure 6c.



	Wgt	RX Fire - Heavy fuels only...				RX Fire - Areas of opportunity...				Mech Treatment & RX Fire...				Mechanical Treatment Only...			
Outcomes		Target (	Partial s	Limited	Alt	Target (	Partial s	Limited	Alt	Target (	Partial s	Limited	Alt	Target (	Partial S	Limited	Alt
Probability		39	50	11		57	36	7		71	21	7		64	29	7	
Totals		51.0	48.2	30.9	47.4	54.7	47.8	32.4	50.6	60.8	58.7	35.3	58.6	58.3	52.5	46.7	55.8
⊟ Southwest Zone		33.1	32.0	16.6	30.7	33.1	28.8	15.7	30.3	35.6	33.7	16.5	33.8	28.2	23.4	20.0	26.2
⊟ Reduce Potential for		11.3	6.7	2.1	8.0	7.8	3.9	1.9	6.0	3.5	2.1	0.3	3.0	2.4	1.2	0.0	1.9
Reduce Flame Lengths	9	75.0	50.0	10.0	55.3	34.0	17.0	8.0	26.1	13.0	10.0	3.0	11.6	0.0	0.0	0.0	0.0
Reduce FIL's to non-	12	40.0	20.0	10.0	26.7	40.0	20.0	10.0	30.7	20.0	10.0	0.0	16.4	20.0	10.0	0.0	15.7
⊟ Improve Stand Condition		7.9	6.7	2.1	6.7	9.3	7.1	2.1	8.0	10.0	9.5	1.5	9.3	4.0	3.7	3.4	3.9
FRCC Condition Class	10	75.0	60.0	10.0	60.3	90.0	65.0	10.0	75.4	96.0	90.0	5.0	88.2	40.0	35.0	30.0	37.9
Disease (Southwest	1	50.0	70.0	90.0	64.4	40.0	60.0	90.0	50.7	50.0	60.0	80.0	54.3	10.0	20.0	40.0	15.0
⊟ Improve Initial Attack...		13.9	11.2	2.7	11.3	13.7	10.5	2.0	11.7	12.3	10.0	2.7	11.1	9.5	6.3	4.4	8.2
Improve Defensibility	12	100.0	80.0	20.0	81.1	80.0	66.0	10.0	70.0	71.0	62.0	16.0	65.1	30.0	20.0	10.0	25.7
Improve Accessibility	6	28.0	24.0	4.0	23.3	64.0	40.0	12.0	51.7	60.0	40.0	12.0	52.3	96.0	64.0	52.0	83.7
Minimize RX Fire Escape	12	0.0	60.0	80.0	38.9	20.0	60.0	80.0	38.6	80.0	99.0	99.0	85.4	100.0	100.0	100.0	100.0
⊟ Northeast Zone		17.9	16.3	14.3	16.7	21.5	19.0	16.7	20.3	25.2	25.1	18.8	24.7	30.1	29.1	26.7	29.6
⊟ Improve Stand Condition		7.0	6.0	2.0	5.9	8.2	6.3	2.0	7.1	8.7	8.4	1.4	8.1	3.5	3.2	3.0	3.4
FRCC Condition Class	9	75.0	60.0	10.0	60.3	90.0	65.0	10.0	75.4	95.0	90.0	5.0	87.5	40.0	35.0	30.0	37.9
Disease (Northeast Zone)	1	50.0	70.0	90.0	64.4	40.0	60.0	90.0	50.7	50.0	60.0	80.0	54.3	10.0	20.0	40.0	15.0
⊟ Sociopolitical Relationships		10.9	7.9	5.0	8.7	10.9	7.9	5.0	9.4	11.6	9.3	6.5	10.8	14.4	13.7	11.5	14.0
Maintain Agency Image	7	50.0	20.0	10.0	30.6	50.0	20.0	10.0	36.4	60.0	40.0	30.0	53.6	80.0	70.0	40.0	74.3
Avoid or Minimize	9	85.0	75.0	50.0	76.1	85.0	75.0	50.0	78.9	85.0	75.0	50.0	80.4	100.0	100.0	100.0	100.0
Miminize RX Fire Escape	12	0.0	20.0	60.0	16.7	20.0	40.0	80.0	31.4	40.0	60.0	90.0	47.9	100.0	100.0	100.0	100.0

Figure 6c: Matrix representation of multi-attribute scoring model components.

LESSONS LEARNED

The original intent of this project was to bring the structure and logic of decision analysis and related decision science principles to the process of developing and evaluating fuel management programs. During the course of this project, we learned that:

- *Some of the major problems in developing and implementing specific fuels projects often derive from their lack of a programmatic organization and definition.*

  Projects are developed without a comprehensive rationale that includes not only issues within the administrative unit, but also considerations of factors and impacts outside of the administrative unit, including the need to obtain community or public support for agency actions associated with fuel management. Sometimes projects are developed because they offer a large return in terms of, for example, return to condition class or wildland-fire risk reduction. On the other hand, these projects may not survive the NEPA process due to their public impacts and/or internal agency controversies about their impacts or safety. From a decision science perspective, projects such as these result in an *opportunity cost*: the effort expended on developing the project is at the expense of developing other projects that may have had a higher probability of success, though a lower return with respect to resource management objectives. In other words, sometimes it is better to do a relatively low return project (in favor of a higher return but higher implementation risk project) if it keeps a program moving and leads to a higher likelihood of doing larger (and more ambitious) projects in the future. We found relatively limited tendencies for a strategic approach to fuel management program development in the pre-NEPA stage. The focus tended to be on developing a collection of very detailed projects with comparatively less emphasis on overall program strategy.

- *Field-level organizations differ widely in how they approach the development of fuel management projects and programs.*

  Some of this is due to the differing types fuels problems that different units face. Other factors include staffing, experience and opportunities to implement fuel management activities. As a result of these differences, and regardless of their source, it is important to recognize that a one-size-fits-all approach to supporting or aiding fuel management program development will likely succeed in some places and fail in others. As a corollary, it is also likely the case that a highly successful fuel management demonstration in one site or unit will not necessarily transfer to other units. At present we have no models that indicate which units might benefit from the work done at a demonstration unit. For the work undertaken in this project, we found that keeping the conceptual framework fairly broad and the software prototype fairly flexible we were able to provide meaningful advice and direction to a number of units and groups.

- *Structured decision support requires field-level training in the decision and risk sciences for the concepts to have appreciable meaning and applicability.*

  We found a fairly wide range of acceptance of the fundamental concepts on which the FPSA software is based, despite agency policies and directions that emphasize the need for well-analyzed decisions. We attribute this to differing levels of education, training and experience of field personnel with the tools and techniques of the decision and risk sciences. At one level, this is a science delivery problem. The solution we advanced in this project is to take the science to the field, present the science in terms of grounded and field-relevant principles, and offer follow-up consultation and advice as needed. This may not be the most cost-efficient approach, but it can be very effective. As part of this project we developed a *Decision Science Shortcourse* that can be applied as a one-day workshop or as a half-day workshop and consultation. It can also be expanded to three or four days with the addition of more case studies and classroom exercises. The course uses a modularized approach to allow for expansion or contraction of topics and emphasis. The course covers the fundamentals of multi-attribute decision analysis as well as basic principles in risk assessment and risk communication. We plan to expand the Shortcourse to include a section on Portfolio Theory as applied to resource management decision making.

- *Improving decision making processes through science delivery and technology transfer takes time and distributed effort.*

  In the course of this project, we interacted, consulted, facilitated and advised approximately 60 individuals on the use of decision and risk science principles to improve fuel management program development. These interactions were face-to-face and do not include the distribution of materials and presentation materials that may have been done subsequent to their involvement with us. These connections need to be periodically reinforced and strengthened through continued interaction and the application of the conceptual approach developed in this project to fuel management problems unique to their particular unit or circumstances. Based on our experience in this project, we advocate a facilitated consultation model for field training and technology transfer that puts software directly in the hands of field-level personnel along with the necessary scientific expertise to apply that software to a problem that has utility for the local unit.

DELIVERABLES & ACCOMPLISHMENTS

Proposed Deliverables	***Status/Accomplishment***
Annual progress reports	Annual progress reports completed
Final report describing the activities and findings of the project	Final report completed
Software prototype of a decision support tool for prescribed fire decision making	Prototype available from Donald MacGregor at donaldm@epud.net.
Technology transfer, science delivery, and project outreach	Papers and publications: • MacGregor, D.G., Dammann, C., & Anderson, J. (2003). Evaluating Designs for Fuel Management Projects: Application of a Multi-attribute Framework. Proceedings of the Second International Wildland Fire Ecology and Fire Management Congress. Orlando, FL, Nov. 16-20, 2003: American Meteorological Society. • MacGregor, D.G., & Haynes, R.W. (2005). Integrated research to improve fire management decision making. Gen. Tech. Rep. PNW-GTR-630. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. • MacGregor, D.G., Finucane, M., & González-Cabán, A. (in press). Risk Perception, Adaptation and Behavior Change: Self-protection in the Wildland-Urban Interface. In B. Kent & C. Raish (eds). *Wildfire and fuels management: Risk and human reaction*. Washington, DC: Resources for the Future. • MacGregor, D.G. (in press). The future of fire in bioregional management. *Futures.*

	Consultations and workshops directly related to project activities: • Humboldt-Toiyabe NF, Carson District: Consultations and workshop on multi-attribute decision modeling for fuels management decision making. • Central Oregon Fire Management (COFMS): Workshop and consultation on multi-attribute decision modeling for fuels management program development. • BLM - Coos Bay District: Workshop and consultation on multi-attribute decision modeling for fuels management program development. Additional presentations and workshops conducted as part of science delivery and project outreach: • Region 6 Forest Supervisors Annual Retreat: Workshop on multi-attribute decision analysis. • Northwest Geographic Area Coordination Center (NWCC): Workshop on multi-attribute decision analysis. • Wildland Fire Leadership Council (WFLIC) Working Group on Large Fire Costs: Consultation and presentation on multi-attribute decision analysis in fire and resource management. Other Linkages and project-related demonstrations: • Columbia Gorge NSA: Information package, outreach and site consultation. • Region 3 Fuels Management: Information package and outreach. • Bitterroot NF: Information package and outreach.

PROJECT TEAM AND ACKNOWLEDGEMENTS

This project was supported by a number of key individuals who provided expertise in a number of areas.

Carl Dammann, USDA Forest Service retired, provided fire management expertise and assisted in developing the conceptual framework as well as working with field personnel during early stages of the project.

John Anderson, Balance Technologies, Missoula, MT, provided the computer programming for FPSA.

Nick Reyna, Rocky Mountain Research Station, served as the initial technical contact for the project and provided help and guidance during the initial development of the conceptual framework. He served in this capacity while he was a member of the Forest Health Technology Enterprise Team (Fort Collins, CO). His role as agency technical contact was assumed by Frank Sapio for the later half of the project, and we give special thanks to Frank for the service he has provided.

We also thank the numerous field personnel who graciously work with us as we developed the conceptual model and refined the software prototype, including Louisa Evers, Sue Stewart, Kelly Martin and Earl Burke.