A TECHNICAL COMPARISON MODEL: CLASS A FOAM COMPARED TO WATER AS AN EXAMPLE

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Water has been used to fight fire for centuries. The Bureau of Land Management (BLM) relies on a fleet of over 400 water engines as its primary fire suppression technology in Great Basin fuels.

Class A foam is a relatively new approach to fire suppression. The foam concentrates were introduced in the early 1980's (Schlobohm and Rochna 1987). Proportioning and foam-generating devices have been modified to meet the demands of the wildland fire workplace.

There are two arguments against the use of Class A foam. First, the use of foam technology requires investment beyond that necessary to operate a conventional water-pumping system. For example, foam concentrate that may cost $9.00 per gallon and is proportioned at 0.5 percent will cost $22.50 for every treatment of a 500-gallon tank. Installing a foam proportioner will cost anywhere from $200 to $4,000. Aspirating nozzles cost between $20 and $500. Compressed air foam systems range from $5,000 to $20,000, depending on components.

A second argument is that the improvements foam may offer are unnecessary. As a result of years of experience with water, engines are managed to handle the typical workload of fire frequency and behavior. The argument is that extreme fire situations, such as large numbers of large fires in a few hours which tax the capabilities of water engines, would do the same for foam engines.

Advocates for the use of Class A foam argue that foam makes water more productive. For example, when engines using water extinguished 100 chains of fireline in grass and brush fuels of the Lakeview BLM District, similar engines using foam extinguished 133 chains (Schlobohm and Rochna 1987). The difference was attributed to water engines routinely doubling back to catch rekindles while foam engines continued moving ahead.

No documented method exists to determine if an investment in Class A foam is cost effective. Is there a fire scenario for which the use of foam saves money? For which fireline intensity levels does foam use cost more than water alone? Fire managers must guess the answers to these questions as they consider dispatch to fires and off-season investment in their engines.

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PURPOSE

The purpose of this paper is to develop a process or model for comparing a new technology against an existing technology. The comparison is based on productivity, cost, and workload parameters. The parameters determine annual expected values for each technology. Differences in expected values are tested for significance. The process can help the fire manager assess the role of the new technology in local resource, fuel, and fire conditions.

THE COMPARISON MODEL

The model for comparing fire suppression technologies is presented in figure 1. The model is designed to quantify the annual efficiency of differing suppression forces against identical historical fire scenarios. Suppression forces for each technology are defined by production, effectiveness, and cost. Fire scenarios are defined by size and perimeter over time. The efficiency of each technology is determined by optimizing the dispatch of the forces to each fire scenario. This is the measure of efficiency analysis.

Workload is defined by frequency of fires described by fireline intensity level. One relationship of efficiency and workload is expected value, which is determined through a decision-tree analysis. This is the expected value analysis.

The difference in expected values is evaluated for significance by a test of the null hypothesis. The null hypothesis test supports a decision either for the current or the new technology. This is the statistical analysis of the null hypothesis.

A second relationship of efficiency as a function of workload examines those portions of the workload for which each technology is the choice. This is the workload analysis.

Although the model is generic, each step will now be explained in detail with the example of Class A foam and water.

ALTERNATIVES

A test of the null hypothesis requires the analysis of two alternatives:

1. There is no difference between the use of water and the use of foam.
2. There is a difference between the use of water and the use of foam.

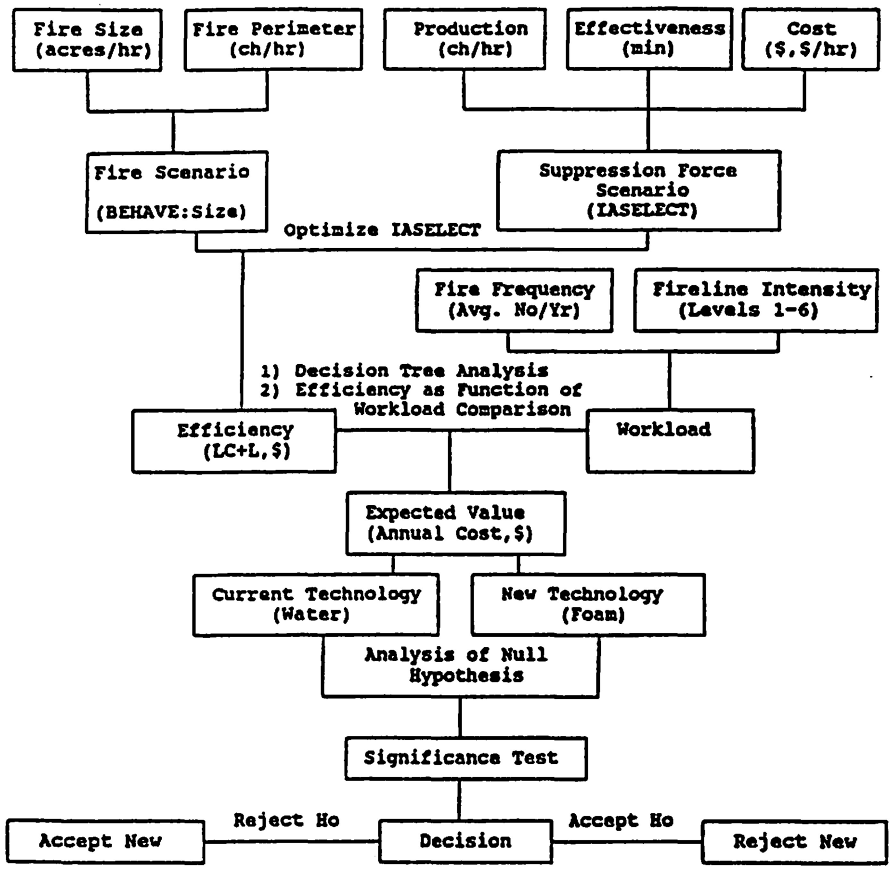

Figure 1—The fire suppression technology comparison model.

Current (water) technology in this case is a set of suppression forces modeled after a BLM district in the Great Basin. The water forces set includes 12 identical ICS type 5 water engines, two water tenders, and one type 2 bulldozer.

New (foam) technology is defined as the current technology plus or minus those characteristics that make it different from the current technology. The foam forces set includes the exact same 12 engines and their complement of tenders and bulldozer. The engines, however, have foam equipment and concentrate appropriate for Great Basin fires. Specifically, each foam engine has the least expensive automatic proportioner and enough concentrate to work one 8-hour shift. A very wet foam is made from standard water nozzles that have the same flow rate as those on the water engines.

MEASURE OF EFFICIENCY ANALYSIS

Optimizers—In this model, least cost plus resource loss (LC+L) is a measure of efficiency for a specific fire. LC+L is a function of production, effectiveness, and cost.

Computer programs such as IASELECT (Wiitala 1990) and the Initial Attack analyzer have been developed to obtain values for efficiency measures as a function of these parameters. IASELECT optimizes suppression force dispatch based on LC+L for specific fires. It is used in this model because (1) it performs the desired optimization calculations, (2) it can be narrowed in scope, and (3) it is readily adjusted.

The Suppression Forces Scenario—IASELECT requires several descriptive inputs for its analysis. Suppression forces are described as accurately as possible.

Each suppression force is assumed to be always available in the analysis to simplify the comparison and reduce the number of externalities. In reality, each suppression force is rarely available for each fire.

Suppression force effectiveness or use duration indicates how long apparatus or personnel are useful once they arrive on a fire. Use duration is how IASELECT accounts for time when a suppression force is not productive, such as an engine returning to a water source for a tank refill.

Use duration for the engines is determined by tank capacity and water flow rate. Each engine has an 850-gallon tank. Each engine is assumed to flow 5 gallons per minute continuously until the tank is empty. Since this flow rate is appropriate for both water and foam on applications to Great Basin fuels, effectiveness is assumed to be equal for each technology:

850 gallons @ 5 gallons/minute = 170 minutes
= use duration

Production rates for water engines and bulldozers are taken from the National Wildfire Coordinating Group Fire Line Handbook. Foam engine production is based on water engine production rates.

Table 1—Fire growth scenario for FM1 FIL6

Ignition to containment	Fireline to be built	Area of fire
Hours	*Chains*	*Acres*
1	291	402
2	583	1,607
3	874	3,615
4	1,166	6,427
5	1,457	10,042
6	1,749	14,460
7	2,040	19,681
8	2,332	25,706

Production is a critical element of this analysis because it is a key measure of the difference between the technologies, and yet the values for water and foam are weakly supported. Water engine production rates are widely used, but their origins are no different than production rate values currently available for foam: they are best guesses.

The production rate selected for foam is from the Lakeview example described in the introduction. Foam engines were one-third more productive than accompanying water engines. This production rate is selected because it is based on fuels and flow rates similar to those in the model.

Costs are derived from district planning data for equipment and personnel costs. For simplification, each engine is assumed to be equally staffed.

Foam engine costs are identical to water engines except for the additional cost of foam-related materials. These materials include a $2,000 automatic proportioner amortized over 10 years at $0.14 per hour and foam concentrate used at 0.5 percent to water. The cost schedule for foam concentrate is $14 per hour based on concentrate cost of $9.33 per gallon. These materials are appropriate for the tactics and fuels in this model.

The Fire Growth Scenario—The suppression forces are compared by their efficiency at containing fires of historically recorded growth. Fire growth scenarios consisting of area and perimeter increase data are located from records or created from fire growth models and input into IASELECT.

Two fuel models are most common to the Great Basin BLM lands: Fire Behavior Prediction System FM 1 (FM 1), short grass, and FM 5 (FM 5), brush (2 feet). The model has been run to make the foam-water comparison in both fuel models. These two models characteristically have 1-day burning periods. Therefore, time inputs are in hours from 1 to 8. Fires are assumed to ignite in early to midafternoon. A scenario of fire growth is computed for each fire intensity level. Table 1 is one of 12 scenarios (6 FILs per Fuel Model) created for the water-foam comparison. Growth was computed from historical rate of spread records (10-year average at 50th percentile).

Selection of Least Cost + Resource Loss—IASELECT now combines each fire growth scenario with each suppression force scenario. The analyzer will select a subset of the suppression forces to contain each fire at every possible timeframe for the smallest cost.

Three additional factors affect this selection: resource value change, mop-up costs, and cost of uncontained fires. Resource value loss estimates are found in district planning data. Mop-up costs are not included in this example because mop-up is limited in FM 1 and FM 5 and mop-up is often simply a method of staging suppression forces.

Every fire may not be contained in the 8-hour timeframe. If the resources cannot achieve containment, the least cost plus resource loss of an "escaped" fire is estimated by the sum of the resource loss and cost of all equipment and personnel after 8 hours.

Table 2 summarizes the least cost plus resource loss for each fire scenario.

EXPECTED VALUE ANALYSIS

The Workload Scenario—Improvements in efficiency alone may not justify a change in the current technology. Historical records for some jurisdictions indicate low fire frequency burning about 1 acre per year x total. Does this workload demand improved suppression technology?

Workload is the annual frequency of fire intensity levels. Annual frequencies were taken from Firefamily for two fire management zones (FMAZ) in the Boise District from 1980 to 1989. FMAZ 1 is dominated by the grass fuel model; FMAZ 2 by the brush model. These are the frequencies in table 2.

Expected Value—A common technique for relating costs per event to event frequency is an expected value analysis. In this model the expected value is the total annual cost anticipated, given the least cost plus resource loss per fire (LC+L) and the fire frequency. Table 2 is arranged like a decision tree to display this analysis. Expected cost plus loss per fire (EC+L) is the LC+L times the probability of annual occurrence.. Expected annual cost per fire is the sum of the EC+L. The expected value or total annual cost for all fires is the annual cost per fire times the number of fires.

In FM 1, the expected value for foam is $761,217 less than the value for water. In FM 5, the expected value for foam is $335,838 less than the value for water.

STATISTICAL ANALYSIS OF THE NULL HYPOTHESIS

Paired Comparison—Foam and water technologies are compared against the same fire scenario in a paired comparison. Each fire scenario provides a measure of the differences in the efficiencies of the technologies. For example, differences for LC+L by fire scenario are as shown in table 3. A paired comparison evaluated these differences. For FM 1 and FM 5, the null hypothesis can be rejected with certainty at the 99 and 98 percent levels, respectively.

WORKLOAD ANALYSIS

Workload is examined with respect to the difference in least cost plus resource loss. The difference indicates an economic advantage and advantages can be arranged to suggest when each technology is appropriate (table 4).

Table 2—Least cost plus resource loss by fire intensity level

Fire scenario	Acres burned	Least cost + loss per fire	Avg. annual frequency	Prob. of occur.	Exp. cost + loss per fire	Exp. total annual cost/fire	Exp. val: total annual cost
Water							
FM1FIL1	13	$ 192	14	0.179	$ 34		
FM1FIL2	165	688	23	.295	203		
FM1FIL3	288	1,766	28	.359	634	$39,226	
FM1FIL4	1,304	75,776	10	.128	9715		$3,059,652
FM1FIL5	6,978	394,874	2	.026	10,125		
FM1FIL6*	25,706	1,444,184	1	.013	18,515		
FM5FIL1	25	192	6	.176	34		
FM5FIL2	315	2,264	10	.294	666		
FM5FIL3	485	2,752	12	.353	971	59,051	
FM5FIL4[1]	5,574	194,365	4	.118	22,866		2,007,726
FM5FIL5[1]	10,873	372,831	1	.029	10,966		
FM5FIL6[1]	23,405	800,619	1	.029	23,548		
Foam							
FM1FIL1	13	192	14	.179	34		
FM1FIL2	93	639	23	.295	188		
FM1FIL3	288	1,654	28	.359	594	29,467	
FM1FIL4	733	43,595	10	.128	5,589		2,298,435
FM1FIL5	3,101	176,706	2	.026	4,531		
FM1FIL6	25,706	1,445,376	1	.013	18,530		
FM5FIL1	25	192	6	.176	34		
FM5FIL2	315	1,976	10	.294	581		
FM5FIL3	485	2,513	12	.353	887	49,173	
FM5FIL4	3,135	111,347	4	.118	13,100		1,671,888
FM5FIL5[1]	10,823	373,822	1	.029	10,995		
FM5FIL6[1]	23,405	801,610	1	.029	23,577		

[1]"Escaped" fire: not contained by suppression forces in 8 hours.

This examination suggests that there are distinct fire intensities, not just fuel models, for which one technology is more appropriate than the other.

No advantage occurs when fires are small enough to be contained with a less expensive technology (the bulldozer). Foam use is economically advantageous on fires that foam suppression forces can contain in the 8-hour period. This is especially true of fires causing measurable resource damage (FIL 4-5 in this example) because foam use reduces acres burned. The difference in efficiency during escaped fires is equal to the difference in equipment cost between the two technologies. Water is cheaper to use when the fire cannot be contained.

Table 3—Differences for LC+L by fire scenario

Fire scenario	LC+L water	LC+L foam	Difference
	Dollars		
FM1FIL1	192	192	0
FM1FIL2	688	639	49
FM1FIL3	1,766	1,654	112
FM1FIL4	75,776	43,595	32,181
FM1FIL5	394,874	176,706	218,168
FM1FIL6	1,444,184	1,445,376	(1,192)
FM5FIL1	192	192	0
FM5FIL2	2,264	2,264	288
FM5FIL3	2,752	2,513	239
FM5FIL4	194,365	111,347	83,018
FM5FIL5	372,831	373,822	(991)
FM5FIL6	800,619	801,610	(991)

SELECTION OF ALTERNATIVE

The example use of this comparison model supports the use of foam for fire suppression in FM 1 and 5. Expected values predicting annual savings in fire suppression costs of $761,217 and $335,838, respectively, are statistically supported by the rejection of the null hypothesis that no savings would occur.

DISCUSSION

Limitations to the model and the example used to describe it are due to simplification. Tactics, effectiveness, production rates, availability, and fire growth rates are some of the parameters that must be more accurate.

The strength of the model is its flexibility. Parameters such as production, cost, and fire size are based on the most accurate information available. Yet a resource allocation program such as IASELECT is designed to facilitate

Table 4—Workload with respect to difference in least cost plus resource loss

FM	FIL	LC+L Difference	Advantage
1	1	0	None
1	2	49	Foam
1	3	112	Foam
1	4	32,181	Foam
1	5	218,168	Foam
1	6	1,192	Water
5	1	0	None
5	2	288	Foam
5	3	239	Foam
5	4	83,018	Foam
5	5	991	Water
5	6	991	Water

changes in inputs. Fire managers can play the "What if?"game. For example, a manager may be considering the purchase of Class A foam equipment. Is this a good idea in the first place? If so, how much investment is necessary? The manager can make (at least) two comparisons using this model: the first, a comparison of water to foam priced at an entry level; the second, a comparison of water to foam priced to meet all possible fire scenarios.

Class A foam is a technology not unlike other new ideas in that we are struggling to define its role. Stories are common. Facts are not as common. When relevant data arrive, a method of sorting out if and when to use each technology will be necessary. Managers can guess what role foam has for them, but a model like the one presented can help justify their actions toward foam and water.

The workload analysis suggests a decision to send water or foam to a fire could be based on fuel model and expected fire intensity. Dispatch could be prioritized to send suppression forces to fires at which they are most advantageous.

In this example of the model, the resource loss of fires with FIL 5 and 6 is more important to determining total LC+L than the increase in production foam offers. But if a manager can anticipate a majority of moderate fire intensities, then smaller fires, earlier containment, and lower costs with foam use are supported by the example.

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