IMPLEMENTATION OF A WILDLAND FIRE PROTECTION PLANNING SYSTEM BY A STATE RESOURCE MANAGEMENT AGENCY: SIMULATION PROVES MORE USEFUL THAN OPTIMIZATION[1]

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Abstract.--Fire protection planning issues in California were best addressed by non-optimizing simulation because problem identification, agency and university capabilities, and technology transfer considerations would render ineffectual any system based upon the more traditional cost plus net value change paradigm.

Keywords: Urban-wildland interface, non-market valuation, cost plus net value change, least cost plus loss.

INTRODUCTION

Several alternative models of initial attack have been developed to provide an economic framework for wildfire protection, at least partly in response to the U.S. Forest Service's legal mandate to explicitly consider relative resource values. FOCUS (Bratten et al., 1981), FEES (Mills and Bratten, 1982), and NFMAS (U.S.D.A., 1982) differ in their methodological approach to the simulation of wildfire occurrence, behavior, and control, but rely upon the same optimization concept -- minimization of cost plus net value change (C+NVC).

The C+NVC criterion evolved from concepts first articulated by Sparhawk (1925), and further developed by many, including Flint (1928), Hornby (1936), Craig (1945, 1946), and Arnold (1949). The essence of this criterion is that:

> ...protection level is optimized when the combined costs of prevention (including presuppression), suppression, and damage are minimized. These three functions are assumed to vary predictably with changing levels of presuppression expenditure, fire management effort, or acreage burned ...The resulting combined function is a u-shaped curve, with the minimum point representing the optimum presuppression expenditure (Gorte and Gorte, 1979).

Since 1985, the California Department of Forestry and Fire Protection (CDF) has been collaborating with researchers from the University of California's Department of Forestry and Resource Managment to develop a Fire Protection Planning System (FPPS). Although many elements of NFMAS were incorporated into FPPS, the C+NVC concept was not. University researchers and CDF staff agreed from the onset that issues of problem identification, agency and university capabilities, and technology transfer would render ineffectual a system based upon C+NVC. Reflection upon FPPS's development and implementation appears to bear out the wisdom of this decision. While the CDF's planning problem has some unique elements, it is largely representative of that faced by other non-federal fire control agencies.

INSTITUTIONAL AND HISTORICAL BACKGROUND

The CDF is a large firefighting organization by any standards. It provides wildland fire protection on 32 million acres of public and private land. Firefighting expenditures accounted for approximately 85$ of its 1989-90 budget of 200 million dollars, not including the substantial, separately appropriated, "emergency fund" expenditures incurred fighting major wildfires. The CDF is overwhelmingly a line organization, with relatively few staff stationed at its Sacramento headquarters. Its Fire Protection Planning staff consists of only three full-time professionals, augmented by a few student interns.

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FPPS was not the first, nor is it likely to be the last, wildland fire protection planning framework considered by or developed for the CDF. In the early 1980s, significant time and resources were devoted to the development of a station matrix for each CDF fire station. Although these matrices provided valuable and comprehensive descriptions of the status quo, they quickly proved unsuitable for performing "what-if' analysis. At about the same time, the U.S. Forest service encouraged the CDF (along with other non-federal fire control agencies) to adopt the NFMAS planning framework, and in particular, its initial attack assessment component (IAA). Implementation of NFMAS was attempted on three of CDF's twenty-two ranger units with disappointing results. As these results were being assessed, the State of California's fiscal condition began to deteriorate, spawning extraordinary and ongoing regulatory (State Board of Forestry), legislative (Legislative Analyst), and executive (Department of Finance) pressure on the CDF to justify and control firefighting expenditures.

PROBLEMS WITH THE C+NVC PARADIGM

The planning problems faced by the CDF and the U.S. Forest service are similar. Each must address multiple and sometimes conflicting objectives, including the control of damage to timber, rangeland, residential, watershed, wildlife, and aesthetic systems. But the differences between the agencies' planning problems are at least as striking as the similarities. Accordingly, while C+NVC may be an appropriate paradigm for U.S. Forest Service planning, we believe that problems related to non-market valuation and the agency's decisionmaking process and legal mandate severely limit its utility to the CDF and, by extension, to many other non-federal fire control agencies. In a rough national assessment of fire protection on non-federal wildlands using NFMAS, the USFS (1983) concluded that:

> Loss of current and future timber supplies accounts for 79 percent of the total losses from fire. The loss of improvements (residences, fences, and other structure, both on and off site) accounts for 19 percent of total losses. Although timber and improvements are the dominant loss categories on a national basis, losses of other resources such as range, watershed, and wildlife are significant in some Fire Analysis Zones.,

While this assessment may be a legitimate characterization of the protection issues in some states (e.g., Washington, Oregon, or Minnesota), it most certainly does <u>not</u> reflect the situation in California. CDF protected wildlands may be characterized as either: (1) having structure losses or value changes in 'other resource* systems dominate C+NVC calculations; or as (2) having the uncertainty associated with changes to non-market resource systems render C+NVC calculations essentially meaningless in the formulation of public policy. Either characterization is legitimate, depending upon one's conceptual frame of reference.

The difficulty of forecasting changes in resource conditions and valuing of these changes depends upon the type of wildland under protection. Timber losses are comparatively easy to forecast and value. By contrast, changes to non-market resource systems like watersheds or wildlife habitat are dependent upon on spatial or temporal dimensions that are difficult to incorporate into simulation models of firefighting effectiveness. Further, valuation of changes to such systems is conceptually and empirically problematic, and will always remain so. Site and situation-specific considerations further complicate forecasts of losses of structures, although their valuation is relatively straightforward.

The relevance of the C+NVC paradigm to the CDF has diminished due to recent increases in population density in the urban-wildland interface. Many other non-federal fire control agencies also have protection responsibilities on private unincorporated lands situated between urban centers and public reserves. Inevitably, their wildfire planning problems will come to resemble the CDF's more closely than the U.S. Forest Service's.

The C+NVC paradigm's reliance upon identification of potential Pareto improvements is consistent with current U.S. Forest Service planning guidelines to consider relative resource values (e.g., NFMA regulations, 36 CFR § 219.27 (a) (2)1 and authorization to:

> ...cooperate with State Foresters, or equivalent State officials, in developing systems and methods for the prevention, control, suppression, and prescribed use of fire on rural lands and in communities that will protect human lives, agricultural crops, livestock, property, other improvements, and natural resources (Cooperative Forestry Assistance Act of 1978).

The legal mandates of non-federal fire control agencies may be quite different. The CDF's legal mandate is to provide "equal protection for similar areas'. Although it is not difficult to derive an economic interpretation for either "equal* or 'similar', this vague mandate is typical of the considerable management discretion granted to non-federal agencies. This type of mandate may also be viewed as consistent with the difficulty of achieving 'objectivity" with respect to any environmental system characterized by risk (Douglas and Wildavsky, 1982). As Johnson and Covello (1987) note:

> ...one of the most important findings to emerge from the psychological literature on risk perception is that people take into consideration a large number of factors in

evaluating the seriousness of a risk. These factors include, among others, catastrophic potential, familiarity, voluntariness, and dread.

Where homes, lives, or treasured ecosystems (e.g., Yellowstone) are at risk, the relevance of these findings is obvious. No matter how appealing economists and planners may find the C+NVC paradigm (or the underlying principles of marginal analysis, monetary valuation, and identification of potential Pareto improvements) we must be careful to avoid building decision-support systems that fail to reflect critical social and cultural considerations (Davis, 1965).

In light of these problems, it is hardly surprising that the overwhelming majority of CDF decision-makers could be characterized as suspicious of a C+NVC-based planning model, or indeed of any planning model designed to provide a "single solution' or "optimal budget". Their suspicion can not be dismissed as simply an aversion to limits on managerial discretion or a misplaced reliance on "experience". The same decision-makers have proven to be willing and able to accept a planning model that is consistent with the marginal decision-making process characteristic of their past efforts to rationalize investment and deployment decisions for firefighting resources, i.e., a model in which the focus is upon the effectiveness of identifiable firefighting resources in a familiar geographic context.

FPPS

FPPS consists of four Pascal programs (Figure 1): FBDMOD (calculates fire behavior using the NFDRS), MERGE (associates fire behavior estimates with historical fire records), FPPSTATS (calculates distributional characteristics of fire load), and CFES-IAM (simulates initial attack), and CFESDB (a Paradox database application for managing and querying CFES-IAM simulation inputs and results).

CFES-IAM simulation results are presented in four kinds of output screens or printouts, and are also saved to a datafile for input to CFESDB. Simulation results for particular representative fire locations are shown in 'Event List' screens (Figure 2), These results are aggregated for reporting at the level of fire management analysis zones (FMAZs) (Figure 3). Utilization of individual firefighting resources is displayed in "Expected Annual Missions* screens (Figure 4). Finally, success in containing fires within simulation time and size limits is displayed in an "Initial Attack Success' screen (Figure 5).

EVALUATION OF FPPS DEVELOPMENT AND IMPLEMENTATION

That the FPPS analysis system has been as successful as it has thus far can in large part be traced to the dedication of the outstanding, dedicated individuals serving on the agency staff. Certainly, it is rare for an effort of this scope to be mounted with so little staff support. Only three agency staff, one of them an administrator, have been assigned to expedite this analysis, and all are charged with a host of other duties. The human resources constraint is binding, has greatly slowed the development and implementation of FPPS, and has been largely responsible for some costly mistakes. There has been no budget for a full-time staff programmer, forcing reliance upon a succession of undergraduate and graduate university students working on summer contracts, or on a part time basis. Though some were enrolled in computer science programs, these students were often new to programming, and learned many of their skills on-the-job, through trial and error. None had any background in wildfire protection or modeling, so it was unrealistic to expect them possess a level of understanding (of the data for which they were writing processing programs) that would permit them to assess the reasonableness of the output from their computer programs. Lack of programming experience and frequent redeployment of the planning staff on other agency analyses and the turnover rate contributed to an inadequate understanding of exactly what goes on in the FPPS programs, undermining their ability to detect programming bugs early on. An overarching emphasis on ease-of-use and data entry error-trapping motivated by the lack of computer experience among field personnel resulted in programs that were full of flash, but hardly bug-free.

The planning staff's lack of experience in designing, developing and maintaining computerized databases, and the field employees' lack of computer experience were other serious obstacles to successful implementation. Because of this inexperience, the planning staff was inclined to automate the data processing to the maximum extent possible. Towards this end, they contracted with the authors through the University of California to hire a student to develop RBase applications; however, the relatively primitive capabilities available in RBase at that time rendered that effort a failure. When this became clear, UC researchers wrote Pascal code to achieve a suitable degree of automation outside of RBase, and the databases became mere repositories. These programs were turned over to the CDF student programmers for interface development and maintenance.

Even more problematic has been the task of maintaining data integrity throughout the analysis process. The fire history databases have always contained records that appeared unlikely, but could not easily be verified. While most keypunch errors could be corrected, multiple reports of the same fire incident were quite difficult to determine, and the common practice of entering a final fire size of 0 for both small fires (less than .1 acre) and for non-fire incidents (like emergency medical responses) added to the confusion. Because of the distributed implementation, there is limited quality control over the CFES-IAM input data

Fire Protection Planning System

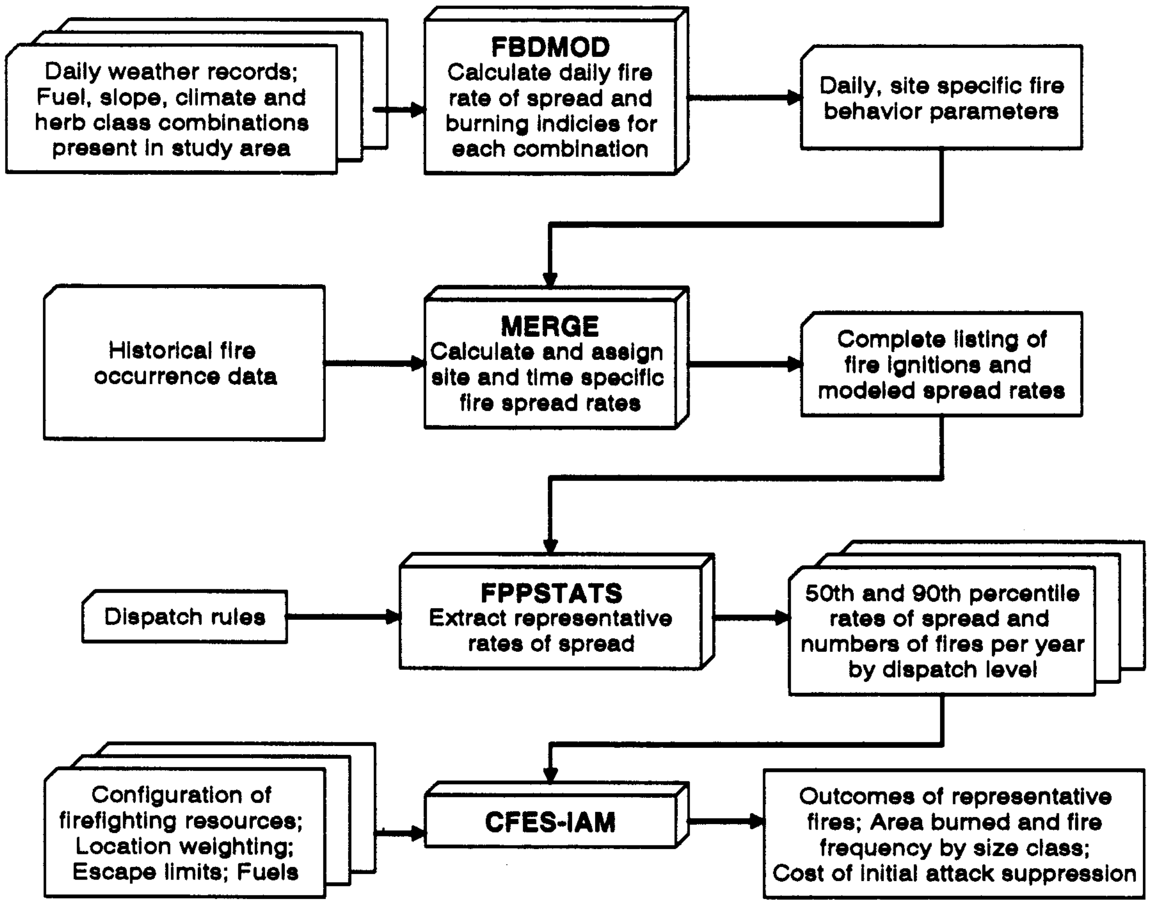

Figure 1.--Data flow diagram for the Fire Protection Planning System. Micro-computer programs are indicated in bold face type.

File: SNCAM.CF1 CFES-IAM OUTPUT SCREEN # 101

EVENT LIST FOR RFL # 1

FDL/ ROS %ile	ROS CH/HR	PERIM. INCREASE RATE CH/HR	TIME TO CONTAINMENT MINUTES	ACREAGE FINAL OR ON ARR. OF LAST RESOURCE	# OF RES. USED/ AVAIL.	UNCONTAINED PERIM ON ARR. OF LAST RES.	AGGREG. PRODUC. ON ARRIVAL OF LAST RES.	NUMBER OF FIRES PER YEAR	SUPPRESS. COSTS $
L/50	0.0	0.0	0	0.00	0/34			0.0	0.00
L/90	0.0	0.0	0	0.00	0/34			0.0	0.00
M/50	30.4	73.6	11	1.45	2/37			4.3	0.00
M/90	110.7	268.1	ESL @ 81	877.72	24/37			1.1	UNKNOWN
H/50	56.7	137.3	53	100.93	17/40			2.1	0.00
H/90	137.2	332.3	ESL @ 92	1739.30	34/40			0.5	UNKNOWN

Figure 2.--Event List output screen from the California Fire Economics Simulator.

File: SNCAM.CF1 CFES-IAM OUTPUT SCREEN # 113

EXPECTED ANNUAL ACREAGE BURNED IN CONTAINED FIRES FOR ALL RFLS

FDL	0-0.25	0.25-3.0	3.0-50	50-100	100-300	AVERAGE FIRE SIZE	TOTAL ACRES
L	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	0.00	19.37	325.44	0.00	0.00	6.37	344.80
H	0.00	0.00	63.21	520.16	1255.63	71.28	1839.00
TOTAL	0.00	19.37	388.64	520.16	1255.63	27.33	2183.80

EXPECTED ANNUAL NUMBER OF FIRES BY SIZE CLASS

FDL	0-0.25	0.25-3.0	3.0-50	50-100	100-300	ESL	TOTAL FIRES
L	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	0.00	21.21	22.07	0.00	0.00	10.82	54.10
H	0.00	0.00	1.44	9.08	10.11	5.16	25.80
TOTAL	0.00	21.21	23.52	9.08	10.11	15.98	79.90

Figure 3.--Expected Annual Fire Statistics output screen from the California Fire Economics Simulator.

File: SNCAM.CF1

CFES-IAM OUTPUT SCREEN # 114

EXPECTED ANNUAL MISSIONS

ID CODE	LOW FDL	MEDIUM FDL	HIGH FDL	TOTAL	MISSION COSTS
LNUB2576	0.00	3.68	5.93	9.61	$ 0
LNUB2563	0.00	3.68	5.93	9.61	$ 0
LNUB3864	0.00	3.68	7.59	11.26	$ 0
SCUB6176	0.00	9.41	11.04	20.46	$ 0
SCUB6169	0.00	9.41	11.04	20.46	$ 0
SCUB4184	0.00	35.92	21.88	57.80	$ 0
SCUB4161	0.00	35.92	21.88	57.80	$ 0
CZUB1175	0.00	9.63	10.17	19.79	$ 0
SNUB2174	0.00	1.08	0.52	1.60	$ 0
SCUB3183	0.00	17.53	12.59	30.12	$ 0
SCUB3179	0.00	17.53	12.59	30.12	$ 0
SCUB3281	0.00	9.74	10.11	19.85	$ 0
SCUB2275	0.00	19.26	12.07	31.33	$ 0
SCUB1165	0.00	19.26	13.52	32.78	$ 0
SCUB1178	0.00	19.26	13.52	32.78	$ 0

Figure 4.--Expected Annual Missions output screen from the California Fire Economics Simulator.

File: SNCAM.CF1

CFES-IAM OUTPUT SCREEN # 120

INITIAL ATTACK SUCCESS

PERCENTAGE OF FIRES CONTAINED WITHIN SIMULATION SIZE AND TIME LIMITS

RFL	LOW FDL	MEDIUM FDL	HIGH FDL	TOTAL	SUPPRESSION COST FOR CONTAINED FIRES
1	100.0	100.0	80.0	93.5	0
2	100.0	100.0	80.0	93.5	0
3	100.0	100.0	80.0	93.5	0
4	100.0	100.0	80.0	93.5	0
5	100.0	100.0	80.0	93.5	0
6	100.0	100.0	100.0	100.0	0
7	100.0	100.0	80.0	93.5	0
8	100.0	80.0	80.0	80.0	0
9	100.0	100.0	80.0	93.5	0
10	100.0	100.0	100.0	100.0	0
11	100.0	100.0	100.0	100.0	0
TOTAL	100.0	98.6	89.6	95.7	0

Figure 5.--Initial Attack Success output screen from the California Fire Economics Simulator.

files or simulation nomenclature. When simulation outputs are loaded into a master database (CFESDB) in Sacramento, they usually contain some errors (due to faulty inputs) that go undetected for several months. Within the CDF, there still appears to be some hope, however unrealistic, that an application can be written to automate all queries to CFESDB. The nature of the queries is so varied that an intensive instruction of Sacramento planning staff in the art of ad hoc database query, probably via a standardized protocol like QBE or SQL, appears to offer the best chance of future success. Though the planning staff strongly desires field level self-sufficiency in answering "what-if" questions, the current state of relational databases and the background and time constraints of field personnel make this an unlikely prospect in the near term.

Partly because agency administrators in Sacramento had little, if any, experience working with analytic models generally, let alone, computer simulation models, confusion about the capabilities of FPPS and the range of analyses that could be conducted using it was not uncommon. After the existence of FPPS became generally know throughout the CDF organization, (thanks to a high profile rollout at all levels of the agency), CDF brass began to turn to the fire protection planning staff when a crisis arose with a request to find a solution using FPPS. These requests occasionally indicated an incomplete understanding of what FPPS is or how it works. Some requests would have required data not yet collected. Quite possibly, the briefing sessions at which these administrators were introduced to the simulator fired up their imaginations about what kind of analyses would be desirable.

Despite these difficulties, FPPS is enjoying a degree of success at the central and regional levels. Rightly or wrongly, as a result of consistent lobbying and early ad hoc FPPS analyses that proved valuable, most CDF administrators have come to hold FPPS in reasonable esteem. At the ranger unit level, early adopters have used the model to explore all kinds of alternatives, from repositioning a fire station to dropping air tankers from most dispatches, and have usually found that the model confirmed their intuition. At the regional and Sacramento (central) levels of CDF, administrators have run numerous scenarios in preparation for the deepest budget cuts the agency has ever seen. While these FPPS users strongly desire a model that yields cut-and-dried answers to the question of which firefighting resources to idle, they have accepted that they cannot escape the responsibility for such decisions and seem to appreciate having this tool available to enhance their assessment of the options.

As with most simulators deployed in an operational context, a principle benefit has been the enhancement of agency staff's understanding of the system that they guide and plan for. Part of this understanding results from the process of formalizing decision rules to be built into CFES-IAM and its more sophisticated descendent, CFES-IAM version 2. Agency personnel, especially at the higher administrative levels, were often ill equipped to answer the model-builders' questions, so considerable opportunities for expert surveys and "Delphi" knowledge acquisition were exploited. Ancillary benefits of these sessions included a heightened awareness among Sacramento staff of the situations faced in the field and the methods used to address them, and a higher degree of respect by the field personnel for the Sacramento staff, both because of their perception of the utility of FPPS and the self esteem generated by the "mucky-mucks" seeking their expert opinion.

CONCLUSIONS

In the development of FPPS, we abandoned the C+NVC paradigm and tried to work within the decision-making framework to which the agency was accustomed. Borrowing liberally from NFMAS (and especially its IAA model), we limited the scope of FPPS to a manageable problem (initial attack). We cast the model in terms of the utilization of identifiable firefighting resources (e.g., the Santa Rosa engine) in easily visualized situations (e.g., high population density grasslands along Highway 101). This greatly simplified our task as consultants -- we were able to focus our attention on the part of the problem that was realistically amenable to quantification by a couple of researchers, rather than forced to design a system to reduce a mass of questionable data to a single decision criterion. But most importantly, this strategy produced outputs that enhanced, rather than threatened, the CDF's decision-making process.

To conclude on a philosophical note, if we (the members of the SAF E4 working group) want to keep our egos in check, we need only stop and make an objective appraisal of the degree to which the models we develop have been successfully integrated into our clients' management decision-making. Our track record is abysmal. We assume that everyone in E4 wants their models to be actually used and honestly wants to be responsive to the needs and mission statements of land grant universities and government agencies that fund our work. If this is true, we must all be ready to jettison time-honored economic paradigms that have outlived their usefulness (or that never had anything useful to say). In the case of wildfire protection planning on non-federal wildlands, it is time to allow the C+NVC paradigm to gracefully depart to the nether regions where bi-metalism and mercantilism now reside.

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