Fire Program Analysis System– Preparedness Module[1]

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Abstract

Following the 1994 fire season in the United States of America the five federal wildland fire agencies and bureaus within the Departments of Agriculture and Interior along with the State Foresters conducted a review of the Federal Fire Policy. Lack of a common, interagency fire planning and budgeting system was identified as a weakness amongst the federal agencies. The implementation plan identified one of its action items as the development and implementation of a common, interagency fire planning and budgeting system.

The Fire Program Analysis System – Preparedness Module (FPA-PM) incorporates the use of the National Fire Danger Rating System, Energy Release Component for developing probability distributions of fuel moistures with associated probability distributions of wind speed to be used for fire behavior calculations. Weather observation data required for the distribution of wind speeds and fuel moistures is often problematic or missing, FPA-PM utilizes a GRID weather database to fulfill weather observation data when local data is unavailable.

Employing an optimization model for developing a cost effective frontier for fire planning is a key component to FPA-PM and is a new process for the five federal wildland fire agencies. The model is dependant upon land management objectives coupled with fire management strategies, reflected in weights assigned to each Fire Management Unit. Weights reflect the priority or relative importance for initial attack and wildland fire use for resource benefit one Fire Management Unit to another.

The results of the FPA-PM will be utilized for the development of the fiscal year 2007 budget request for the five federal wildland fire agencies and bureaus.

Introduction

Following the 1994 fire season in the United States of America the five federal wildland fire agencies and bureaus within the Departments of Agriculture and Interior along with the State Foresters conducted a review of the Federal Wildland Fire Policy. Lack of a common, interagency fire planning and budgeting system was

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identified as a weakness amongst the federal agencies. The implementation plan for the Federal Fire Policy identified one of its action items as the development and implementation of a common, interagency, fire planning and budgeting system. At the conclusion of the 2000 fire season in the United States another review of the Federal Wildland Fire Policy was conducted. One outcome of the 2000 review was the National Fire Plan developed as part of the response to the 2000 fire season in the United States. One action item from the National Fire Plan was to evaluate the feasibility of developing a common fire planning and budget process for Local, State and Federal wildland fire agencies to use. This action item was assigned to the State Forester of Colorado, Jim Hubbard; a report entitled "Developing a Landscape-scale Fire Planning Analysis and Budget Tool" (aka Hubbard Report) followed. The report provides guidance and a conceptual framework to the Fire Program Analysis System Core Team for design and build.

Following the acceptance of the Hubbard Report by the various land management agencies, a briefing provided to United States Congress resulted in direction to design, build and implement a focused initial attack preparedness analysis, now known as the Fire Program Analysis Preparedness Module (FPA PM). The date for implementation of the Preparedness Module is October 1, 2004. Analysis results will be used to develop the Fiscal Year 2007 Preparedness Budget. Additional FPA modules are anticipated in future years to address the planning and budget needs of other elements of fire management programs (e.g. large fire and fuels management).

Organizing for Success

Upon receipt of the Congressional Direction with the accompanying implementation date, the National Fire and Aviation Management Executive Board appointed a Project Manager and Core Team Business Leader. These individuals developed a project charter containing the scope of the project, projected budget and associated organization to ensure success. This organization included a Core Team made up of representatives from each of the five federal wildland fire agencies and bureaus that make up the majority of wildland fire protection for the United States. The agencies and bureaus of the federal wildland fire agencies are the United States Department of Agriculture, United States Forest Service and United States Department of Interior, Bureau of Land Management, Bureau of Indian Affairs, Fish and Wildlife Service and National Park Service.

The Core Team is directed by a steering committee to ensure that the business requirements for initial attack preparedness and wildland fire use are represented within the Preparedness Analysis.

Preparedness Model Inputs

The Fire Planning Unit (FPU) is the geographic extent of the fire management area that will be analyzed with FPA PM. An FPU may represent one or many agencies and will have a single fire scenario assigned to it. The fire scenario is a statistically modeled representation of the ignitions within a FPU. A fire year can be subdivided into sensitivity periods. Sensitivity periods are measured in two week intervals throughout the calendar year and are used to capture seasonal variability of

resource/fire management objective. Sensitivity periods start January 1 and end December 31.

Sensitivity periods allow the user to change the relative importance of managing modeled fire events within the FPU throughout the year.

The FPU is subdivided into Fire Management Units (FMU). Fire Management Units are spatially designated polygons defined by objectives, management constraints, topographic features, access, values to be protected, political boundaries, fuel types, major fire regimes groups, and so on that set it apart from the management characteristics of an adjacent unit. Fire Management Units are the basic geographic area used in the FPA PM analysis. Modeled fire events, relative importance (weights) and fire resource arrival times from dispatch locations will be associated with each FMU.

Fire Occurrence and Fire Behavior

The Personal Computer Historical Analysis (PCHA) application will be utilized to provide historical analysis of fire occurrence and fire behavior in FPA PM. The PCHA application will develop a probabilistic fire scenario for the Fire Planning Unit and calculate fire behavior for the individual modeled fire event.

The probability of a fire occurring is calculated based upon historic fire occurrence data for the Fire Planning Unit. In the Western United States and Alaska most wildfires are caused by lightning. The weather conditions that produce lightning fires typically result in simultaneous ignitions. These fires along with those that occur individually are represented within a fire scenario. Fires that have similar fire behavior characteristics, such as those that occur at Fire Intensity Level 1 can be grouped together. Fire Intensity Levels (FIL) are representations of flame lengths that are put into categories as described in Table 1.

The fire event data with its associated fire behavior is passed to a data transformer (described later) on its way to the optimization routine.

In order for a fire frequency distribution to be calculated the location of each historical fire record must be known so that it can be assigned to a FMU. The total number of fires plotted within each FMU have associated data elements that describe them, one being discovery date. Using the discovery date a probability can be calculated of a modeled fire event and simultaneous fires could occur on any given day.

Personal Computer Historical Analysis will be used to determine fire behavior attributes of the fire scenario for use within the optimization routine. Additional fire behavior inputs into PCHA for use in FPA PM are fuel type, weather, fuel moisture, slope, elevation and aspect. FPA PM utilizes Fire Behavior Prediction System surface fuel models and associated canopy cover, stand height, crown base height and crown bulk density to model the potential of passive and active crown fire.

Weather data in terms of wind speed and relative humidity may be derived from a fire weather station that is associated with the FMU or may be retrieved from the GRID weather database. The GRID weather database utilizes all available weather

stations within an area to determine coverage for all areas of interest within the United States.

The GRID weather option interpolates weather data from known stations and applies it to points of ignition for modeled fire events. GRID weather adjusts data to account for changes in slope, aspect and elevation.

Fuel moistures used as inputs into PCHA for fire behavior calculations will be determined for all Fire Management Units within a Fire Planning Unit based upon the National Fire Danger Rating System (NFDRS) fuel model G. Fuel model G is the only fuel model within NFDRS that contains all of the size classes and categories of fuels, i.e. one-hour, ten-hour, one hundred-hour, one thousand-hour, live herbaceous and woody. Using the Energy Release Component (ERC) for fuel model G (ERCg) coupled with fire occurrence data, a regression analysis has been completed nationwide (including Alaska) to determine the probability of a fire occurring. Based upon the percentile of ERCg calculated per Fire Management Unit there are correlating fuel moistures for each of the size classes of fuels. These fuel moistures will be used with associated wind speed distributions in conjunction with each Fire Behavior Prediction System (FBPS) surface fuel model, and canopy attributes identified within a Fire Management Unit to calculate a rate of spread and flame length for every combination of fuel moisture and wind speed. Slope, elevation and aspect will be entered into PCHA by their representative proportions in preparation for using probabilistic analysis.

Outputs from PCHA that will be utilized in the FPA PM optimization routine are Rate of Spread (ROS) and Fire Intensity Level (FIL). Rate of Spread will be used to determine the amount of fireline perimeter that exists at different time periods.

Table 1— *Fire Intensity Levels*

FIL	Flame Length
1	0 - 2
2	2.1 - 4
3	4.1 – 6
4	6.1 – 8
5	8.1 – 12
6	12.1 +

Fire Intensity Levels are used to communicate the impact that the fire will have on natural and cultural resources. Fire Intensity Levels also assist in determining the effectiveness that various fire resources will have in relation to stopping the spread of the fire. As a guideline, people with hand tools alone will not be effective in stopping the spread of fires with flame lengths greater than four feet; they will need assistance from either engines, dozers, air tankers or any combination of mechanical and aerial fire resources that produce chains of fire line.

Fire Resources

The Preparedness Model requires several inputs; most of these inputs are passed to the Data Transformer and then onto the Optimization Routine, see Figure 1. Fire Resource data with their associated attributes will be characterized by their travel time, deployment cost and production rate (chains per hour) from a Dispatch Location to a Work Load Point. The initial version of FPA PM has only one Work Load point per Fire Management Unit. Workload points are used to calculate the arrival time of fire resources from their Dispatch Location to the area of concern or where the work generally occurs.

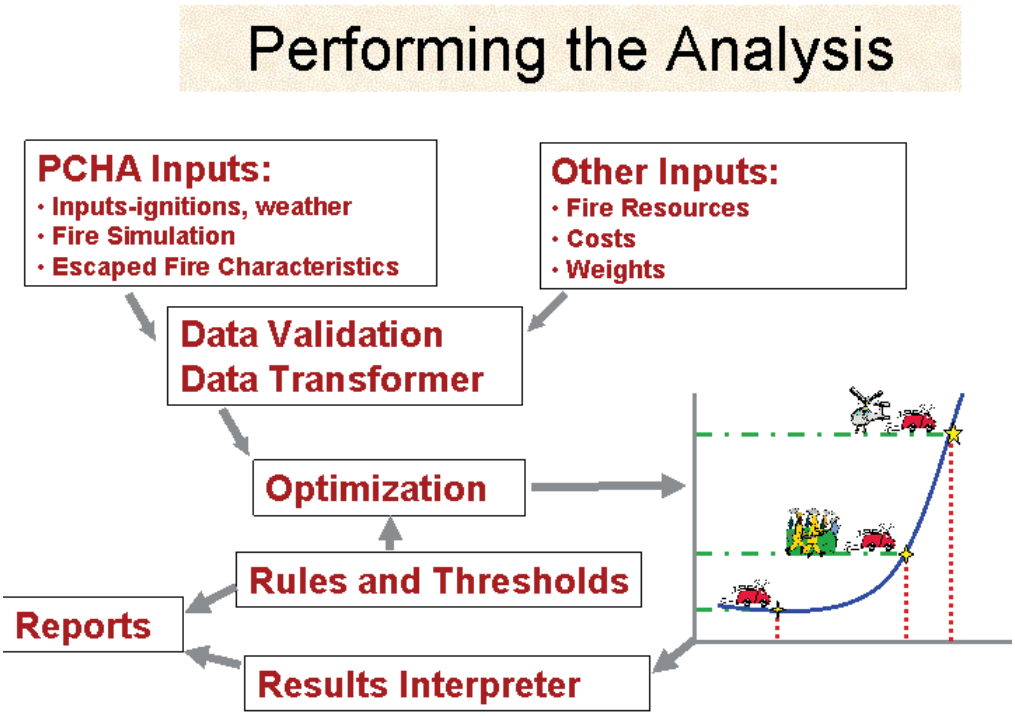


Figure 1—Performing the Analysis

The fireline production rate used for a specific fire resource is determined by Kind, Category, Type and Staffing in relation to the surface fuel model and a specific condition along with an associated percent slope. Fire resource fireline production rates are assigned to each ground based fire resource including helitack, rappelers and smokejumpers using standards developed by the National Wildfire Coordinating Group, Fire Equipment Working Team.

Weights

A critical piece of information needed by the system to translate land management objectives for initial response into the optimization formula is an indication of the relative importance to respond to unplanned ignitions under different circumstances. This will be accomplished through the application of relative weights to each fire management unit (FMU) within the fire planning unit (FPU). For ignitions that are

being modeled for aggressive initial attack, conceptually the model takes the weights applied to each fire management unit and multiplies the weight by the unburned acres for each analysis. The result is called weighted acres protected (WAP). The mathematical model strives to maximize the number of weighted acres protected across a fire season.

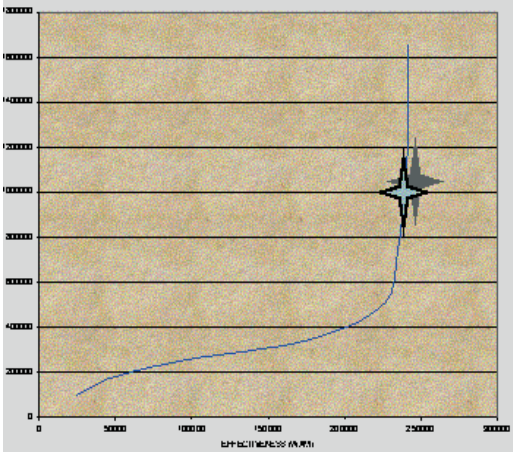
Optimization

The FPA preparedness model will utilize a linear optimization approach (integer programming) to establish the cost effectiveness frontier (See Figure 2) of weighted acres protected (WAP). The integer program will maximize weighted acres managed for a given cost level. The optimization model will then be run iteratively across a range of total cost constraints. The range of total costs will be determined by the minimum and maximum cost levels to be analyzed. The budgeted portion of total cost will also be calculated.

The integer program will model accomplishment of a set of representative wildland fires for each FIL and sensitivity period in each FMU. If the fire management objective for the ignition is suppression, containment is modeled and achieved if the sum of the fire line constructed exceeds the fire perimeter in any time period. The acres burned would result in a reduction in the total number of WAP. Each type of fire suppression resource (e.g. engines, hand crews, etc.) has an associated fire line production rate, preparedness cost and utilization cost. If the fire management objective for the ignition is Wildland Fire Use (WFU), production and cost would be estimated by the duration of the WFU event.

Expenditures and the effectiveness of wildland fire use fires will be optimized along with the suppression ignitions. Wildland Fire Use burned acres would result in an increase in weighted acres managed (WAM). The integer program will deploy fire resources to attempt to maximize the firefighting effectiveness of a given total cost.

If the model is unable to manage a fire within its cost allotment, then the fire is assumed to have escaped initial response and its size defaults to a statistically determined final fire size. All escaped fire acres result in a reduction in WAM. (Rideout and Kirsch 2002).



Cimarron FPU

FPU Acres	225,000
Weighted Acres Managed	240,000
Initial Response Cost	$1,000,000
Preparedness Budget	$850,000
Actual Acres Burned	7,490

FMU	# Fires	Acres Burned	FMU Objective Threshold	Objective Met
1	10	674	700	Yes
2	14	941	2500	Yes
3	3	5875	950	No

Initial Response Organization

Resource Location	Resource	Budgeted	Existing	Cost	Owner
Jackstraw Station	Engine, Type 6	Yes	Yes	$115,000	USFS
Hollywood Airport	Helicopter, Type 3	Yes	No	$265,000	?
Main Office	Hand Crew, 20-person, Type 2	Yes	Yes	$400,000	BLM
Fire Management Officer	Overhead	Yes	Yes	$70,000	NPS
Colton County Jail	Hand Crew, 3-Person	No	Yes	$90,000	Colton County
Initial Response Suppression Cost				$60,000	
Total Initial Response Cost				$1,000,000	

Figure 2—Example page of how to determine the cost effectiveness frontier.

Post Optimization

The Data Transformer will pass certain "Run parameters" to the Results Interpreter at the time that it initiates a call to the Optimizer. These parameters will enable the Results Interpreter to monitor the status of the Optimizer, making that status available to users who inquire about their results. If the Optimizer returns an "infeasible" message or other error, the Results Interpreter shall make the necessary notifications. Once the Results Interpreter determines that an individual Run has completed, it will begin its primary functions.

Disaggregate Optimizer Fires

The Data Transformer is allowed to take mathematically sound "shortcuts" as it prepares data for the Optimizer by grouping identical individual fire ignitions into one Optimizer Fire Event, increasing weights and costs accordingly. The Data Transformer will notify the Results Interpreter of any such allowed shortcuts it determined advantageous and implemented for each Run. Upon being notified that a Run of the Optimizer has completed, the Results Interpreter will adjust the raw Optimizer outputs to reinstate original input fire data.

In addition, the Results Interpreter will segregate dollars by Agency and Unit, and will create the capital budget indicated for dispatch locations or stations and fire resources. Where user input is needed in order to make decisions about Optimizer outputs (e.g. which Unit should an engine belong to where one or more are indicated for an inter-agency station), the Results Interpreter shall identify the required choices

for user interaction. FPA PM Users are able to specify desired Management Objectives, including acres burned by FMU, FIL, and Sensitivity Period.

The Optimizer passes to the Results Interpreter the results of each fire ignition, including acres burned. By matching the results with other available information about each fire ignition (FIL, FMU, and Sensitivity Period), the Results Interpreter can determine compliance with desired objectives.

This compliance will be stored along with the other outputs, and made available for user reports.

It should be recognized that the Fire Program Analysis System – Preparedness Module and future modules are under development while this paper and symposium are being under taken.

For the most recent, up to date information regarding this system please visit the following website:http://fpn.nifc.gov.

Summary and Conclusion

The FPA PM system will result in a consistent, common fire budget and planning tool used by five federal land management agencies. The system will use a statistical representation of historic fire events and weather data and, applying optimization, will determine the most effective fire organization to meet land management objectives at a variety of budget levels. The results will be used to develop national fire preparedness budgets and assist in budget allocations back to field units.

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