Technical Formulae Used by the FPA Prevention Model
PR_004_TP

Fire Planning Analysis (FPA) designed the Prevention Model (FPA-PV) using algorithms developed in the 1990s[1] when they were implemented in a series of prevention planning tools including:

- Build Fire Behavior Data (BuildFBD),

- Prevention Workload Analysis (PWA), and

- Risk Assessment and Mitigation Strategies (RAMS).

The algorithms required slight modification to gather information for the FPA Prevention Module. Earlier applications modeled fire frequency over a range of flame length classes. FPA models the probability of preventing an ignition. Additionally, earlier models required planners to enter large quantities of prevention work items. FPA simplifies this by requiring Fire Planners to enter only total hours by specific prevention activity category per FMU and by lumping the total general hours invested in activities that affect the entire FPU.

In FPA, Fire Planners enter hours for two types of prevention work:

- General Actions: Prevention activities that benefit more than one Fire Management Unit (FMU), typically an entire Fire Planning Unit (FPU).

- Specific Actions: Prevention activities, including community actions, which benefit a specific FMU.

This document explains the FPA-PV algorithms and provides an example for context. For information on the FPA-PV module, refer to Understanding the Fire Program Analysis (FPA) Prevention Module PR_014_WP.

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[1] Prevention Workload Analysis (PWA) occurred in 1995. PWA was designed to enhance National Fire Management Analysis System (NFMAS) that also provided IIAA. Surveys were developed and sent out to hundreds of federal and state prevention experts soliciting input. The specific algorithms, (pf) preventability factors, and effectiveness factors were developed from this information. Brian Booher and Dick Chase were the initial developers. PWA2, PWA99 and RAMS were created using this information.

Model Inputs

- List of alternative prevention programs, one designated as the historic prevention program.

  p = the prevention program being modeled.

  h = that prevention program identified as the historic program.

- Hours spent on General Actions for each prevention program.

  GA_p = General Action hours for prevention program "p".

- Hours spent on Specific Actions for each prevention program "p" for each prevention activity group "g".

  $SA_{p,f,g}$ = Specific Action hours for prevention program "p", FMU "f", and prevention activity group "g".

There are seven prevention activity groups:

1	2	3	4	5	6	7
Patrol	**Signs**	**Law Enforcement**	**Hazards**	**Public Contact AND Communities**	**Inspections**	**Administration**

Figure 1: Prevention Activity Groups

Model Output

- Probability of a potential fire ignition of statistical cause "c" remaining – not being prevented – under prevention program "p" in FMU "f".

  $FRP_{p,f,c}$ = probability of a potential ignition in FMU "f" of statistical cause "c" becoming a fire (not being prevented) under prevention program "p".

Statistical Cause	c
Equipment Use	1
Smoking	2
Campfire	3
Debris Burning	4
Railroad	5
Arson	6

Statistical Cause	c
Children	7
Miscellaneous	8

Figure 2: Statistical Causes for Human-Started Ignitions

Summary of Model Input and Output Variables

p = the prevention program being modeled

h = that prevention program identified as the historic program

GA_p = General Action hours for prevention program "p"

f = FMU being modeled

g = prevention activity group (1-7)

$SA_{p,f,g}$ = Specific Action hours for prevention program "p", FMU "f", prevention activity group "g".

c = statistical cause (1-8, does not include lightning)

$FRP_{p,f,c}$ = probability of a potential ignition in FMU "f" of statistical cause "c" becoming a fire (not being prevented) under prevention program "p".

Total Specific Action hours for the entire FPU are calculated by summing the Specific Action hours for all FMUs:

SAT_p = Total Specific Action hours for the FPU under prevention program "p".

Model Example

Consider the following inputs for prevention program "p", modeled in FMU "f":

- General Action hours (GA_p and GA_h):

FPU General Action Hours	
In Prevention Option "p":	1600
In Historic Option:	1200

Figure 3: General Action Hours for Example

- Total Specific Action hours ($SAT_{p,f}$ and $SAT_{h,f}$):

FPU (All FMUs) Specific Action Hours	
In Prevention Option "p":	5000
In Historic Option:	4500

Figure 4: Total Specific Action Hours for Example

- Specific Action hours for FMU "f" ($SA_{p,f,g}$ and $SA_{h,f,g}$):

FMU Spec Action Hrs	Patrol	Signs	Law Enforcement	Hazards	Public Contact AND Communities	Inspections	Administration
In Prevention Option:	100	200	500	100	300	110	250
In Historic Option:	80	150	500	200	250	100	250

Figure 5: Specific Action Hours for the Example FMU

The Prevention model outputs for these example inputs are:

$FRP_{p,f,c}$ = probability of a potential ignition in FMU "f" of statistical cause "c" becoming a fire (not being prevented) under prevention program "p".

Statistical Cause	c	FRH(p,f,c) (Historic Probability of an Ignition Becoming an Unpreventable Fire)	$FRP_{p,f,c}$ (Probability of an Ignition Becoming a Fire After Prevention Actions Taken)
Equipment Use	1	0.9718051	0.8401170
Smoking	2	0.9666679	0.8483260
Campfire	3	0.9408344	0.8015630
Debris Burning	4	0.9529894	0.8206580
Railroad	5	0.992441	0.8696090
Arson	6	0.9891822	0.9244690
Children	7	0.9598598	0.8265750

Statistical Cause	c	FRH(p,f,c) (Historic Probability of an Ignition Becoming an Unpreventable Fire)	FRP$_{p,f,c}$ (Probability of an Ignition Becoming a Fire After Prevention Actions Taken)
Miscellaneous	8	0.9823992	0.8934960

Figure 6: Probability of a Potential Ignition in Example FMU becoming an Unpreventable Fire under the Prevention Program

The modeled results in Figure 6 show the decrease in probability of potential ignitions (FRP) becoming an unpreventable fire from historic levels (FRH) when an investment of 1,600 hours of General Prevention Activities and 5,000 hours of Specific Prevention Activities are made.

The remainder of this paper explains the exact calculations for this example, starting by introducing some additional intermediate value variables.

Model Variables, Including Intermediate Value Variables

p = the prevention program being modeled

h = that prevention program identified as the historic program

GA_p = General Action hours for prevention program "p"

f = FMU being modeled

g = prevention activity group (1-7)

$SA_{p,f,g}$ = Specific Action hours for prevention program "p", FMU "f", prevention activity group "g".

c = statistical cause (1-8, does not include lightning)

$FRP_{p,f,c}$ = probability of a potential ignition in FMU "f" of statistical cause "c" becoming a fire (not being prevented) under prevention program "p".

Additionally, FPA calculates the total Specific Action hour for the entire FPU by summing the Specific Action hours for all FMUs:

SAT_p = Total Specific Action hours for the FPU under prevention program "p".

n = number of FMUs in FPU

$EH_{p,f,g}$ = Effective Hours

$RAT_{p,f,g}$ = Program to Historic Ratio

$SRAT_{p,f,g}$ = Sigmoid Ratio

$RF_{p,f,c}$ = Reduction Factor

$UF_{p,f,c}$ = Unconstrained Factor

$FRH_{p,f,c}$ = Factor Relative to Historic

$FRP_{p,f,c}$ = Factor Relative to Potential

PF_c = Preventability Factor for cause "c"

$EF_{g,c}$ = Effectiveness Factor of prevention activity group "g" against cause "c"

Preventability Factors:

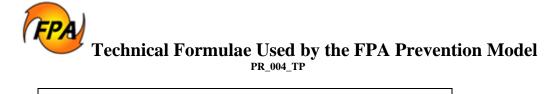|	Statistical Cause	PF(c) = Preventability Factor
1	Equipment Use	0.15675
2	Smoking	0.1395
3	Campfire	0.17375
4	Debris Burning	0.16125
5	Railroad	0.14125
6	Arson	0.07
7	Children	0.16125
8	Miscellaneous	0.0995

Figure 7: Preventability Factors for Example

Effectiveness Factors for the Prevention Activity Groups:

Where:

- g1 = Patrol,
- g2 = Signs,
- g3 = Law Enforcement,
- g4 = Hazards,
- g5 = Public Contact and Communities,
- g6 = Inspections, and
- g7 = Administration

Stat Cause		g=1	g=2	g=3	g=4	g=5	g=6	g=7
1	Equipment Use	0.4	0.3	0.6	0.6	0.55	0.6	0.4
2	Smoking	0.4	0.4	0.5	0.2	0.45	0.35	0.3
3	Campfire	0.6	0.5	0.7	0.4	0.7	0.6	0.4
4	Debris Burning	0.6	0.4	0.6	0.4	0.6	0.55	0.4
5	Railroad	0.3	0.1	0.5	0.6	0.35	0.45	0.3
6	Arson	0.4	0.2	0.5	0.2	0.3	0.2	0.2
7	Children	0.4	0.3	0.4	0.2	0.65	0.35	0.3
8	Miscellaneous	0.3	0.3	0.3	0.2	0.4	0.3	0.2

Figure 8: Effectiveness Factors for Example

Formulae

$$SAT_p = \sum_{f=1}^{n} \sum_{g=1}^{7} SA_{p,f,g}$$

$$EH_{p,f,g} = SA_{p,f,g} + GA_p * SA_{p,f,g}$$

$$RAT_{p,f,g} = EH_{p,f,g} / (2.5 * EH_{h,f,g})$$

$$SRAT_{p,f,g} = 0.5 + 1.5 * (RAT_{p,f,g} - 0.5) / (ABS(RAT_{p,f,g} - 0.5) + 1.0)$$

$$RF_{p,f,c} = \prod_{g=1}^{7} (1 - SRAT_{p,f,g} * EF_{g,c}$$

$$UF_{p,f,c} = 1.0 - PF_{g,c} + PF_{g,c} / RF_{h,f,c}$$

$$FRH_{p,f,c} = (1.0 - PF_c) + RF_{p,f,c} * (UF_{p,f,c} + PF_c - 1.0)$$

$$FRP_{p,f,c} = FRF_{p,f,c} / (1.0 + PF_c)$$

Detailed Calculations for Example

Using the example inputs and formulae, FPA derives these values:

$GA_p = 1600$

$GA_h = 1200$

$SA_{p,f,1} = 100$

$SA_{p,f,2} = 200$

$SA_{p,f,3} = 500$

$SA_{p,f,4} = 100$

$SA_{p,f,5} = 300$

$SA_{p,f,6} = 110$

$SA_{p,f,7} = 250$

$SA_{h,f,1} = 80$

$SA_{h,f,2} = 150$

$SA_{h,f,3} = 500$

$SA_{h,f,4} = 200$

$SA_{h,f,5} = 250$

$SA_{h,f,6} = 100$

$SA_{h,f,7} = 250$

$SAT_p = 5000$

$SAT_h = 4500$

$EH_{p,f,g} =$

EH, g=	1	2	3	4	5	6	7
Option "p":	132	264	660	132	396	145.2	330
Historic "h":	101.333	190	633.333	253.333	316.667	126.667	316.667

Figure 9: Effective Hours per Prevention Activity Group

$RAT_{p,f,g} =$

RAT, g=	1	2	3	4	5	6	7
Option "p":	0.52105	0.55579	0.41684	0.20842	0.50021	0.45853	0.41684
Historic "h":	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Figure 10: Program Historic Ratio per Prevention Activity Group

$SRAT_{p,f,g} =$

SRAT, g=	1	2	3	4	5	6	7
Option "p":	0.53093	0.57926	0.38484	0.16137	0.50032	0.44027	0.38484
Historic "h":	0.36364	0.36364	0.36364	0.36364	0.36364	0.36364	0.36364

Figure 11: Sigmoid Ratio per Prevention Activity Group

Final Values =

Cause	c	RF(p,f,c)	RF(h,f,c)	UF(p,f,c)	FRH(p,f,c)	FRP(p,f,c)
Equipment Use	1	0.203982487	0.248720174	1.47348	0.9718051	0.8401168
Smoking	2	0.27419137	0.360275499	1.2477	0.9666679	0.8483264
Campfire	3	0.133836495	0.202942977	1.6824	0.9408344	0.8015628
Debris Burning	4	0.169016469	0.23856833	1.51466	0.9529894	0.8206583
Railroad	5	0.338004865	0.357115945	1.25428	0.992441	0.8696088
Arson	6	0.389350961	0.460519824	1.082	0.9891822	0.9244693
Children	7	0.269022986	0.358186945	1.28893	0.9598598	0.8265747
Miscellaneous	8	0.381013585	0.462896294	1.11545	0.9823992	0.8934963

Figure 12: Final Calculations for Example