Development of a Risk-Based Decision Support Tool to Assist Fire Departments in Managing Unwanted Alarms

Task 5 Deliverable – Model and Tool for Assessing Policies

Final Report

Prepared by:

John R. Hall, Jr., PhD

National Fire Protection Association
Fire Analysis and Research Division

THE FIRE PROTECTION RESEARCH FOUNDATION

FIRE RESEARCH

THE FIRE PROTECTION RESEARCH FOUNDATION
ONE BATTERYMARCH PARK
QUINCY, MASSACHUSETTS, U.S.A. 02169-7471
E-MAIL: Foundation@NFPA.org
WEB: www.nfpa.org/Foundation

FOREWORD

From 1980 to 2009, the number of fire department emergency responses more than doubled, from 10.8 million to 26.5 million, primarily driven by the more than tripling of medical aid calls, from 5.0 million in 1980 to 17.1 million in 2009. Fire department budgets have not kept pace with this rising volume of workload, and particularly in recent years, there has been increased concern about the cost of unnecessary responses. From 1980 to 2009, the number of emergency responses to fires fell by more than half, from 3.0 million to 1.3 million, and the number of emergency responses for fires or mutual aid fell by about one-fifth, from 3.3 million to 2.6 million, but emergency responses to "false" alarms more than doubled, from 0.9 million to 2.2 million. The unwanted alarm issue changed over the past third of a century from a problem of malicious false alarms to an issue of non-fire activations of automatic detection and alarm systems.

From the point of view of the fire department, a response to a condition that does not need fire department action in order to avoid loss is both a waste of resources and a needless risk of injury during the response. Response to unwanted alarms is an issue that is receiving increasing attention at the community level.

On May 3, 2011, the U.S. Fire Administration, National Fire Protection Association and International Association of Fire Chiefs co-sponsored a national Summit to initiate a dialogue on this issue. Stakeholders representing alarm design, manufacture, and installation, standards development, and emergency responders from a range of communities were present. Design and manufacturing, installation and maintenance, and enforcement issues were discussed.

The Summit identified a number of possible approaches to the issue, including a greater understanding of the sources of unwanted alarms, deeper knowledge of how the provisions in the National Fire Alarm and Signaling Code can assist enforcement, and best practices for emergency response. Also identified was the value of a tool which can be used at the community level to assess risks, and cost/benefit of strategies to reduce these risks, including appropriate emergency response protocols, enforcement of inspection and maintenance requirements, community education, etc.

This project was initiated by the Fire Protection Research Foundation to develop and implement this tool. The goal of this project was to develop a practical, model-based tool that can be used by local fire departments with local data (to the extent possible) when deciding among courses of action to deal with unwanted alarms. The tool uses a generic model, combined with local data when available and national data when necessary, to estimate costs, fire losses and other impacts of strategies.

This report describes the tool and the underlying model that estimates costs, losses and other impacts for alternative strategies. It includes national data needed for calculating fire losses under alternate strategies. A local data form was also developed for this project and is part of a separate report.

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The content, opinions and conclusions contained in this report are solely those of the author.

PROJECT TECHNICAL PANEL

Tom Antal, Antal & Associates, Inc

Tony Apfelbeck, Fire Marshal/Building Official city of Altamonte Springs, FL

Shane Clary, Bay Alarm Company

Steve Forster, Chief Fire Marshal/Division Chief Tualatin Valley Fire and Rescue Department (IAFC Representative)

Dave Frable, GSA

David Kerr, Fire Marshal Plano, TX Fire Department (IFMA Representative)

James Milke, University of Maryland

Warren Olsen, Fire Safety Consultants, Inc and Illinois Fire Inspectors Association

Brad Pabody, U.S. Fire Administration

Rodger Reiswig, SimplexGrinnell

Tom Presnak, UL

Steve Wisely, APCO International HQs

Daniel Finnegan, Siemens, Foundation Board of Trustees Liaison

Lee Richardson, NFPA Staff Liaison

Steven Sawyer, NFPA Staff Liaison

PROJECT SPONSORS

Automatic Fire Alarm Association (AFAA)	Tom Hammerberg, AFAA
Central Station Alarm Association (CSAA)	Ed Bonifas, ADS Inc
	Steve Doyle, CSAA
Electronic Security Association (ESA)	Merlin Guilbeau, ESA
	Anthony Mucci, ADT
National Electrical Manufacturers Association (NEMA)	Isaac Papier, Honeywell
Security Industry Association (SIA)	Don Erickson, SIA
	Jay Hauhn, ADT

Unwanted Alarm Project – Task 5 Deliverable
Model and Tool for Assessing Policies
Final Edition

Project for the Fire Protection Research Foundation

John R. Hall, Jr.

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National Fire Protection Association
Fire Analysis and Research Division

Executive Summary

The goal of this project is to develop a practical, model-based tool that can be used by local fire departments with local data (to the extent possible) when deciding among courses of action to deal with unwanted alarms. The tool will use a generic model, combined with local data when available and national data when necessary, to estimate costs, fire losses and other impacts of strategies.

Any alternative strategy will be assessed relative to a *baseline*, which will presumably consist of current practices. Current practices are presumed to have been developed and implemented before departments began to introduce verification and/or modified response strategies to deal with concerns over a high volume of alarms with a high likelihood of not needing a fire department extinguishment response. Relative to the baseline, an alternative strategy may result in some favorable changes (e.g., reduced costs of response) and some unfavorable changes (e.g., increased losses due to delayed or reduced response to some fires). An alternative strategy will be evaluated by balancing the favorable and unfavorable changes to see whether the net effect is favorable or unfavorable.

The anticipated user is the local fire department trying to decide whether to introduce new strategies to reduce costs associated with unwanted alarms. These strategies might involve (a) verification of the key facts of an alarm considered questionable, (b) modification of response, either to accommodate verification or to reduce resource commitments to an alarm considered questionable, or (c) actions designed to reduce the frequency of unwanted alarms.

The model within the tool will be designed to estimate costs, losses and other impacts for the alternative strategies.

The model is constructed in the format of a *decision tree*, where some branching points correspond to choices that might be made in a strategy or policy and other branching points correspond to different possibilities, such as fire self-extinguishing vs. fire growing to engulf an entire building (and everything in between). The branching points that involve chance rather than choice will pick up the different ways in which incidents may occur and develop.

In high-level terms, a user of the tool will run the model on the baseline data to obtain a reference point of costs and losses under current policies and strategies. Then, the user will run the model a second time after converting the policy or strategy into changes in the parameters.

At the end of the calculations, the user will have information that points to the *net changes in losses and costs associated with a switch to alternative strategies*.

The model is set up for separate analysis of several different property use groups:

1. Property Use 100-199, 500-599 (**<u>commercial and business</u>**)
   a) Hours when such properties are normally open, occupied and staffed (10 am to 10 pm).
   b) Hours when such properties are normally closed, unoccupied and unstaffed (10 pm to 10 am).
2. Property Use 200-299 (**<u>educational</u>**)
   a) Hours when such properties are normally open, occupied and staffed (8 am to 4 pm).

b) Hours when such properties are normally closed, unoccupied and unstaffed (4 pm to 8 am).

3. Property Use 300-399 (**institutional**)
4. Property Use 420-489 (**residential** excluding dwellings)
5. Property Use 600-799 (**industrial** and manufacturing)
6. Property Use 800-899 (**storage**); for purposes of model parameter estimation, only Property Use 891 (warehouse) is used, which avoids undue influence by barns, stables, sheds, outbuildings, and residential garages.

Wherever probabilities are needed, a choice must be made between local data and default data. The principal advantage of using local data is that the user will incorporate local conditions – and in particular, any local variations from the places that provided the default data. Local data produces results that are more relevant and more persuasive to local decision-makers.

However, a locality is likely to have a very limited quantity of data, relative to the quantities of data needed for most of the parameter estimates in the model. The model and associated form are set up to provide default values for the parameters at every stage, while also telling the user what data to collect to prepare estimates from local data, as well as guidance on when to defer to the default data based estimates.

The model develops a tree using the following branches:

1. Separating commercial alarm calls into fires and non-fires. This is based on local experience or default data and can be modified in sensitivity analysis to reflect possible effects of an alarm certification program or other approach to reducing non-fire alarms.

2. Separating fires into those needing extinguishment and those not needing extinguishment.

3. Separating fires needing extinguishment into four groups defined by fire size (based on fire spread or extent of flame damage) – confined to object of origin, confined to room of origin, confined to floor of origin, extended beyond floor of origin.

4. Calculating cost per call and, for fires only, eight measures of loss – civilian deaths and injuries per 100 fires, direct and indirect property damage per 100 fires, firefighter deaths and injuries on the fireground or during response or return per 100 fires.

5. Rules for assigning fire size changes, time credits, and/or time penalties, based on:
    a. Specifics of verification and response strategy,
    b. Predicted effect of strategy on call volume and hence on availability of closest unit to respond
    c. Predicted effect of strategy (e.g., sending reduced response) on need for additional units to respond to address a more severe incident than initial response anticipated
    d. Time of day and building size as proxies for presence of people in position to provide rapid, accurate visual verification and confirmation to fire department

6. Rules for translating time credits or penalties into modifications in expected losses.

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Introduction and Overview

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The anticipated user is the local fire department trying to decide whether to introduce new strategies to reduce costs associated with unwanted alarms. These strategies might involve (a) verification of the key facts of an alarm considered questionable, (b) modification of response, either to accommodate verification or to reduce resource commitments to an alarm considered questionable, or (c) actions designed to reduce the frequency of unwanted alarms.

The model within the tool will be designed to estimate costs, losses and other impacts for the alternative strategies.

Deliverables for the project are as follows:

- Task 2 was the literature review;
- Task 3 will be the form to be used by local fire departments to collect data needed by the tool and not already collected in an existing local data base;
- Task 4 was the identification of candidate alternative strategies; and
- Task 5 is the development of the tool itself, including any modeling, with specification of data needs and assembling of national data needed

This report is the final deliverable for Task 5, incorporating comments received from the advisory panel. It includes national data needed for calculating fire losses under alternate strategies.

How the Model Works

The model is constructed in the format of a *decision tree*, where some branching points correspond to choices that might be made in a strategy or policy and other branching points correspond to different possibilities, such as fire self-extinguishing vs. fire growing to engulf an entire building (and everything in between). The branching points that involve chance rather than choice will pick up the different ways in which incidents may occur and develop.

The first challenge is to construct the model so that it focuses attention on those calls where a decision needs to be made. The second challenge is to set up the model so that it can be used for a range of different definitions of “unwanted alarm.”

NFPA 72 defines an *unwanted alarm* as an alarm that is not the result of a potentially hazardous condition. That is a fairly narrow definition. For a fire department, an alarm of fire is a request for resources to extinguish a fire. Therefore, from the fire department perspective, an unwanted (fire) alarm is an alarm that requests extinguishment resources when they were not needed. Narrowly speaking, this could be a situation with no potential to develop into a fire. More broadly speaking, it could mean a situation that is not a fire or a fire that does not need extinguishment, because it has self-extinguished or has been extinguished by people already on the scene.

The model has been designed to distinguish fires from non-fires and fires needing extinguishment from fires not needing extinguishment. A department that wishes to send the same response to any fire, whether or not it needs extinguishment, will not need the components that distinguish fires by need for extinguishment, and the tool will allow those departments to ignore those elements.

The model asks what the actions will be, based on the strategies and policies in place, and then calculates losses.

CAUTION: Departments may wish to send some kind of response to controlled fires or reports of smoke odors or spills that could have led to fires – to take steps to make sure these incidents do not turn into uncontrolled, unwanted fires or to investigate circumstances to try to prevent such incidents in the future. The model is not set up to estimate the effects on losses of any change in policies for handling such calls. This is a limitation of the model that should be noted when it is used.

The model is constructed in several steps:

- Step 1 sets model parameters that describe the *mix of alarms* (fire vs. unwanted), the *mix of fires* (needing or not needing extinguishment), the *mix of sizes of fires* needing extinguishment, and the *rates of losses and costs per call*, all done separately for different property use groups.

- Step 2 allows the user to modify the model parameters to reflect *conditions that may exist before an alarm comes in*. For example, some characteristics – such as a history of unwanted alarms at an address – might be statistically related to a higher likelihood that any alarm received will turn out to be unwanted. Other characteristics – such as certification of alarm systems at the address – might be statistically related to a higher likelihood that any alarm received will turn out to be a fire. If there is a basis for estimating how much more or less likely unwanted alarms are under those conditions, then you can run the model to see how much difference that makes in the results.

- Step 3 modifies the model so that it can incorporate a *verification strategy*, including delays in response while verification occurs (and taking account of the likelihood that a real fire will be reported by other means during verification) and delays in response in the event of incorrect verification or of unsuccessful attempts at verification combined with a strategy of not responding without positive verification.

- Step 4 modifies the model so that it can incorporate a change in *response strategy* (policy). In particular, if the strategy means that more or fewer resources will be sent to certain classes of alarms (e.g., more to alarms that are positively verified, fewer to alarms that are not) – or at a higher or lower speed (e.g., emergency vs. non-emergency mode), then these modifications allow the effects of those changes to be incorporated into the estimates of outcomes.

- Step 5 sets up parameters to be used in estimating *cost per call*, possibly differently for different types of calls. Then the model can calculate changes in losses and changes in costs, permitting the user to examine the balance between the two.

How the Tool is Used

In high-level terms, a user of the tool will run the model on the baseline data to obtain a reference point of costs and losses under current policies and strategies. Then, the user will run the model a second time after converting the policy or strategy into changes in the parameters.

> CAUTION: The model does not work well if some alarms are diverted or triaged under current policies, are never seen by the fire department, and so will not be included in the baseline of calls. The model is designed to estimate how outcomes would have changed if different strategies and policies had been used on the same mix of calls experienced in the baseline period.

There may be a range of values for some parameters, which will provide a range of cost and loss estimates for baseline and alternative strategy. There may be several variations of a strategy that are considered worthy of evaluation.

At the end of the calculations, the user will have information that points to the *net changes in losses and costs associated with a switch to alternative strategies*. It may be necessary to apply average monetary values for a statistical life and for a statistical injury in order to provide a net total for each alternative.

The tool, as developed, is used directly to assess the impact of alternative verification and response strategies and policies. Other strategies – like a program to certify alarm systems throughout the community or to replace existing alarm systems with better performing systems – will produce benefits in terms of changes to the model parameters. By running the model with those changes, the user will obtain estimates of changes in losses that can be compared with the costs of running the program.

Local vs. default data

Wherever probabilities are needed, a choice must be made between local data and default data. The principal advantage of using local data is that the user will incorporate local conditions – and in particular, any local variations from the places that provided the default data. Local data produces results that are more relevant and more persuasive to local decision-makers.

However, a locality is likely to have a very limited quantity of data, relative to the quantities of data needed for most of the parameter estimates in the model. There may be enough to support estimation of the percentage of alarms that are fires and the percentage of fires that need extinguishment, though probably not separate estimation for different property use classes. There probably will not be enough data to support solid estimates of the percentages of fires needing extinguishment by fire size or to estimate average loss per fire needing extinguishment for the different types of losses.

The model and associated form are set up to provide default values for the parameters at every stage, while also telling the user what data to collect to prepare estimates from local data, as well as guidance on when to defer to the default data based estimates.

Setting Up the Model

Step 1: Setting up the model to estimate losses

The estimation of costs will be addressed at the end, not as part of this discussion of the loss-estimation aspects of Step 1.

Setting up different property use groups for separate analysis

Here is a suggested way of separating and aggregating major property use groups:

7. Property Use 100-199, 500-599 (**commercial and business**, high occupancy but not round-the-clock)
   a) Subgroup 1a: Hours when such properties are normally open, occupied and staffed. We have used 10 am to 10 pm as our estimate.
   b) Subgroup 1b: Hours when such properties are normally closed, unoccupied and unstaffed. We have used 10 pm to 10 am as our estimate.
8. Property Use 200-299 (**educational**, not round the clock, higher-vulnerability people)
   a) Subgroup 2a: Hours when such properties are normally open, occupied and staffed. We have used 8 am to 4 pm as our estimate.
   b) Subgroup 2b: Hours when such properties are normally closed, unoccupied and unstaffed. We have used 4 pm to 8 am as our estimate.
9. Property Use 300-399 (**institutional**, round the clock, higher-vulnerability people)
10. Property Use 420-489 (**residential** excluding dwellings, occupied round-the-clock, often by people who are vulnerable because they are asleep)
11. Property Use 600-799 (**industrial** and manufacturing, low to medium density of people)
12. Property Use 800-899 (**storage**, low density of people); for purposes of model parameter estimation, only Property Use 891 (warehouse) is used, which avoids undue influence by barns, stables, sheds, outbuildings, and residential garages, all of which have much larger shares of reported fires than of fires reported from commercial alarm systems.

The first decision is which of these property use groups to include in the analysis. Some communities will choose to respond to some properties, such as educational and institutional properties, while verification is going on or even if there is no positive verification result. Properties with many high-risk or high-vulnerability people are the kinds of properties most likely to be removed from the analysis and removed from any change in strategies.

Separating fires from non-fire calls and separating fires by whether extinguishment was needed

Calls received for a specific property use group need to be split into fires and non-fires. Then the fires need to be split into those needing extinguishment and those not needing extinguishment.

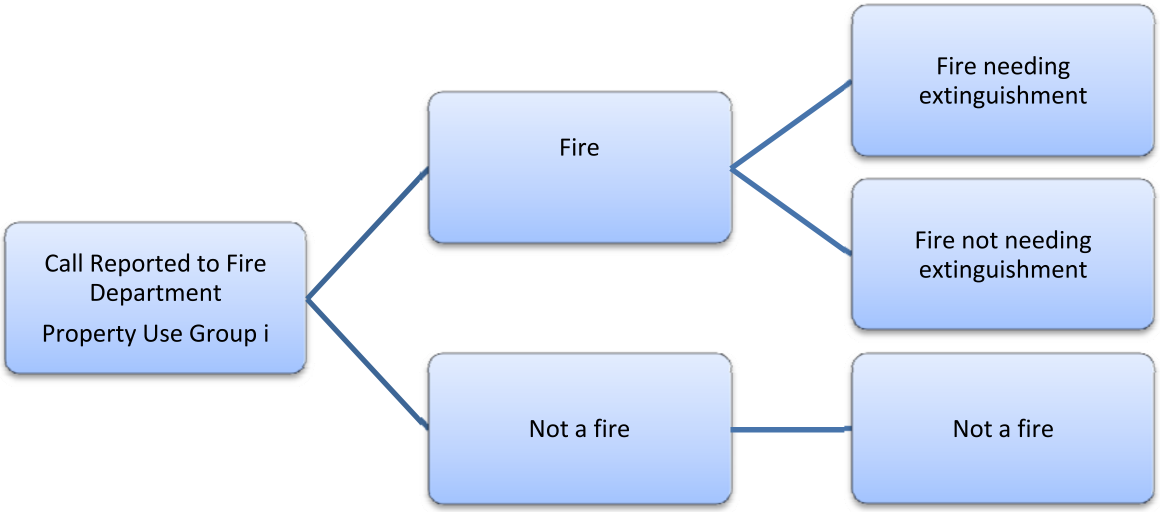
The latter split is done using the Action Taken code in NFIRS:

Action Taken 10 can be treated as a partial unknown and proportionally allocated over Action Taken 11-17. None of the sources of reference data performed this step. If this calculation is done using 2006-2010 NFIRS data, it results in the following percentage increases in calls needing extinguishment:

- 9% for commercial and business properties
- 14% for educational properties
- 19% for institutional properties
- 10% for residential excluding dwellings
- 8% for industrial properties
- 5% for storage properties

- 11 = Extinguishment performed by fire service personnel

Figure 1. Unwanted alarms decision and event tree, from reported call to whether fire needs extinguishment



Define probabilities of splitting from "Call Reported to Fire Department/Property Use Group i" as:

- p_{1i} = probability call is a fire
- p_{1Ni} = probability call is not a fire = 1- p_{1i}

Table 1. Percentage of calls that are fires, by Property Use group

Property Use group	Likelihood that a call is a fire
Tualatin calls, 2007-2011 [62 fires out of 8,771 calls]	0.7%
Calls analyzed by Ed Bonifas, 2011-2012 [113 fires out of 10,482 calls]	1.1%
Plano calls [36 fires out of 9,329 calls]	0.4%
Plano – Commercial and business occupancies (Property Use 100-199 and 500-599) [7 fires out of 2,771 calls]	0.3%
Plano – Educational occupancies (Property Use 200-299) [2 fires out of 603 calls]	0.3%
Plano – Institutional (health care and correctional) occupancies (Property Use 300-399) [1 fire out of 585 calls]	0.2%
Plano – Residential occupancies excluding one- or two-family dwellings (Property Use 420-489) [15 fires out of 1,489 calls]	1.0%
Plano – Industrial occupancies (Property Use 600-799) [0 fires out of 154 calls]	0.0%
Plano – Storage occupancies (Property Use 800-899) [0 fires out of 220 calls]	0.0%
Plano – Excluded occupancies (Property Use 000, 400-419, 900-999, Unknown) [11 fires out of 3,507 calls]	0.3%
Plano – Total without excluded occupancies [25 fires out of 5,822 calls]	0.4%
All data combined [211 fires out of 28,582 calls]	0.7%

Plano provided the only data where both calls and fires were distinguished by Property Use group. The industrial and storage occupancies had no fires recorded but had so few calls that the overall 0.4% percentage could still apply. That percentage would have predicted only one fire in each of the industrial and storage property use groups.

The default overall value for p_{1i} (probability call is a fire) is 0.7%, with no variations by Property Use group. **Use local data or this default value to complete the first split shown in Figure 1.**

Define probabilities of splitting fires by whether extinguishment was or was not needed as:

- p_{2Ei} = probability fire needs extinguishment
- p_{2i} = probability fire does not need extinguishment = 1- p_{2Ei}

Table 2. Percentage of fires that need extinguishment, by Property Use group

Property Use group	Likelihood fire needs extinguishment
Tualatin, 2007-2011 [13 out of 62 fires]	21%
NFIRS, 2006-2010 (no allocation of Action Taken 10), not limited to fires reported by commercial alarms	44%
NFIRS – Commercial and Business	54%
NFIRS – Educational	33%
NFIRS – Institutional	28%
NFIRS – Residential Excluding (One- or Two-Story) Dwelling	41%
NFIRS – Industrial	66%
NFIRS – Storage (warehouse only)	74%

The Tualatin data provides the only overall estimate based on commercial alarm calls only, while the NFIRS data provides the only separate estimates by property use. A user can employ an overall estimate based on local data or the Tualatin estimate. Then multipliers can be applied, based on the NFIRS estimates, to produce estimates for each Property Use group. (For example, Commercial and Business would have a multiplier of 1.22 = 54%/44%, the NFIRS percentage for Commercial and Business divided by the NFIRS percentage for all properties combined.)

Table 3. Default values for probability fire needs extinguishment, by Property Use group

Property Use group	NFIRS-based multiplier to convert overall to estimate for Property Use	Likelihood fire needs extinguishment using Tualatin overall percent as default
Overall	Estimated locally	21%
Commercial and Business	1.22	26%
Educational	0.76	16%
Institutional	0.64	13%
Residential Excluding Dwelling	0.93	20%
Industrial	1.49	31%
Storage (warehouse only)	1.67	35%

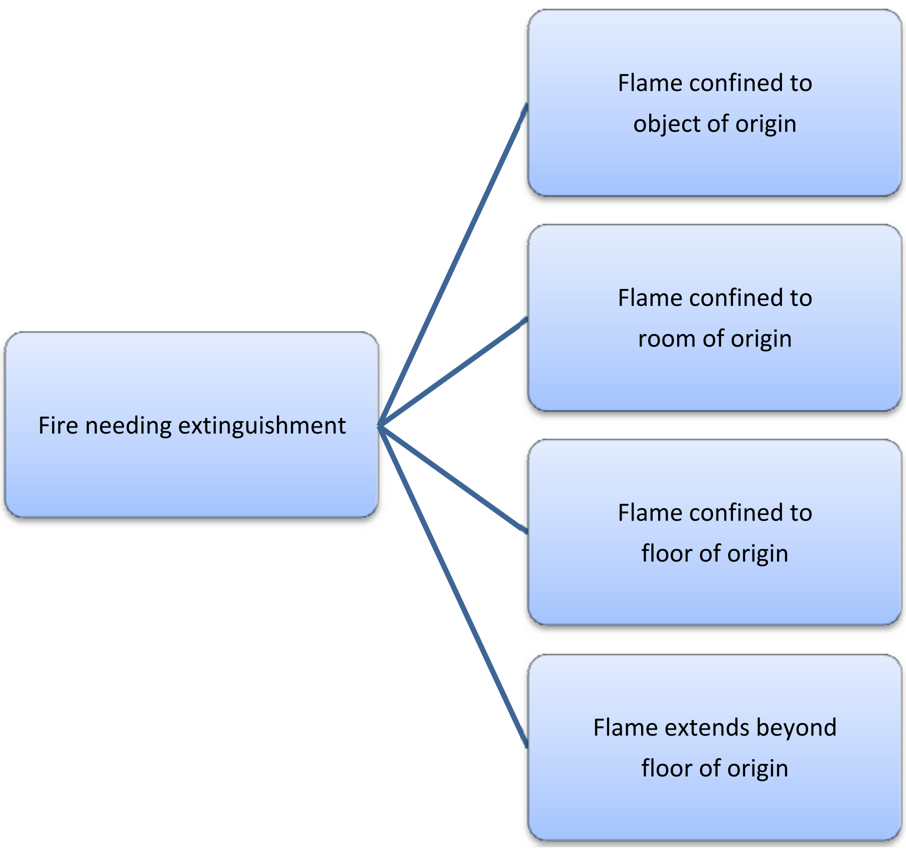
<u>Use Table 3 to fill in the second split shown in Figure 1 in the model.</u> <u>The default overall value for P_{1Fi} (probability fire needs extinguishment) is set at 21%, based on the Tualatin data. Variations by Property Use group will almost never be calculated using local data alone but will be calculated by applying the Table 3 (second column) multipliers either to the overall value from local data or to the default overall value.</u>

Separating fires needing extinguishment by fire size

Having isolated the fires needing extinguishment, the model needs to divide those fires by size, which will in turn be used to estimate losses. One of the principal ways in which the model describes the effects of changes in strategies and policies is by changing the mix of fire sizes for the fires needing extinguishment.

Fire size is characterized using the NFIRS Fire Spread data element, which identifies four fire sizes shown in Figure 2. The final category – fires extending beyond floor of origin – is a combination of two categories identified in NFIRS – confined to building of origin and beyond building of origin. The latter category tends to have few fires (an exception is the storage occupancy category) and does not reliably contain the largest fires, which is why it is better folded into the previous category.

**Figure 2. Unwanted alarms decision and event tree,
splitting fires needing extinguishment by final size of fire**



Define probabilities of splitting from "Fire needing extinguishment" as:

- p_{3i} = probability has final extent of fire size equal to one of the four sizes described above.

The p_{3i} values, if summed from i = 1 to 4, will total 1.

Table 4 provides values of p_{3i}, including data from two sources for all Property Use groups combined and data from one source for each of the six Property Use Groups.

Table 4. Percentage of fires needing extinguishment by final fire size, by Property Use group

Property Use group	% confined to object of origin*	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Data from Bonifas (based on 113 fires)	69%	20%	7%	4%
NFIRS – overall but not limited to commercial alarm based calls	57%	20%	6%	18%
Commercial and business	49%	19%	5%	27%
Educational	61%	21%	3%	15%
Institutional	71%	18%	3%	8%
Residential excluding dwelling	60%	21%	6%	13%
Industrial	46%	16%	4%	33%
Storage (warehouse only)	36%	20%	6%	39%

* Includes fires reported as confined or contained under Incident Type.

The data from Bonifas is consistent with the view that not only are (a) calls sent from commercial alarms less likely to be fires than calls in general and (b) fires reported from commercial alarms less likely to need extinguishment than reported fires in general, but also (c) fires needing extinguishment and reported from commercial alarms are more likely to be small (69% vs. 57% for fires confined to object of origin) and much less likely to be very large (4% vs. 18% for fires extending beyond floor of origin).

<u>We expect that no user will have enough local data to estimate these percentages using local data. At this stage of the model, all users are expected to use default data.</u> We propose using the data from Bonifas to set the fire size percentages for the overall case (all Property Use groups combined).

We want to use the data supplied by Bonifas with the NFIRS data to derive estimates for the different Property Use groups. We use a stepwise adjustment procedure as follows:

- Start with the NFIRS distribution for a particular Property Use, for example, for Educational, 61% confined to object, 21% confined to room, 3% confined to floor, and 15% beyond floor or building
- For each fire size, create a multiplier by dividing the NFIRS overall percentage into the Bonifas overall percentage. Therefore:
  - For confined to object, the multiplier is 69%/57% = 1.22
  - For confined to room, the multiplier is 20%/20% = 1.00
  - For confined to floor, the multiplier is 7%/6% = 1.23, and
  - For beyond floor or building, the multiplier is 4%/18% = 0.23

- Now multiply each NFIRS percentage by the appropriate multiplier. For example, for Educational:
  - For confined to object, 1.22 x 61% = 75%
  - For confined to room, 1.00 x 21% = 20%
  - For confined to floor, 1.23 x 3% = 4%, and
  - For beyond floor or building, 0.23 x 15% = 3%

- The resulting percentages probably will not sum to 100%, as they need to do; in the example, they sum to 103%. Therefore, divide each percentage by the sum of the percentages. For example, for Educational:
  - For confined to object, 75%/103% = 73%
  - For confined to room, 20%/103% = 20%
  - For confined to floor, 4%/103% = 4%, and
  - For beyond floor or building, 3%/103% = 3%

Use Table 5 to complete the splits shown in Figure 2 for the model. Table 5 provides such derived default values for fire size percentages overall (from the Bonifas data) and for each Property Use group (adjusted from the NFIRS data by use of the Bonifas data, in the manner described). Most of the estimates for specific Property Use groups are relatively similar to the overall estimates, with the notable exception of Storage properties, where there is a much higher likelihood that a fire needing extinguishment will be quite large.

Table 5. Recommended default values for percentage of fires needing extinguishment by final fire size, by Property Use group

Property Use group	% confined to object of origin*	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Overall	69%	20%	7%	4%
Commercial and business	66%	20%	7%	7%
Educational	73%	20%	4%	3%
Institutional	79%	16%	4%	2%
Residential excluding dwelling	70%	20%	7%	3%
Industrial	66%	19%	6%	9%
Storage (warehouse only)	55%	25%	10%	11%

Estimating losses based on characteristics of call, including size of fire

If you combine Figures 1 and 2, you obtain a tree with these end points:

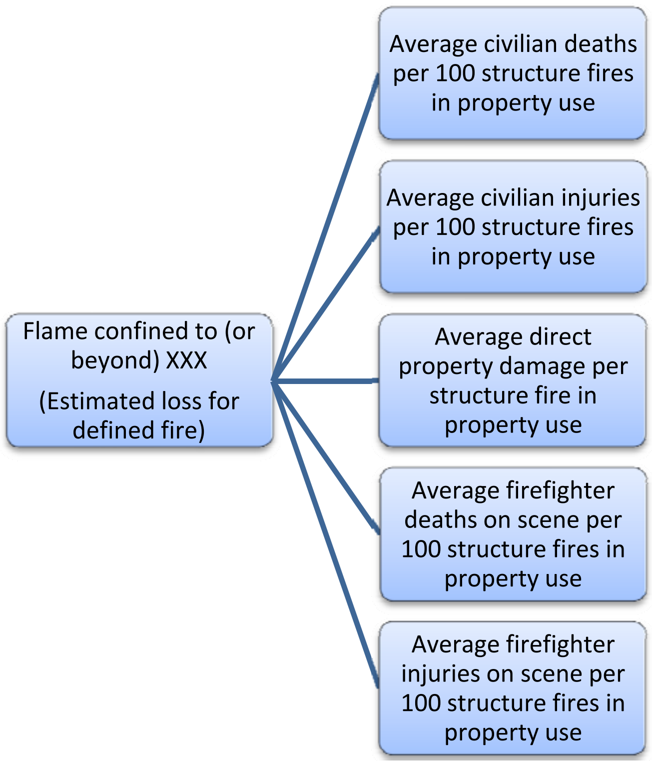
(a) not a fire call,
(b) a fire but one not needing extinguishment, or
(c) a fire of one of the four indicated fire sizes.

Now, we need to attach losses to each of these possible conditions, and in the next section, we will attach costs as well. For purposes of this analysis, only fires have losses that are counted.

Figure 3 shows the five principal types of losses to be incorporated. All losses are for fires only, and because none of the alternative strategies being considered here will change the losses at fires not needing extinguishment, losses are only estimated for fires needing extinguishment.

No local user can be expected to be able to estimate loss per fire by Property Use group, need for extinguishment, and fire size. On the other hand, it seems unlikely that local values of loss per fire will be different from national estimates for fires reported by commercial alarms after both Property Use group and fire size have been taken into account. Therefore, this part of the model assumes that every user will be working with default data. Loss rates for Figure 3 are estimated from NFIRS national estimates for civilian deaths, civilian or firefighter injuries, and direct property damage, and NFPA's Fire Incident Data Organization (FIDO) for firefighter deaths.

Figure 3. Unwanted alarms decision and event tree, quantification of loss per fire for end-points of tree – civilian and on-scene firefighter deaths and injuries, direct damages

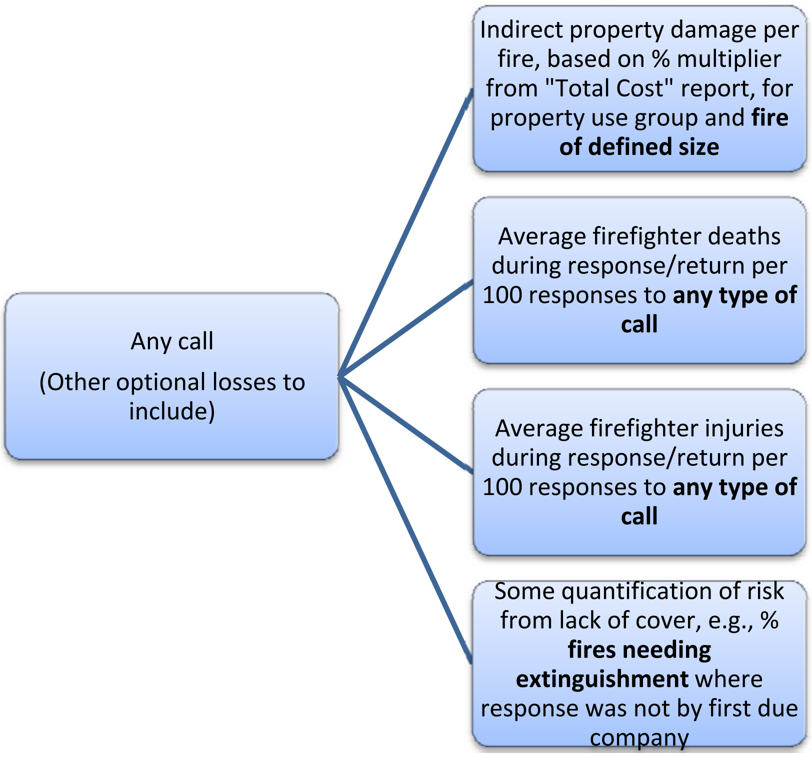


Use Appendix A to enter default values for Figure 3. In Figure 3, all fire losses are estimated separately for different Property Use groups, and all fire losses except firefighter deaths on scene are estimated separately for different fire sizes. (Firefighter fatalities are not coded as to the size of the fire where the fatal injury occurred.)

Because non-fire calls from commercial alarm systems are assumed not to involve any significant damage, let alone any damage that would change based on the speed and size of the response, there is no attempt to estimate civilian deaths and injuries or direct property damage for non-fire calls. However, firefighter deaths and injuries are possible on scene at any emergency response. The rate of firefighter deaths per 100 non-fire calls is so low that it is estimated as zero, but the rate of firefighter injuries per 100 non-fire calls is high enough to be estimated and is included.

Figure 4 describes four other types of losses that might be incorporated.

Figure 4. Unwanted alarms decision and event tree, quantification of loss per fire for end-points of tree – indirect damages, response/return casualties, risk from lack of cover



Use Appendix A to enter loss rates for the first three types of loss shown in Figure 4. The first type of loss in Figure 4 is indirect loss (such as business interruption). It applies only to fires needing extinguishment, for the same reasons already discussed, and can be estimated as a percentage add-on to the estimated direct property damage, using multipliers taken from the NFPA *Total Cost of Fire* report.[1] The multipliers are given in Appendix A.

The second and third types of loss in Figure 5 are firefighter deaths and injuries during response or return. These risks apply to any emergency response. The rate of firefighter deaths per 100 response/return calls is provided by Property Use group for all fire calls, with no differentiation based on fire size, in Appendix A. The rate of firefighter injuries per 100 response/return calls is provided for all fire calls, with no differentiation based on fire size or Property Use group, in Appendix A. Firefighter death rates per 100 response/return calls to non-fire emergencies are so low that they are treated as zero. The rate of firefighter injuries per 100 response/return calls is estimated for non-fire calls as equal to the rate for fire calls.

Wait for a later section to enter changes in loss rates for the last type of loss (risk from lack of cover) shown in Figure 4. The last loss rate shown in Figure 5 – quantification of risk from lack of cover – involves additional thought on how best to measure the risk in a form that can be combined

[1] John R. Hall, Jr., *The Total Cost of Fire in the United States*, NFPA Fire Analysis & Research Division, February 2012.

with other losses. For example, percentage of time per day spent without recommended coverage can't be readily converted to deaths, injuries, or monetary losses.

The model addresses this in a highly simplified manner by looking at the impact of call volume on the ability to send the first alarm response to fires needing extinguishment. Specifically, the model looks at the volume of fires plus false alarms (using the NFPA annual survey category of false alarms, without the refinements of types of false alarms and treatment of good-intent calls possible with NFIRS).

CAUTION: This approach implicitly assumes that all other emergency calls – including hazardous condition and hazardous material calls, but especially emergency medical calls – do not draw on the same response resources as are sent to fires. If that is not correct, then even a sharp reduction in false alarm volume will have a negligible effect on total call volume, which is and will be dominated by medical calls. In fact, several other types of emergency responses are typically more common than false alarms.

If this simplified approach is acceptable and the assumption setting aside emergency call volume not involving fires or false alarms is considered reasonable, then the model uses local-data estimates of the <u>percentage of fires needing extinguishment where the response was not the first alarm response because the latter were still busy on another call</u>.

By comparing the Tualatin average annual number of non-fire calls from commercial alarm systems with the NFPA recent annual reports on reported fires and false alarms for similar-sized communities, we can very roughly estimate that <u>non-fire calls from commercial alarm systems constitute nearly half of the combined total of fires and false alarms reported from any source</u>. Therefore, any strategy that eliminates responses to nearly all non-fire calls from commercial alarm systems will be estimated to reduce percentage of calls with first alarm company busy by nearly half.

Specifically, let P_{rcv} be the percentage of fires needing extinguishment that will be assigned a time credit (because the verification strategy is estimated to Reduce Call Volume – hence RCV – enough to allow more responses by the closest units).

- **P_{rcv} = (1/2) x [Based on local data, % of fires where response is *not* by nearest unit]**

If necessary due to limitations of local data, percent of calls can be substituted for percent of fires. It is assumed that this parameter will not be calculated separately by Property Use group and would not be expected to vary much by Property Use group in any event. More details will be provided in the later section on Steps 3-4.

Step 2: Modifying the model to incorporate additional situation data

Incorporating "bad flags" such as alarm history at a specific address

If there are a large number of unwanted alarms a year in the community, then chance alone will mean that some properties have multiple unwanted alarms and other properties do not.

Suppose there were 10,000 commercial buildings with alarm systems and they had 1,000 unwanted alarms a year. Then you would expect nearly 1,000 buildings a year to have at least one unwanted alarm, and the fact that a particular building had had an unwanted alarm in the past year would not lead you to conclude that its risk of unwanted alarm was higher from the many more buildings that had not had unwanted alarms. It could be unlucky rather than worse. In fact, you would expect about 80 buildings a year to have two unwanted alarms and about 8 buildings a year to have three unwanted alarms, all based on chance if the occurrence of any two unwanted alarms is statistically independent.

This kind of thinking may lie behind the NFFAA/FARA Model Fire Alarm Ordinance, cited in the project literature review, which is built around a fee for more than three false alarms per year.

In the example included in that article, roughly 19% of alarms were in buildings that had more than one unwanted alarm. (The math to produce this estimate has been omitted.) This was based on an overall rate of one unwanted alarm for every 10 buildings with alarm systems. If the overall rate was higher, then the percentage of alarms occurring in buildings with multiple unwanted alarms would be higher. If the rate was lower, the percentage for multiple unwanted alarms would be lower.

This 19% of alarms occurred in just under 1% of the buildings, which would be the "repeat offenders" in this example. That 1% of buildings (just under 100 properties) might be unlucky and not deserve to be fined, but that is also a small enough group of installations that it could be affordable and practical to use a lower threshold of two false alarms in a year to trigger a review of the building's system. Triggering a review on the basis of just one false alarm a year would mean reviewing nearly 9% of the buildings or nearly a thousand properties, which might be impractical.

According to the study cited in the literature review, Tualatin found about 15% of their buildings were repeat offenders. If their overall unwanted alarm rate per building with commercial alarm was much higher than in this example – more like one or two per system per year – then their percentage of repeat offenders would be right in line with an assumption of equal risk of unwanted alarms across the entire community. If not, then they might be able to justify a lower threshold for fees or for mandatory system review.

The conclusion from these calculations is that some significant frequency of multiple unwanted alarms per year is to be expected even if there is no variation in the risk of unwanted alarms across the systems. There may be enough evidence to justify targeted strategies – such as fines, fees or mandatory system reviews – but there probably will not be enough evidence to justify changes in the model's formulas.

<u>"Bad flags" – indicators that a system has performed worse than other systems – are therefore not used as a basis to modify the model. They can be appropriately used in the design and operation of a program of fees and/or mandatory system reviews.</u> <u>**The model is not set up to provide any penalties for "bad flags".**</u>

Incorporating "good flags" such as certification of systems

In the first draft of the model, two approaches were suggested for estimating the impact of certification of systems on the systems' rate of unwanted alarms. One was based on a very small study in the literature review that suggested a 75% reduction in the rate of non-fire alarms in problem properties (and no reduction in fires that are not working fires).

The second approach used the NFIRS coding on type of false alarm to construct estimates based on the hypothesis that a good program might eliminate the equipment-related false alarms but not change the behavior-related false alarms, using the NFIRS coding to make that split between equipment-related and behavior-related false alarms. This suggested a 50-60% reduction in the non-fire share of commercial alarm calls.

The advisory panel agreed without dissent that these estimates were much higher than what they were seeing in the field, but no one provided data to support a different estimate. One participant offered his impression that 20-30% was more realistic.

The model is not set up to provide any credits for "good flags". Given the state of knowledge, the model has been designed with no built-in modifications to incorporate good flags.

Instead, **users may choose to conduct a sensitivity analysis based on changes to the probability that a commercial alarm system call is a fire.**

The default value for that probability is 0.7%.

- If a program reduced non-fire share of commercial alarms by 20%, the default value would rise to 0.9%
- If the reduction was 30%, the default value would be 1.0%
- If the reduction was 50%, the default value would be 1.4%
- If the reduction was 60%, the default value would be 1.7%
- Even if the reduction was 75%, the default value would rise only to 2.7%. That is four times the base default value and might be high enough to tilt the analysis, which is why a sensitivity analysis could be useful. However, it is important to be aware that even an extraordinarily effective program would still leave the user's community with a commercial alarm system call volume dominated by non-fire events.

See Appendix B for detailed calculation rules to use in such a sensitivity analysis.

Steps 3 and 4: Modifying the model to incorporate alternative verification and response strategies

The model uses several different modifications to estimate the effects of alternative verification and response strategies.

- Some strategies will result in delayed responses. The associated time penalties will be translated into changes in the estimated losses per fire, based on an adaptation of available simple models of fire growth as a function of time. Some strategies may result in quicker responses (as in the earlier discussion of the positive effect of reduced impacts from lack of coverage), and so the model will also be modified to incorporate time credits as well as time penalties.
- Some verification attempts will get bad information, but some commercial alarm reports will be followed almost immediately by in-person reports of the same incident. Based on the discussions at the advisory panel meeting, including the impressions of fire officers who have studied the phenomena in their own communities, both these phenomena are real and should be incorporated into the modeling, even though we lack data capable of confirming or quantifying their frequency.
- Some responses may be made larger or smaller, faster or slower, based on the results of verification attempts. This includes changes in the quantity of resources sent and changes in the use or non-use of emergency mode response speed.

We begin with some necessary assumptions.

-
- Assumption 1: When an occupancy has a high density of on-site population, in-person reports of a real fire will occur nearly simultaneously with the report from a commercial alarm system. The following will be assumed to have high-density on-site population:
  - Residential excluding dwelling (Property Use 420-489)
  - Institutional (Property Use 300-399)
  - Commercial and business during operating hours of 10 am to 10 pm (Property Use 100-199 and 500-599)
  - Educational during school hours of 8 am to 4 pm (Property Use 200-299)

  The following will be assumed **never** to have high-density on-site population:
  - Industrial (Property Use 600-799)
  - Storage (Property Use 800-899)
  - Commercial and business outside operating hours of 10 am to 10 pm (Property Use 100-199 and 500-599)
  - Educational outside school hours of 8 am to 4 pm (Property Use 200-299)

- Assumption 2: We will divide the fires in occupancies with low density of on-site population into three groups:
  - Fires when no one is in the building (estimate of the percentage of fires with this condition developed from FIDO records). It will be assumed that verification attempts will fail for these fires. If the strategy is to respond normally after failed verification attempts, then there will be a verification time penalty. If the strategy is not to respond normally unless verification is successful, then the model will assume the fire will grow large enough to be seen by and reported by a passerby, which means fire size is increased to beyond floor of origin.
  - Fires when someone is in the building but the building is large enough that it is likely verification cannot be conducted (first estimate percentage of fires where someone is in the building from FIDO records; then estimate percentage of fires where building has 2+ stories or a main floor size footprint of at least 5,000 square feet). It will be assumed that verification will incorrectly report no fire when there is a fire in these cases. The model will assume the fire will grow large enough to be seen by and reported by a passerby outside the building, which means fire size is increased to beyond floor of origin.
  - Fires when someone is in the building and the building is small enough that it is likely verification will be accurate (100% minus the percentages for the other groups). It will be assumed that verification will be successful and accurate in these cases. There will be a verification time penalty.

Combining modifications to the model to this point

In Step 1, the user will have applied these calculations:

- Figure 1, first split: Using a local-data-based estimate or the default value of 0.7%, the model will have separated fires from non-fire calls, for each Property Use group.

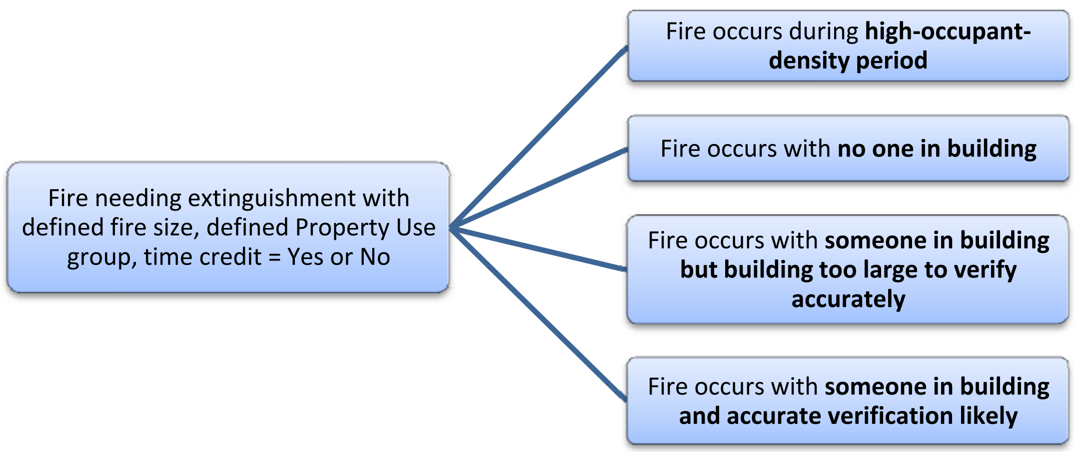
- Figure 1, second splits: Using default percentages from Table 3 or default Property Use multipliers from Table 3 with a local-data-based estimate for the overall percentage, the model will have separated fires needing extinguishment from fires not needing extinguishment, for each Property Use group.

- Figure 2 splits: Using default percentages from Table 5, the model will have separated fires needing extinguishment into four fire-size groups, for each Property Use group.
- Figure 3 and 4 data: In the baseline, Figures 3 and 4 specify nine types of loss for which loss rates are attached to each *end cell* from Figures 1 and 2. (For each Property Use group, there will be six end cells – non-fire calls from Figure 1, fires not needing extinguishment from Figure 1, and fires needing extinguishment by each of four sizes from Figure 2).

Step 2 ended up not making any changes to the model. Steps 3 and 4 will provide a basis for additional splits after the Figure 2 splits, resulting in more end cells requiring loss and cost data, as well as some changes in the rules for assigning that data.

Figure 5 splits each Figure 2 end cell – consisting of a fire needing extinguishment, a fire size and a Property Use group – into four cells based on (a) time of day (for two of the six Property Use groups), (b) size of building (used as a proxy for the ability of a small skeleton crew to accurately verify a fire when asked to do so), and (c) the presence or absence of someone in the building during hours when the property probably is not open for business.

Figure 5. Unwanted alarms decision and event tree – conditions that can lead to time penalty, time credit, or fire size penalty



The first step in making the splits shown in Figure 5 is to determine what percentage of fires, by size of fire, will occur during high-density-occupancy hours. As noted when the six Property Use groups were first defined, Institutional properties and Residential Excluding Dwelling properties are assumed to be densely occupied at all times, while Industrial and Storage properties are assumed never to be densely occupied.

That leaves Commercial and Business properties and Educational properties. Table 6 indicates what percentage of fires of a defined fire size occur during high-density-occupancy hours, for each of these two Property Use groups.

This completes the data needed to assign probabilities to the top cell of the four cells in Figure 5.

Table 6. Default values from NFIRS for percentage of fires occurring during high-occupant-density hours, by final fire size and by Property Use group

Property Use group	% confined to object of origin*	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Commercial and Business	62%	56%	51%	46%
Educational	48%	50%	40%	30%

*Includes fires defined as confined under NFIRS Incident Type.

Whatever is left needs to be split among the other three cells. The next step is to estimate what percentage of fires outside high-density-occupancy hours occur when no one is on premises, for the four Property Use groups that are not assumed to be occupied at high density all the time. NFIRS does not have any data relevant to this question, but NFPA's Fire Incident Data Organization (FIDO) does. FIDO is a data base of mostly larger fires, and it is not large enough to support different estimates by fire size.

Therefore, the model uses these **parameters for likelihood there is no one on site** for all fire sizes:

- Commercial and Business – 65% of fires during low-density period have no one on premises
- Educational – 66%
- Industrial – 30%
- Storage – 51%

The final step is to divide those fires with someone on premises but low-density occupancy into buildings large enough to make accurate verification unlikely vs. those small enough to make accurate verification reasonably likely.

The model assumes that the threshold on building size can be set as <u>two or more stories in height</u> (assuming the person contacted cannot only easily verify what is on his or her floor) <u>OR more than 5,000 square feet of footprint</u> (assuming that interior walls or tall shelves or tall work stations will defeat an attempt to scan an area this large for evidence of fire).

Table 7 provides the default values for all fire sizes for each Property Use group. The high-density period line (top row for each Property Use group) is 100% for all fire sizes for Institutional and Residential Excluding Dwelling, 0% for all fire sizes for Industrial and Storage, and shown in Table 6 for Commercial and Business and for Educational. The second row is 0% and so not shown for Institutional and Residential Excluding Dwelling.

For the other four Property Use groups, the parameters for no one on site are multiplied by 100% minus the top row percentages. The splits for the third and fourth rows are based on derived percentages that are not shown in the report multiplied by 100% minus the first and second row percentages.

Table 7. Default values from NFIRS and FIDO for percentage of fires needing extinguishment falling in each of the four cells of Figure 5, by final fire size and by Property Use group

	Percentage of fires occurring at indicated time of day and with indicated density of population on site and indicated building size			
Property Use group	**confined to object of origin**	**confined to room of origin**	**confined to floor of origin**	**beyond floor of origin**
Commercial and business …				
…and during high-density period	62%	56%	51%	46%
…and with no one on premises	25%	29%	32%	35%
…and with low-density on-site population in large building	6%	8%	11%	9%
…and with low-density on-site population in manageable small building	8%	7%	6%	10%
…and any condition above	100%	100%	100%	100%
Educational …				
…and during high-density period	48%	50%	40%	30%
…and with no one on premises	34%	33%	39%	46%
…and with low-density on-site population in large building	10%	12%	15%	12%
…and with low-density on-site population in manageable small building	8%	5%	5%	12%
…and any condition above	100%	100%	100%	100%
Institutional …				
…and during high-density period (condition applies to all fires)	100%	100%	100%	100%
Residential Excluding Dwelling …				
…and during high-density period (condition applies to all fires)	100%	100%	100%	100%
Industrial …				
…and during high-density period	0%	0%	0%	0%
…and with no one on premises	30%	30%	30%	30%
…and with low-density on-site population in large building	51%	52%	56%	40%
…and with low-density on-site population in manageable small building	19%	18%	13%	30%
…and any condition above	100%	100%	100%	100%
Storage …				
…and during high-density period	0%	0%	0%	0%
…and with no one on premises	51%	51%	51%	51%
…and with low-density on-site population in large building	11%	11%	17%	7%
…and with low-density on-site population in manageable small building	38%	38%	32%	42%
…and any condition above	100%	100%	100%	100%

Now that the model has all the probabilities needed to estimate the likelihood of every end cell, it is necessary to provide rules for assigning loss rates to end cells. Table 8 indicates how penalties and credits are assigned, based on the verification and response strategy and the fire characteristics specified in Figure 5. If the department sends a standard response with no delay for verification, using verification only to turn around apparatus en route, then the model assumes such a strategy has no effect on costs or losses.

Table 8. Rules for penalties and credits, based on fire characteristics from Figure 5 and response strategy

Verification and response strategy	High occupant density	No one in building	Low density; large building	Low density; small building
Complete verification before responding; respond if verification neither confirms nor disconfirms fire	May be time credit for reduced call volume	Verification time penalty; may be offset if time credit for reduced call volume	False disconfirmation Increase fire size to beyond floor of origin; response only for passerby report	Verification time penalty; may be offset if time credit for reduced call volume
Complete verification before responding; respond only if confirmed as fire	May be time credit for reduced call volume	Increase fire size to beyond floor of origin; response only for passerby report	False disconfirmation Increase fire size to beyond floor of origin; response only for passerby report	Verification time penalty; may be offset if time credit for reduced call volume

Note the several references to a possible time credit. As noted earlier, the likelihood of that time credit will be given by the parameter P_{rcv}, which was defined at the end of the section on Step 1. The implementation of time credits will consist in the development of two tables of fire loss adjustment rules, one where time credits apply and one where they do not. The combined rule will be to apply the rule where time credits apply and multiply that by P_{rcv}; then apply the rule where time credits do not apply and multiply that by (100% - P_{rcv}); and finally add the two terms to obtain the revised loss rates.

The next step is to translate the notion of time credits and time penalties into detailed rules for modifying the assigned loss rates.

What is the effect of a time penalty or time credit?

In engineering analysis, it is not unusual to model fires using a formula where fire size or severity is set equal to a constant times the square of elapsed time.[2] There are four such curves, each defined by the time required for a fire to grow from ignition to a heat release rate of 1 megawatt. These curves reasonably represents the time from fire confined to object of origin (close to size at ignition) to fire just about to spread beyond room of origin.

- Ultrafast fire (e.g., upholstered furniture), 75 seconds to 1 megawatt
- Fast fire (e.g., cartons on pallets), 150 seconds to 1 megawatt
- Medium fire (e.g., solid wood furniture), 300 seconds to 1 megawatt
- Slow fire (e.g., dense wood products), 600 seconds to 1 megawatt

The next step is to estimate the length of the time penalty or credit, and develop a formula translating time change into a change in estimated loss. The draft model proposed a 180-second time penalty. The advisory panel agreed that was too long. A period of 30 seconds was identified as more

[2] Table 5-11.2 and related text, *SFPE Handbook of Fire Protection Engineering*, 4th edition, SFPE and NFPA, Quincy, MA, 2008.

reasonable and more typical. It is suggested that the time credit of being able to send the nearest units might also be estimated as 30 seconds.

If for context, you look at the difference in average property damage per fire, by Property Use group, when going from a fire confined to *object of origin* to a fire confined to *room of origin*, the increase in damage looks like this:

- Up by a third for Storage
- Up by 2-to-1 for Industrial
- Up by 4-to-1 for Commercial and Business
- Up by 5-to-1 for Educational and Institutional
- Up by 10-to-1 for Residential Excluding Dwelling

Now if you add or subtract 30 seconds to a fire that is midway through growing from ignition to 1 Megawatt in size, it will have this effect, depending on the fire growth rate category of the fire:

- For a Medium fire, adding 30 seconds will add 44% to fire severity and subtracting 30 seconds will subtract 36% from fire severity;
- For a Fast fire, adding 30 seconds will roughly double fire severity and subtracting 30 seconds will subtract 64% from fire severity; and
- For an Ultrafast fire, adding 30 seconds will roughly triple fire severity and subtracting 30 seconds will subtract 96% from fire severity.

It is proposed that the model use Ultrafast fires for Residential Excluding Dwelling; Fast fires for Commercial and Business, Educational, and Institutional; and Medium fires for Industrial and Storage properties, when calculating time penalties going from confined-to-object to confined-to-room and time credits going from confined-to-room to confined-to-object. The implied multipliers will be applied to loss rates (from Appendix A) for all types of loss.

There is nothing smaller than confined-to-object, and so there is no time credit adjustment for a fire of that size.

When going from a fire confined to *room of origin* to a fire confined to *floor of origin* (or the reverse, from confined-to-floor down to confined-to-room), the change in damage per fire is:

- Up by 2-to-1 for Commercial and Business, Industrial, and Storage
- Up by 3-to-1 for Residential Excluding Dwelling
- Up by 5-to-1 for Educational and Institutional

When going from a fire confined to *floor of origin* to a fire *beyond floor of origin* (or the reverse), the increase in average property damage per fire looks like this:

- Up by a third for Storage
- Up by 2-to-1 for Educational and Institutional
- Up by 3-to-1 for Commercial and Business, Residential Excluding Dwelling, and Industrial

Therefore, the model will apply the same multipliers proposed above for all fire sizes and Property Use groups except Residential Excluding Dwelling, which will be based on a Fast fire except when going between confined-to-origin and confined-to-room, when it will be based on an Ultrafast fire.

Tables 9-10 provide a summary of changes to be applied to loss rates – that is, all the rates shown in Figures 3-4 – with Table 9 addressing fires where a time credit applies and Table 10 addressing fires where no time credit applies. In the rows labeled "no one on premises", A applies if the strategy is to respond normally if verification fails, and B applies if the strategy is not to respond unless fire is positively verified.

Table 9. Default values for changes in loss rates and/or fire size, by final fire size, Property Use group and other conditions – when time credit applies

Property Use group	% confined to object of origin	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Commercial and business …				
…and during high-density period	No change	Minus 64%	Minus 64%	Minus 64%
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	No change	No change	No change	No change
Educational …				
…and during high-density period	No change	Minus 64%	Minus 64%	Minus 64%
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	No change	No change	No change	No change
Industrial …				
…and during high-density period	No change	Minus 36%	Minus 36%	Minus 36%
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	No change	No change	No change	No change
Institutional	No change	Minus 64%	Minus 64%	Minus 64%
Residential Excluding Dwelling	No change	Minus 96%	Minus 64%	Minus 64%

Table 9. Default values for changes in loss rates and/or fire size, by final fire size, Property Use group and other conditions – when time credit applies (continued)

Property Use group	% confined to object of origin*	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Storage …				
…and during high-density period	No change	Minus 36%	Minus 36%	Minus 36%
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin	A.No change B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	No change	No change	No change	No change

Table 10. Default values for changes in loss rates and/or fire size, by final fire size, Property Use group and other conditions – when no time credit applies

Property Use group	% confined to object of origin	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Commercial and business …				
…and during high-density period	No change	No change	No change	No change
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.Add 100% B.Increase size to beyond floor of origin	A.Add 100% B.Increase size to beyond floor of origin	A.Add 100% B.Increase size to beyond floor of origin	A.Add 100% B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	Add 100%	Add 100%	Add 100%	Add 100%

Table 10. Default values for changes in loss rates and/or fire size, by final fire size, Property Use group and other conditions – when no time credit applies (Continued)

Property Use group	% confined to object of origin	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Educational …				
…and during high-density period	No change	No change	No change	No change
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.Add 100% B.Increase size to beyond floor of origin	A.Add 100% B.Increase size to beyond floor of origin	A.Add 100% B.Increase size to beyond floor of origin	A.Add 100% B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	Add 100%	Add 100%	Add 100%	Add 100%
Institutional	No change	No change	No change	No change
Residential Excluding Dwelling	No change	No change	No change	No change
Industrial …				
…and during high-density period	No change	No change	No change	No change
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.Add 44% B.Increase size to beyond floor of origin	A.Add 44% B.Increase size to beyond floor of origin	A.Add 44% B.Increase size to beyond floor of origin	A.Add 44% B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	Add 44%	Add 44%	Add 44%	Add 44%

Table 10. Default values for changes in loss rates and/or fire size, by final fire size, Property Use group and other conditions – when no time credit applies (Continued)

Property Use group	% confined to object of origin	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Storage …				
…and during high-density period	No change	No change	No change	No change
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.Add 44% B.Increase size to beyond floor of origin	A.Add 44% B.Increase size to beyond floor of origin	A.Add 44% B.Increase size to beyond floor of origin	A.Add 44% B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	Add 44%	Add 44%	Add 44%	Add 44%

Table 11 uses the parameter of P_{rcv} to combine Tables 9-10 into a unified set of rules for modifying loss rates.

Table 11. Default values for changes in loss rates and/or fire size, by final fire size, Property Use group and other conditions – time credits included and weighted

Property Use group	% confined to object of origin*	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Commercial and business …				
…and during high-density period	No change	Minus 64% x P_{rcv}	Minus 64% x P_{rcv}	Minus 64% x P_{rcv}
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.Add 100% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 100% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 100% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 100% x (100%-P_{rcv}) B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	Add 100% x (100%-P_{rcv})	Add 100% x (100%-P_{rcv})	Add 100% x (100%-P_{rcv})	Add 100% x (100%-P_{rcv})

Table 11. Default values for changes in loss rates and/or fire size, by final fire size, Property Use group and other conditions – time credits included and weighted (Continued)

Property Use group	% confined to object of origin*	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Educational …				
…and during high-density period	No change	Minus 64% x P_{rcv}	Minus 64% x P_{rcv}	Minus 64% x P_{rcv}
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.Add 100% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 100% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 100% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 100% x (100%-P_{rcv}) B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	Add 100% x (100%-P_{rcv})	Add 100% x (100%-P_{rcv})	Add 100% x (100%-P_{rcv})	Add 100% x (100%-P_{rcv})
Residential Excluding Dwelling	No change	Minus 96% x P_{rcv}	Minus 64% x P_{rcv}	Minus 64% x P_{rcv}
Institutional	No change	Minus 64% x P_{rcv}	Minus 64% x P_{rcv}	Minus 64% x P_{rcv}
Industrial …				
…and during high-density period	No high density period	No high density period	No high density period	No high density period
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.Add 44% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 44% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 44% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 44% x (100%-P_{rcv}) B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	Add 44% x (100%-P_{rcv})	Add 44% x (100%-P_{rcv})	Add 44% x (100%-P_{rcv})	Add 44% x (100%-P_{rcv})

Table 11. Default values for changes in loss rates and/or fire size, by final fire size, Property Use group and other conditions – time credits included and weighted (Continued)

Property Use group	% confined to object of origin*	% confined to room of origin	% confined to floor of origin	% beyond floor of origin
Storage …				
…and during high-density period	No high density period	No high density period	No high density period	No high density period
…and with no one on premises A.Strategy is respond when verification fails. B.Strategy is no response unless fire verified	A.Add 44% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 44% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 44% x (100%-P_{rcv}) B.Increase size to beyond floor of origin	A.Add 44% x (100%-P_{rcv}) B.Increase size to beyond floor of origin
…and with low-density on-site population in large building	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin	Increase size to beyond floor of origin
…and with low-density on-site population in manageable small building	Add 44% x (100%-P_{rcv})	Add 44% x (100%-P_{rcv})	Add 44% x (100%-P_{rcv})	Add 44% x (100%-P_{rcv})
Residential Excluding Dwelling	No change	No change	No change	No change
Institutional	No change	No change	No change	No change

Characterizing a verification and response strategy

A response strategy means a strategy for responding to an “alarm,” the term used here to mean any report of an (alleged) emergency within the scope of the fire department’s responsibilities.

A “strategy for responding to an alarm” means a Standard Operating Procedure (SOP) or other set of rules that describes decisions about the response, based on the information the department has. The strategy provides clear rules on whether and how to respond based on initial information. The strategy also provides rules on how the response should be modified if additional or changed information is received after the original alarm. This additional or changed information could be the result of *verification*, and there is a corresponding strategy for when and how to attempt verification.

Figure 6 is a matrix showing how a response strategy could be defined, for a specified Property Use group.

The matrix assumes that there is a larger response defined for the Property Use and a smaller response defined as well. Elsewhere in the document, these are referred to as normal and reduced responses, respectively, but the terminology can be modified if a department considers the smaller response to be the normal response and the larger response to be sent only when available information justifies it.

In this example, the department's policy is to (a) require alarm companies to attempt verification, within the limits of NFPA 72; (b) send the alarm to the fire department when received but tagged as verification underway; (c) send an immediate larger response to any alarm received for an address where the alarm systems are certificated or otherwise flagged as highly reliable; (d) send a larger response to any alarm verified as a fire, whether it is verified as a working fire or not; (e) send a smaller response at non-emergency-mode speed to any alarm where verification has failed within the time allowed by NFPA 72; and (f) send no response while verification is underway or where there is no information to determine that verification is not necessary.

Figure 6. Example of a generic verification and response strategy for a defined Property Use group

Information available / situation data	Send larger response in emergency mode	Send no response	Send larger response in non-emergency mode	Send reduced response in emergency mode	Send reduced response in non-emergency mode
Call received from alarm system, verification not required for Property Use	X				
Call received from alarm system, systems at address are certificated	*X*				
Call received from alarm system, verification is underway		X			
Call received from alarm system, verification has failed or time for verification has expired					X
Call received from alarm system, verified as not a fire and not an emergency		X			
Call received from alarm system, verified as emergency but not fire (e.g., gasoline spill)		*X*			
Call received from alarm system, verified as fire but unverified whether working fire	X				
Call received from alarm system, verified as working fire	X				

In the first italicized row, the model will not reflect this status information and so the model set-up will ignore this row. The model is not set up to treat properties differently except based on Property Use and in some cases time of day.

In the second italicized row, the strategy may be to send no fire response, but there will be a standard response based on type of incident, which may draw on some of the same resources. From the model's point of view, every non-fire call is like every other non-fire call; there is no attempt to track losses except for losses incurred en route or during return.

In some cases checked as "no response", the department might still send some personnel to investigate and write up the incident (e.g., as input to a non-incident program on ways to reduce the rate of commercial alarms supposedly for fires but triggered by non-fire events).

The previous section showed how to incorporate changes to fire sizes and changes to losses based on time effects (additional or reduced delay in responding), based on effects of a verification and response strategy. There are other changes that may result from a verification and response strategy. One is to respond at the lower speed of non-emergency mode. Another is to respond with reduced forces.

Response in non-emergency mode

Response in non-emergency mode will involve an additional time penalty, as response times will tend to be longer. We do not have any data or expert consensus on how long the typical time penalty will be. It is likely to be proportional to the normal travel time in emergency mode, and it may be quite different in rush hour vs. other times or in densely packed downtowns vs. lower density outer suburbs, small towns, or rural areas.

It is suggested that users address these issues ***only* in a sensitivity analysis**. We know so little about the consequences of response in non-emergency mode that we should be more concerned to learn whether it makes a large difference or a small difference rather than to imagine that we now have a more inclusive basic model that will give us better estimates with all changes incorporated.

Wherever there is a verification time penalty indicated, apply a time penalty (the same 30 second standard used for verification delays) to fires that will be handled in non-emergency mode.

- Use the same loss rate multipliers (add 44% or 100%) recommended for use with other types of time penalties
- If the strategy is to respond with no delay for verification but in non-emergency mode, then the response in non-emergency mode will be the only source of a verification time penalty. Use Table 11 as is to modify loss rates and fire sizes.
- If the strategy is to respond after verification and in non-emergency mode, then there are two sources of verification delay, which compound. Two additions of 44% would be an addition of 107% (1.44 x 1.44 = 2.07), not 88% (44% + 44% = 88%). Two additions of 100% would be an addition of 300% (2.0 x 2.0 = 4.0), not 200% (100% + 100% = 200%).
- The rules in Table 11 are changed:
    - Add 100% x (100%-P_{rcv}) ⇒ Add [300% x (100%-P_{rcv}) + 100% x P_{rcv}]
    - Add 44% x (100%-P_{rcv}) ⇒ Add [107% x (100%-P_{rcv}) + 44% x P_{rcv}]

Response with reduced firefighting resources

Any response has the potential to deliver more or fewer firefighting resources than the emergency proves to require. For example, if you sent enough apparatus and firefighters to handle a working fire but found no fire or a fire already out on arrival, then you sent more than you needed and most if not all of the cost of your response was wasted. If you sent a delayed response expecting to investigate and document a fire out on arrival and found a working fire, then you sent less than you needed and your strategy probably resulted in additional fire growth and increased fire loss.

The same trade-off arises with regard to small working fires versus fully involved buildings. You don't send enough resources to every alarm to handle the worst possible fire you might find, and that means that sometimes you will need multiple alarms. A multiple-alarm fire is likely to have more loss than it would have had if all those resources had been dispatched at the outset, but that loss needs to be balanced against the increase in cost of response to the far more numerous smaller fires that don't need anything more than a standard first response.

The more information you have, the better you can match your response to the needs of the incident except (a) the needs may grow while you are gathering that additional information and (b) the information you gather may be wrong, resulting in a worse match – or no better a match – than you would have had without the information.

To evaluate changes in size of response, you need to identify what size fires can be effectively handled by a given size of response versus what size fires will require more resources, delivered after a delay, resulting in more fire growth and more loss than would have occurred if all the needed resources had been sent initially.

It is suggested that users address these issues ***only*** **in a sensitivity analysis**. As with responses in non-emergency mode, we do not have enough relevant research or data to build these aspects into the model with confidence.

A simple approach might look like this:

- Assumption 1: All responses can be described as "normal" and "reduced".
- Assumption 2: A normal response can handle all fire sizes except beyond floor of origin; a reduced response can handle all fire sizes except beyond room of origin, namely, all except confined to floor of origin and beyond floor of origin.
- Assumption 3: The consequences of a greater need for second alarms can be estimated using a standard time penalty of 30 seconds.
- <u>Therefore, the sensitivity analysis should modify the model so that:</u>
    - <u>all fires confined to floor of origin and switched from normal to reduced response will incur a time penalty, and</u>
    - <u>all fires confined to floor of origin and switched from reduced to normal response will incur a time credit</u>.

Note that the model is set up to assume that the normal response is the one with more resources. If the department response policy is to use reduced response in all cases except when verification justifies additional resources, then the model is not set up to analyze that strategy. In that case, the existing strategy is already what would be an alternative strategy for most departments.

Putting It All Together

Now that the elements of the model are spelled out (except for the estimation of costs per call, which will be handled later), it is possible to walk through the way the model can be used as a tool. The tool will include the model in the form of an Excel spreadsheet template. When the steps below instruct you to insert data, they mean that you should enter data in the template.

1. Decide which of the six Property Use groups will be included in the analysis. Analyze each group separately. Even if you combine Property Use groups when estimating model parameters – developing a single parameter value for use with multiple Property Use groups – you will still conduct the analysis separately on each Property Use you choose to analyze.

2. Collect the data required by the Unwanted Alarm Strategy Assessment Tool Form.

3. Using data collected in Block 1 of the Form or the default value near the top of p.8, between Tables 1 and 2, insert your estimate, for each Property Use, of the percent of commercial alarm system calls that are fires.
    - You now have two groups of calls for each Property Use – fires and non-fire calls.

4. Using data collected in Block 2 of the Form with the default multipliers shown in Table 3 OR using only the default values shown in Table 3, insert your estimates, for each Property Use, of the percent of fires (reported by commercial alarm systems) that need extinguishment.
    - You now have three groups of commercial alarm calls for each Property Use – fires needing extinguishment, fires not needing extinguishment, and non-fire calls. (See Figure 1.)

5. Using the default values shown in Table 5, insert your estimates, for each Property Use, of the percent distribution among 4 fire sizes of fires that need extinguishment.
    - You now have six groups of commercial alarm calls for each Property Use – fires needing extinguishment with each of four fire sizes, fires not needing extinguishment, and non-fire calls. (See Figures 1 and 2.)

6. Using data collected in Block 3 of the Form, estimate what percentage of fires could **not** be sent a first alarm response because those resources were still involved in responding to other calls. Divide that percentage by two and call it P_{rcv}.

7. Using the default values shown in Table 7, insert your estimates (for each Property Use and each of the four fire-size-defined groups of fires not needing extinguishment) of the percent distribution among 4 possible conditions – (a) fires at times when there is a high density of people on site, (b) fires when no one is on site, (c) fires when there is not a high density of people on site, but there are people there, but the property is too large for accurate verification to be expected, and (d) fires when there is not a high density of people on site, but there are people there and the property is small enough to expect verification to be accurate.
    - You now have 18 groups of calls for each Property Use, as each of the four groups based on fires needing extinguishment has been split into four sub-groups based on more detailed characteristics, and the other two groups – fires not needing extinguishment and non-fire calls – still remain. (See Figures 1, 2 and 5.)

8. <u>Using the default values shown in Appendix A, modified using Table 11, insert your estimates, for each Property Use and each of the 18 call groups, of estimated average losses per call or per 100 calls, for each of the eight types of losses – civilian deaths and injuries, direct and indirect property damage, firefighter deaths and injuries on scene, and firefighter deaths and injuries during response or return. Run the model and obtain loss numbers for your baseline (current response and verification strategy).</u>
    - Every one of the 18 groups of calls for each Property Use now has nine numbers associated with it – the percentage weighting that represents its share of total commercial alarm system calls for that Property Use and eight loss rates for different types of loss. (See Figures 1 through 5.)

9. <u>Set up and run the model for any sensitivity analyses you wish to conduct.</u>
    - Consider a sensitivity analysis on responses in non-emergency mode (see p. 30).
    - Consider a sensitivity analysis on responses that send increased or decreased resources, based on verification results (see pp. 30-31).
    - Consider a sensitivity analysis on the impact of a community-wide program to reduce alarming signaling fire when there is no fire (see p. 16).

10. <u>Convert non-economic losses to economic form.</u>
    - Following the lead of NFPA's annual *Total Cost of Fire* report, previously cited, dollar figures of $5 million per death and $250,000 per injury can be used.
    - These economic conversion figures can also be varied in sensitivity analyses.

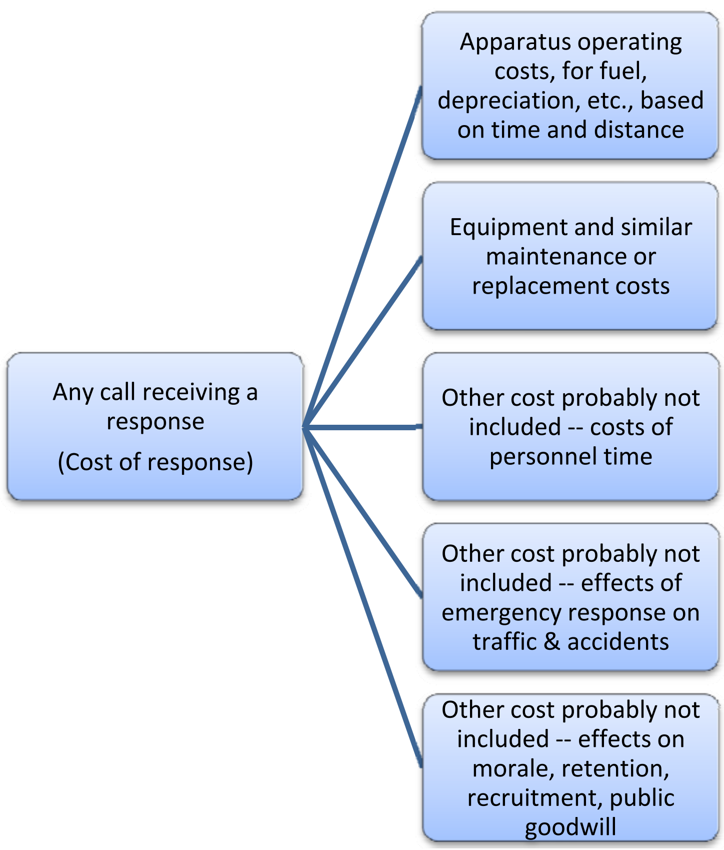
11. <u>Add in cost per call calculations (see next section) and discuss.</u>
    - Add up all cost and loss estimates, and compare the baseline total (for your current practices) to the total for a proposed alternative response and verification strategy.
    - Also compare both totals to the results of any sensitivity analyses.
    - The local team considering and evaluating the alternative strategy will want to discuss the comparisons of the different totals. There are many simplifying assumptions in the model, and the team should try to decide whether they have a sufficient comfort level in what the model is telling them. If the team agree that they would prefer different assumptions, that does not mean that it will be practical to set different specific assumptions and rework the model in that fashion. Instead, the team will want to discuss how – and how much – they think the results would change with different assumptions.
        - <u>Remember that the goal is to reach broad agreement on which strategy is better, overall and for each Property Use group.</u> The discussion may lead to useful changes in which Property Uses are included in the alternative strategy or in the specifics of how the strategy will work (for example, whether or not to respond when verification fails). The goal is NOT to spend time improving the model or the estimates past the point where the team agrees they have enough information to make their decisions and choices.
    - If the cost plus loss total is <u>higher for the baseline</u> than for the alternative strategy AND the difference is large relative to the size of the baseline total (say, at least 20%), then the alternative is probably a better choice. If this statement remains true after you check sensitivity analyses – that is, none of the sensitivity analyses looks worse than the baseline or only slightly better than the baseline – then the superiority of the alternative is reinforced.

- If the cost plus loss total is lower for the baseline than for the alternative strategy AND the difference is large relative to the size of the baseline total (say, at least 20%), then the alternative is probably a bad choice. If this statement remains true after you check sensitivity analyses – that is, none of the sensitivity analyses looks worse than the baseline or only slightly better than the baseline – then the inferiority of the alternative is reinforced.
- If the cost plus loss total is similar for the baseline and the alternative strategy – that is, the difference is small relative to the size of the baseline total (say, less than 20%) – then the local team's discussion will probably expand. If the decision is really close – or if sensitivity analyses indicate that changes in the model lead to different conclusions on which strategy is better – then every assumption and aspect becomes more important. It is important that the local team talk through the evidence, especially when it does not all point clearly in the same direction.

Estimating costs per response

Costs will be associated with any response and can change based on the response strategy. Figure 7 provides an overview of costs that might be considered relevant.

Figure 7. Possible elements in cost per response



There have been very few published cost analyses in the context of the unwanted alarm issue. Most such analyses stop with an estimate of the number and percentage of received calls that will not incur the costs of response under an alternative strategy of verification and response based on verification.

It is worth noting the distinction between fixed costs and marginal cost. Fuel costs and maintenance costs will vary based on the extent of use of equipment. If fewer runs are required, then fewer costs of this type will be incurred. These marginal costs are reduced if runs are reduced. Fixed costs are different. The purchase price of a fire engine will not change based on how much it is used, and there is little evidence to suggest that the time to replacement will become shorter if usage (number of responses) varies within the ranges departments are looking at here.

A similar point can be made about personnel costs. It does not make sense to include personnel-related costs unless those costs would be incurred only if an emergency response is made. Career firefighters will be on duty regardless, and any payments to or benefits for volunteer firefighters also will rarely vary based on volume of calls. Departments that pay firefighters on a per-call basis would be an exception, and those costs are not captured in this model.

Therefore, the most appropriate approach is probably to estimate marginal costs per call based on some combination of costs per mile and costs per hour of operation.

Most fire departments operate in communities where the community's financial department develops and maintains cost per mile figures for various types of equipment, as part of annual budgeting and planning decisions. Costs per hour are more difficult to find, and many of the involved costs – such as fuel and maintenance costs – are also incurred during travel and may be fully allocated in the calculation of costs per mile, leaving no other costs to be allocated.

A paper by Wolf provides a simple basis for combining these two sources of cost.[3] He equates one hour of operation (for an apparatus) to two miles of operation in his simple formula. Ideally, one would like to have a simple formula like this with a more detailed and broadly based cost analysis exercise directly supporting it, but in the absence of such calculations, this seems a reasonable number to use.

This is the proposal for estimating costs per call for use in the model:

1. <u>The user should obtain an approved cost per mile figure for each type of apparatus.</u> Find out what costs are included, and try to make sure that maintenance, servicing and other such marginal costs are included or, if not included, are added in for use in the model.

2. <u>For each type of equipment or resource (e.g., personal protective clothing) requiring cleaning, maintenance, refilling, or other servicing (involving out-of-pocket costs) after every use, develop estimated average cost figures per servicing.</u> If this is too difficult, there is no requirement that anything other than primary apparatus be included in the calculation.

3. <u>Using data collected in Block 4 of the Form, for each Property Use group, for each type of apparatus (with a different cost per mile figure in #1), calculate the total number of miles (M), hours (H), and responses (C). Calculate M/(M+2H) and multiply it by the cost per mile figure in #1 to obtain the revised cost per equivalent mile (where hours are converted to equivalent miles).</u>

[3] Mark A. Wolf, *Fire Apparatus Replacement/Refurbishment Determination*, paper submitted to the Ohio Fire Executive Program, June 2003.

4. Using data collected in Block 5 of the Form, for each Property Use group, for each type of response strategy (e.g., standard vs. reduced) and each type of response (i.e., from non-fire call to fire needing extinguishment and extending beyond floor of origin), complete a template below for each type of apparatus and each type of equipment (or other resource) on row 1, giving number of apparatus or equipment used.

5. Using data collected in Block 4 of the Form, for each Property Use group, for each type of response strategy (e.g., standard vs. reduced), complete a template below for each type of apparatus on rows 2 and 3, giving number of miles and number of hours per response.

6. Using the results of #3, for each Property Use group, for each type of response strategy (e.g., standard vs. reduced), enter cost per equivalent mile for each type of apparatus in row 4 of its template, and enter cost per response for each type of equipment in row 2 of its template.

7. Perform all calculations to complete entries in all templates. Add entries across all apparatus types and all equipment types to obtain total cost per response figures, for each Property Use group, for each type of response strategy (e.g., standard vs. reduced) and for each type of call – non-fire, fire not needing extinguishment, or fire needing extinguishment of one of the four fire sizes.

8. Incorporate the results in the model in #11 of the 11-part "Putting It All Together" sequence for using the model.

Complete one of these matrix tables for each type of apparatus (e.g., engine, ladder, ambulance), not for each piece of apparatus, using local data as assembled on the Form for local data and parameters values calculated as described above.

		Structure fire where extinguishment was performed				
Separate block for each Property Use group and for each type of response (e.g., standard, reduced)	**Non-fire call**	**Fire not needing extinguish-ment**	**Confined fire or fire confined to object of origin**	**Fire confined to room of origin**	**Fire confined to floor of origin**	**Fire extended beyond floor or beyond building of origin**
Apparatus Type i – number used	a.	b.	c.	d.	e.	f.
Apparatus Type i – miles per response average	g. [Same average distance regardless of nature of call]					
Apparatus Type i – hours per response average	h.	i.	j.	k.	l.	m.
Apparatus Type i – cost per equivalent mile (from #3 applied to #1 above)	Q. [Same cost per equivalent mile regardless of nature of call]					
Apparatus Type i – total cost per response	=aQ (g+2h)	=bQ(g+2i)	=cQ(g+2j)	=dQ(g+2k)	=eQ(g+2l)	=f Q(g+2m)

Complete one of these matrix tables for each type of non-apparatus equipment for which there are maintenance, repair, or replacement costs large enough to be worth including and in a form that can be described in a per-call or per-hour-of-use basis (e.g., hoses, SCBA, personal protective clothing), using local data as assembled on the Form for local data and parameters values calculated as described above.

		Structure fire where extinguishment was performed				
Separate block for each Property Use group and for each type of response (e.g., standard, reduced)	**Non-fire call**	**Fire not needing extinguish-ment**	**Confined fire or fire confined to object of origin**	**Fire confined to room of origin**	**Fire confined to floor of origin**	**Fire extended beyond floor or beyond building of origin**
Equipment Type j – total number used on response	a.	b.	c.	d.	e.	f.
Equipment Type j – cost per unit per response	Q. [Same cost per unit regardless of nature of call]					
Apparatus Type j – total cost per response	=aQ (g+2h)	=bQ(g+2i)	=cQ(g+2j)	=dQ(g+2k)	=eQ(g+2l)	=f Q(g+2m)

Strategies Other Than Verification and Response Strategies

These are what we have called non-incident strategies. They were included in the scope of the project because it was believed that these strategies – generally aimed at upgrading the performance of commercial alarm systems in the community – could be effective enough to change the balance of costs and benefits when considering an alternative verification and response strategy.

It has become clear that these strategies, while valuable and desirable, are unlikely to have that kind of impact. As noted earlier, when more than 99% of calls are not fires, even universal adoption of an extraordinarily effective program to reduce alarming to non-fire events is likely to leave non-fires outnumbering fires by a wide margin.

To be clear: Strategies to reduce alarming to non-fire events are highly desirable and can produce great benefits, but these benefits are not likely to be great enough to make verification obviously unnecessary.

Given those results, it seems appropriate to disconnect these strategies from the main project goals of developing a tool for considering alternative verification and response strategies and judging those alternatives by their impact on combined costs and losses. Only the option of a sensitivity analysis is retained for these strategies.

Furthermore, the literature review provided useful insights and synthesis of past analysis on these strategies, and that will continue to have value, even if that material is no longer directly incorporated into the model and the tool.

Appendix A. Using NFIRS and FIDO Data to Develop Loss per Fire Estimates

Shown in this appendix are estimates to use in the model as called for in Figures 3 and 4.

Firefighter deaths are so few in number that they have been analyzed using 1980-2010 data. Prior to 1999, structure status information – such as vacant, idle, under construction or under demolition – was incorporated into the Property Use codes, in the 910-919 range. To permit the two year ranges to be used together, firefighter deaths and fires with Property Use coded in the 910-919 range were proportionally allocated over Property Use codes in the 100-899 range.

In keeping with the results of a special study referenced and described in NFPA's *Total Cost of Fire* reports, indirect fire damages are estimated as a percentage of direct damages. The percentage multipliers used are as follows:

- Commercial and business occupancies – 25%
- Educational properties – 25%
- Institutional properties – 25%
- Residential properties excluding one- or two-family homes – 10%
- Industrial occupancies – 65%
- Storage occupancies – 10%

Non-fire calls also exclude EMS calls and mutual aid calls. Firefighter deaths and injuries on site or during response or return (relative to non-fire emergency responses) cannot be subdivided by Property Use group, and so the same four firefighter casualty rates are used for all Property Use groups for non-fire calls.

Firefighter deaths at the fireground and firefighter deaths and injuries during response or return cannot be subdivided by size of fire, and so the same rate of firefighter deaths per 100 calls is used for any fire size at a particular Property Use group.

Firefighter injuries during response or return also cannot be subdivided by Property Use group, and so the same rates of firefighter injuries per 100 calls is used throughout the analysis.

Commercial and business occupancies (Property Use 100-199 and 500-599)

Fire characteristics	Civilian deaths per 100 calls	Civilian injuries per 100 calls	Direct damages (thousands) per call	Indirect damages (thousands) per call
Fire needing extinguishment and confined to object of origin	0.03	0.71	$7.35	$1.84
Fire needing extinguishment and confined to room of origin	0.08	2.67	$31.21	$7.80
Fire needing extinguishment and confined to floor of origin	0.13	2.90	$65.40	$16.35
Fire needing extinguishment and beyond floor of origin	0.28	3.04	$200.27	$50.07
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.00	0.00	$0.00	$0.00

Fire characteristics	Firefighter deaths per 100 calls on site	Firefighter injuries per 100 calls on site	Firefighter deaths per 100 calls response/ return	Firefighter injuries per 100 calls response/ return
Fire needing extinguishment and confined to object of origin	0.015	3.36	0.002	0.018
Fire needing extinguishment and confined to room of origin	0.015	18.32	0.002	0.018
Fire needing extinguishment and confined to floor of origin	0.015	47.97	0.002	0.018
Fire needing extinguishment and beyond floor of origin	0.015	63.46	0.002	0.018
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.000	0.060	0.000	0.018

Educational occupancies (Property Use 200-299)

Fire characteristics	Civilian deaths per 100 calls	Civilian injuries per 100 calls	Direct damages (thousands) per call	Indirect damages (thousands) per call
Fire needing extinguishment and confined to object of origin	0.00	0.86	$5.44	$1.36
Fire needing extinguishment and confined to room of origin	0.00	2.47	$26.99	$6.75
Fire needing extinguishment and confined to floor of origin	0.00	2.10	$140.03	$35.01
Fire needing extinguishment and beyond floor of origin	0.00	2.53	$246.75	$61.69
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.00	0.00	$0.00	$0.00

Fire characteristics	Firefighter deaths per 100 calls on site	Firefighter injuries per 100 calls on site	Firefighter deaths per 100 calls response/ return	Firefighter injuries per 100 calls response/ return
Fire needing extinguishment and confined to object of origin	0.003	0.90	0.001	0.018
Fire needing extinguishment and confined to room of origin	0.003	17.00	0.001	0.018
Fire needing extinguishment and confined to floor of origin	0.003	40.26	0.001	0.018
Fire needing extinguishment and beyond floor of origin	0.003	74.38	0.001	0.018
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.000	0.060	0.000	0.018

Institutional (health care and correctional) occupancies (Property Use 300-399)

Fire characteristics	Civilian deaths per 100 calls	Civilian injuries per 100 calls	Direct damages (thousands) per call	Indirect damages (thousands) per call
Fire needing extinguishment and confined to object of origin	0.02	2.45	$3.52	$0.88
Fire needing extinguishment and confined to room of origin	0.59	10.20	$18.81	$4.70
Fire needing extinguishment and confined to floor of origin	1.59	4.18	$87.21	$21.80
Fire needing extinguishment and beyond floor of origin	1.00	8.41	$206.46	$51.62
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.00	0.00	$0.00	$0.00

Fire characteristics	Firefighter deaths per 100 calls on site	Firefighter injuries per 100 calls on site	Firefighter deaths per 100 calls response/ return	Firefighter injuries per 100 calls response/ return
Fire needing extinguishment and confined to object of origin	0.001	1.65	0.000	0.018
Fire needing extinguishment and confined to room of origin	0.001	12.16	0.000	0.018
Fire needing extinguishment and confined to floor of origin	0.001	49.19	0.000	0.018
Fire needing extinguishment and beyond floor of origin	0.001	43.95	0.000	0.018
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.000	0.060	0.000	0.018

Residential occupancies excluding one- or two-family dwellings (Property Use 420-489)

Fire characteristics	Civilian deaths per 100 calls	Civilian injuries per 100 calls	Direct damages (thousands) per call	Indirect damages (thousands) per call
Fire needing extinguishment and confined to object of origin	0.06	1.17	$1.54	$0.15
Fire needing extinguishment and confined to room of origin	1.05	9.96	$14.24	$1.42
Fire needing extinguishment and confined to floor of origin	1.97	14.60	$49.14	$4.91
Fire needing extinguishment and beyond floor of origin	3.28	15.21	$138.05	$13.81
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.00	0.00	$0.00	$0.00

Fire characteristics	Firefighter deaths per 100 calls on site	Firefighter injuries per 100 calls on site	Firefighter deaths per 100 calls response/ return	Firefighter injuries per 100 calls response/ return
Fire needing extinguishment and confined to object of origin	0.004	1.48	0.001	0.018
Fire needing extinguishment and confined to room of origin	0.004	23.16	0.001	0.018
Fire needing extinguishment and confined to floor of origin	0.004	75.44	0.001	0.018
Fire needing extinguishment and beyond floor of origin	0.004	105.73	0.001	0.018
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.000	0.060	0.000	0.018

Industrial occupancies (Property Use 600-799)

Fire characteristics	Civilian deaths per 100 calls	Civilian injuries per 100 calls	Direct damages (thousands) per call	Indirect damages (thousands) per call
Fire needing extinguishment and confined to object of origin	0.01	1.79	$23.12	$15.03
Fire needing extinguishment and confined to room of origin	0.11	4.37	$52.00	$33.80
Fire needing extinguishment and confined to floor of origin	0.61	5.62	$102.19	$66.42
Fire needing extinguishment and beyond floor of origin	0.35	3.31	$281.03	$182.67
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.00	0.00	$0.00	$0.00

Fire characteristics	Firefighter deaths per 100 calls on site	Firefighter injuries per 100 calls on site	Firefighter deaths per 100 calls response/ return	Firefighter injuries per 100 calls response/ return
Fire needing extinguishment and confined to object of origin	0.013	12.13	0.002	0.018
Fire needing extinguishment and confined to room of origin	0.013	21.19	0.002	0.018
Fire needing extinguishment and confined to floor of origin	0.013	84.28	0.002	0.018
Fire needing extinguishment and beyond floor of origin	0.013	39.43	0.002	0.018
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.000	0.060	0.000	0.018

Storage occupancies (warehouse only for civilian deaths, civilian injuries, direct and indirect damages, and firefighter injuries on site) (Property Use 800-899)

Fire characteristics	Civilian deaths per 100 calls	Civilian injuries per 100 calls	Direct damages (thousands) per call	Indirect damages (thousands) per call
Fire needing extinguishment and confined to object of origin	0.00	1.12	$14.66	$1.47
Fire needing extinguishment and confined to room of origin	0.00	1.60	$33.76	$3.38
Fire needing extinguishment and confined to floor of origin	0.78	8.41	$93.45	$9.35
Fire needing extinguishment and beyond floor of origin	0.77	1.79	$248.22	$24.82
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.00	0.00	$0.00	$0.00

Property Use Group	Firefighter deaths per 100 calls on site	Firefighter injuries per 100 calls on site	Firefighter deaths per 100 calls response/ return	Firefighter injuries per 100 calls response/ return
Fire needing extinguishment and confined to object of origin	0.008	8.66	0.003	0.018
Fire needing extinguishment and confined to room of origin	0.008	15.67	0.003	0.018
Fire needing extinguishment and confined to floor of origin	0.008	30.12	0.003	0.018
Fire needing extinguishment and beyond floor of origin	0.008	77.66	0.003	0.018
Fire not needing extinguishment	Not needed because no strategy will alter these values in the model			
Non-fire call	0.000	0.060	0.000	0.018

Appendix B. Modifying Model Parameters to Reflect System Certification or Other "Good Flags" on Addresses

The model incorporates community-wide certification of systems by reducing the number of non-fire calls flowing into the alarm system and fire department at the beginning. Non-fire calls are one type of unwanted alarm. Certification is not intended to reduce reporting of fires not needing extinguishment.

The reduction factors may be property use group specific (q_i) or may be the same factor used across the board (e.g., q_i =75%, for all i). The new factors must be re-normalized to reflect the fact that calls have been taken out of the database.

- p_{1i} = probability call is a fire and therefore corresponds to the share of baseline commercial alarm calls, for Property Use group i, that are fires
- $1-p_{1i}$ = probability call is not a fire and therefore corresponds to the share of baseline commercial alarm calls, for Property Use group i, that are not fires
- Let N = total number of baseline (commercial alarm) calls
- Then Np_{1i} = total number of baseline fire calls from commercial alarms
- And $N(1-p_{1i})$ = total number of baseline commercial alarm calls that are not fires

Now apply the certification-reduction factors:

- It is still true that Np_{1i} = total number of fire calls from commercial alarms
- It is now true $N(1-p_{1i})(1-q_i)$ = total number of commercial alarm calls that are not fires
- It is therefore true that $N[p_{1i} + (1-p_{1i})(1-q_i)]$ = new total number of commercial alarm calls

Therefore:

- $p'_{1i} = p_{1i} / [p_{1i} + (1-p_{1i})(1-q_i)]$ = new probability that call is a fire and new share of commercial alarm calls, for Property Use group i, that are fires.
- $1-p'_{1i} = [(1-p_{1i})(1-q_i)] / [p_{1i} + (1-p_{1i})(1-q_i)]$ = new probability that call is not a fire and new share of commercial alarm calls, for Property Use group i, that are not fires.

The new p'_{1i} values are now used in the model where the p_{1i} values were used before.

ATTACHMENT A

MEMORANDUM

TO: Unwanted Alarm Modeling Tool Project

FROM: John Hall

DATE: January 11, 2013

SUBJECT: Proposed Modification to a Few Loss per 100 Fire Parameters

While transferring the final report data into the Excel template form of the model, I noticed that some of the loss-per-100 fire parameters need some tweaking.

The premise of the model is that losses go up when fires get bigger. This means loss per 100 fires, for any type of loss, should rise as fire size increases, through the four groups we use for fire size – confined to object of origin, confined to room of origin, confined to floor of origin, and beyond floor of origin. NFIRS data is used to provide default values for these loss-per-fire parameters.

The problem arises with the estimates for confined to floor of origin, because this size typically has a small number and share of fires, making it more susceptible to distortion by a single large-loss fire.

What I propose to do when this occurs is to reset the parameters, usually by setting the confined to floor and beyond floor parameters equal, both based on pooled data for all fires with flame damage beyond room of origin.

This memorandum should be attached to the final report as a modification of what is in it.

Here are the specific changes I propose:

Which parameters are changed?	Old version	New version
Educational properties – civilian injuries per 100 fires	Conf object – 0.86 Conf room – 2.47 Conf floor – 2.10 Beyond floor – 2.53	Change conf floor to 2.50, interpolating between the two very similar parameter values for conf room and beyond floor
Institutional properties – civilian deaths per 100 fires	Conf object – 0.02 Conf room – 0.59 Conf floor – 1.59 Beyond floor – 1.00	Set both conf floor and beyond floor equal to 1.17, which is the number you get if you combine all data for fire sizes beyond room of origin
Institutional properties – firefighter fireground	Conf object – 1.65 Conf room – 12.16	Set both conf floor and beyond floor equal to 45.49, which is the number you get if you combine all data

injuries per 100 fires	Conf floor – 49.19 Beyond floor – 43.95	for fire sizes beyond room of origin
Which parameters are changed?	**Old version**	**New version**
Institutional properties – civilian injuries per 100 fires	Conf object – 2.45 Conf room – 10.20 Conf floor – 4.18 Beyond floor – 8.41	Set conf room, conf floor and beyond floor all equal to 9.07, which is the number you get if you combine all data for fire sizes beyond object of origin
Industrial properties – civilian deaths per 100 fires	Conf object – 0.01 Conf room – 0.11 Conf floor – 0.61 Beyond floor – 0.35	Set both conf floor and beyond floor equal to 0.38, which is the number you get if you combine all data for fire sizes beyond room of origin
Industrial properties – civilian injuries per 100 fires	Conf object – 1.79 Conf room – 4.37 Conf floor – 5.62 Beyond floor – 4.69	Change conf floor to 4.53, interpolating between the two similar parameter values for conf room and beyond floor
Industrial properties – firefighter fireground injuries per 100 fires	Conf object – 12.13 Conf room – 21.19 Conf floor – 84.28 Beyond floor – 39.43	Set both conf floor and beyond floor equal to 44.59, which is the number you get if you combine all data for fire sizes beyond room of origin
Storage (warehouse) properties – civilian deaths per 100 fires	Conf object – 0.00 Conf room – 0.00 Conf floor – 0.78 Beyond floor – 0.77	Set both conf floor and beyond floor equal to 0.77, which is the number you get if you combine all data for fire sizes beyond room of origin
Storage (warehouse) properties – civilian injuries per 100 fires	Conf object – 1.12 Conf room – 1.60 Conf floor – 8.41 Beyond floor – 1.49	Set both conf floor and beyond floor equal to 2.45, which is the number you get if you combine all data for fire sizes beyond room of origin

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Institutional properties – firefighter fireground	Conf object – 1.65 Conf room – 12.16	Set both conf floor and beyond floor equal to 45.49, which is the number you get if you combine all data

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Industrial properties – civilian injuries per 100 fires	Conf object – 1.79 Conf room – 4.37 Conf floor – 5.62 Beyond floor – 4.69	Change conf floor to 4.53, interpolating between the two similar parameter values for conf room and beyond floor
Industrial properties – firefighter fireground injuries per 100 fires	Conf object – 12.13 Conf room – 21.19 Conf floor – 84.28 Beyond floor – 39.43	Set both conf floor and beyond floor equal to 44.59, which is the number you get if you combine all data for fire sizes beyond room of origin
Storage (warehouse) properties – civilian deaths per 100 fires	Conf object – 0.00 Conf room – 0.00 Conf floor – 0.78 Beyond floor – 0.77	Set both conf floor and beyond floor equal to 0.77, which is the number you get if you combine all data for fire sizes beyond room of origin
Storage (warehouse) properties – civilian injuries per 100 fires	Conf object – 1.12 Conf room – 1.60 Conf floor – 8.41 Beyond floor – 1.49	Set both conf floor and beyond floor equal to 2.45, which is the number you get if you combine all data for fire sizes beyond room of origin