Managing the Economic Risks of Fire

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1. Introduction

The cost of purchasing, installing, and maintaining fire safety systems constitutes a significant and increasing share of the owning and operating cost of buildings. The National Fire Protection Association (NFPA) estimates fire safety investment costs to range between three and nine percent of new construction costs, depending on construction type.[1] Selecting the "best" fire protection investment package is a complex problem that involves difficult tradeoffs between reducing and transferring exposure to fire loss risks (risk exposure). Risk exposure may be reduced, and even avoided, by investing in fire protective devices, building design, equipment, and furnishings, and improvements in fire safety education and operating procedures. Risk exposure may be transferred by purchasing fire insurance. By optimizing the tradeoffs among reducing and transferring risk exposure, substantial cost savings could be realized while maintaining or even raising current safety levels.

Fire risk management means controlling risk exposure. Typically, risk exposure may be neither fully avoided nor fully transferred. They may not be fully avoided because the costs and aesthetics of making a building completely fire safe are prohibitive. They may not be fully transferred because insurance does not cover all losses from a catastrophic fire. For many businesses, the indirect, or business losses from fire are the most troublesome and enduring. A major fire can cause business interruption and market share losses which may result in crippling a company's growth or even threatening its survival. Indeed, fully 40 percent of insured small businesses that suffer a major fire never reopen.[2]

During the 1980's, important advances worldwide in fire modeling and prediction resulted in the development of fire risk assessment methods by the United States, Australia, and Japan.[3] Coupled with great strides in microcomputer capabilities,

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[1]Built-in fire safety costs as a percent of new construction costs are 3 percent for private residential construction, 9 percent for private nonresidential construction, and 4 percent for public building construction. John R. Hall, Jr., "Calculating the Total Cost of Fire in the United States," Fire Journal, Vol. 83, No. 2, March/April 1989, p. 70.

[2]W.P. Meade, A First Pass at Computing the Cost of Fire Safety in a Modern Society (Chapel Hill, NC: The Herndom Group, Inc., March 1991), p. I-2.

[3]R.W. Bukowski *et al.*, Fire Risk Assessment Method: Description of the Methodology (Quincy, MA: National Fire Protection Research Foundation, July 1990); Building Regulation Review Task Force, Microeconomic Reform: Fire

these methods have been partly or fully incorporated into PC-based analytical tools. The PC-based tools serve to make the most current understanding of fire behavior and risk accessible to researchers, fire protection engineers, and code officials. By incorporating economic analysis into the risk assessment software, the scope of this technology transfer could be extended to include decision makers at the microeconomic level, such as insurers and building designers, owners, managers, and tenants.

The purpose of this paper is to define a comprehensive framework for fire risk management and to propose an agenda for its implementation. The comprehensive framework requires economic modeling in three major areas: risk management, loss estimation, and fire protection costing.

2. Risk Management

Fire insurance is a means of transferring risk exposure from the insured party to the insurance provider. The cost of the transfer is reflected in insurance premiums. Insurance premiums are to some extent controllable since they are based in part on the risk exposure accepted by the insurer. One way of lowering the insurer's risk exposure (and premiums) is by reducing the coverage or raising the deductible amount, thereby transferring some risk exposure back to the insured. The drawback, of course, is a rise in the expectation of uninsured losses. Another way of lowering risk exposure is by investing in fire-safe technologies for which the insurer lowers premiums. The drawback is a rise in fire safety investments costs. These are some of the tradeoffs involved in fire risk management.

In general, the decision problem involves two basic risk management tools, fire safety investments and fire insurance, as seen in table 1. For fire safety investments, choices need to be made among the available technologies and their placement. For example, investing in an expensive, but highly effective, halon extinguishment system is likely to be more economically efficient for a building's computer room than for its warehouse. The risk exposure is far greater in the computer room with its high-value equipment and irreplaceable data than in the warehouse that stores inexpensive, easily replaceable supplies. Choices among technologies, however, are limited by two constraints. First, the investment package must provide a level of safety that meets or exceeds local fire code requirements. Second, the decision maker may face a budget constraint for fire safety investments.

Regulation, National Building Fire Safety Systems Project (Australia, May 1991); and Japanese Ministry of Construction, Report on the Development of Fire-Preventive Designs for Buildings [in Japanese] (Tokyo, Japan, December 1988).

Table 1. Fire Risk Management

Risk Management Tool	Decisions	Constraints
Fire Safety Investments[a]	Which Technologies Where Best to Apply	Fire Codes Budget
Fire Insurance	Coverage Types Coverage Amounts Deductible Amount	Budget

[a]Includes investments in fire-protective devices, building design, equipment, and furnishings, and in improvements in fire safety education and operating procedures.

The other risk management tool is fire insurance. Here, decisions need be made regarding extent and types of coverage as well as amount of deductibles. Coverage types include property damage, liability, and business interruption. Of course, the more extensive the coverage and the lower the deductible, the higher the premiums. Again, the decision maker may face a budget constraint--this time a limit on premium expenditures.

Fire risk management involves a number of exogenous and endogenous decision variables, all of which play an important role. The exogenous variables are those which, although they are important, are in practice determined by forces outside the scope of fire risk management decisions. They **are not** controllable. Examples of these are location,[4] occupancy, and architectural style (e.g., number of stories). The endogenous variables are determined by forces operating within the fire risk management system. They **are** controllable. Examples of these are the costs of fire safety investments, insurance premiums, and uninsured losses. Indeed, these costs are all determined by fire safety investment and insurance decisions.

The total cost of fire risk management over the life of a building can be expressed as follows:

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[4]In extreme cases, fire-related concerns may affect location decisions. Areas with particularly strict code requirements, for example, may be avoided due to their particularly high fire protection costs. Alternatively, unusually high fire risk exposure may motivate an organization to locate on multiple sites rather than one central location.

RiskMgtCost = FirProtCost + InsPrem + E(UninsLos),

where

RiskMgtCost = Present value of fire risk management costs,
FirProtCost = Present value of fire protection investment and maintenance costs.
InsPrem = Present value of fire insurance premiums, and
E(UninsLos) = Present value of expected uninsured losses.

The insured seeks to minimize the total cost of fire risk management. To a certain extent, fire safety investments and insurance are tradable. The more fire-safe the building, the less the need for insurance, and vice versa. Expected uninsured losses are the most likely losses, over the lifetime of the building, of (1) property not insured to full replacement value, (2) uninsured liability and business losses, and (3) deductibles. Expected uninsured losses are based on the likelihood of fire in that building type, its fire safety, and the insurance policy. Due to the low probability of a major fire in most buildings, expected uninsured losses will tend to be low.

Decision makers, however, do not base their investment and insurance choices solely on the **expectation** of uninsured losses. In fact, most businesses buy more insurance than dictated by expected uninsured losses for two reasons: to protect themselves from having losses above the average, and from having losses sooner than the average.[5] Of most concern is protection against catastrophic loss, or losses way above average. The decision maker seeks to limit uninsured losses in the unlikely event of the worst-case fire scenario. Losses from the worst-case fire scenario are referred to as **maximum** probable uninsured losses. The decision maker can lower the level of maximum uninsured losses by selecting greater fire safety and more insurance coverage. The limit on maximum uninsured losses should be the level beyond which the business can no longer survive, or maximum **survivable** losses. Maximum survivable losses are fixed.

In sum, the decision maker seeks to minimize fire risk management costs under the condition that maximum uninsured losses (MaxUninsLos) do not exceed maximum survivable losses (MaxSurvLos). This optimization problem can be expressed as follows:

Minimize RiskMgtCost = FirProtCost + InsPrem + E(UninsLos)

Subject to

$$\text{MaxUninsLos} \leq \text{MaxSurvLos}$$

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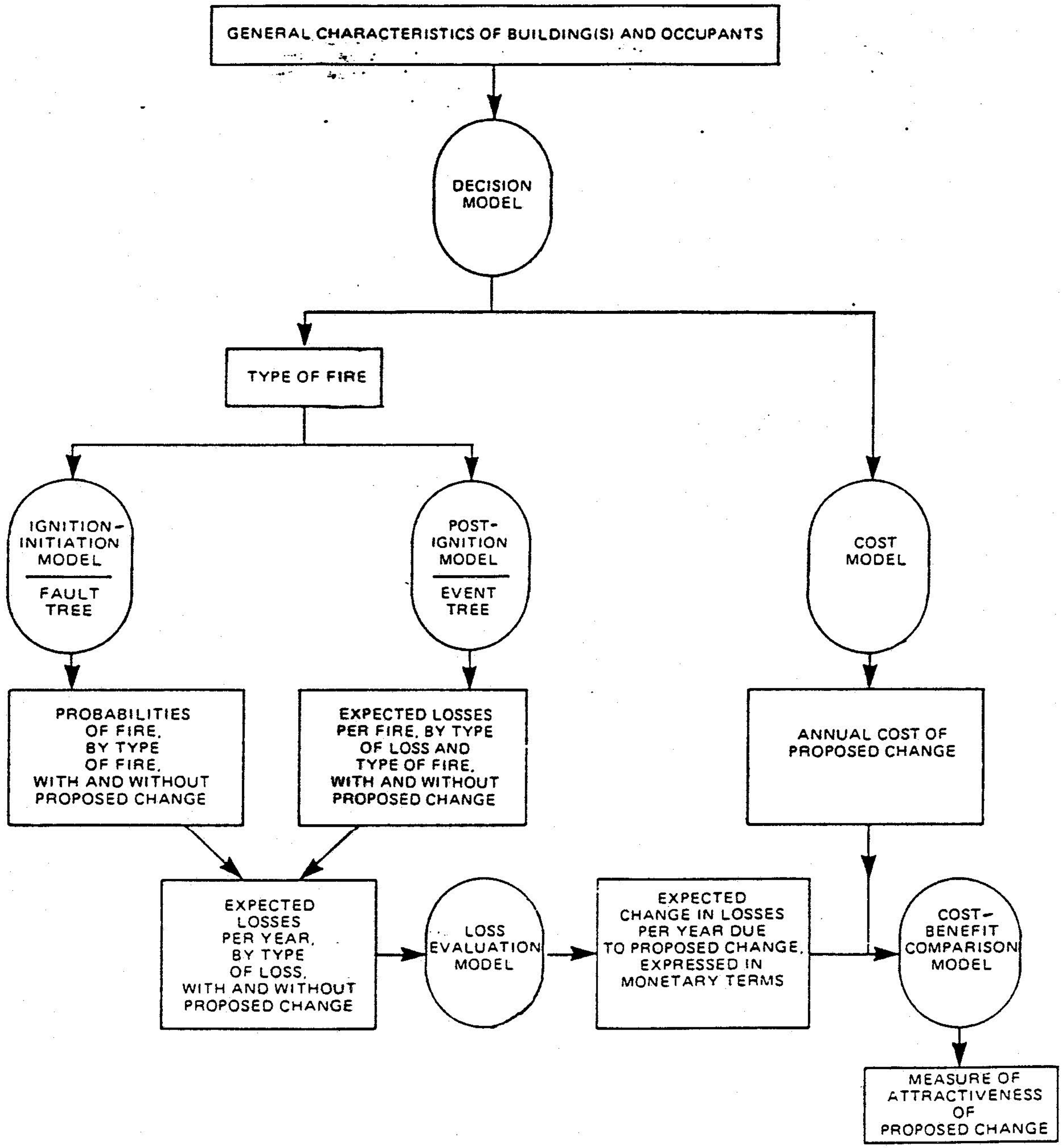
[5]R.T. Ruegg and S.K. Fuller, A Benefit-Cost Model of Residential Fire Sprinkler Systems, NBS Technical Note 1203 (Washington, D.C: National Bureau of Standards, November 1984), p. 82.

The analyst should examine each possible investment/insurance package, ruling out those whose maximum uninsured losses exceed the maximum survivability constraint. The package with the lowest combined investment, insurance premium, and expected uninsured costs should then be selected. If none of the investment/insurance packages meet the maximum survivability constraint, the analyst should consider slowly raising the budget constraint and/or relaxing the survivability constraint until a package is found that meets these requirements.

Several factors reduce the size of the optimization problem by limiting the number of possible investment/insurance packages. Each package must not exceed the budget constraint. The investment portion must be technically feasible and must meet or exceed fire codes. Finally, there will be a limited number of investment/insurance packages because investment and insurance choices are interdependent. That is, not all insurance policies are compatible with every fire safety level. For example, insurance carriers sometimes impose requirements on protective systems beyond the codes. Specific methods of optimization can be explored in the operations research literature. Because of the expected limited number of possible packages, though, optimization is assured through systematic analysis of all possible combinations of investment/insurance packages.

To implement the fire risk management model proposed above, the building under analysis needs to be specified in great detail, as required by existing fire risk assessment methods. The risk management model, in fact, can be built by expanding these risk assessment methods to include all types of loss and by extending them to include evaluation (in addition to assessment) of fire risk. Figure 1 was developed by NFPA's John Hall and displays various models involved in fire risk management (including both risk assessment and risk evaluation models). It provides an excellent starting point for discussion and helps identify the missing pieces. The decision model and the ignition-initiation and post-ignition models together perform risk assessment--they estimate the severity and probability of fire in a well-defined building. The risk assessment methods developed by the U.S., Australia, and Japan all include these three models, but they all focus exclusively on loss of life. None assess property damage, liability, or business losses. Suggestions for expanding risk assessment to include these losses are offered below in section 3. Note that the U.S. method is the only one that includes fire incident data in its ignition-initiation model. Furthermore, the software implementation of the U.S. method, HAZARD I, is extensive and sophisticated. For these reasons, the U.S. method (hereafter referred to as HAZARD) is the most suitable candidate for expansion and extension.

A logical extension to HAZARD is risk evaluation, or measuring the importance of a particular change in risk. Hall's three models for risk evaluation are a cost model, loss evaluation model, and cost-benefit comparison model (see figure 1). These models ignore insurance decision making, a key ingredient in comprehensive fire risk management. Incorporating insurance decisions is the major enhancement proposed here and results in replacing Hall's loss evaluation and cost-benefit models with the



Source: John R. Hall, Jr., "Fire Risk Analysis," Fire Protection Handbook, 17th edition (Quincy, MA: National Fire Protection Association, 1991).

Figure 1. A Risk Management Conceptual Framework.

risk management model outlined in this section. The purpose of Hall's loss evaluation and cost-benefit comparison models is to combine costs and benefits (or reductions in losses) that accrue over time into a single measure of economic worth for comparison with alternatives. This involves valuing fatalities in terms of dollars, a highly controversial and uncertain task. Moreover, decision makers are unlikely to base fire investment and insurance selections on such measures of worth. Instead, they seek to minimize their costs and expected losses while at the same time meeting the life safety requirements imposed by current fire codes. This objective is the rationale behind the risk management model outlined above. It is proposed as a more comprehensive risk management framework. It avoids monetizing fatalities and yet integrates important decision variables into a single economic cost measure for comparison across alternatives. This new risk evaluation method includes a new cost model (outlined in section 4) and the risk management model proposed above.

3. Loss Estimation

3.1 Property Damage

To estimate uninsured property losses for input to the risk management model, a property damage evaluator needs to be added to HAZARD. One way to estimate uninsured losses is to evaluate the risk exposure of uninsured property only. A more accurate and informative way, however, is to evaluate risk exposure for all property and then deduct insured losses. The latter approach is recommended because a full property damage evaluator would help indicate the extent of business losses, and would be extremely useful for other applications. Research to implement this approach involves four tasks: (1) investigate fire incident reporting, (2) develop a taxonomy of building contents and average costs, (3) modify HAZARD's tenability model to assess physical damage, and (4) translate physical damage into monetary losses.

First, fire statistics should be investigated to determine exactly how property damage losses are reported. Ideally, the property damage evaluator would be structured to parallel fire incident reporting. This would permit model validation so that, just as HAZARD's predicted fatalities can now be compared to observed fatalities, predicted property losses could be compared to observed losses. Examples of questions to ask about reported property losses are:

In how much detail are property damage data collected?

What are the categories of property damage loss?

Are monetary values assigned on an original or a replacement cost basis?

The second task is to develop a taxonomy of building contents consistent with fire incident reporting categories. The taxonomy might include, for each item, its description, location, size, materials, and average unit cost. Note that only property of substantial worth need be included. From a data file based on this taxonomy, users of HAZARD could "build" and "furnish" their building and, using their own or the default cost data, assess its value.

The next task would be carried out by fire modeling experts. For all fire scenarios relevant to the building under analysis, the extent of physical damage to property must be assessed. Task Two will provide input data on property size, location, and materials composition. Physical damage includes, if possible, the effects of heat, smoke, and corrosive products from fire.

Finally, physical damage can be translated into monetary losses using the average unit costs specified in Task Two. If the physical damage results indicate a replacement is required, the average cost will be applied, and if a repair is indicated, a lesser amount will be used to convert physical damage into monetary losses.[6]

3.2 Liability

Liability has become more important to risk management over the last two decades as U.S. courts have broadened its scope. Liability is no longer based strictly on negligence; any fire that results in personal or property damage can result in liability claims, no matter what the cause.[7] Property liability even includes fire-related damage to the environment. Liability insurance may be purchased to protect against this risk exposure, but only up to a point. Jury awards can far exceed insurance coverage in the worst cases.

Theoretically, liability is addressed by the risk management model. Liability concerns can lead to greater investment in fire protection and more insurance coverage. These in turn will affect uninsured losses. Implementation, though, requires further work. The difficulty arises in quantifying uninsured liability losses because, unlike property damage, there is no upper limit. Further modeling of decisions on liability protection may lead to workable solutions.

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[6]The fire simulation software ARGOS, developed by the Danish Institute of Fire Technology, generates a very rough estimate of property damage from fire. It is impossible to comment on the method for converting physical to monetary damage, as the method is not documented. A major weakness of the software is that the user is required to input the heat and smoke sensitivity of the building and its contents. The property damage evaluator proposed here would have these data built in.

[7]Meade, A First Pass at Computing the Cost of Fire Safety, p. III-8.

3.3 Business Losses

Fires are becoming less acceptable as an ongoing business risk as decision makers increasingly realize a major fire can trigger a permanent loss of market share. Business interruption losses are estimated to be three to four times greater than property losses. Some insurance coverage may be available to protect cash flow by paying incoming bills, but insurance cannot compensate for skilled personnel moving to other companies, customers lost to competitors, and destroyed records. To make matters worse, it may cost millions of dollars to prepare the insurance claim.[8]

One way to estimate business losses is to use some multiple of property damage. However, it is unlikely that business loss is truly a linear function of property damage, and the amounts in question are large enough to warrant further work. Property damage is certainly a key factor in determining business losses. The greater the property damage, the longer the business interruption, which in turn means the larger the market share loss. The larger the market share loss, the lower the probability of survival. But other factors may play an important role as well. A regression model should be developed and tested to predict business losses based upon property damage and other parameters such as original market share and type of business. Uninsured losses for use in the risk management model may then be estimated by deducting insured losses.

4. Fire Protection Costing

The risk management model needs present value costs for each possible investment/insurance package. A standard method of economic evaluation will be used to combine and discount investment, maintenance, and insurance costs to their equivalent present value. The standard method is ASTM's Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems.[9]

Investment costs are available for some fire protection technologies in widely-used construction cost manuals such as those published by the R.S. Means Company. These annually-updated manuals report installed unit costs including labor, materials, equipment, overhead, and profit. Locality adjustments are available to account for regional price differences. For those technologies for which published data are unavailable, manufacturers and contractors may be contacted for price information.

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[8]Meade, A First Pass at Computing the Cost of Fire Safety, p. I-2, III-2, III-7.

[9]"Standard Practice for Measuring Life-Cycle Costs of Building and Building Systems (E 917-89)," 1991 Annual Book of ASTM Standards, Vol. 04.07 (Philadelphia, PA: American Society for Testing and Materials, 1991), pp. 762-774.

Data on future costs, such as routine servicing and maintenance of the fire detection and fire suppression equipment, may be available from the U.S. Army Corps of Engineers' Construction Engineering Research Laboratory (CERL). CERL has developed an extensive database for estimating maintenance and repair costs over 25 years. The database covers four major building systems: (1) architectural, (2) electrical, (3) plumbing, and (4) HVAC. Again, for those technologies for which published data are unavailable, manufacturers and contractors may prove informative. Alternatively, these data may be obtained through interviews with users of the technology.

In costing alternative investment packages, it is important to remember that only marginal, or differential, costs are relevant. This is because alternatives will always be compared against the base case. The base case meets minimum requirements of prescriptive fire codes. A cost that will be incurred no matter what the investment package, even if it is solely for the purpose of fire protection, need not be collected.

Insurance availability is unique to the specific building context. The analyst can supply data on premiums, deductibles, and coverage types and amounts. Data input can be facilitated through built-in lists and help screens.

5. Conclusion

The fire risk management model proposed here could be used to assess the overall impact of any change that could make fires more or less likely, more or less severe, or more or less costly. Fire codes dictate the minimum level of fire safety. They are driven by life safety concerns. But the economic risk of fire may be so great that it pays to protect against fire to an even greater degree, both through fire safety investments and through insurance. By incorporating the risk management model into HAZARD, insurers and building designers, owners, managers, and tenants will have a useful tool to make informed decisions about this most complex and important issue.