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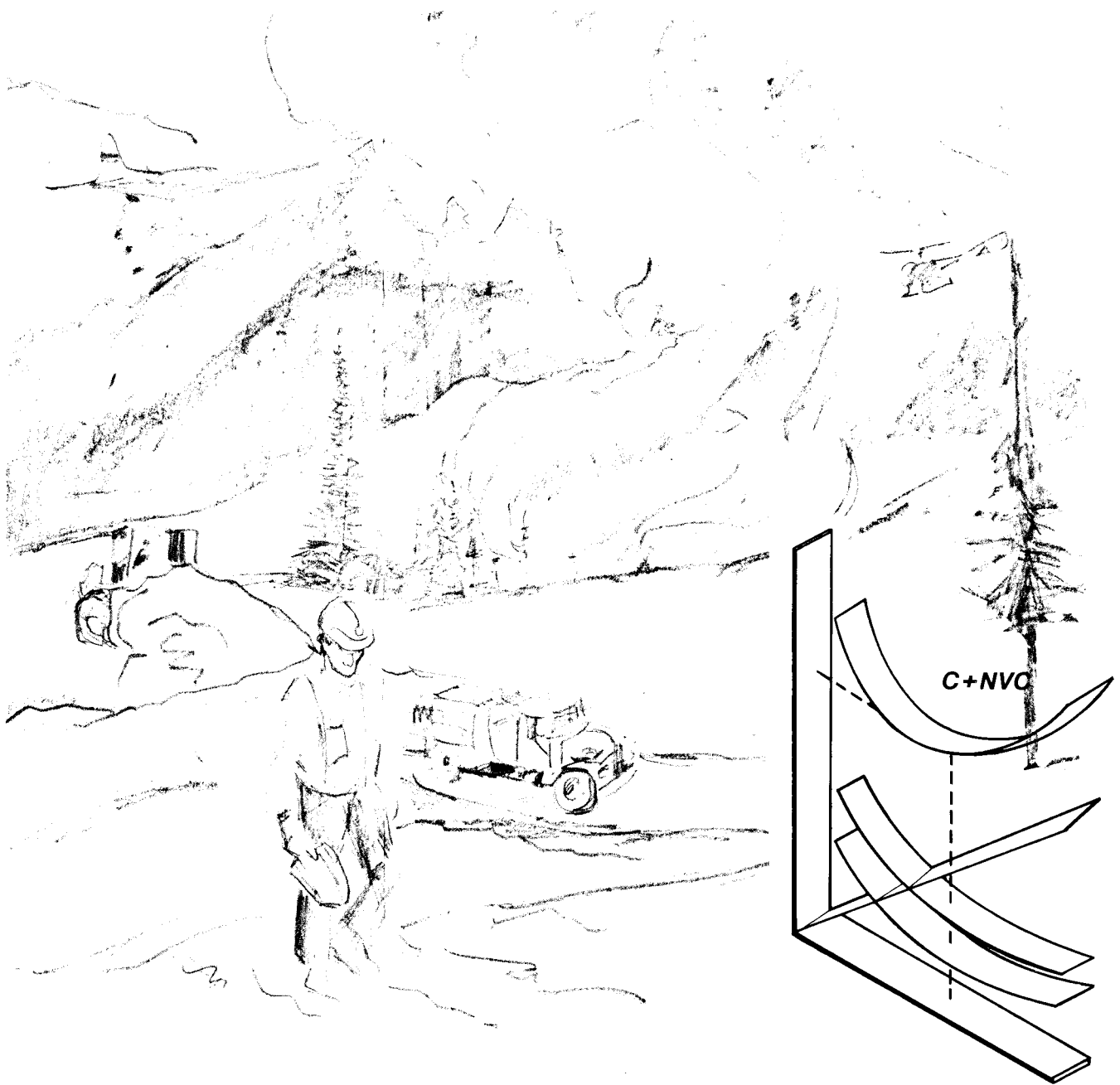
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Economic Cost of Initial Attack and Large-Fire Suppression

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Since 1975, the economic efficiency of fire management programs has received increased emphasis in the Forest Service, U.S. Department of Agriculture fire management planning and budgetary allocation process. That year, the U. S. Office of Management and Budget (OMB) asked the Forest Service to estimate the real costs of changes in its fire management program and to identify [sic] the best fire management practices by evaluating appropriate costs and returns. In 1978, during a review of the Forest Service fire management program budget for fiscal year 1979, the U.S. Senate Appropriations Committee noted a dramatic increase in fire suppression costs without a corresponding increase in apparent benefits. The Committee requested the Forest Service to "conduct a cost-benefit analysis of both suppression and suppression activities ... " as a basis for future budget requests (U.S. Senate 1978).

In response to the questions raised by the OMB and the U.S. Senate (1978), the Forest Service made several changes in its fire management policy. By 1978, fire management programs must be not only cost-effective but must be compatible with land management objectives. Now, success probability and economic efficiency, as measured by the minimization of cost plus net value change, are necessary criteria for selecting among fire suppression actions (U.S. Department of Agriculture, Forest Service 1981).

Economic efficiency is also the criterion to be used in judging fire management programs in several states. The California Department of Forestry (CDF), for example, has been asked by the State legislature to reflect more accurately fire damage estimates. The State legislature also asked CDF to evaluate changes in damages resulting from an increase or decrease in fire programs budget. Wisconsin and Alabama also are addressing the question of economic efficiency in fire programs (Mills 1980). A cost estimate of fire management activities is a necessary input into the economic analysis now required.

This report describes a procedure to estimate the economic costs of initial attack and large-fire suppression actions of fire management programs. It explains a measure called fire management input unit cost estimate and how it is used to determine the economic costs of such actions. A sample application illustrates how the procedure works.

FIRE MANAGEMENT PROGRAM COMPONENT COSTS

Fire management program component costs have been categorized in numerous ways. One study, for example, concentrated on direct protection costs, dividing them into two categories (Sparhawk 1925):

- *Primary protection*--Includes the cost of fire management organization for prevention, detection, and suppression. Organizational costs include personnel, equipment, and improvements, and are determined in advance.

- *Actual cost of suppression*--Includes temporary labor, subsistence, transportation, and the time of Forest personnel taken from other work. For a finer resolution, fire management program costs are divided into fire prevention, fire detection, fuel modification, suppression activities, and fire suppression (Gale 1977). The first four categories combined represent Sparhawk's primary protection costs.

A different breakdown was used to define the costs of protection by Davis (1974). Fire program costs included prevention, suppression, prescribed fire, mechanical fuel treatment, and fire planning. In addition, general fire system costs, including general administration and planning management information, and public involvement were identified (Davis 1974). Although a different breakdown, all cost elements discussed by Davis (1974) are included in the prevention and suppression categories developed by Gale (1977).

Other studies have developed cost categories based on the premise that fire program decisions should consider the program's total cost effect over time. With this principle, two major cost categories were defined (Newport 1972)--investment costs and operational costs. Investment costs are one-time expenditures for facilities, equipment, or both, required to initiate the system. Operational costs are the recurring costs of operating, supporting, and manning the fire control system or subsystem.

The main problem with all the approaches to cost the fire management programs discussed previously is that none of them, with the possible exception of Newport (1972), ad-

addressed the question of economic costs. All efforts concentrated on categorizing accounting costs. Distribution or overhead costs to the various functions is seldom considered. Also, the concept of opportunity cost is rarely used in evaluating the total cost of the fire management programs. In general terms, the opportunity cost of the current use of some good or of some input is its worth in some alternative use (Mishan 1976). The procedure proposed here corrects these oversights in computing the economic cost of fire management programs.

FIRE MANAGEMENT INPUT UNIT COST

The procedure developed here uses a per-unit cost to estimate the cost of a fire management program on an input-by-input basis (McKetta and others 1981). Fire management inputs (FMIs) are the production units used in initial attack and large-fire suppression organizations to which physical control parameters can be ascribed; for example, a 20-person category-I crew that can produce X chains of fireline in a given period of time.

The unit cost estimates are used initially to determine the fire season fire program standby costs, that is, the total cost of having the fire program available. In the Forest Service these costs are called *presuppression costs*. The budget level for any fire program is converted into a list of FMIs available to fight fires during the season by means of the FMI unit cost. To determine the fire management program standby costs, several steps are taken. One, the total budget is allocated to the various program functions. Two, the allocated money is assigned to different FMIs within the functions. Three, the dollars allocated to the various functions (two above) are translated into an FMI list, for example, number of pumpers available for the season. Because half units cannot be bought, the resulting FMI list is corrected for fractions by rounding to the closer integer. Then the program level is adjusted for the integer solution accordingly. This whole process gives the fire program season standby costs.

The standby or presuppression costs represent only a part of the *cost* figure in the cost plus net value change equation used to evaluate economic efficiency of different fire management [sic] programs. The second part in the *cost* figure is the cost of using the fire management inputs in actual firefighting or suppression costs. The total cost of the fire program is the standby or presuppression cost plus the use or suppression costs. The FMI unit cost estimates are used to obtain the use cost above and beyond the fire program standby cost through the procedure explained in this report.

The main objectives in developing the FMI unit cost are to ...

- Identify budgetary costs that should be allocated to a specific FMI.
- Incorporate FMI economic costs that are not typically included in accounting data.

- Convert fixed costs of each FMI to a variable cost element that is relevant for long-term fire management organization planning and optimization process.

- Display the variable costs on a dollar-per-hour basis for each FMI in distinct categories, which represent "standby" and "on-fire" costs during either normal or overtime hours. Standby costs are incurred for a certain period during the year, regardless of whether the FMIs are used.

After these objectives are accomplished, all direct and indirect costs of having available and using the fire management inputs are charged to the FMIs. All applicable overhead costs, such as personnel management costs, are distributed to the FMIs on the basis of their firefighters' use of various overhead support functions. An opportunity cost to the organization for the use of their own capital in facilities is distributed to the FMIs using the facilities. (An equivalent rental rate of similar private facilities in the same area where the agency facilities are located is used to determine the opportunity cost [González-Cabán and others 1982]). The opportunity cost is then allocated over the FMI's availability and is converted into a portion of the variable unit cost. The unit cost reflects the cost of the fire management inputs in a variable cost form, providing a better means for estimating the economic cost of alternative fire management programs to be tested in planning a fire organization.

With the per-unit-cost approach, all cost information relevant to an FMI is integrated as one cost rate, thereby making simulation cost aggregation easier. The unit cost approach also increases flexibility so that the cost procedure can be uniformly applied by all organizations with fire protection responsibilities. A more detailed explanation of the FMI unit cost development can be found in works by McKetta and others (1981) and González-Cabán and others (unpubl.) As an example, the unit cost for a category-I crew must consider all the components in developing the composite unit cost (*table 1*).

ECONOMIC COST

The economic cost procedure determines only the cost of the initial attack and large-fire actions functional categories to date of the fire management program. The aggregation process described will be used to estimate the total economic cost of a fire management program as cost estimates of the other functional categories become available.

Acquaintance with the overall cost scheme will assist in understanding the cost procedure (*fig. 1*). The cost procedure needs all of the following basic information to compute the suppression costs of any FMI sent to a fire (*fig. 1*):

- Type and number of FMIs sent to a fire;
- Time the FMIs were sent to the fire;
- Time the FMIs spent in firefighting activities;
- Time the FMIs spent in nonfirefighting activities; and,
- Travel time for the FMIs to get to the fire.

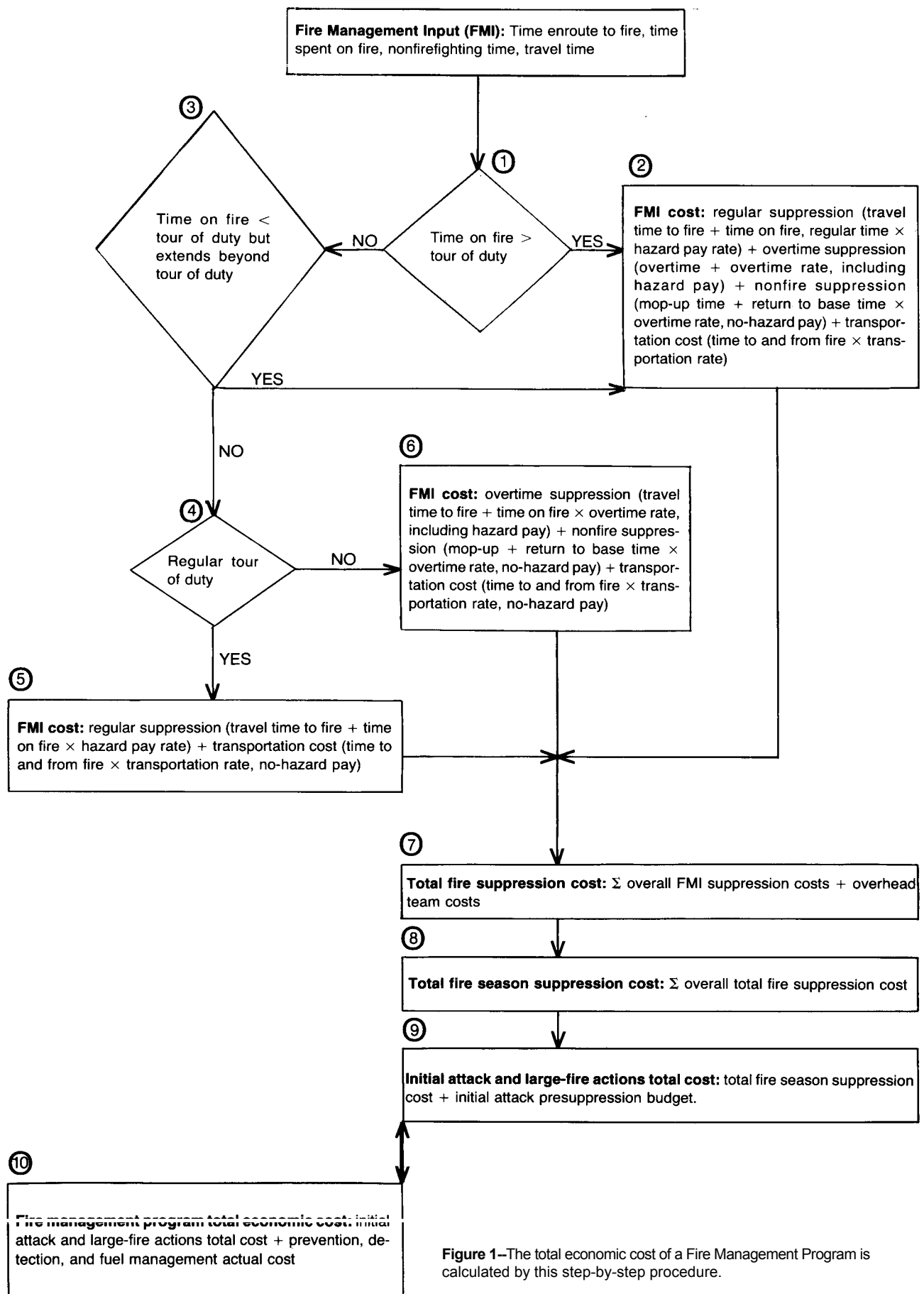


Figure 1—The total economic cost of a Fire Management Program is calculated by this step-by-step procedure.

First, it is determined whether an FMI sent to a fire remained on the fire longer than the regular tour of duty. If this is true, the FMI suppression cost for that fire equals the regular suppression cost plus overtime suppression cost plus nonfirefighting activities cost plus transportation costs. Any activity taking place after the fire has been declared contained (a fireline has been built around the fire perimeter) is considered a non-firefighting activity. The distinction is that during this time the FMIs do not draw a hazard pay premium. Hazard pay is a compensation above and beyond base pay for dangerous work done. As the fire is contained, it is no longer considered a high risk area so the hazard pay premium stops. The FMI's return trip to base camp is a nonfirefighting activity.

If the FMI time spent on the fire is less than the regular work period but extends beyond the regular tour of duty, the FMI suppression cost is the same as in the previous example. If the FMI stays on the fire during the regular tour of duty, the FMI suppression cost for that fire equals the regular suppression cost plus transportation cost. If, however, the FMI's time spent on the fire is outside the regular tour of duty, the suppression cost for that fire equals the overtime suppression plus nonfirefighting suppression plus transportation cost.

Immediately after dispatch to a fire, all FMI crewmembers start drawing hazard pay premium. As mentioned earlier, however, during the return trip to home base and during that time in which the FMIs are in nonfirefighting activities, the FMI crewmembers do not collect hazard pay premium. The different pay rates for the FMI crewmembers depend on the activity being performed. When the FMIs are waiting to be sent to a fire they get pay at the standby rate. While in transit to a fire they get pay at the standby or overtime basic pay (one and one-half times the standby rate), depending on time of day and tour of duty, plus hazard pay premium. These are called regular suppression pay and overtime suppression pay, respectively. While on the fire the FMI crewmembers get paid the same as when in transit to the fire. Once the fire is declared contained all FMI crewmembers stop drawing a hazard pay premium and their pay reverts to the standby or overtime pay, again depending on time of day and tour of duty. In summary, there are four different pay rates that differ by hazard pay premium and tour of duty.

Once the necessary information for all FMIs used in a particular fire is collected, the sum of all costs equals the total FMI suppression cost for that particular fire. Emergency suppression expenditures are not budgeted at the beginning of the fiscal year, but are covered in supplemental appropriations made by Congress or State legislatures to cover all fire-related expenditures not appropriated in fire presuppression budgets. To determine the total cost of the initial attack and large-fire action of any fire management program, therefore, it is necessary to keep records of suppression funds spent during initial attack and large-fire actions throughout the fire season. The regular tour of firefighting duty of any FMI is always paid out of the presuppression budget. Hazard premium pay, overtime suppression, overtime, and transportation cost while firefighting are charged to emergency fund expenditures.

When the cost procedure presented here is applied over an entire fire season, total costs of the initial attack and large-fire action functions of a fire management program are accounted for. When cost estimates for other functional activity categories are completed, the total cost of a fire management program can be estimated. Although the present procedure deals only with initial attack and large-fire suppression, for reasons of completeness, costs of the other functional activities will be added to estimate the fire management program economic cost. The costing procedure will eventually be extended to include the cost of prevention, detection, and fuels management functional activities.

Because actual firefighting or any other activity while on the fire during the FMI regular tour of duty is covered under the presuppression budget, only the suppression or emergency costs need to be estimated. As explained earlier, standby costs pay for the FMI's availability period, including any action during the regular tour of duty.

Mathematically, the total suppression [sic] cost of any particular fire management input during a fire is given by equation 1:

$$SC_{ik} = [RT_{ik} (PUR_i - PUS_i) + (OT_{ik} \times PUO_i) + \sum_M (OTNS_{ik} \times PUON_i) + (\sum_j ETT_{ijk} \times CH_{ij})] \quad (1)$$

Table 1--Unit cost for a category-I fire fighting crew

Activity status	Total	Supplies	Pay	Training	Special training	Equipment	Facilities	Overhead	Misc.	Supervisor	Subsist.
Standby suppression	275.66	7.97	165.91	19.55	0.0	0.0	19.01	63.23	0.0	0.0	0.0
Small fire	305.26	7.97	195.41	19.55	0.0	0.0	19.01	63.23	0.0	0.0	0.0
Large fire	384.31	7.97	195.41	19.55	0.0	0.0	19.01	63.23	0.0	6.51	72.63
Small fire On overtime	364.16	7.97	254.41	19.55	0.0	0.0	19.01	63.23	0.0	0.0	0.0
Large fire On overtime	444.41	7.97	254.41	19.55	0.0	0.0	19.01	63.23	0.0	7.62	72.63

in which

- SC_{ik} = total suppression cost of input i for fire k.
 RT_{ik} = regular time in firefighting activities of input i while on fire k (including travel time to fire).
 OT_{ik} = overtime in firefighting activities of input i while on fire k (including travel time to fire).
 $OTNS_{ik}$ = overtime in nonfirefighting activities of input i while on fire k (including mop-up and travel back to base).
 PUR_i = per unit cost of input i while in regular time firefighting activities.
 PUO_i = per unit cost of input i while in overtime firefighting activities.
 $PUON_i$ = per unit cost of input i while in overtime non-firefighting activities.
 PUS_i = standby rate of input i.
 TT_{ijk} = travel time of input i by method j for fire k.
 CH_{ij} = cost per hour traveled of input i by method j.
 i = 1, 2, 3 ... N, input identifier.
 j = 1, 2, 3 ... M, travel method.
 k = 1, 2, 3 ... F, fire identifier.

Equation 1 expresses the total suppression cost of any FMI sent to a fire. The total suppression cost for all inputs used in fighting fire k is derived by summing across all inputs. The cost of any fire overhead teams used in the management of the fire needs to be included as part of the cost of the fire. The overhead teams are not directly related to any specific FMI and their composition depends on fire size. It is easier, therefore, to allocate their cost to any FMI used as a variable cost lump sum on a per-fire basis and always assign their cost to emergency funds. The total suppression cost of any fire is given by:

$$TSC_k = \sum_i^N SC_{ik} + O_k \quad (2)$$

in which

- TSC_k = total suppression cost of fire k
 O_k = overhead team cost.

The fire season total suppression or emergency cost equals the summation over all fires of the suppression cost per fire, as computed by equation 2.

$$FSSC = \sum_k^F TSC_k \quad (3)$$

in which

- $FSSC$ = total suppression cost for the entire fire season.

To determine the fire season total cost of initial attack and large-fire actions, the fire season total suppression or emergency charges are added to the presuppression budget for initial attack for the planning year.

Therefore,

$$FSC = FSSC + IAB \quad (4)$$

in which

- FSC = fire season initial attack and large-fire suppression action "total costs.
 $FSSC$ = fire season total suppression or emergency fund charges.
 IAB = initial attack presuppression budget.

As mentioned earlier, the procedure explained here determines the economic cost of the initial attack and large-fire actions of a fire management program. As unit cost estimates for prevention, detection, and fuels management activities of a fire management program are developed, the procedure will be used to determine the total economic cost of a fire program.

Equation 5 integrates all fire program functional activity costs into a fire management program total economic cost:

$$ECFP = FSC + PPC + DPC + FPC \quad (5)$$

in which

- $ECFP$ = economic cost of the fire management program
 PPC = prevention program cost
 DPC = detection program cost
 FPC = fuels management program cost.

SAMPLE APPLICATION

In this example, the cost procedure is applied to a simulated fire. All cost computations are done to demonstrate the procedure.

The fire was reported at 1445, and the area burned 175 acres. The fire was declared contained at 1945. Total containment time was 5 hours. There were 2 additional hours of nonfirefighting activities, including mop-up actions. (After the fire is contained all pay reverts to standby or overtime depending on tour of duty; therefore, the nonfirefighting status was assigned to all FMIs during this period.) The fire was declared out by 2145. In addition to the 2 hours of nonfirefighting activities, travel time of some FMIs who remained on the fire until declared out need to be added to the nonfirefighting time. The difference between time of arrival and containment is the FMI's time on firefighting activities on the fire. Air tankers are different; they do not remain on the fire all the time, but return to base for reloading. Air tankers, total firefighting time, and travel time are the same. The per-unit cost estimates developed by McKetta and others (1981) are used in this example.

The fire management inputs sent to the simulated fire are these:

Fire Management Input (FMI)	Unit size	Quantity
Pumper crew	2 persons (250 gal)	3
Air tanker	PV2	1
Air tanker	B26	1
Helitack crew	2 persons	4
Category-I crew	20 persons	3
Smokejumpers	2 persons	5
Pumper crew	3 persons (500 gal)	3

The first step is to determine the total time spent by each FMI sent to the fire (*table 2*). The total time spent by a smokejumper team will be computed here to show how the calculation is done. The smokejumper team arrived at 1500 and remained on the fire until 1945. The total time spent on the fire broken into different time classes, as presented in *table 2*, is as follows: regular suppression (regular tour of duty, assume tour of duty ends at 1700), 2.25 hours (includes travel time to the fire); overtime suppression (after regular tour of duty), 2.75 hours; overtime (nonfirefighting status, travel time back to home base), 0.25 hours.

In total, the smokejumper team remained 5 hours in firefighting status on the fire at different pay rates because of tour of duty and 0.25 hour in nonfirefighting status. It is assumed that all five smokejumper and helitack teams arrived and departed together. All other FMIs, although the same kind, may have arrived at different times. In this example it is also assumed that all dispatches to the fire take place once the fire is reported. This will ease the travel time computation. Differences in arrival times account for FMI base location.

After total time spent on the fire is computed for all FMIs, the suppression cost for each FMI is calculated. This is done by multiplying the unit cost rate by the time each FMI remained on the fire or attended to other activities (equation 1). The cost of the smokejumper teams will be computed here to show the procedure. (The fire and FMI total suppression cost are shown in *table 3*.)

$$SC_{ik} = [RT_{ik} (PUR_i - PUS_i) + (OT_{ik} \times PUO_i) + (OTNS_{ik} \times PUON_i) + (M \sum_j TT_{ijk} \times CH_{ij})]$$

$$= [11.25 (\$39.96 - \$36.43) + (13.75 \times \$62.21) + (0.50 \times \$54.60) + (0.50 \times \$1000)] = \$1422$$

Once the cost of all FMIs used in the fire is determined, summing yields the total suppression cost of the FMIs. The FMIs total suppression cost is \$30,274 (*table 3*). To determine the total suppression cost of the fire, the cost of overhead teams must be added (equation 2). In this example, the overhead team cost was \$5000. (This is a hypothetical figure until a procedure to compute the cost of overhead team usage is developed.) The total cost of the fire, therefore, equals the total FMI cost (*table 3*) plus \$5000, or \$35,274.

The same procedure, as just described, is followed for all fires simulated during a fire season. For each fire, the emergency fund or suppression charges are summed. At the end of the fire season, total cost charged to emergency funds is added to the initial attack presuppression budget to obtain the total cost of initial attack and large-fire actions for the fire season (equation 4).

Table 2--Total regular suppression time, overtime suppression time, nonfirefighting time, and travel time

Fire Management Input (FMI)	Regular suppression	Overtime suppression	Nonfire-fighting ¹	Travel time
Pumper crew (250 gal)	2.25	2.75	0.75	1.50
Pumper crew (250 gal)	2.25	2.75	0.75	1.50
Pumper crew (250 gal)	2.25	2.75	3.25	2.50
Air tanker (PV2)	4.66	---	---	4.66
Air tanker (B26)	3.50	---	---	3.50
Helitack crew	¹ 19.00	² 11.00	² 1.32	⁴ 0.66
Category-I crew	2.25	2.75	0.42	0.84
Category-I crew	2.25	2.75	0.42	0.84
Category-I crew	2.25	2.75	1.25	2.50
Smokejumper	³ 11.25	³ 13.75	³ 1.25	⁴ 0.50
Pumper crew	2.25	2.75	0.75	1.50
Pumper crew	2.25	2.75	0.58	1.16
Pumper crew	2.25	2.75	3.00	2.00

¹Includes mop-up time plus travel time back to base.

²Four helitack teams, each remained 2.25 hours in regular suppression, 2.75 hours in overtime suppression, and 0.33 hours in nonfirefighting status.

³Five smokejumper teams, each remained 2.25 hours in regular suppression, 2.75 hours in overtime suppression, and 0.25 hours in nonfirefighting status.

⁴All helitack and smokejumper teams are deployed at the same time.

To complete the example, assume an initial program level of \$1,162,000. Seventy percent (\$813,400) of the program level is assigned to initial attack actions. A fire season of 120 days is also assumed. All figures, including suppression charges for the season, prevention, detection, and fuels management are hypothetical and used for exposition purposes only. A number of x fires occurred during the simulated fire season and their costs calculated, as explained previously. The integration pro-

Table 3--Fire management input (FMI) and total fire suppression cost

Fire Management Input (FMI)	Quantity	Total suppression cost (SC _{ik}) (dollars)
1. Pumper crew (250 gal)	3	721
2. Air tanker (PV2)	1	¹ 11,361
3. Air tanker (B26)	1	² 8,529
4. Helitack crew	4	1,249
5. Category-I crew	3	5,615
6. Smokejumpers	5	1,422
7. Pumper crew (500 gal)	3	1,377
FMI total fire suppression cost		30,274

¹Includes the cost of our loads of retardant at \$0.80/gal. Both air tankers have a 1200-gal tank capacity.

²Includes the cost of three loads of retardant at \$0.80/gal.

cess at the end of the fire season leads to the economic cost of the fire management program. Assuming suppression charges of \$1,250,000 for the simulated season, the fire season initial attack and large-fire action total cost equals \$2,063,400 (summing the initial attack presuppression budget [\$813,400] and suppression charges [\$1,250,000]).

Equation 5 is used to compute the economic cost of the fire management program for the season. Assuming \$58,100 for prevention, \$116,200 for detection, and \$174,300 for fuels management, the economic cost of the fire program for the season equals \$2,412,000 (\$58,100 + \$116,200 + \$174,300 + \$2,063,400).

All costs, regardless of who pays them, must be identified and accounted for. Even if an agency does not actually bear some direct costs of a fire management program, the cost can conceptually be charged to the fire program. Only by assigning all the costs incurred to the beneficiary program can the true cost of the programs be determined. Development of similar procedures for the other functional categories of a fire management program--detection, prevention, and fuels management--will provide the capability to estimate the total economic cost of the fire management program.

The cost procedure described is designed for use by any land management or resource management agency with fire management responsibilities. It is applicable to organizations that use different budgetary systems and allocate costs between agencies. The economic cost information described here will be used in the Fire Economics Evaluation System (FEES) model (Mills and Bratten 1981) being developed by the Pacific Southwest Forest and Range Experiment Station to evaluate the economic efficiency of alternative fire management programs.

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González-Cabán, Armando. **Economic cost of initial attack and large-fire suppression.** Gen. Tech. Rep. PSW-68. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1983. 7 p.

A procedure has been developed for estimating the economic cost of initial attack and large-fire suppression. The procedure uses a per-unit approach to estimate total attack and suppression costs on an input-by-input basis. Fire management inputs (FMIs) are the production units used. All direct and indirect costs are charged to the FMIs. With the unit approach, all cost information relevant to an FMI is integrated as one cost rate, thereby making simulation cost aggregation easier. Also, flexibility is increased so that the cost procedure can be uniformly applied by all organizations with fire protection responsibilities. Once the necessary information for all FMIs used in a particular fire is collected, the sum of all costs equals the total FMI suppression cost for that fire. As unit cost estimates for prevention, detection, and fuels management activities are developed, the procedure will be used to determine the total economic cost of a fire management program.

Retrieval Term's: economic cost, fire management program costs, fire suppression cost, fire economics.