Attachment 1: Effectiveness, Efficiency, & Performance Measures

Effectiveness, Efficiency and Performance Measures (EEP's) have been developed as a means to assess and conduct trade-off analysis among potential investment alternatives at both the local Fire Planning Unit (FPU) and at the National level. These EEP's were created based on the Federal Wildland Fire Policy developed in 1995 and reaffirmed in 2001, the "10-year Comprehensive Strategy", and the "Developing an Interagency, Landscape-scale Fire Planning Analysis and Budget Tool" report.

The five EEP's were developed as a direct response to the Wildland Fire Leadership Council's (WFLC) following broad management concerns:

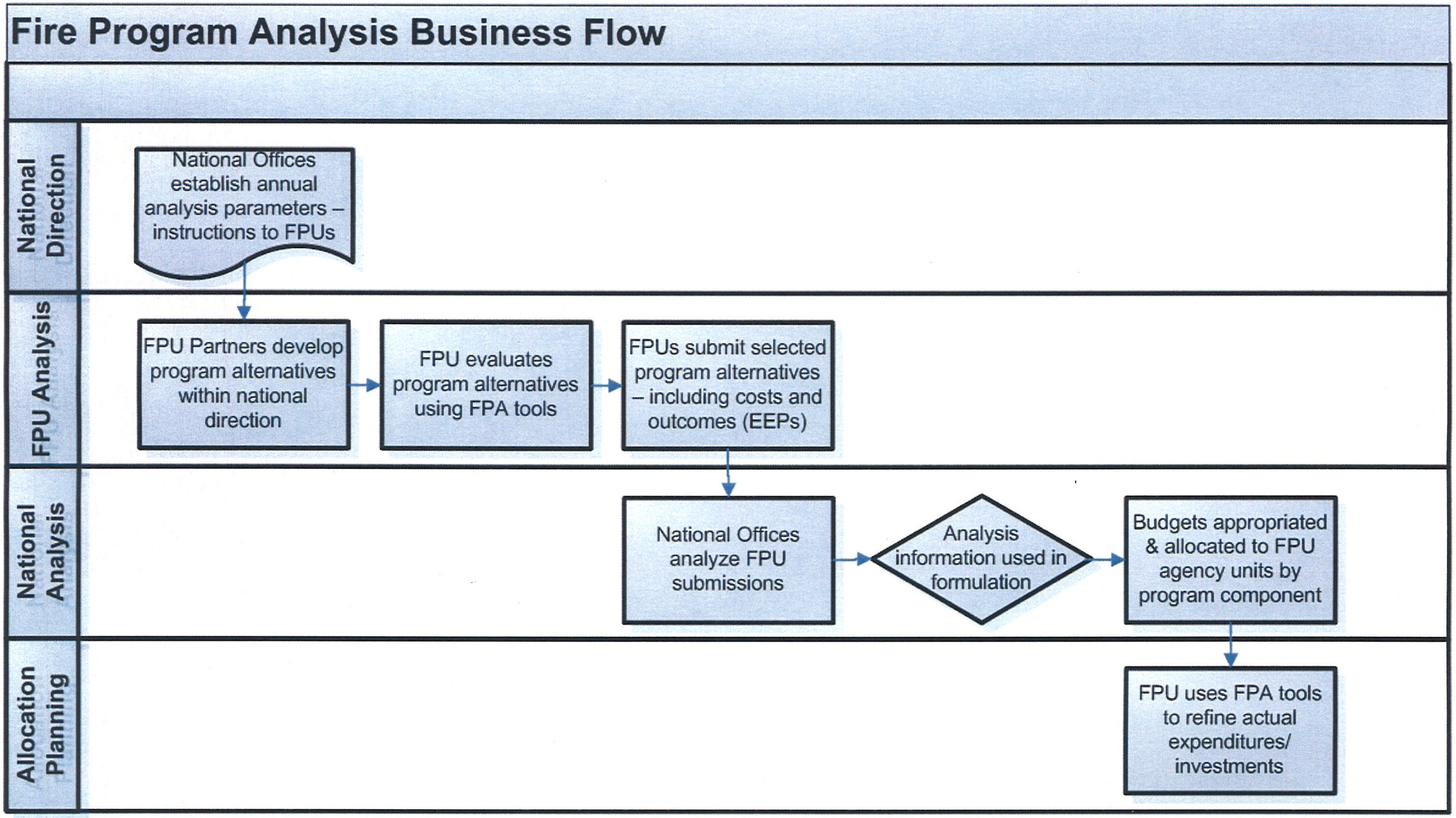
1. Growing annual suppression costs for large fires.
2. Fires that occur and cause significant damage within the WUI.
3. Fires that cause severe impacts to highly valued resources.
4. Concerns with prevention and suppression of unwanted and unplanned fires.
5. Attaining fire and fuels management objectives on federal lands.

These management concerns were translated into the following quantifiable measures of effectiveness, efficiency, and performance (EEPs). Alternative investments are assessed at both the local and national level based on how well they contribute to

1. Reducing the probability of occurrence of costly fires.
2. Reducing the probability of occurrence of costly fires within the Wildland Urban Interface.
3. Increasing the proportion of land meeting or trending toward the attainment of fire and fuels management objectives.
4. Protecting highly valued resource areas from unwanted fire.
5. Maintaining a high initial attack (IA) success rate.

These five EEPS are used in evaluating the alternative investments that are created by local planners based on their Fire Management Plans. Alternatives that reflect highest EEP scores at the locale level are then submitted to National Planners for trade-off analysis to help inform the budget planning process.

Attachment 2: Business Process



Fire Program Analysis Business Flow

Attachment 3: FPU Decision Support System

While there are many tools and techniques that fall under the general heading of decision support, the term, *decision analysis*, is reserved for a set of techniques that explicitly model the relationships between a decision and its likely consequences. The most widely adopted quantitative form of decision analysis is Bayesian decision analysis. The term is derived from the Reverend Thomas Bayes, who described one of the basic axioms of probabilistic reasoning in the mid-eighteenth century.

Bayesian decision analysis begins by deconstructing the causal pathways between a decision and the range of possible outcomes into a series of steps or events. Many of these steps are probabilistic; that is, they may or may not occur with a given probability. Bayes theorem allows one to calculate the probability of an entire sequence of events and thus assign probabilities to any number of possible outcomes. Modern computer software allows graphical expression or modeling of the series of interconnected events and rapid calculation of associated probabilities. These models, known as Bayesian Belief Networks (BBN) or influence diagrams, allow users to conduct a comparative risk assessment that compares and analyzes the trade-offs among competing risks associated with several alternative actions.

Bayesian belief networks are very effective for modeling situations where some information is already known and incoming data are uncertain or partially unavailable (unlike rule-based or "expert" systems, where uncertain or unavailable data result in ineffective or inaccurate reasoning). These networks also offer consistent semantics for representing causes and effects (and likelihoods) via an intuitive graphical representation. Because of all of these capabilities, BBNs are being increasingly used in a variety of domains where automated reasoning is needed.

An important fact to realize about BBNs is that they are not dependent on knowing exact historical information or current evidence. That is, BBNs often produce very convincing results when the historical information in the conditional probability tables or the evidence known is inexact. Given that humans are excellent at vague linguistic representations of knowledge (for example, "it will probably rain tomorrow"), and less adept at providing specific estimates, the ability to be effective despite vagaries in the input information is particularly advantageous. This robustness in the face of imperfect knowledge is one of the many reasons why BBNs are increasingly used as an alternative to other probabilistic models.

Advantages of Decision Support System (Bayesian Belief Networks)

- Easy to explain how a system arrived at a particular recommendation, decision, or action.
- It is possible to diagnose problems: networks can be run in multiple directions.
- With sensitivity analysis, managers can vary inputs and assess changes due to those inputs.

Attachment 4: National Trade-off Model

A key purpose of FPA is to develop cost effective fire programs.

The national trade-off model will allow managers to assess trade-offs in terms of multiple effectiveness measures at different budget levels.

The effectiveness of each FPU will be measured by multiple Effectiveness, Efficiency and Performance Measures (EEPs). There will be at least five EEPs that will be used in the National Trade-off model to help budget planners decide where money should be spent and in which fire program component. FPA provides decision support called Multi-Criteria Decision Analysis (MCDA). A key concept behind MCDA is that there is no "best" answer, but rather understanding of the trade-offs between what are often conflicting objectives.

Multi-Criteria Decision Analysis[1] is a procedure aimed at supporting decision makers whose problem involves numerous and often conflicting evaluations. In FPA, the EEPs can sometimes conflict. For example, an FPU can increase IA success by containing more fires in the backcountry while letting fires in the WUI escape. In this case, the IA success increases while putting more WUI at risk. MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process.

The national trade-off model uses a goal programming approach to support decision makers' understanding of trade-offs of the EEPS at different budget levels.

Examples:

- The target IA success rate might be 100% and the target proportion of WUI at risk zero percent. Unwanted deviations from this set of target values are then minimized in an achievement function. The goals are often weighted (e.g., the proportion of WUI at risk might be more important than the IA success on a given FPU). Thus, increments moving towards zero percent WUI at risk would count more (receive a higher weight) in the achievement function than increments towards 100% IA success.

- There are similar trade-offs between short term IA success and cumulative impacts. Initial attack success achieved next year, at the expense of fuels treatments, could contribute to an increased probability of adverse consequences 20 years from now.

Goal programming supports the multi-objective decision making inherent in fire program decision making. Goal programming can handle large numbers of variables, constraints and objectives. The solution represents a good mix of trade-offs from the perspective of the decision makers.

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[1] Adapted from http://en.wikipedia.org/wiki/Multi-criteria_decision_analysis

Attachment 5: Initial Response Simulator

The Initial Response Simulator (IRS) module will provide the ability to analyze different wildland fire initial response organizations and their associated impacts to the entire fire management program. Results of the simulation can be used as inputs into additional models to test the effect and or impact upon the entire fire management program.

IRS uses the Fried and Fried containment algorithm[2].; production capability and fire resource availability can be specified as stochastic or deterministic. In Fried and Fried, the shape of the fire is modified as suppression occurs along the perimeter. The model simulates containment capability for the fires that are determined to be contained based upon user defined inputs; it passes the fires determined to escape onto the appropriate response model for additional analysis.

Connection to Fire Probability Modeling:

- IRS outputs are inputs into the Wildland Fire Susceptibility Index (WFSI) and provide the means to create Final Fire Size – Rate of Spread relationship curves. These curves provide the capability to model a potential final fire size for those fires that escape.
- Each initial response organization modeled with IRS can provide a new WFSI score based upon the ability of those organizations to suppress fires.
- Those fires that escape in the IRS module could be used as inputs into the Large Fire Simulator for further modeling.

Attachment 6: Large Fire Probability Surrogate

Wildland Fire Susceptibility Index (WFSI) or a similar GIS derivation will be used as a surrogate for the probability of an acre burning in the Fire Program Analysis System. Alternative WFSI may be developed using differing fire resource organizations, fuel complexes on the landscape, and the reduction of human caused fires through prevention activities.

The WFSI integrates the probability of an acre igniting and the expected final fire size based on the rate of spread in four weather percentile categories into a single measure of wildland fire susceptibility. Due to some necessary assumptions, mainly fuel homogeneity, it is not the true probability. Because it will be used consistently across all areas being analyzed, it allows for comparison and ordination of areas as to the likelihood of an acre burning.

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[2] Fried, J.S. and B.D. Fried, 1996. Simulating Wildfire Containment with Realistic Tactics. Forest Science (42) 3 1996 pg. 267-281

Attachment 7: Large Fire Simulator

The large fire simulator determines burn probability and fire effects. These two characteristics, when applied to valued resources, are used to determine risk, or expected loss. Alternative fire management scenarios (budget, fuels, preparedness, prevention) can be evaluated by examining relative changes in risk.

Inputs: Landscape data layers are needed for spatial inputs into the large fire simulator model, and will need to be developed at the FPU level, or LANDFIRE data can be substituted. Historical weather and fire data are obtained from representative NFDRS or RAWS stations to develop a historical data set for wind speed and direction, and Energy Release Component (ERC). Historical fire weather used with the large fire simulator can be derived from data currently in the Personal Computer Historical Analysis (PCHA) developed in FPA-PM. A time-series analysis randomly develops thousands of ERC trends. Weather streams are developed for geographical areas incorporating several, or many, FPUs in order to simulate large fires across FPU boundaries.

Simulation: The Initial Response Simulator determines which fires escape initial response simulation limits. These fires are then placed on the landscape. The ERC trends and weather streams are used to simulate the growth of escaped fires on the landscape, using the FlamMap fire model. Burn probability is calculated by dividing how many times a cell burns by the total number of simulations. A large number of simulations would be required to develop a rigorous probability surface.

Outputs: Outputs of the large fire simulator include a distribution of flame length, burn probability, and final fire size. Flame length is important in calculating fire effects on valued resources. FPUs can update significant changes in their landscape, such as fuels treatments or large fires, by changing relevant landscape files. Fuels treatments can be characterized by changes in fuel model and canopy characteristics layers, which then can be "tested" by the landscape fire simulator. Changes in burn probability and fire effects can be quantified. This can be a useful tool for the FPU to validate the effectiveness of fuels treatments.

Effects and Cost of Suppression: The effects of suppression on large fire size are characterized by including a suppression sub-model. Historical suppression effects are analyzed and then applied to the large fire being simulated, effectively "shrinking" the final fire size to demonstrate the effects of suppression. The suppression sub-model would not be used for Wildland Fire Use fires. To determine cost of large fires, fire cost is indexed to final fire size using historical data. The relationship of cost to fire size has already been established through several projects, such as the work of K. Gebert et al, and those approaches will be utilized in the FPA model.

Attachment 8: Vegetation Change Modeling

The most likely candidate model for evaluating vegetation change is the Vegetation Disturbance Dynamic Tool (VDDT). VDDT is a modeling framework that allows users to create and test descriptions of vegetation dynamics by simulating the role of succession, disturbance agents, and management actions on vegetation change.

VDDT assumes that the landscape has been stratified into units with similar succession pathways.

The disturbance-related pathways must specify, for each unit, the type of disturbance (wildland fire, stand replacing fire, non-lethal fire, prescribed fire, etc.), its probability (which defines the return frequency) and its impact on vegetation.

For each year of the simulation, VDDT cycles through the landscape, generates a random number, and determines whether each landscape unit merely gets a year older, moves to a new succession class, or has a disturbance applied to it.

Model results can be viewed as the changes in the distribution of the units in different categories (such as succession class, structural stage, cover type or area disturbed by different disturbance types) at a single point in time.

VDDT can be used at the FPU level to model the effects of particular vegetation treatments (including "no action") as pathways between current and future condition.

VDDT can be used at the FPU level to examine the delta between desired and current condition.

VDDT can be used to measure how well an FPU is achieving its fire and fuels management objectives (EEP).

VDDT does not consider economics or include cost effectiveness when evaluating vegetation treatments.

VDDT does not simulate contagion in space (e.g., wildfire) or time (e.g., insect outbreaks).

VDDT model results are dependent on correctly estimating succession and disturbance relationships, and disturbance and weather probabilities. This is further dependent on local level knowledge of ecology, correct and accessible vegetation data, and the proper training and time to use the model.

Attachment 9: Large Fire Suppression Effectiveness

A complete picture of the fire program, as envisioned by the "Developing an Interagency, Landscape-scale Fire Planning Analysis and Budget Tool" report, would include an analysis of the effectiveness of the fire suppression effort directed at large and extended attack fires.

The effectiveness of large fire suppression would be considered alongside other management actions. This would enable trade-off analyses among funds budgeted for large fire suppression work, fuels, and preparedness. However, once a wildfire escapes initial attack, that escaped fire will receive some level of fire management response commensurate with the local LMP/FMP. This leaves only limited discretionary ability to shift fire suppression funds to other management actions such as fuels or fire prevention.

The analysis could also identify those places where large fire suppression dollars are most effectively spent; however, this discretionary action is also limited in reality by law, prior commitments, and politics.

Constructing a large fire effectiveness model has not been previously undertaken. Thus, there is an element of uncertainty associated with successfully completing this task. To quantify the effectiveness of large fire organizations, we would need to calculate the reduction in fire size that results from having a large fire organization in place on a fire that escapes initial attack. Unfortunately, the productivity and effectiveness of large fire suppression organizations have yet to be determined. Researchers would be involved to try to correlate the numbers of resources used to contain large fires and success.

The inclusion of this model into FPA would entail considerable engagement of research and development. In addition, the varieties of resources that support large fires are not completely funded by fire. The large fire workload contribution of federal/state militia and overhead, plus the use of contract crews and equipment, makes it difficult to parse out where fire funds can best be invested in presuppression resources.

The large fire simulator develops the ability to model discretionary actions such as fuels and prevention to forecast a change in large fire probability. The outcomes of these discretionary actions would include estimates of potential large fires acres burned and large fire costs. This approach would result in a forecast of results from investing in discretionary actions, and their impact on large fires.

The large fire suppression effectiveness module would build on the large fire simulator outcomes to also include the tactics associated with large fire suppression and its costs. If successful this would enable trade-off analyses that include initial attack, fuels, and suppression activities.

Attachment 10: Analysis of Fuel Treatment Effectiveness

Managing wildland fuels with the intent to reduce fire severity or extent is a core component of federal fire policy, yet it is one of the more difficult activities to evaluate in terms of effectiveness. Fuels are complex and dynamic. At any point in time and space, fuels comprise a mosaic of live and dead vegetation, which in turn is the result of growth and mortality influenced by past management history, climate, and disturbance. These same fuels can burn with different intensities depending on seasonal weather patterns, ignition conditions, and even minute-by-minute changes in wind and humidity.

All five options identified for the FPA analysis utilize national and regional direction in allocating fuel treatment resources. Specifically, the use of a regional prioritization tool such as EMDS is fully compatible and complementary to the proposed FPA analyses. For example, if the EMDS analysis suggests that increased fuel treatments in a particular FPU would be advantageous, various alternatives could be constructed and analyzed at the FPU level that reflect this perspective. One would expect the FPA analysis to demonstrate that fuel treatments would be effective in this case, given the logical consistency between the coarse-scale EMDS analysis and the finer-scale FPU analysis. If not, then the findings offer an opportunity to examine both approaches to understand the discrepancy and perhaps adjust one or both. Because the EMDS and FPA processes are compatible and complementary, each will benefit from the results of the other –EMDS inputs can utilize the results of the FPA analyses and vice versa.

The various models within each option vary considerably in how they model fuel treatments and estimate treatment effectiveness. All options make simplifying assumptions, and all options are sensitive to data inputs and model parameterization. None can claim inherently to be more accurate than another, although the more mechanistic and spatially explicit modeling approaches offer greater confidence in discerning the potential differences among treatment alternatives because of increased precision.

Option 1 relies on a simplistic representation of treatment options, fuels, and wildland fire. FPU analysts will likely be asked to judge the extent to which various treatment options would affect overall abundance of fuel types, continuity of fuels, proximity of high-risk fuels to high-value resources and WUI, and other gross measures of fuel conditions. These measures would then be linked with other contributing factors to project changes in the likelihood of fires of varying severity, extent, and consequences in terms of resource damage.

In Option 2, the addition of the Initial Response Simulator (IRS) requires greater spatial detail in the allocation of fuel treatments and their effect on fuel loadings. Fires ignite and burn differently depending on fuel types, and the resources available to respond to the fires vary depending on location. Thus, the spatial relationship of fuels to preparedness resources is important. Results from the IRS can be used to help estimate the same probabilities needed in Option 1.

Option 3 introduces a more spatially explicit analysis of fire and thus is more sensitive to the precise location of fuels. Each pixel in the landscape has a different probability of burning depending on its fuel type and contextual variables such as topography and historical fire frequency. Fuel treatments are modeled as changes in the spatial distribution of fuel types, which change fire probabilities. Off-site effects of fuels treatments might be handled indirectly by changing underlying fire-size distributions, but this approach has not been validated.

The large fire simulator incorporated in Options 4 and 5 models the relationship between the spatial distribution of fuels and fire extent and severity mechanistically. Fuel loads (affected by treatments) interact with weather and topography to affect fire rate of spread in a spatially explicit manner. Thus the pattern of fuel loads influences the final fire footprint in terms of size, pattern, and severity. The result is that all acres are affected by the treatment of some. Thus, the models will be relatively sensitive to changes in fuel conditions and able to identify specific areas of the landscape that either could benefit most from fuel treatments, or produce the greatest off-site benefit if treated. The other advantage of this model is that large fires are closely coupled to weather, which means that fire intensity at a pixel is estimated only under conditions of a simulated fire occurrence, not by choosing arbitrary points on a probability distribution as done in WFSI. Sensitivity to fuels and weather in this model is a mixed blessing, however, in that it also implies sensitivity to errors or uncertainty in input data and model assumptions.

Option 5 is the only option that attempts to model vegetation dynamics explicitly through time and incorporate disturbance factors such as insects and drought that likely affect future fuel conditions. By linking vegetation dynamics and fire, this option provides a means of examining the long-term sustainability of wildland systems under an integrated fire and resource management program.