FIRE DEATH SCENARIOS AND FIRESAFETY PLANNING

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Each of the millions of fire incidents that occur yearly is the outcome of a fateful chain of events. Some of these events are the result of the circumstances surrounding the fire; others are usually the consequences of human action. However, if the sequence of events could be broken, i.e., if one of the links in the chain could be removed, the end result would not occur. It follows that the more we know about the events and their causal connection, the greater is the possibility of interfering with the chain and avoiding fire loss.

A useful method for analyzing such real world events is to construct typical "scenarios" to describe a series of events leading up to fire loss. The scenario concept is a common tool in long-range planning;[1] we are interested in scenarios as an aid to formulating action plans for firesafety focused on both the present and the near future.

The purpose of this article is to introduce the scenario concept to firesafety program planning and to show how the available data, although imperfect, can be used to develop a quantitative ranking of scenarios for the most distressing aspect of fire losses: fire death.

Leaving aside the human behavioral aspects, it is possible to describe any fire incident in terms of the type of loss and the circumstances that surround it. This can be done using six characteristics:

Circumstances
1) Type of Loss — Death, injury, and /or property;
2) Type of Occupancy — Residential, industrial, etc.;
3) Time — Day, night;
4) Ignition Source — Smoking, electrical appliances, etc.;
5) Item Ignited or Agents of Spread — Apparel, furnishings, etc.;
6) Direct Cause of Loss — Smoke and gas, heat and flame.

For example, a death caused by a smoldering mattress might be described as: (1) death; (2) residence; (3) night; (4) smoking; (5) furnishings; (6) smoke and gas.

This approach can yield over a thousand possible, different scenarios for each of the three kinds of fire loss, depending on the number of elements in each of the categories. A system of 5,040 different scenarios was recently employed by the National Bureau of Standards' Center for Fire Research in developing a research plan.[2]

The most important function of the scenario is to focus attention on the ways in which the causal chain can be broken. But not all scenarios are equally likely to occur, so the second step is to identify the ones that

[1] See, for example, R. Zentner, "Scenarios in Forecasting," *Chemical and Engineering News*, Vol. 53, No. 40 (October 6, 1975), p. 22, and references cited therein.

[2] "Reducing the Nation's Fire Losses, the Research Plan," Center for Fire Research, National Bureau of Standards, January, 1976.

represent likely situations and the ones that do not. The smoking-in-bed scenario, for example, is a significant occurrence, but there are many conceivable scenarios that may be largely artificial. Therefore, a selection process must take place, leading to a ranking of the most important scenarios. Ideally, they would be listed in order of the contribution to actual fire losses that each represents.

The best way to achieve this would be by an analysis of fire loss statistics. However, in order to rank 5,000 scenarios, one needs in-depth data on hundreds of thousands of selected fire incidents. While the National Fire Data System of the National Fire Prevention and Control Administration will eventually be able to provide the necessary statistics, the present data are too limited to allow the job to be done properly.

In the interim, two options are available. A nonquantitative approach can be used to rank the scenarios by "expert judgment," or the scenarios can be simplified by removing categories and combining elements until a point is reached where actual data can be used. Both options are imperfect. The nonquantitative approach is only as good as the experts' judgment,[3] and the data-based approach limits the amount of information that the scenario can presently supply. In the long run, however, the quantitative approach is the method of choice simply because increasingly good statistics will eventually eliminate the need for oversimplification.

In anticipation of that time, and to demonstrate the surprising amount of information that can be gained now from a quantitative approach, we have surveyed the available data to identify and rank what appear to be the most frequent scenarios for fire death in the United States. The top fourteen of these are reported in this article. Together, they are believed to account for almost two-thirds of the nation's fire deaths.

Fire Death Scenarios

Figure 1 is a schematic illustration of a simplified scenario classification system. Note that "time of day" and "direct cause of loss" are omitted; this information is not yet included in most fire death reports. In addition, the term "agents of spread" has been dropped in favor of the simpler term "item ignited." Although existing data sources contain some information on

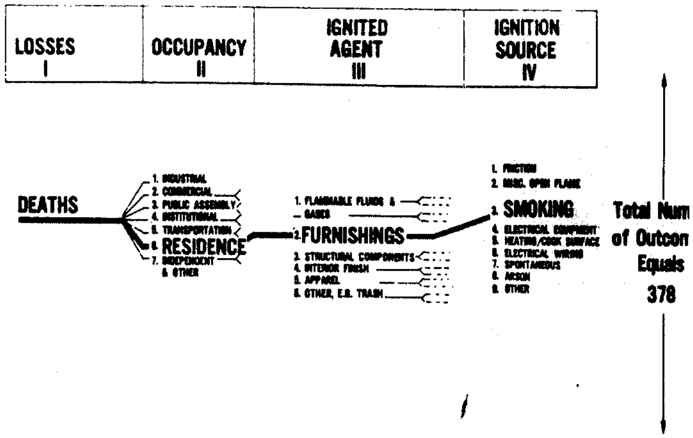

Figure 1. Elements of fire scenario and specific loss paths.

spread agents, the data-processing techniques for reducing the appropriate terms to a proper format are still incomplete. Thus, for the present, we have restricted the discussion to "item ignited." Associated with each death is one of seven occupancies, one of six ignited items, and one of nine ignition sources. A given path through the Figure, such as the one shown in boldface type, constitutes a single scenario. For the system shown, there are 518 different possible scenarios. Occupancy category No. 7, listed as "independent," reflects the fact that in a number of fire death cases, such as many of those involving apparel or those occuring outdoors, specifying the occupancy is not important in understanding how the incident occurred. In such cases, therefore, the circumstances surrounding the death are, in effect, "independent" of occupancy.

In principle, ranking the scenarios in order of importance involves: 1) ranking occupancies in order of frequency of fire death; 2) for each occupancy in turn, ranking the item ignited by frequency of fire death; and 3) for each ignited agent, similarly ranking the ignition sources. Data needed to accomplish these rankings are not generally available. For example, the statistics that the NFPA publishes yearly[4] on fire losses cannot be used because reported fire deaths cannot be connected to specific circumstances. In other words, they do not allow us to say, for example, how many deaths are caused by toxic gases from smoldering furniture ignited by a cigarette. In fact, there is presently *no* single source for these data. However, we were able

[3] Both NBS and the NFPA presently rely partially on the nonquantitative Delphi technique in their planning activities. See W. Middendorf, "A Modified Delphi Method of Solving Business Problems," *IEEE Transactions on Engineering Management,* Vol. EM–20, No. 4 (November 1973), p. 130.

[4] See "Fires and Fire Losses Classified, 1974," FIRE JOURNAL, Vol. 69, No. 5 (September, 1975), p. 43.

to combine features of four different systems to yield the necessary statistics. The four systems are:

1) **The FIDO (Fire Incident Data Organization) file** maintained by NFPA. This is a computerized file of fire experience; data collection began in 1971. Approximately 30,000 fire-related incidents are in the data base. Each is characterized by some 60 coded attributes.[5] The incidents are primarily fires causing death, injury, or major property loss ($50,000 or greater). However, the coded fires include approximately 11,000 fatalities, or about 20 percent of all fire deaths in the United States in the period from 1971 to 1975. A little more than one-third of these deaths are filed in sufficient detail to permit identification of the ignition source and ignited agent. This compilation is the largest known US source of in-depth fire death data, and is the mainstay of this study. Since the FIDO file is maintained from reports submitted by fire departments, relatively few fire fatalities caused solely by apparel fires are included. This reflects the fact that the apparel fire is usually small, and often is not reported to the fire service.

2) **National Fire Data System (NFDS)**, of the National Fire Data Center, National Fire Prevention and Control Administration. The NFDS currently contains about 60,000 incidents reported by the fire services from various cities in California, Colorado, and Florida, including approximately 140 fatalities.

The NFDS was queried (from the NFPA's remote terminal in Boston) as to where the fire deaths occur, as a check on FIDO's occupancy figures. The results are shown in Table 1A. Agreement between FIDO and NFDS was remarkably good. Inspection of the Table shows only two areas where significant differences appear. The first difference is that FIDO includes more mobile home deaths than NFDS does. These figures are probably a reflection of the NFPA's three-year effort to obtain data on mobile home fires. The second difference is in the percentage of fire deaths in motor vehicles. While it is possible that this number is understated by FIDO, the small number of deaths presently in the NFDS (the difference between 4 percent and 10 percent of all NFDS fire deaths is only eight deaths) makes drawing any conclusions premature. In general, the two sets of figures agree well.[6]

[5] See J. Ottoson, "Attribute Analysis," *Fire Technology*, Vol. 11, No. 1 (February, 1975), p. 29.

[6] The comparison is heartening in itself, but the routine process by which it was made is a landmark. To have the resources of the NFDS available to the fire community on a routine basis is a major advance in the communication and exchange of fire data.

Table 1.
Where US Fire Deaths Occur

1A. Reported by Fire Departments

Occupancy	*NFPA (FIDO)*		*NFPCA (NFDS)*	
	Percentage of Fire Deaths			
Residential	84		76	
One- and Two-Family		52		55
Apartment		20		16
Mobile Home		7		1
Other		5		4
Institutional	2		2	
Public Assembly	2		1	
Commercial	1		1	
Industrial	4		4	
Motor Vehicles	4		10	
Others	3		6	
	100		100	

1B. FIDO Data, Adjusted for Unreported Categories

Occupancy	*Percentage of Fire Deaths*	
Residential	72	
Independent of Structure	14	
Apparel		11
Apparel Plus Flammable Fluids		3
Motor Vehicles	4	
Industrial	3	
Institutional	2	
Public Assembly	2	
Commercial	1	
Others	2	
	100	

3) **"Accidents Caused by Fires and Flames"** in *Vital Statistics of the United States*, Volume II (Mortality), compiled annually by the National Center for Health Statistics (CHS), Bureau of Vital Statistics, US Department of Health, Education and Welfare. The data are taken from vital statistics information compiled at the state level. Fire deaths are broken down roughly by occupancy, but no additional information such as ignition source and agent is provided. Apparel fire deaths are included, but motor vehicle fire deaths are excluded.

4) **Flammable Fabrics Accident Case and Testing System (FFACTS)**, developed at the National Bureau of Standards, and now maintained by the Consumer Product Safety Commission. This file contains detailed information on ignition sources for about 3,300 apparel-related fire incidents, including 300 fire deaths.

Despite the fact that no single data base contains all the necessary information, the four listed here can

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be used[7] to yield a representative picture of US fire deaths. The most complete file of fire experience is FIDO, but it does not fairly depict the entire fire death picture, since apparel-related fires are under-represented. The CHS statistics, on the other hand, give a representation of apparel-related deaths, but do not reflect motor vehicle-related fires. Each of these two sources is missing one category, but since they are not missing the same one, it is a simple mathematical exercise to correct both sets of statistics for the missing categories.[8] The FIDO data, corrected for apparel-related fire deaths, are shown in Table 1B. This list of fire deaths by occupancy was then broken down into percentages by scenario, using FIDO, or, in the case of apparel fires, using FFACTS.

The Top Fourteen Fire Death Scenarios

The most common fire death scenario, by far, is the residential furnishings fire caused by smoking materials, which alone accounts for 27 percent of fire deaths. This figure was derived as follows. First, we estimate that 72 percent of the nation's fire deaths occur in residences, as shown in Table 1B. Of all residential fire deaths in the FIDO file, 54 percent involved the ignition of furnishings. Roughly half of this total was contributed by soft goods (principally mattresses and bedclothes), and half by upholstered furniture. Of all residential fatalities involving furnishings in the FIDO file, 70 percent were reportedly ignited by smoking materials. Thus the fraction of total fire deaths associated with the residential-furnishings-smoking scenario is (72% x 54% x 70% =) 27%. The percentages associated with the other scenarios were similarly derived. We report here only those scenarios that accounted for 2 percent or more of fire deaths; they total fourteen.

Table 2.
The Top Fire Death Scenarios

Rank	*Occupancy*	*Item Ignited*	*Ignition Source*	*Percent of US Fire Deaths*
1	Residential	Furnishings	Smoking	27
2	Residential	Furnishings	Open Flame	5
3	a. Transportation	Flammable Fluids	Several	4
	b. Independent (Residential)	Apparel	Heating and Cooking Equipment	4
	c. Residential	Furnishings	Heating and Cooking Equipment	4
6	a. Independent	Apparel/ Flammable Liquids	Several	3
	b. Residential	Flammable Liquids	Heating and Cooking Equipment	3
	c. Residential	Flammable Liquids	Open Flame	3
	d. Independent	Apparel	Open Flame	3
10	a. Residential	Interior Finish	Heating and Cooking Equipment	2
	b. Residential	Interior Finish	Electrical Equipment	2
	c. Independent	Apparel	Smoking	2
	d. Residential	Structural	Electrical Equipment	2
	e. Residential	Trash	Smoking	2
				66
	Others, all less than 2 percent of total			34
				100

The top fourteen fire scenarios are shown in Table 2. Together, they account for about 66 percent, or nearly two-thirds, of fire deaths in the United States, based on available data.

Residential furnishings fires alone account for 36 percent of the total deaths (scenarios 1, 2, and 3c).

Three scenarios tie for third place, each accounting for about 4 percent of fire deaths. The transportation scenario, 3a, primarily represents the ignition of gasoline, which is generally the result of motor vehicle accidents. Precise ignition sources in this scenario were difficult to pinpoint. They were variously reported as friction, hot surface, and the like. We have therefore grouped them together as "several."

Scenario 3b, the apparel fire death ignited by heating and cooking equipment, is listed as independent of occupancy, but in fact it could also be called a residential fire death, since the ignition almost always occurs in the home.

Three of the four fires in sixth place involve flammable fluids. Scenario 6a, the apparel fire in which flammable liquids play a role, was caused, like the vehicle fire death, by a variety of ignition sources. An

[7] For the details of this procedure, see F. Clarke and J. Ottoson, "Developing Fire Scenarios From Available Data," *Fire Technology*, in press.

[8] Aircraft-related fire deaths are not part of either set, and therefore they could not be included in the overall exercise.

important segment of this scenario is the well-known "barbecue grill" fatality, involving the improper use of a gasoline or charcoal starter. Scenarios 6b and 6c, which together account for 6 percent of all fire deaths, are ignitions of a flammable fluid in the home, such as an explosion caused by a gas leak. Scenario 6d includes the case of a child playing with matches.

Scenarios 10a and 10b both involve ignitions of interior finishes, principally wall and floor coverings, by appliances or electrical wiring. Scenario 10c, another apparel fire, is the direct result of smoking. Scenario 10d is the only significant instance in which a residence's structural members, such as framing, are ignited directly – in this case, by faulty wiring. Scenario 10e is the result of a residential trash fire. This extremely common cause of fires[4] is a relatively uncommon cause of fire death.

In several instances, the reporting or classification system was inadequate to define precisely even these abbreviated scenarios. For example, the role of flammable fluids in apparel and residential fires is not adequately described. The role of these materials, which often play an intermediary role in the fire chain, needs to be clarified.

Implications for Firesafety Program Planning

Some sort of fire loss ranking system is basic to any attempt to plan and evaluate firesafety programs. The scenario concept has proven to be a useful tool in planning, both at the NFPA and in the federal fire effort. As the nation's new fire data system matures, more and better data will permit existing scenarios to be reranked and new ones to be formulated. The scenarios will also be expressible in more detail, approaching something like the six-component system discussed earlier. As the scenarios become more detailed, all firesafety programs designed to reduce life loss can be focused with correspondingly greater precision. Nevertheless, there are at least three points, of importance to any planning effort, that are already clear.

1) Note that, with the exception of transportation and apparel fires, **all scenarios that involve 2 percent or more of the fire deaths occur in the home.** Thus, fatalities occuring in large office buildings, for example, or in nursing homes, are a very small part of the whole fire death picture, despite the public attention they attract. It is vital to protect these occupancies, but at the same time, the more glaring aspects of the problem cannot be ignored. In particular, the residential fire fatality and the role of furnishings therein need to be recognized as crucial points for action if fire losses are to be substantially reduced.

Indeed, the national goal[9] of reducing fire losses by 50 percent, as established by the National Commission on Fire Prevention and Control, *cannot* be accomplished unless the residential problem is addressed, simply because there is far less than 50 percent of the deaths in all other occupancies combined.

2) Those features of a residence normally controlled by building codes, such as structural components and interior finish, are seldom the items first ignited in fatal fires. This distinction belongs far more often (36 percent vs. 6 percent) to furnishings. In other words, the building contents, not the building itself, is the most likely starting point for a fatal fire. Consequently, breaking the fire chain in its early stages may best be done through such measures as improving the ignition resistance of materials, or installation of a residential smoke detector.

3) The scenarios highlight some areas where foreseeable technology will be of little or no help. Examples of these are scenarios involving the ignition of flammable fluids, either in conjunction with apparel or residential fires. It is helpful to recognize these areas clearly, so that other, more promising techniques, such as education of the public, can be brought to bear upon them.

The scenario approach is, in principle, extendable to other areas of fire losses – injury and property damage – as well as to fire deaths. Its capabilities are presently limited on all fronts, however, by the available data. Nevertheless, we have tried to show that, even with these limitations, scenarios are useful now in shaping our attack on the fire problem. △

[9] See *America Burning – The Report of the National Commission on Fire Prevention and Control* (Washington, D.C.: US Government Printing Office, 1973).