Total cost of fire in Canada: an initial estimate

Schaenman, P.; Stern, J.; Bush, R.; TriData Corporation

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The National Research Council of Canada
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TriData Corporation
1500 Wilson Boulevard
Arlington, Virginia 22209
(703) 351-8300

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TriData Corporation of Arlington, Virginia undertook this research and is solely responsible for the estimates. Philip Schaenman was Project Manager and Principal Researcher. Reade Bush, Jeffrey Stern, and J. Gordon Routley of TriData contributed ideas and research. Charlene Cullen was responsible for logistics and report production.

EXECUTIVE SUMMARY

The total cost of fire to Canada has never been estimated in detail before. It is much larger than most people are likely to realize — on the order of $11 Billion Canadian per year. The base year used in this analysis, 1991, yielded lower than average direct losses, costs for construction and costs for insurance overhead; the total costs were even higher five years ago, and are probably higher today.

The major cost components are direct losses ($1.7B), the cost of the fire service ($2.2B), the cost of fire protection in structures ($3.3B), the cost of fire protection in equipment, vehicles and operations ($2.3B), insurance overhead ($0.4B), indirect losses ($0.3B), the attributed value of fire deaths and injuries ($1.2B), and miscellaneous other costs ($0.1B).

Not all of these major cost elements are easily estimated, even as to their order of magnitude. In 1994 the National Research Council of Canada contracted with TriData Corporation of Arlington, Virginia to take a first pass at estimating the total cost of fire and each of the major elements building on previous Canadian and U.S. studies. The taxonomy of cost sub-elements, that was developed is similar to the categories used in estimating the total cost of fire in the United States, but goes into more detail.

The text discusses the sources and assumptions used in making these estimates so that adjustments can be made as better data becomes available. The report recommends a number of follow-on studies needed to refine these estimates.

The direct losses and indirect losses from fires, and the costs attributed to injuries and deaths may be thought of as what society pays for the direct and indirect losses caused by fires. They total about $3.2B.

The cost of fire services and cost of fire safety built into structures, equipment, and operations are what society spends to protect itself from fire. They total about $7.9B.

"Insurance overhead" may be viewed as the cost society pays to spread losses across a wider base than just the victims. It totals $0.4B.

Thus, Canada is spending about $8B a year to reduce losses down to $3B a year. Many billions in losses are being averted annually. It would be of interest in a future study to estimate the magnitude of the losses averted.

Some people may prefer to consider as the minimum total loss the cost elements that can be estimated with greater confidence than the rest. These include direct losses, the cost of the fire services and insurance overhead, for a total of $4.4B. But it is clear that the rest of the cost picture is large, certainly in billions, even if difficult to estimate, and thus the conclusion is clear: <u>the cost of fire is not "just" the $1-2B in direct dollar loss that is usually quoted, but surely at least $5B and probably over $11B per year</u>. It is a much larger issue economically than most people in Canada probably realize. That should be an important input to national, provincial, and local policy decisions.

The dimensions of the cost components, and the various subcomponents that were considered are shown in the following table. All costs here and throughout the report are in Canadian dollars.

ELEMENTS OF THE TOTAL COST OF FIRE		
Type of Cost (and Major Components)		Estimated Cost (and Range)
I.	Direct Dollar Losses from Fires	$1.7B (1.5–1.8)
	Fires reported to the Provinces by the fire service or insurance companies	
	Fires that go unreported to the fire service and insurance companies	
	Forest and Wildland Fires	
II.	Cost of Fire Services	$2.3B (2.1–2.6B)
	Municipal career or part-paid fire departments Personnel (including benefits/social costs) Hardware: Fire apparatus, supplies, equipment, vehicles Stations Water system (fire-related cost)	
	Volunteer departments Hourly or per call wages Equipment Pensions Attributed cost of replacing volunteers (option to include)	
	Industrial Fire Brigades	
	Provincial and national fire forces (including fire marshals)	
	Military firefighting forces	
	Management of forest fires	

ELEMENTS OF THE TOTAL COST OF FIRE		
	Type of Cost (and Major Components)	Estimated Cost (and Range)
III.	**Cost of Fire Protection in Structures (Buildings and Other Engineered Structures)**	$3.3B ($2.8-3.9)
	Active Fire Protection Systems Detection, alarms, sprinklers, halon and other suppression agents. Extinguishers, standpipe systems, smoke control systems..	
	Passive Fire Protection (above structural needs) Fire-rated construction elements, e.g.,ceilings floors, walls, doors, cladding, compartmentation. Extra exiting	
	Fire Protection in Building Systems Fire-rated components and design of permanent electrical and mechanical systems	
	Maintenance of Fire Protection Systems and Passive Features	
IV.	**Cost of Fire Protection in Equipment, Vehicles, Goods and Industrial Operations** (beyond what is needed to function or for shock protection; e.g., tipover switch in a kerosene heater, gas shutoff valves, protection around fuel tanks in cars.)	$2.3B ($1.7-3.3B)
	Equipment and Vehicles Civilian Military (including ships, planes)	
	Industrial Operations (e.g., fire safety training, fire drills; electrical, gas and oil industry safety operations.)	
V.	**Insurance Overhead and Profit** Total cost of premiums less payouts.	$0.4B ($0.4-0.5)

ELEMENTS OF THE TOTAL COST OF FIRE		
	Type of Cost (and Major Components)	Estimated Cost (and Range)
VI.	**Indirect Losses from Fire** Indirect Losses to Businesses, including: Business interruption losses Temporary displacement expenses Long term losses in market share Secondary losses in dependent businesses Indirect Losses to Residences, including: Temporary lodging, vehicles and other living expenses Litigation Legal Costs (before and after a fire) Settlements Tax Losses (or Gains) Environmental Impacts of Fires and Fire Protection (e.g., halon impact on ozone layers; aquifer damage from runoff of contaminated water; air pollution.)	$.3B ($.1-.4B)
VII.	**Attributed Cost of Lives Lost and Injuries from Fires** Civilian and Firefighter Casualties Reported and Unreported Casualties Deaths Medical costs, funeral costs, attributed value of life lost Injuries Medical expense, attributed cost of pain, suffering, and lost income	$1.2B ($.2-1.6B)
VIII.	**Miscellaneous Costs** Regulatory, Research, and Testing National and provincial fire agencies and associations Disaster recovery	$0.1 ($.04-.15B)
		Total: $11.6B ($8.8-14.3B)

Future Studies Needed

This report is an initial pass at a very broad subject area that has received little attention in Canada and most other nations. The methodology for making the estimates needs refining. Also, more data is needed where the methodology is clear but the data lacking. Even where data exists, such as for direct losses and for fire department expenditures, there are major problems in the lack of consistently used definitions within and across provinces.

The following are some of the higher priority areas needing further attention to improve the estimates:

Fire Losses	—	A national fire data system with consistent, compatible definitions and collection approaches for direct dollar losses from fire departments and insurance companies.
	—	Consistent and comprehensive reporting of indirect losses for residential and non-residential fires (at the least, what the insurance industry pays out for indirect losses).
Fire Service Budgets	—	Estimates of the total expenditures in the volunteer fire service.
Industrial Fire Safety Costs	—	A method for identifying and estimating cost impacts of fire protection on industrial operations.
	—	Cost of industrial fire brigades
Product Safety	—	Costs of fire-safety built into products (one of the most varied and difficult areas to approach).
Insurance Industry	—	Cost of indirect losses
	—	Overhead attributable to fire-related insurance
Built-in Fire Safety in Engineering Construction	—	Cost of fire safety investments in petroleum industry

- Cost of fire safety investments in gas industry
- Refined estimate of fire-related costs of waterworks.
- Fire safety investments in electric industry; road construction, and selected other engineering construction.

Built-in Fire Safety in Buildings

- Especially, the cost of fire safety in detached dwellings (a small part of a large investment).
- Refined estimate for industrial and institutional structures.

Conclusions

Improved knowledge of the overall cost of fire and its components can be important for setting national priorities in fire research and fire protection programs. It also can be useful within industries to track costs vs. benefits of fire protection strategies. This study is a start; many refinements are needed.

Comparisons of the total costs of fire with other nations will shed light on how well Canada is doing, and how the large investment in fire safety affects the safety from fire and the competitive position of the nation. To the best of our knowledge Canada has gone further with this study than any other nation in understanding its total costs from fire. The estimation of the total cost of fire needs to be commenced or improved in every industrial nation to improve the selection of national and international strategies in fire protection.

CHAPTER 1. INTRODUCTION

The total cost of the ancient issue of fire protection is much greater than most would suspect. It is on the order of $11 Billion per year for Canada, when all costs are totalled and converted into a common, commensurable indicator: dollars.

The total cost is much greater than just the value of property destroyed by fire each year. The cost of the fire services; the cost of fire protection built into buildings and equipment; the cost of fire insurance overhead; the many indirect costs of fire for business interruptions, medical expenses, and temporary lodging; the value to society of the injuries and deaths caused by fire; and many other related costs add up to a very large economic impact. The same is true for any industrialized nation, but most nations have not estimated this total cost at all, and very few have done it in detail.

Some may argue that disasters stimulate the economy, and that the economic multiplier effects of recovery activities such as rebuilding and relandscaping may offset some of the costs. However, it seems useful to estimate the costs alone, as a measure of losses and expenditures that almost everyone would probably prefer to see spent otherwise. This report thus focuses only on the costs of fire and not on any economic stimulation from fires.

Purpose

It is important to understand the total cost of the fire problem for several reasons:

- To alert the public and decisionmakers in government to the economic magnitude of the fire problem, which is often underestimated

- To compare the fire problem with other problems facing the nation, so that some rationale is used in the allocation of resources

- To track progress over time

- To stimulate prevention and mitigation efforts

- To help defend budgets

It also is important to estimate and track trends in the magnitude of the main ***components*** of the total cost of fire, to assist in fire protection policy tradeoffs. The apparent and hidden costs of fire protection need to be compared to the losses averted and losses incurred. Eventually some quantitative understanding of how investments in protection affect total costs needs to be established.

Objectives and Scope

This study attempts to a) identify all of the major factors that comprise the total cost of fire to the nation of Canada, b) make preliminary estimates for each major component, and c) outline the most important areas that require more work, and where possible, the next steps to refine the estimates. This has not been attempted before for Canada.

The study built on the methodology developed for making similar estimates in the United States over the last 15 years, and a recent effort by Quebec (Bordeleau 1993). The National Fire Laboratory of the National Research Council of Canada engaged

TriData Corporation of Arlington, Virginia to undertake this study. TriData staff had been involved in making the initial estimates of the cost of fire in the United States.

This study was viewed as a starting point to be refined in the future. While it is exciting to break new ground such as this study does, it also proved to be somewhat frustrating because of the many questions that had to go unanswered within the scope of this effort but that were clearly answerable if pursued further. This study is as much as an identification of the availability of various types of information and the family of studies needed to make better estimates of the various cost components, as it is a methodology for undertaking the estimate, and a set of preliminary estimates. The report identifies strengths and problems with some of the available Canadian databases. A number of recommendations for further studies and refinements of data are made throughout this report.

All assumptions and sources are shown, so that as better information becomes available, or as readers wish to make other assumptions, different estimates can be developed from this starting point. To put this effort in perspective, we know of no nation in the world that would claim it has a satisfactory estimate of the total cost of its fire protection. It is a very difficult undertaking, and few have spent much effort on it. This is but the beginning of the process.

History of Analogous Studies in the U.S.

This attempt to make estimates for Canada is based on the experience gained in a series of studies undertaken in the United States over the past 15 years.

The first modern attempt to estimate the total cost of fire for the United States was undertaken by the U.S. Fire Administration (USFA) as a project for a team of fire protection engineering students from Worcester Polytechnic Institute (WPI) circa 1980.

This initial estimate was based on first cut thinking about the problem. It has been quoted and requoted, though the methodology was far from satisfying. Nevertheless, it was a good starting point.

A more recent effort to estimate the total cost of fire was made by an economist, William Meade, for the (U.S.) National Institute of Standards and Technology in 1992.[1] It drew heavily on the initial WPI study, and relied on in-depth discussions with a small number of experts in various fields, including many from industry. The Meade report expanded our insight into the wide range of areas in which fire protection is built into our society. It made initial estimates of some new cost areas, that, though crude, have yet to be improved upon. The Meade report was criticized in an article in *Fire Technology Magazine* by David Thomas, who lamented the lack of a sound basis for many of the estimates, and described an approach for improving one area of estimates — the cost of built-in fire protection.[2] This present report for Canada actually does start to use some of the methodologies that Thomas suggested.

Dr. John Hall, former member of the fire data analysis team at the U.S. Fire Administration, has been the head of fire data analysis at NFPA for over a decade. He has made a series of estimates of the total cost of fire that builds on the WPI and Meade estimates. His most recent estimates of the total cost of fire were made in 1993.[3] We used part of Hall's latest methodology to leap-frog forward with estimates for Canada. Hall also has shown how the components of the total cost of fire shift in magnitude over time. He also divided the cost estimates into the more solid estimates and the looser, more handwaving part of the estimates.

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1 "A First Pass at Computing the Cost of Fire in a Modern Society," William Meade, The Herndon Group, March 1993; prepared for Center for Fire Research, National Institute of Standards and Technology, Gaithersburg, Maryland.

2 "Concerned Comments on Meade's "First Pass at Computing the Cost of Fire Safety in a Modern Society," David J. Thomas, *Fire Technology*, First Quarter 1993, pp 69-75.

3 *The Total Cost of Fire in the United States through 1991*, NFPA Report, Dr. John Hall, August 1993.

When we started this project, we thought certain estimates such as the direct cost of fire loss and the cost of the fire service would be relatively easy to obtain, so that our efforts could be devoted to some of the softer data elements. We were wrong. There really are no solid data elements at all. All of the components need further work. Because some are the basis for more decisions than others, we spent more time on the total losses of fire, the cost of the fire service, and the cost of the built-in protection than we did on some of the other components. All need to be looked at more closely in future studies.

Overview of Cost Categories

The taxonomy used here for the various elements of the cost of fire protection is generally similar to that used by Meade, Hall, and WPI. Additional details have been added to help explain the larger categories, and to emphasize subsets of the totals that are likely to be most important to Canada.

The first major category of the cost of fire protection is the ***direct losses from fire*** — what was burned up or damaged by fires. This is the most common statistic quoted when people talk about the cost of fire, but it is only a small fraction of the total. Among the main questions in estimating direct loss are: Does one use insurance estimates or fire department estimates? How does one handle uninsured losses? What is the extent of the unreported losses?

The second major category is the ***cost of the fire service***. This is primarily the costs of local paid and volunteer fire departments, plus the cost of forest fire management. Among the major issues here are the lack of routine collection of this data; how to compute the costs of the volunteers; and how to allocate a portion of the operations of the municipal water supply to the cost of fire protection. It is important to include the costs of benefits and overhead for firefighters, and the cost of fire apparatus and stations;

these costs are treated differently in the budgets of different municipal departments, and we must be careful in making comparisons. Sometimes a separate capital budget is used. Sometimes benefits or "social costs" are not included with the fire department's budget.

A third major category is the cost of ***insurance overhead***. One doesn't want to double count the cost of insured losses that are paid for by a portion of premiums. But the premiums taken in by insurance companies are much larger than the totals paid out. The issues here are how to estimate the overhead and profit that are paid for the privilege of getting insurance, and how to separate fire-related insurance from other kinds of insurance.

A fourth major category is the ***indirect loss*** from fire. Indirect loss includes business interruptions, costs of temporary lodging, tax losses, loss of market share, legal expenses, and many other categories. Many of the costs are difficult to estimate, especially in light of the proprietary nature of data collected by insurance companies. This area needs work in the future to further refine what should be included, let alone how to estimate the costs.

Three other major categories of the cost of fire are the ***cost of fire protection built into buildings***, the ***cost of fire protection built into equipment***, and the ***cost of fire protection built into business operations***. The cost of active fire protection systems are clear conceptually but difficult to estimate for the whole population of new buildings. The cost of fire protection built into "engineered structures" such as refineries and power plants also need to be considered. The cost of passive built-in fire protection is not entirely clear conceptually: How do you count aspects of buildings that provide fire protection but also protection from other hazards, e.g., strong winds. The cost of fire protection built into equipment is even more difficult to estimate because there are so many more types of equipment than buildings. There is a major conceptual problem of where to draw the line between fire protection built into equipment so that it may remain operative, versus fire protection that is meant to guard against the equipment starting fires beyond the equipment itself. The cost of operations affected by fire consideration includes training of employees in fire safety, diseconomies of scale from having to limit the quantities of flammables used at any one time in certain places, the cost of special transportation considerations for flammables, the use of special containers for flammables, and time lost evacuating buildings from false alarms.

Finally, there is the *cost of deaths and injuries*. Part of these costs are conceptually clear if difficult to estimate, such as the cost of medical treatment, funeral expenses, and lost time from work. Other more conceptually difficult and to some, distasteful, costs are the value of a life, and of pain and suffering, but costing such aspects of losses is done all the time as part of cost effectiveness studies, to put all impacts on a commensurable basis. The reader can choose to include or not include these costs.

Organization of the Report

Each major category of the cost of fire protection will be addressed in a separate chapter. In each chapter, we present the assumptions and sources of data upon which the estimates are based, and the model used to make the computations. In some places more than one approach is provided to illustrate the range of estimates that result from different assumptions or approaches. This will allow others to make their own estimate if they have better approaches to the assumptions or computations. Every one of the costs discussed here could be refined further.

At the end of the report, there is a summation of the individual cost component estimates to form a grand total. There also is an independent estimate of the grand total made by scaling down U.S. estimates, and an estimate made by scaling up an estimate of the total cost of fire made by Quebec, as additional points of comparison.

An Appendix estimated the total cost of fire to one province, Ontario, which helped support this study.

All costs in this report are given in ***Canadian dollars*** unless otherwise stated.[4]

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4 A Canadian dollar was approximately .75 U.S. dollars at the time of this study, and that ratio is used for approximate comparisons here.

CHAPTER 2. DIRECT DOLLAR LOSS

The starting point for estimating the total cost of fire is the direct dollar losses from property damage. Sometimes direct loss is mistakenly thought of as the total cost of fire. In fact, it is less than one-sixth of the total cost.

Definitions

The direct dollar loss from fire is the value of property that is destroyed or damaged by fire or fire protection efforts. It includes damage by flame, heat, smoke, water, other extinguishing agents, and firefighting actions (e.g., holes cut in a roof or windows broken for ventilation).

A conceptual problem in estimating the "loss" from destroyed property is whether to use the cost of repairing or replacing what is damaged, or the depreciated value of what is damaged, or the market value prior to damage. These can be three different quantities. If an entire house is destroyed, is the loss the market value of the house or the cost to rebuild the same house? Rebuilding or replacing a used object with a new object adds value to what was there before.

In general, insurance companies pay depreciated costs or no more than market value, whichever is smaller. That is a generally accepted convention that is supposed to be used when there is a total loss. When there is a partial loss, such as destruction of one room in a house, the cost that is supposed to be used is the cost to make the room whole again, even if it results in somewhat better condition than it was in the first place, e.g., including a new paint job.

When insurance company estimates of loss are used, the loss should be estimated without considering insurance deductibles. That is, the estimated loss is not what actually gets paid by the insurance company to the victim, but rather the assessed value of the loss prior to any deductibles being taken.

Also, the direct dollar loss should not include any indirect costs such as temporary lodging or business interruption, regardless of whether they are paid for by insurance; the indirect losses are tallied separately, to avoid confusion and improve the quality and comprehensibility of the estimates.

The Canadian System of Reporting Fire Losses

Canada's direct dollar losses from fire are reported in an annual report compiled by the Fire Commissioner of Canada.[5] The Fire Commissioner's office collects estimates from each Provincial Fire Marshal, National Defense, and Indian Reserves. It adds in losses from federal properties. Not included are most of the losses from forest and wildlands fires.

The Provincial Fire Marshals and Fire Commissioners collect fire loss data from two primary sources: insurance companies and fire departments. Both are by Canadian law required to submit a report including the dollar loss for every fire reported to them. When both an insurance company and fire department report information on the same fire, the provincial office is supposed to choose whichever appears to provide the better loss estimate. Usually that would be taken to be the insurance company's estimate, because they have professional adjusters making the estimate, they have more time to make the estimate, they see the damage after much of the debris is cleaned up, and they

5 *Fire Losses in Canada,* Annual Report 1991, Association of Canadian Fire Marshals and Fire Commissioners.

can make the estimates in daylight (firefighters often file reports on fires they have only seen at night).

Canada's Potential Advantage versus the U.S. System —Canada's system for estimating fire losses, if implemented as intended, should give better quality estimates than the system used in the United States. Canada theoretically collects data from every fire department and from insurance companies on every fire known to either source. In many states in the United States, it is up to each fire department as to whether it participates in their state's fire incident reporting system. The National Fire Incident Reporting System (NFIRS) in the U.S. receives data on slightly less than 50 percent of the fires reported to the fire service. Further, it is solely left to the fire department to provide the best loss estimate to the state; insurance companies do not report their information to local or state fire data systems. A local fire department may use an insurance adjuster's estimate, but the department is not required to consider it. Some do and some do not. Often the fire incident reports are submitted before the insurance company makes an estimate.

Canada's System as Implemented —Unfortunately, the Canadian system of collecting fire loss data does not get implemented in practice entirely as intended. The provinces have widely differing practices in how they make their loss estimates. There also is much variation from province to province in the degree to which they receive cooperation and full reporting from the departments in their province.

A fundamental problem that makes it extremely difficult to implement the data collection system as planned is that, in at least some provinces the ***method of identifying a fire submitted by an insurance company can be totally different from the way it is identified by a fire department.*** The fire department uses the date of the fire and its own incident number. The insurance company may or may not use the same date (it may use the date the fire damage was first viewed rather than the date the fire occurred, especially when a fire starts before midnight and continues past midnight). The fire department may use different nomenclature from the insurance company for describing the community in which the fire occurred. For example, the insurance company may use the name of a locality or a town within a fire district, while the fire department uses the name of the district. Also, there may be more than one insurance company involved in a fire involving multiple occupancies, and each company may identify the fire differently. It would be vastly preferable if both sources (insurance company and fire department) used the same identifier so that the matches could be made by computer. In Manitoba this apparently already is being done by requiring insurance companies to use fire department report forms.[6] The nature of the reporting by insurance companies varies province to province, which in turn increases the variance in the methodology province to province.

The Ontario Fire Marshal's Office relies primarily on fire department reports for its loss estimate. It has found that unless it devoted enormous staff resources to doing the detective work to match insurance and fire department reports, it can match with confidence less than one in ten fires.[7] Alberta, Manitoba, and Quebec all felt that they were carrying out the mandate to match fires betweens insurance companies and fire departments in a fairly rigorous manner. British Columbia received insurance data for about one-third of its fires and said its success rate in matching insurance reports to fire reports was 99 percent.

Most of the provinces did not know whether the estimates from various insurance companies and fire to fire were consistent in approach, e.g., did the reported loss include deductibles or not? Did the estimates include indirect as well as direct costs? Did a blank in the "other" or indirect loss line mean that there was no indirect loss, or just that it was not reported? Were the losses what the insurance company paid the owner?

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6 Private communication, Louise Hornbeck, Office of the Fire Commissioner, Manitoba, October 1994.

7 Private communication, Mary Prencipe, Ontario Fire Marshal's Office, January 1994.

Manitoba was one province that did believe they received reasonably consistent estimates from insurance reports; there may be others.[8]

There also may be a small problem as to whether the fires reported in a given year by an insurance company are the fires that were adjusted in the calendar year or the fires that occurred in the calendar year. The set of fires reported in a given year by fire departments and insurance companies may differ because of these end effects.

Errors from Using a Single Reporting Source (Insurance or Fire Departments) — Some fires are reported only by a fire department and not by an insurance company because the property owners are uninsured or self-insured or the owner did not want the insurance company to know of the fire. In other fires, only the insurance company may receive a report on the fire, and not the fire department. For example, a residence might have $1,000 insured damage to a sofa or a rug from a small fire that the family was able to extinguish itself. Or an industrial fire brigade extinguishes a fire, and the company reports the loss to its insurance company without calling the local fire department. *Using both fire department and insurance company estimates together is the best approach to ensure capturing losses from all fires.*

In provinces that base their loss estimates primarily on fire department data, fires reported to insurance companies but not to a fire department will be missed. How much loss is missed that way is unknown; it is probably less than 5 percent, since the larger loss fires become known. However, there may be many small fires reported to insurance companies only, and their total loss may be significant.

There is a second, larger type of underestimating when fire department loss estimates are relied on: firefighters tend to underestimate losses. To get a feel for the

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8 Private communication, Louise Hornbeck, Office of the Fire Commissioner, Manitoba, October 1994.

difference between insurance adjusters estimates and firefighters estimates of losses, we obtained from the Ontario Fire Marshal's Office a sample of 100 fires for which the loss estimates had been provided by both an insurance company and a fire department. In about three-quarters of the fires, the insurance company had the higher estimate; in one-quarter the estimates were very close or the fire department was lower. Overall, the total loss estimate for the 100 fires from the insurance adjusters was 25 percent higher than from the fire department's report. This stands to reason because of the adjusters' better knowledge of the things that need to be paid for and their better circumstances for making the estimate. Estimates of large fires can throw a sum off one way or the other, but in the two large losses included in the sample of 100 fires here, the insurance company was higher on one and the fire department on the other.

Some fire departments do not report all of their fires to the province. Some fire departments, usually rural volunteer departments, do not report at all. A rough estimate of this underreporting by a representative of the Canadian Association of Fire Chiefs was that perhaps 15-20 percent of fires attended by the fire service were not reported to the provincial fire marshals for one reason or another, but less than that much dollar loss may be missed because of the tendency to report the larger fires. Saskatchewan estimated that about 30-35 percent of fires were not reported to them. Nova Scotia estimated 30-40 percent. The Northwest Territories and Quebec estimated 5 percent. Manitoba estimated 1 percent because of excellent compliance by the fire service and insurance companies. No one had a study to back up this data. There is probably better reporting by municipalities than small volunteer departments, and so the percentage of total losses reported may be high.

If provinces base their data primarily on insurance reports, some or all uninsured losses would be missed. However uninsured losses are thought to be small because it is difficult to deny anyone insurance in Canada, and most people and businesses do get insurance, according to several people in insurance-related associations. An experienced insurance adjuster estimated the magnitude of the uninsured direct loss to be on the order of five percent.[9] Ontario found that in 1991, almost 80 percent of their $383M loss was known to be in insured property, less than 4 percent was known to be in uninsured property and the insurance status of the remaining 16 percent was unknown. Thus, considering Ontario losses with known insurance status, 4/84 = 4.8 percent were in uninsured property[10] — very good agreement with the insurance adjuster's estimate. New Brunswick estimated for us that $1M out of $16M loss was uninsured (6 percent). Nova Scotia estimated that $2M of $32M was uninsured (6 percent). Quebec estimated that $37.5 of $373.5 M was uninsured (10 percent). The foregoing implies that the direct fire loss estimates in provinces that rely primarily on insurance company estimates would be underreported by at least 5 percent, and more if not all fires reported to insurance companies were reported to the province.

Another problem considered was reporting of the portion of insured losses that were deductibles. However, insurance deductibles in Canada were said by one source to be very low. Typically a business might have a $500 deductible and a household a $100 deductible. Some large businesses have larger deductibles. If insurance companies did not report deductibles, that would amount to $19M for businesses and $3M for residences nationally. We know that many provinces and the Insurance Bureau of Canada believe they are getting the full estimate without deductibles deleted. Overall, this aspect of underreporting is likely to be small.

Errors even with multiple sources — All provinces, even the provinces that use both fire department and insurance adjuster data, and that succeed in getting close to 100 percent of both sources to report close to 100 percent of the fire losses known to each, still have at least two sources of underreporting to content with: unreported fires and Federal Crown Corporation and provincial property losses.

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9 Glen Gibson, Adjusters Canada.

10 Private communication with Mary Prencipe, Ontario Fire Marshal's Office, September 1994.

First, and usually the largest concern, are the losses from fires not reported to anyone by a household or business or institution. A U.S. study in 1973[11] found that only about one out of every ten household fires was reported to fire departments; the non-reported fires tended to be minor, but might have caused monetary damage. Property losses from unreported household fires were estimated at about five percent.

Industrial fire losses also are underreported. Discussions with a number of large industries have found that they report perhaps only five percent of their fires, because they handle the rest within their gates, do not need outside help, and have high insurance deductibles. One mining company in Alberta was said to routinely have six fires per day that each cost $500 replacement of a part, or a total loss of about $900,000 per year.[12] About one out of eight fires in this company were reported. It was viewed as the cost of doing business. The Alberta Provincial Fire Marshal estimated that unreported industrial losses were probably at least 25 percent above reported industrial losses. We have no estimates for other occupancy categories, but they are probably in the range of 5–10 percent.

A second class of errors may come from omitting fires in Federal Crown Properties. Federal Crown Corporations include the Canada Port Authorities, Canada Post Service, Atomic Energy, and Canadian Broadcasting Corporation. Their fires are not subject to reporting to the Fire Commissioner. Their losses probably are in the millions per year on the average, with an occasional large ship fire or port fire exceeding that, but not often.

A third and very large class of error comes from omitting losses from forest fires. The Canadian Forest Service, part of National Resources Canada, estimates that fires in

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11 National Fire Household Survey, National Bureau of Standards, 1973.

12 Conversation with Fire Marshal's Office, Alberta, January 1994.

commercially logged forests cause approximately $150M losses per year. (The data from the Forest Service is available by province, but most of these losses are not included in the data reported to the Fire Commissioner of Canada by each province.) The Forest Service's loss estimate does not include any value for parklands that burn, because many of these fires are considered a natural part of forest ecology.[13] One might assign a loss to parkland fires if tourism were affected, or the aesthetic damage large, but that is not their practice. It should be realized that no value is ascribed to thousands of acres destroyed by fire.

Most of the cost of homes or other buildings destroyed by forest fires should be included in the structural property losses reported to the provinces, but this was not verified. Also note that the "special," "farm," and "miscellaneous" categories of fire losses reported to Provincial Fire Marshals and Commissioners may have some of the forest fire losses included, so we will estimate a range of $130–150M for the forest fire addition.

Table 2–1 summarizes the types of underreporting discussed in the sections above, along with initial estimates of correction factors.

13 Private communication with Al Sinnard, head of fire management for the Canadian Forest Service.

TABLE 2-1. POSSIBLE SOURCES OF SYSTEMATIC ERRORS IN PROVINCIAL FIRE LOSS REPORTING	
Potential Error Sources	**Potential Underreporting**
If Province relies primarily on insurance reports:	
▪ Fires in uninsured properties	About 5 percent
▪ Fires reported to insurance company but not reported by insurance company to Provincial office	1-30 percent (no study)
▪ Exclusion of deductibles	Probably negligible
▪ Inclusion of indirect losses mixed in with direct losses	Probably minor, but needs checking for industrial fires especially
If Province relies primarily on fire department reports:	
▪ Fires reported to insurance company but not to fire department	About 5 percent
▪ Firefighters' underestimate of losses per fire	About 25 percent
▪ Losses from fires reported to fire departments but not by fire department to Province	1-30 percent
For All Provinces:	
▪ Unreported fires in industry	25 percent
▪ Unreported fires in households	5 percent
▪ Unreported fire in other occupancies	5-10 percent
▪ Fires in Federal Crown Corporation properties	Relatively small
▪ Forest and Wildland fires	Large; available from Forest Service

It is clear from discussions with each provincial fire marshal's or commissioner's office that the total fire loss being reported in virtually every province is an understatement of the true total direct fire loss, and that the estimates need to be adjusted for the underestimated and unreported portion of the loss. None of the provincial offices makes any adjustments in their loss estimates to account for the fire losses they know they are missing.

Minimum Direct Loss Estimates

Tables 2-2 and 2-3 show the unadjusted fire loss reported by each province to the Fire Commissioner of Canada and the loss by occupancy type (industrial, commercial, residential, etc). They also show the national totals, including federal, Indian reserve and Defense fire losses (but not including most forest and wildland fires, which are reported separately). These are minimum estimates that are not adjusted for underreporting. The trend in these estimates, when put into constant dollars as in Table 4, can be taken as reasonably reflective of the direction in which the fire loss problem is going. These totals underestimate the total direct dollar loss, for reasons explained above, but are good lower bound estimates.

Table 2-2 shows that the total direct loss reported to the Fire Commissioner of Canada was $1.24B in 1991. Table 2-3 shows that 45 percent of that loss was in residences and another 37 percent in "special" properties, most of which are vehicles. Table 2-4 shows the trend in the annual dollar loss in 1991 dollars. The 10-year average loss is $1.26B in 1991 dollars. The 1991 loss was $1.24B. Since 1983, the annual losses adjusted for inflation have been remarkably flat. On a per capita basis, there is a slight downward trend, by the amount the population has grown.

TABLE 2-2
FIRE LOSSES, 1991 AND 10-YEAR AVERAGE
PROPERTY LOSSES BY JURISDICTION

Jurisdiction	Population 1991	Number of Fires		Dollar Loss		Per Capita $ Loss	
		1991	10-Year Average	1991 $	10-Year Average	1991 $	10-Year Average
Alberta	2 545 555	7 678	8 354	112 156 281	124 357 811	44.06	51.87
British Columbia	3 282 060	7 671	7 598	174 991 021	140 391 942	53.32	47.12
Manitoba	1 091 945	5 085	6 184	48 502 816	49 288 326	44.42	45.41
New Brunswick	723 900	2 023	1 844	16 098 661	17 049 936	22.24	23.93
Newfoundland	568 475	689	846	22 867 595	17 666 091	40.23	31.35
Nova Scotia	899 945	2 472	2 495	31 768 838	24 359 555	35.30	27.74
Ontario	10 084 885	23 129	23 465	383 083 821	288 355 761	37.99	30.80
Prince Edward Island	129 765	838	779	5 308 316	4 566 874	40.91	36.14
Quebec	6 895 965	14 485	14 492	373 562 387	304 002 673	54.17	45.81
Saskatchewan	988 930	2 929	2 908	38 707 867	34 732 955	39.14	34.67
Northwest Territories	57 650	212	173	7 312 728	5 851 785	126.85	114.33
Yukon	27 800	275	194	3 156 832	1 782 020	113.56	69.24
National Defence	110 183	202	204	6 194 622	3 148 446	56.22	16.34
Indian Reserves	283 406	356	329	8 377 944	9 587 794	29.56	6.34
Federal Properties	217 818	106	202	7 626 476	5 386 662	35.01	13.15
Summary	27 908 282	68 150	70 067	1 239 716 205	1 030 528 361	772.98	594.24

From *Fire Losses in Canada, 1991,* ACFM and FC

TABLE 2-3. FIRE LOSSES BY PROPERTY CLASSIFICATION SUMMARY OF FIRES BY PROPERTY CLASSIFICATION								
Classification	**Number of Fires**	**% of Total**	**$ Loss**	**% of Total**	**Injuries**	**% of Total**	**Deaths**	**% of Total**
Residential	30 484	44.73	563 958 106	45.49	2 530	72.78	333	85.82
Assembly	2 116	3.10	77 828 425	6.28	108	3.11	6	1.55
Institutional	567	0.83	4 618 388	0.37	53	1.52	9	2.32
Business and personal service	617	0.91	22 057 686	1.78	28	0.81	0	0.00
Mercantile	2 106	3.09	129 366 677	10.44	154	4.43	2	0.52
Industrial manufacturing	1 499	2.20	137 062 441	11.06	119	3.42	2	0.52
Storage	1 820	2.67	71 287 810	5.75	99	2.85	3	0.77
Special	25 504	37.42	150 574 486	12.15	265	7.62	26	6.70
Farm	1 489	2.18	55 518 513	4.48	23	0.66	2	0.52
Miscellaneous	1 948	2.86	27 443 673	2.21	97	2.79	5	1.29
Total	68 150	100.0	1 239 716 205	100.0	3 476	100.0	388	100.0

From *Fire Losses in Canada*, 1991, ACFM and FC

TABLE 2-4. TREND IN CANADIAN FIRE LOSSES			
	Reported Fire Loss[14] (Millions)	Consumer Price Index[15]	Adjusted Fire Loss — 1991 Dollars (Millions)
1982	$1014	83.7	$1528.9
1983	839	88.5	1196.4
1984	944	92.4	1289.3
1985	935	96.0	1229.1
1986	985	100.0	1243.1
1987	966	104.4	1167.7
1988	1018	108.6	1183.0
1989	1128	114.0	1248.7
1990	1237	119.5	1306.4
1991	1240	126.2	1240.0
		Ten Year Average:	$1263.3

Adjusted Direct Loss Estimates

Based on the above information and some further assumptions, we can make adjustments in the provincial loss estimates to account for underreporting and underestimating losses. Since each province has a different data compilation policy, we have made estimates separately for each rather than just for the nation as a whole. Undoubtedly this first cut can be refined by each province once the general extrapolation principles are established.

14 Fire losses for a decade, as given in the 1991 Fire Commissioner's report.

15 Canadian Consumer Price Index for each year.

Underestimates from Lack of 100 percent Reporting by Insurance Companies and Fire Departments —Table 2-5 shows the fire loss compilation strategy and estimates of the suspected degree of underreporting of fires by fire departments and insurance companies in each province.

TABLE 2-5. SUMMARY OF SURVEY OF PROVINCIAL FIRE MARSHALS ON SOURCES AND COMPLETENESS OF LOSS DATA

Province	Fire Loss Compilation Strategy			Est. Completeness by Province (Percent)
	Primarily Fire Department Data	Primarily Insurance Adjuster Data	Both Sources	
Alberta			X	
British Columbia			X	99[16]
Manitoba			X	99
New Brunswick			X	
Newfoundland		X[17]		
N.W. Territories			X	95
Nova Scotia			X	60-70
Ontario	X			
Prince Ed. Island		X		
Quebec			X[18]	95
Saskatchewan	X			65-70
Yukon		X		

16 For fires reported to fire departments. Insurance companies provided data on 33 percent of the total number of fires reported. Memorandum to J. Kenneth Richardson, NRC, from Robert J. Jackson, Office of the Fire Commissioner, B.C.

17 Newfoundland receives fire loss estimates from insurance companies, Royal Newfoundland Constabulary and Royal Canadian Mounted Police. Fire departments report fires but not dollar loss. There is no matching of data.

18 Also uses newspaper clippings. Annual estimates are updated after year's end with late insurance data, but loss reported to fire commissioners is not updated.

Taking each province at its own estimate where one was made, and using 1-5 percent underreporting for the others, we get:

Province	Underreporting Factor x	Reported Loss = ($M)	Underreported Loss
Alberta	.01	112	1.1
British Columbia	.01-.05	175	1.8-8.8
Manitoba	.01	49	.5
New Brunswick	.01-.05	16	.2-.8
Newfoundland	.01-.05	23	.2-1.2
N.W. Territories	.05	7	.4
Nova Scotia	.3-.4	32	9.6-12.8
Ontario	.01-.05	383	3.8-19.2
Prince Ed. Island	.01-.05	5	.1-.3
Quebec	.05	374	18.7
Saskatchewan	.30-.35	39	11.7-13.7
Yukon	.01-.05	3	.1
TOTAL			$48-76 M

Overall the range is 4-7 percent above the reported fire loss. Saskatchewan and Nova Scotia may have been unduly self-critical, or the other may be unduly optimistic; the recommendations suggest an easy study to get a more exact number.

Underestimates from Using Fire Service Estimates — We previously estimated that insurance adjusters loss estimates average 25 percent more than fire service estimates.

Again referring to Table 2-5, the Provinces of Ontario and Saskatchewan base their estimates primarily on fire department reports. Ontario said they matched about 10 percent of the fires with insurance estimates. The adjustment in the estimates for the 90 percent of reported losses not matched should be:

($383M + $39M) reported losses x .25 x .9 = $95M.

British Columbia matches about 31 percent of its fires with insurance estimates. So \$175M x .25 x .69 = \$30M.

The other provinces said they matched most but not all fires, or we did not receive information on their approach. We assume for them that 5–10 percent of their data is from fire department-reported fire losses that had no insurance report, and that they could not match another 5 percent of fires for which they used fire department estimates. Thus 627 x (.1–.15) x .25 = \$16–24M.

The total here then is \$141–149M.

Underestimates from fires unreported to insurance companies or fire departments— For fires not reported to either fire departments or insurance companies, we make the following estimates, based on factors discussed earlier:

Unreported Industrial Loss =	.25 x Reported Industrial Loss	= \$34M
Unreported Residential Loss =	.05 x Reported Residential Loss	= 28M
Unreported Other Loss =	(.05–.1) x Reported Loss	= 27–53M
		\$89–115M

Overall Estimate

Table 2-6 shows the various adjustments from underestimates of known fires and underreporting of fires added to the Fire Commissioner's estimate of total loss. We also add in estimates of wildland fires and Crown Corporation fires. The result is a total of \$1.7B for 1991 versus the unadjusted figure of \$1.2B previously reported, and widely quoted. Since some of the estimates of underreporting are soft, we will quote the range as \$1.5–1.8 with \$1.7B as our best estimate. (\$1.4B is the current minimum losses reported by the Fire Commissioner of Canada plus the wildlands fires.)

A more rigorous computation of the loss factors would be a multiplicative model rather than the additive model used in Table 2-6. That is, one would scale up the base estimate to reflect 100 percent reporting by fire departments, then scale that up to reflect underestimates of loss per fire, and then scale that up to reflect fires not reported at all. However, we suspect that there may be some overlap in the scaling of each underestimate; for example, the fires unreported to fire departments may include some reported to insurance companies. And we are uncertain about whether the 25 percent underestimate per fire by fire departments relative to insurance estimates is accurate, since it was based on a sample of 100 fires from one province. Thus to be conservative we did not multiply the scaling factors, which would have increased the estimate by another $100M.

TABLE 2-6. TOTAL DIRECT LOSS (1991)	
Direct Losses by Province	$1.24B
Forest & Wildland Fires	.15
Underestimate from using fire service loss estimates	.14-.15
Underestimate from fires unreported to insurance companies or fire departments	.09-.115
Crown Corporation Fires	.005-.01
Underestimate from lack of 100 percent reporting by fire department or insurance company	.05-.08
Total	$1.7B

Recommendations

1. *The Canadian National Fire Data System rules for reporting to provinces should be reviewed and provided in writing to each province, and to all fire departments and insurance companies.* This is crucial for consistent reporting.

2. *The provinces should describe to the Fire Commissioner of Canada the details of how they actually collect and report their fire data, when submitting their data.* Some provinces may not be able to follow the prescribed norm. It is important to know exactly what is being reported so that one can determine whether adjustments are needed on the estimates submitted, and if so, of what nature. In particular, the data reported should include the percent of fire departments that are reporting, and the percent of the population of the province that is protected by the departments that do not report. That would allow an extrapolation of losses to the whole population. There also should be a note as to whether insurance and fire departments reports are both used to make the loss estimate.

   To estimate the level of underreporting by departments to the provinces, a sample of fire departments could be surveyed by phone as to their total fires for a year. Comparisons could then be made of the total number of fires the departments say they had versus the number of fires they reported to the provincial fire marshal. The underreporting that comes from fire departments not sending in reports on all of their fires to the province might be improved by explaining the importance of underreporting to each department.

3. *Insurance companies should use a consistent practice in the fire data they report to the provinces.* Whatever data reporting policy each insurance company follows should be reported, too, so the provinces know how to use that data. Especially important to know are: What percent of fires known to each company are

reported to the Province? Are deductibles included in the estimate? Are indirect losses included in the estimate? Preferably, the amount of losses for fires not reported by insurance companies should be identified separately from the insured losses for each province. It is important to understand the magnitude of the two components. Also, the amount of insured losses is needed to estimate insurance overhead (as will be seen in a later chapter).

4. *Insurance companies should report losses to the Provinces using the same incident number, date and time as does the fire department, for fires reported to the fire service.* Other fires they report should have some prefix indicating they were not reported to the fire service.

5. *Conduct a once-a-decade national survey of households and businesses to estimate the dimension of fire injuries and dollar losses not reported to either the fire service or insurance companies.*

6. *Conduct an expanded study of the ratio of insurance adjuster estimates of direct loss to fire department estimates for the same fires.* A sample of 500-1,000 fires drawn across all provinces should suffice.

CHAPTER 3. COST OF FIRE SERVICES

A major element of the total cost of fire protection in Canada is the cost of local fire protection, primarily fire departments of various types. In estimating the cost of fire departments, one must include the cost of personnel, including their benefits or "social costs;" either an amortized or actual estimate of the cost of fire department hardware, including apparatus, supplies, equipment, and other vehicles; the amortized cost of fire stations; the portion of the cost of maintaining the water system that is fire-related; and miscellaneous expenses such as for outside training.[1]

Cost of Fire Protection vs. Other Fire Department Services

The Canadian fire services have expanded their repertoire of services beyond fire protection. In many of the larger fire departments, only 20 percent of the calls are for fires. Many fire departments now offer emergency medical services, from first responders to paramedic. Many fire departments play a role in the prevention and mitigation of hazardous materials incidents. While some of these incidents deal with explosives or flammables and may be considered part of fire protection, it is also true that much of the effort is to reduce environmental contamination and prevent exposure to toxic substances. Fire departments also are playing a larger role in non-fire rescue incidents, some of which are also EMS and hazmat incidents, such as the Mississauga train derailment and subsequent evacuation.

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1 The proportion of the cost of building water supply systems that can be attributed to fire protection needs has been accounted for in Chapter 4, as part of the fire-related portion of new construction and should not be double counted. The cost of fire stations is not identifiable in new construction in Chapter 4, and is accounted for here.

One might thus argue that some part of the cost of the **fire services** should not be included in the cost of **fire protection.** The question then is how much.

Most of the services added to the fire service repertoire have been intended to increase productivity while waiting for a fire to occur. Fires per capita have gradually dropped over time, leaving more time for other services and training. Better equipment and apparatus has also increased productivity and safety of firefighters. While some pieces of equipment are primarily for the new services rendered (e.g., defibrillators for EMS, protective suits for hazardous materials incidents, and certain rescue equipment), the vast majority of personnel, most apparatus, all stations, and most equipment would be needed for fire protection if it were the only service provided.

One might argue that the costs of the fire service should be fully allocated across the various services provided, but the decisions to add services have always been made on an incremental cost basis. We therefore recommend deducting from the total cost of fire only the incremental costs of equipment, personnel, vehicles and capital plant not used for fire protection at all.

We estimate that increment to be less than 5 percent overall.

Primary Estimation Approach for Local Fire Services

The cost of local fire protection varies a great deal across Canada, ranging from the relatively high level of service provided by fully-paid municipal fire departments to minimal protection provided in remote areas by small fire departments that use paid on-call volunteers or unpaid volunteers. The relative proportion of the fire service that is volunteer varies significantly from province to province. The level of service provided also varies across volunteer departments. We requested each province to make estimates of the number of fire departments of different types, and the total of their budgets.

In only a few provinces was there a provincial organization that tracked the cost of municipal services, including fire protection. In most provinces, the Provincial Fire Marshal's or Fire Commissioner's office had to undertake a special survey of budgets or make an estimate of their fire departments and budgets to estimate the total cost of municipal fire services. The results of that survey is shown on Table 3-1. The raw total cost of the fire service was estimated at $1.92B.

Except for British Columbia and Quebec, the estimates generally exclude water supply and hydrant costs. British Columbia estimated their water supply cost at 1.8 percent of the total fire department costs. Quebec estimated water supply costs at 5.8 percent of the fire department costs ($21M). Toronto estimated theirs at 2.5 percent. Using Quebec's estimate for itself and 2.5 percent for all others (except British Columbia), an additional $.054B would be added to the $1.92B. Some of the provincial estimates did not include all costs of volunteer departments. We therefore round the estimate up to $2.0B. However, as discussed on page 3-2, part of the cost of fire departments, up to 5 percent, is not for fire protection. Therefore the range is $1.9-2.0B.

A Second Estimation Approach: Cost Per Firefighter

A second approach to estimate the cost of the fire service can be made by estimating the number of firefighters and the cost per firefighter. According to a survey by the Association of Canadian Fire Marshals and Fire Commissioner, there are about 101,000 firefighters, split 24,000 career and 77,000 volunteer (Table 3-2). As a rough cross-check, we collected partial data from provinces on their estimated number of firefighters (Table 3-1). The provincial data was provided to us was generally consistent with the ACFM survey. Counting volunteers is notoriously difficult because some may be only loosely affiliated with their department.[2]

TABLE 3-1. TOTAL COST OF FIRE PROTECTION FOR CANADIAN MUNICIPALITIES AND THE CANADIAN FORCES (1991)						
Province or Government Entity	**Number of Fire Departments**			**Number of Firefighters**		**Estimate of Total Cost of Firefighting ($ millions)**
	All Paid	**All Vol.**	**Composite**	**Paid**	**Vol. or Paid-on-Call**	
Alberta	NA	NA	NA	NA	NA	$196
British Columbia	NA	NA	NA	3,300	9,000	229
Manitoba	3	211	3	1,058	3,444	74
New Brunswick	8	170	10	600	4,800	40-55
Newfoundland	3	292	7	352	5,650	24-27
N.W. Territories	0	52	4	38	716	8
Nova Scotia	3	300	14	NA	7,000	26
Ontario	34	522	100	9,250	17,000	784
Prince Ed. Island	0	43	6	6	1,200	2-5
Quebec	23	879	58	3,785	18,167	374
Saskatchewan	5	500+	4	1,000	5,000	70-75
Yukon	0	NA	4	0	224	3
Canadian Forces				1,383	0	70[3]
RAW TOTAL						$ 1.9B

2 Some estimates of the total number of firefighters have been higher by 100,000 or more because of the uncertainty in the number of volunteers. Based on comments of reviewers we have used the lower, more conservative estimates here. A more complete census of Canadian firefighters would be useful.

3 Includes firefighting training of contractors as well as military and amortized facilities cost.

NOTES FOR TABLE 3-1:

Alberta —The Municipal Affairs Office totaled the fire budgets by locality for 1991.

British Columbia —Department budgets for each jurisdiction were totaled as follows in millions:

Admin.	14.2
Firefighting Staff	128.5
Fire Alarm Systems	2.3
Fire Investigation/Prevention	5.7
Water Supply and Hydrants	1.9
Training	4.0
Fire Station Buildings and Equipment	7.3
Other	64.8
	228.7

Volunteer wages or honorarium are as follows:

$6-10 per hour on emergency calls
$3-8 per hour for training
$400-3,000 per year for Chiefs

Manitoba —The Fire Marshal's office totaled operating funds for 1992 by locality to be $70M. Assume an added 5 percent ($3.5M) for apparatus, station, water supply, and fire alarm systems.

New Brunswick —The Fire Marshal's Office estimates the total cost of fire protection is $55M. The Municipal Affairs Office totaled the 1991 budgets by each locality to be $40M. Includes an estimated $9M spent on equipment and apparatus yearly.

Newfoundland —Based on figures reported by the Fire Marshal's Office and Municipal Affairs Office, an estimated $24-$27M is spent annually on fire protection.

Undetermined number of volunteers receive $300-$400 honorarium annually.

Province grants $1M annually to departments, which is about 75 percent of the total annual funding toward apparatus. Localities pay the remaining 25 percent of apparatus costs.

Northwest Territories —The Fire Marshal's Office estimates this to be $8M annually. The Municipal Affairs Office listed $5M in operational and capital expenses in unincorporated areas during 1992.

Fire Marshal's Office estimates unpaid volunteers log 22,000 hours annually. Paid volunteers log 52,000 hours annually.

Nova Scotia —The Fire Marshal's Office estimates the total cost of fire protection to be $26M annually. Volunteer Wages: $10.44 per hour during emergencies, $5.22 during training. 900 volunteers receive $100 honorarium annually.

Ontario —The Fire Marshal's Office estimates the total cost of fire protection to be $784M annually, including capital and operational expenses.

Prince Edward Island —Based on information from the Fire Marshal's Office and Municipal Affairs Office, an estimated $2-$5M is spent annually on fire protection.

Volunteer honorariums/wages vary from $100 to $10,000 yearly. Few departments give honorariums.

Quebec —Estimate by the Provincial Fire Marshal.

Saskatchewan —Based on information from the Fire Marshal's Office and the Municipal Affairs Office, an estimated $70-$75M is spent annually on fire protection.

Volunteer honorariums/wages vary greatly: $5-$25 per hour.

Yukon —Fire Marshal's Office estimates the cost of fire protection is $2.8M annually.

Volunteer honorariums/wages: $450 average salary per year.

Apparatus expenses:	$250,000 avg. capital expenses for unincorporated areas $275,000 avg. capital expenses for incorporated areas The Territory pays for all equipment and facilities in unincorporated areas. The cost of fire protection in incorporated areas is paid by the municipality.

Canadian Forces— There are 685 military firefighters and 698 civilian firefighters in the Forces. Their budget for 1991 was as follows:

Wages	$49.0M
Training	1.6
Equipment	1.5
Apparatus, consumables, repairs	12.8
R&D	.5
TOTAL	$65.0M

In addition to firefighters per se, the Canadian Forces give some firefighting training to a majority of their members. All military personnel and civilian contractors are required to take a one-day course in first aid and fire extinguisher use every three years. The military personnel number about 70-80,000. We estimate 10,000 contractor personnel. Assuming half the course is fire-related (either firefighting or burn treatment) and rounding up by 10,000 for contractor personnel, there is (1/2 x 90,000 x 1/3 per year) = 15,000 person days, or about $2-3M. The Navy also gives firefighting training to about 2000 sailors a year, ranging from one day to five days each, or about 5,400 training days.[4] Assuming a $50,000-70,000 average loaded cost per person-year, this adds $1-1.5M. Adding in cost of training facilities and trainers, the total training bill is about $3-5M. We will therefore estimate the total Canadian Forces firefighting cost to be about $70M. This excludes the built-in fire safety of buildings, equipment and ships, which should be reflected in later chapters.

The fire department budget per paid firefighter seems to be on the order of $60,000 in 1989-1990, and about $62,000 for 1991. This is based on dividing the total fire department budgets by the number of personnel for several fire departments whose annual reports were available at CAFC:

4 Based on information from Jon Lewis, Manager of the Safety Training Center, in the Navy, Private Communication, October 1994.

TABLE 3-2. ACFM & FC STATISTICAL SURVEY - 1991 FIRE SERVICES IN CANADA							
Province or Territory	**Population**	**Number of Municipalities**	**Number of Fire Services**			**Number of Firefighters**	
			Career	**Volunteer**	**Composite**	**Career**	**Volunteer**
Alberta	2,504,600	376	9	388	28	2,500	8,500
British Columbia	2,935,616	143	22	347	27	3,302	10,026
Manitoba	1,131,929	259	2	210	4	1,013	3,260
New Brunswick	740,000	118	5	174	9	612	4,600
Newfoundland	568,349	310	3	290	7	325	6,011
Nova Scotia	899,942	66	3	154	17	576	5,052
Ontario	9,105,963	832	34	522	100	9,127	16,994
Prince Edward Island	129,000	92	0	40	1	3	1,089
Quebec	6,507,767	1,490	22	775	140	3,600	13,600
Saskatchewan	1,009,613	988	4	360	8	740	6,500
Northwest Territories	54,300	56	0	52	4	35	748
Yukon	30,000	7	1	18	2	24	258
National Defence	132,045	47	53	0	6	1,420	72
Federal Jurisdiction TC		70	70	40	0	700	80
TOTAL	25,749,124	4,854	228	3,370	353	23,977	76,790

		Budget per Firefighter
Dartmouth (1989)	=	$56,000
Vancouver (1991)	=	60,000
Scarborough (1989)	=	60,000
Toronto (1991)	=	63,000
Montreal (1991)	=	62,000

These per capita costs include apparatus, supplies, and other non-personnel costs. The cost of the career portion of the fire service may be estimated as
$62,000 x 24,000 = $1.5B.

To this must be added the cost of the volunteer portion of the fire service. Of the approximately 77,000 volunteers, about 80 percent were said by CAFC to be paid on call and the others pure volunteer. The volunteers are required to have 60 hours of training per year in Ontario and typically attend 60–100 calls of various types. The volunteers were said to be paid in the range of $6–14 per hour. Assuming an average of one hour per minor call and 2–3 hours for working fires or major EMS incidents, averaging about 1.5 hours per call overall, then the annual cost of the paid-on-call volunteer firefighters may be estimated at (180 hours average x $10 average x .8 x 77,000) = $110M[5]. If the hours average 120–180, and if pay averages $8-10, then the range in the estimate would be $70–110M.

It would not be unreasonable to add in the same amount for the unpaid volunteer as a minimum valuation of their time, which would yield a round total for all volunteer "pay" of about $140M. The equipment of the volunteer and ancillary expenses also need to be added. As a rough approximation, consider that 5–10 percent of the cost of a paid

5 The time spent by volunteer firefighters on calls depends on the mix of calls, travel times, and the time spent cleaning up after a call. Some calls are over very quickly or aborted. A sample of calls in volunteer departments can be used to refine the estimate of the average time spent per call, and the average pay. Using the assumptions in the text above, the average on-call firefighter would receive $1,100 - 1,800 per year.

fire department goes to equipment, stations, etc. Thus there is (.05-.1) ($60,000 per year) or about $3,000-6,000 spent per paid firefighter for equipment and structures. Some volunteers in Canada have excellent equipment purchased by their municipality or the province and others have quite old equipment. Assuming the lower end of the amortized equipment and capital expenditures costs per firefighter, or $3,000, then 77,000 x $3,000 = $230M for supplying the volunteers. The overall estimated cost of the fire service in Canada then is:

Career:	$1.5B
Volunteer:	.3-.4B
	$1.8-1.9B

This is in excellent agreement with the $1.9B estimated by the first approach.

A Third Estimation Approach: Cost Per Capita

Another broad check can be made by estimating the cost of fire protection per capita, and multiplying by the total population.

A 1980 study (Williams-Leir) estimated the cost of fire departments per resident of a community as shown below.[6] The Canadian Consumer Price Index was used to convert the estimates to 1991 dollars.

	Per Capita Costs	
	1980	1991
Full time Department	$40-50	$75-94
Composite Department	30-35	56-66
Volunteer	5-35	9-66

6 G. Williams-Leir, "Fire Cost Control in Canada," *Urban Analysis*, Vol. 7, pp. 169-210, 1983.

A study of total fire costs in Quebec estimated the fire department expenditures in 1991 to be less $373.5M for the departments themselves and $21.5M for water supply, for a total of $57.25 per capita (including volunteer protected and career protected population).[7]

Some other examples of per capita fire department expenditures were drawn from the 1989-1992 period, using data from the Fire Department annual reports:

Salt Ste. Marie (1992)	$84.49	
Toronto (1991)	85.23	(Including 2.07 for Water)
Edmonton (1992)	125.70	
Scarborough (1989)	62.73	
Vancouver (1990)	104.20	
Montreal (1991)	122.26	

Assume that 50 percent of the population is protected by full time departments, 10 percent by composite, and 40 percent by volunteers.[8] Estimate the average for paid departments at $100 per capita, based on the city data above. Scale the estimates for composite and volunteers based on the ratios of the average cost per capita for each category of department as presented in the Williams-Leir study, 46:35:19, which yields $76 per capita for composite departments and $41 per capita for volunteers. Then for a Canadian population of 27.9 million:

Paid	27.9 x .5 x $100	=	$1.395B
Composite	27.9 x .1 x $76	=	.212B
Volunteer	27.9 x .4 x $41	=	.458B
			$2.06B

The three approaches are remarkably consistent and yield a range of $1.8-2.1B. As yet another checkpoint: the NFPA/John Hall estimate of the cost of career (paid)

7 Jacques Bédard, Évaluation des coûts économiques de l'incendie au Québec, D.G.S.C., April 1993.

8 Based on the previously mentioned ACFM Survey, these are 228 career, 353 composites, and 3,370 volunteer department in Canada. But the composites protect much smaller populations than the career departments, so one cannot estimate population protected from this —but it is at least roughly consistent with the assumption.

departments in the U.S. was $13.8B; using the Canada/USA population ratio and $1.33 Canadian dollars per USA dollar, the proportional cost for Canada would be $1.95B, again remarkably close agreement.

Other Fire Protection Forces

Fire Management for Forest Fires — The cost of fire management in forests and wildlands is borne by the provinces, and estimated at $430-450M per year by the Canadian Forest Service.[9] This money is separate from what the provinces contribute to their municipalities and volunteer fire service. It includes pre-suppression planning as well as the cost of actual firefighting. Pre-suppression planning includes prevention, detection, training, and infrastructure for the forest services. It also includes establishment of base camps, capital purchases of equipment, seasonal contracts for aerial fire suppression, and fuel. Airborne units also are included here.

The firefighting cost portion of the cost averaged $240M over 1989-1991. Firefighting operational costs include the costs of firefighting once a blaze has been reported, including the budget costs for firefighters and operational support. In areas where mutual aid crews are pulled together, the receiving agency or province pays for all operational costs in accordance with a provincial agreement. Controlled burning costs may also be included in the costs of firefighting. British Columbia usually has the largest expenditure, but in 1991 it was Ontario. Table 3-3 shows the firefighting costs for the three-year period.[10]

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9 Private communication with Al Sinnard, head of Fire Management for National Resources Canada, Canadian Forest Service, August 1994.

10 Private written communication; Gordon Ramsey, Petawava National Forestry Institute, September 1994.

Industrial Fire Brigades —Only relatively large businesses have their own industrial fire brigades. The majority of their personnel are "volunteers" drawn from within the rank of the company. Only a small part of their time is attributable to fire protection. The industrial fire brigades generally have only rudimentary firefighting equipment. We could find no source of data on industrial fire brigades but felt their costs was small and probably less than the roundoff error in the range estimated above for public firefighting forces ($1.8-2.1B). If the industrial fire brigades total less than $40M they would not affect the estimate. It would have been of interest to survey several major corporations to get their budget for fire brigades, but this data was not readily available and seemed low priority relative to other estimates here.

TABLE 3-3. FOREST WILDLAND FIREFIGHTING COSTS ($ Thousands)

Jurisdiction	1989	1990	1991
British Columbia	$64,000	$88,825	$30,744
Alberta	22,397	51,416	28,654
Saskatchewan	42,953	32,533	
Manitoba	63,500	11,875	10,600
Ontario	45,400	31,100	60,500
Quebec	8,912	7,975	22,008
New Brunswick	1,200	4,800	7,200
Prince Edward Island	81	48	87
Nova Scotia	443	318	1,659
Newfoundland	7,055	986	127
Yukon Territory	7,000	6,500	6,600
Northwest Territories	16,750	8,834	11,422
National Parks	500	3,274	3,286
TOTALS	280,191	248,484	182,887

Provincial and Other National Fire Services —The estimates here do include National Defense fire services but do not include budgets for the provincial fire marshal or civilian firefighters. They are relatively very small and included in the estimate of miscellaneous costs in Chapter 10.

Police, Court, and Investigation Costs —Many fires result in some police effort to control traffic and crowds. A small car fire can tie up traffic for an hour or two. A large building fire can tie up traffic and keep 10 or more police officers on the scene for several hours. Officers might also be involved in false alarms and good faith calls until they are known to be benign, and the street or road can be opened.

Police also help investigate arson fires, which accounted for at least 15,629 fires in 1991.[11] They may spend only 1-3 hours per case when there is little evidence and low loss, and several days to weeks for a serious incident. Crime labs to detect accelerants and perform other services also get involved. As cases advance through the courts, court and legal costs accrue.

As a first rough estimate of all of these costs:

Assume 10 police hours for the 7,000 largest fires, and 1 hour average for the rest: 70,000 + 60,000 = 130,000 hours.

Assume 1-2 person-weeks (40-80 hours) of time per arson (including court and lab time): (40-80) x 16,000 = 640,000-1,280,000 hours.

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11 Source: Canadian Centre for Justice Statistics —*Statistics Canada,* as quoted in the ACFM and FC Annual Report on Fire Losses in Canada, 1991.

Then the total range is 777,000–1,410,000 hours or about 400–800 person-years[12].

Assuming $60,000 average loaded salary, the total is $24M–$48M for police work related to fires[13]. This does not include any estimate for police work on false alarms and fire-related calls. It also does not explicitly include costs of private investigators or security for the crime scene, nor any special heavy equipment or other equipment used in the investigation.

Overall Estimate

Table 3–4 shows the overall estimate and the various components.

Table 3–4. COST OF FIREFIGHTING	
Municipal and Military Fire Forces:	$1.8–2.1B
Forest Fire Management:	.43–.45B
Fire-related Police and Court Costs:	.02–.05B
Industrial Fire Brigades	NA[14]
TOTAL	$2.2–2.6B

The range of estimates using a variety of approaches is $1.8–2.1B per year for the local fire service. To this must be added the cost of fire management for forest fires, (another .43–.45B), the cost of police and court activities that are fire related (.02–.05B), plus industrial fire brigades. Our best estimate is $2.4B, with a range of $2.2–2.6B.

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12 This further assumes 30 workdays for holidays, sick leave, and regular leave.

13 Loading of salaries can be done two ways: only benefits added, or all overhead and benefits added. The latter would yield a higher number than used here.

14 Thought to be small enough not to affect rounding to nearest $0.1B.

The major difference between the total cost of fire services for the U.S. and that of Canada is the cost attributed to volunteers time. The U.S. has a huge volunteer fire service that donates much time. The Meade estimate of the value of the U.S. volunteer fire service was based on the number of paid firefighters needed to cover the population protected by the volunteers. That estimate was $30B, or three times the $10B cost of the paid service. In Canada, volunteers are required to put in only 60 training hours per year, and they primarily attend calls only when needed. However, it is likely that the value of the Canadian volunteer firefighters' time is underestimated. If the volunteers' time is valued on the basis of the service costs they save their communities in full-time personnel, there would be another $0.4–1.8B added to the cost of fire in Canada.

Recommendations

1. ***Survey volunteer fire department budgets and volunteer firefighter income in different provinces.*** The survey would collect the overall budgets of volunteer departments. Because of the use of volunteer fundraising in addition to the tax-based part of budgets, the cost per volunteer firefighter is unclear. The number of calls responded to, average time spent per call, number of training hours, and average pay per hour also would be collected for firefighters. An attempt was made in this study to obtain this data from a small sample of volunteer fire departments, but the variance was so large that the data was essentially useless.

2. ***Survey a sample of industrial firms to determine the number of industrial fire brigades and the cost per brigade.*** Also determine the brigade staffing levels, and the staffing mix (volunteers chosen from among employees, full-time firefighters, part-time firefighters).

CHAPTER 4. COST OF FIRE PROTECTION IN STRUCTURES

When considering the total cost of fire to society, many people do not realize the enormous investment made each year in building fire protection into structures of all types (buildings and engineering structures), and the large cost of maintaining the integrity of that fire protection.

The cost of fire protection in structures can be thought of in four major components:

- The cost of active fire protection systems and fire protection equipment installed in structures, such as sprinklers, detectors, and alarm systems;

- The cost of passive fire protection built into structures, such as fire-resistant walls and doors, or spaces between oil tanks or explosives bunkers;

- The cost of fire protection aspects of the built-in equipment that is a permanent part of the structure (e.g. electrical wiring or a heating system), as opposed to the equipment brought in by tenants or owners, such as computers, portable heaters, or welding equipment;

- The cost of maintaining the active and passive fire protection features, such as testing and repairing alarm systems, or repairing doors.

General Approach

To estimate the cost of built-in fire protection, this study and previous studies (Hall, Meade, WPI) start with the annual cost of new construction, divided into major types of structures (residential, commercial, etc.) The percentage of building costs that are attributed to fire protection in each type of structure is then applied to the cost of new construction by type of structure to get national estimates for the cost of built-in fire protection. The cost of new construction includes equipment and systems permanently built into the structure. An additional category, repairs to structures, is considered here separately.

There is an excellent source for the annual value of construction in Canada: the Statistics Canada report called *Construction in Canada*.[1] It includes estimates of construction by major structure type for the nation and for each province. The estimates further break out the construction of buildings from that of other structures such as refineries, waterworks, bridges and tunnels, which have widely varying costs of fire protection.

Total annual construction rose from $28.8B in 1982 to $60.9B in 1991. It stayed about level from 1991 to 1993 ($60.9, 59.9 and 61.3B respectively). In constant dollars, construction increased a whopping 40 percent over the decade 1982 to 1991. However, the 1991 to 1993 amounts are sharply lower than the 1989 to 1990 level of $71B. If we had used 1990 instead of 1991 as the base year for this study, the estimate of built-in fire protection would have been 15 percent higher.

The total dollar value of construction activity in a given year is divided into ***new construction***, which includes new buildings and major renovations to existing buildings

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1 *Construction in Canada 1991-1993*, Statistics Canada, May 1993.

and other structures, and ***minor alterations or repairs***. Major renovations usually must follow the same code requirements as new buildings. Minor alterations and repairs do not involve as much attention to fire protection as do new major alterations. Nevertheless, repairs may include such activities as putting wiring in conduit, replacing circuit breakers, repairing holes in walls, and closing spaces where pipes go through walls or floors, which suggests that some amount needs to be allotted to fire protection from minor alterations.

Another important division of annual construction costs is between ***buildings*** and "***engineering construction***." "Engineering construction" includes bridges, roads, waterworks, and refineries, for example. There are fire protection costs in both categories, and both are considered here. (The previous U.S. studies of the total cost of fire did not include fire protection estimates for most engineering construction.)

Estimating the Market in Active Fire Protection Systems

The cost of fire protection systems were estimated in two ways: directly from manufacturers sales, and as part of estimating various types of fire protection built into structures.

The organizations representing manufacturers of fire protection equipment in Canada said they did not have good national estimates of the total sales of this equipment in Canada for 1991[2]. However, some individuals in different parts of the industry were gracious enough to give us their best estimates of the size of the market. If they were available, the actual total annual sales of fire protection equipment within Canada would be a more accurate estimate of the annual investment in active fire

2 Data collection in the sprinkler industry has recently changed, and the estimates for 1995 and on are expected to be better.

protection than are the estimates we used, which were based on estimated amounts of fire protection in buildings, multiplied by the amount of construction that takes place.

Table 4-1 shows that a rough estimate of the market for fire protection equipment in Canada is $0.6-0.7 B. This estimate excludes smoke exhaust systems and probably central alarm systems. It also excludes smoke doors and all other active compartmentation approaches. And, of course, it excludes passive protection. So it represents some minimum on which to add other cost components.

TABLE 4-1. ESTIMATES OF THE ANNUAL COST OF ACTIVE FIRE PROTECTION EQUIPMENT	
Sprinkler Systems—Based on approximately 3.5 million installed heads per year, plus piping, fittings, and installation.[3]	$300M
Fire Alarm Systems —Based on approximately $130M in equipment, plus installation. Unsure whether this includes central alarm systems.[4]	$250M
Special Hazards —Including halon and non-water systems.[5]	$30-45M
Fire Extinguishers —Hand-held and cart-mounted.[6]	$5-6M
Smoke Controls —Dampers, pressurization	NA[7]
Subtotal	$585-600+
Residential Smoke Detectors —Assuming 10 year life of detectors and 90 percent of households having them: 8.5 million households x .9 with detectors x (1.1-1.25) detectors per household x .1 annual replacement rate x average cost per detector ($43.50)[8]	$37-43M
Residential Smoke Detector Batteries —Assuming half the detectors are battery-operated, and the batteries get replaced annually: 8.5 million households x .9 x .5 x $2-3 batteries per detector x (1.1-1.25) detectors per household.	$8-14M
Subtotal	$45-57M
GRAND TOTAL	$630-657M+

3 Letter from John Galt, Canadian Automatic Sprinkler Association to J. Kenneth Richardson, NRC, August 22, 1994. The approximate size of Canadian sprinkler investment was estimated by multiplying the known number of sprinkler heads sold by the estimated loaded labor cost per head. (The loading includes time for minor maintenance and small projects, and is considered more realistic than simply using the actual installation time.)

4 Conversation with Richard Morris, Cerberus Pyrotronics January 1994.

5 Conversation with Mr. Kahler, Fire Equipment Manufacturers Institute, January 1994.

6 Conversation with Mr. Kahler, Fire Equipment Manufacturers Institute, January 1994.

7 No independent estimate was identified for the smoke controls market. However, their cost is included in estimates of built-in fire protection later in this chapter.

8 The cost of residential hard-wired smoke detectors was estimated at $75 per replacement. Battery-powered detectors were estimated at $12 per detector. We assumed 50 percent of each type, and that 10-25 percent of households with detectors had two detectors.

Estimating Built-in Fire Protection for a Prototypical Building

The opposite approach to estimating the cost of built-in fire protection from the industry-wide market size is to estimate the cost of fire protection for a typical building as a percent of the total building cost, apply that percentage to the total annual construction value for that class of building, and repeat the procedure for all classes of buildings and engineering construction. The data does not exist to do this comprehensively, but it is possible to make a start.

An extraordinary study of the cost of built-in fire protection was sponsored by the NRC Fire Research Laboratory in 1991 as part of studies of the cost of built-in fire safety features versus their impact on fire risks.[9] Two occupancies were included in the study: a typical commercial six-story office building, and a typical 10-story high-rise apartment building. Costs were provided for each passive element of the building for fire resistance ratings of 0, 1, 2, 3, 4 hour (e.g., costs for walls, floors, and ceilings per square meter). Additional estimates were made for different levels of active fire protection systems (detection, alarms, and automatic suppression.) These estimates were made by building contractors, not researchers, and were realistic. They iterated around the designs for an actual building that was constructed.[10]

The study estimated that a typical six-story commercial building with active fire protection that met the current Canadian Fire Code costs 4.3 percent more than a building that had no additional fire protection built in. If the building were built with steel instead of concrete, the fire protection costs would have been 11.4 percent above the no protection level. (The "no protection" base was not literally that; some

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9 "Input into Economic Model of Capital and Maintenance Cost for Fire Protection, Phase I - Office Building," June 30, 1993; Phase II - Apartment Building March 17, 1992. Hanscomb Consultants Inc; for the National Fire Laboratory of the National Research Council, Ottawa, Canada.

10 The costs in the Hanscomb study focused on the structure and did not consider the built-in electrical and mechanical systems —neither their cost nor the percent of their cost attributable to fire safety.

components that cannot be obtained without inherent fire protection, e.g., elevator shafts, were included in the base though one might say that they cost more than what could be built to have an operable elevator.)

A typical residential apartment building with active fire protection was estimated to cost 13.2 percent above the same building without fire protection. The higher percentage for the fire protection of the residential building was not due to its having more fire protection, but rather the lower base cost per square meter for an unprotected residential building compared to an unprotected commercial building.

The results of the NRC study of the two occupancy types are summarized in the first three columns of Table 4-2. The authors of that study, Hansom Consultants Inc., were asked to go back to their original worksheets to and produce the data shown in columns four and five, the relative proportion of active and passive protection in their estimates. "Active" includes sprinklers, detectors, and alarm systems. "Passive" includes walls, floors, doors, and elevators but not the electrical or mechanical systems of the building. Because concrete has inherent fire safety, the cost of the active fire protection system in concrete buildings turned out to be 1.5 to 2.0 times the passive fire protection costs. For steel structures, the active/passive cost ratio is reversed: the passive fire protection costs more than double the active protection, because of the need for protection of structural members, protection of ceiling elements, and other costs.

These estimates of the costs of fire protection above a non-protected building were exactly of the kind recommended in the critical article by Thomas in *Fire Technology* magazine that was referenced in Chapter 1. Even though only two types of buildings were analyzed, those are the best estimates of the incremental cost of fire protection in buildings that we identified.

TABLE 4-2. BUILT-IN FIRE PROTECTION COSTS (NRC — HANSCOMB STUDY)					
	Unit Base Price (per M^2)	**Unit Fire-rated Price (per M^2)**	**Total Cost of Fire Protection**	**Passive Protection Portion**	**Active Protection Portion**
High-rise Office Building (concrete)	$923.24	$972.60	$40.36 (4.3%)	$13.58 (1.5%)	$26.78 (2.9%)
High-rise Office Building (steel)	893.10	994.71	74.88 (11.4%)	27.78 (8.4%)	27.78 (3.0%)
Apartment Building (concrete)	570.46	645.60	75.14 (13.2%)	30.00 (5.3%)	45.14 (8.0%)
Note: All percentages in parentheses in this table are with respect to the unit base price. Estimates exclude tenant alterations, furnishings, fees, taxes, and built-in electrical and mechanical systems.					

As will be discussed below, we used these estimates to alter some of the previous, much rougher estimates of the cost of built-in protection that stemmed from the original WPI study and that had not been updated in more recent NFPA estimates. Meade increased his estimate of the overall cost of fire protection built into industrial buildings based on conversations with a few industries. We suggest a more conservative approach of using the lower estimates that were generated by WPI for occupancies where the NRC/Hanscomb study doesn't give us some basis for improving the estimates.

Residential Construction

Over half of all building construction in Canada is for residences. In 1991, it was $31B out of $52B.[11]

Within residential construction, there has been a major shift in the ratio of apartment construction to single family dwellings over the past 25 years. Canada is building proportionately more single family dwellings than it once did. Whereas in

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11 *Construction in Canada*, op. cit.

1966-1971, average annual apartment construction comprised 42 percent of new start residential construction, it went down to 33 percent by 1976–1981, and to 28 percent for 1986–1991.

One of the implications of this shift in the housing market is that the ***amount invested in the built-in fire safety of residences has dropped considerably on a per dwelling unit basis over the past 25 years.*** There is little fire protection required to be built into single family dwellings, and more people are choosing to live in them. This may be building in a higher risk potential of fire deaths in the future, as population shifts from living in relatively well-protected apartment buildings to single family dwellings. Increased sprinklering of homes would eliminate the problem, but it is not required and only a very small fraction of homes are sprinklered. Therefore, measures such as smoke detectors and public safety education are becoming more and more important to hold the line, as the inherent engineered fire safety of the residential environment is decreasing, relative to the population. Fire safety built into apartment buildings not only helps keep fires confined to within one unit, but also reduces the likelihood of a fire by having better, more professionally maintained heating and electrical systems and much fewer woodstoves and do-it-yourself alterations.[12]

Table 4-3 shows the total cost of new building construction in 1991, subdivided into major types of buildings. The table also shows the estimated percentages and dollar costs for built-in fire protection, using estimates used by NFPA/Hall (and WPI), NIST/Meade, and the present (TriData) study, which builds on the previous studies. We discuss the residential estimates here and the other estimates in the table in subsequent sections.

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12 In 1991, apartments accounted for 20 percent of residential fires, 16 percent of residential fire deaths, and 17 percent of residential fire losses. The death rate was 8.7 per thousand fires, compared to 10.9 deaths per thousand fires in one- and two-family dwellings. And not only were apartment fires less deadly than one- and two-family dwelling fires, but the chances of having a fire were less, too: the rate of fires in apartments (including row housing) vs. one- and two-family dwellings was 1.6 per thousand versus 3.4 per thousand, excluding mobile home fires.

TABLE 4-3. ESTIMATES OF BUILT-IN FIRE PROTECTION IN BUILDINGS							
	Construction	**Fire Protection Costs**					
	Costs ($ Millions)	**NFPA/Hall**	**Cost ($M)**	**NIST/Meade**	**Costs ($M)**	**TriData**	**Costs ($M)**
RESIDENTIAL	30903.5	2.5%	772.6	2.5%	772.6	4.9%	1453.3
Single Homes	10205.9					2.0%	204.1
Semi-detached	634.1					2.0%	12.7
Apartments	4303.3						
High-rise Apartments 60% (est.)	2582.0					13.2%	340.3
Low-rise Apartments 40% (est.)	1721.3					8.0%	137.7
Other	15660.1						
Cottage & Mobile Homes (5%) est.	783.0					2.0%	15.7
Major renovations							
Sngl fam & semi det 65% (est.)	1017.9					2.0%	203.6
High-rise apts. 20% (est.)	3132.0					13.2%	413.4
Low Rise apts. 10% (est.)	1566.01					8.0%	125.3
INDUSTRIAL	2550.7	9.0%	229.6	12.0%	306.1	6.0%	153.0
COMMERCIAL	11239.2	9.0%	1011.5	12.0%	1348.7	6.0%	674.4
INSTITUTIONAL	4355.3	4.0%	174.2	4.5%	196.0	4.5%	196.0
OTHER	2506.0	3.0%	75.2	3.0%	75.2	3.0%	75.2
TOTALS	51554.8	4.4%	2263.1	5.2%	2698.5	4.9%	2551.9

Note: All construction costs in the first column are from "Construction in Canada" 1991 - 1993, by Statistics Canada, except those marked "est.," which are TriData estimates.

Single Family Homes —The Canadian home has about as little required fire protection as the U.S. home. The U.S. estimate of 2.5 percent for the built-in cost of fire protection in residence used by Meade and Hall was a composite for apartment buildings and single-family dwellings. Because we now have a good estimate (13.2 percent) for fire protection of Canadian high-rise apartment buildings as a result of the previously cited NRC study, we needed a separate estimate for one and two family dwellings. If the U.S. composite estimate was about right (which is open to question), then to be consistent, the estimate for one and two family dwellings should be less than 2.5 percent.

The estimate for private homes should reflect the contribution of electrical fire safety precautions, part of which are for reducing electrical shock hazard rather than fires. It also should include protection of heating systems, building code requirements on fireplaces and chimneys, the (minor) cost of smoke detectors, some elements of gas heating system safety, and miscellaneous other fire protection costs. We estimate that the cost is in the 1–2 percent range. Because private homes comprise a large share of new construction, this estimate does make a significant difference and should be refined. We used 2 percent in the calculations. (The importance of refining the estimated cost of fire protection in a single family dwelling is high relative to other data that needs refining.)

Apartments —Fire protection requirements for buildings above four stories are sharply different from others.[13] The national construction estimates for apartments are not subdivided by size of building. However, we estimate that about 60 percent of apartments were built to the standard required for buildings above four stories or a large low-rise requiring advanced fire protection.

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13 The term "high-rise" commonly means "above 6 storeys" in Canada but the Canadian fire code requirements for residences change for structures above 4 storeys, and hence the emphasis on "above 4 storeys."

The estimate is based on the *Report on Housing Construction* and a special analysis run for this study by the Canadian Mortgage and Housing Corporation of the completed new buildings for which the number of stories was reported in 1991.[14] Of 3,047 apartment building completions in 1991, 447 had data on their height. Of the 447, there were 36 (8%) over 4 stories. Assuming that the 8% is about right for the total population of apartment completions, and that the buildings with the most units are likely to be the ones with the most stories, then the 8 percent of the largest structures include 244 buildings, or about all of the 251 buildings with 50 or more units. The buildings with 50 or more units had about 28,000 out of 50,000 units (56 percent). We therefore assumed that about 60 percent of apartment units were in the most demanding residential fire code category.

Although apartment buildings with over 600 square meters of apartments must be built to the most stringent part of the code, regardless of whether over four storeys, most are over four storeys in practice in Canada. Low-rise apartment complexes in Canada usually are subdivided by fire walls into buildings of less than 600 square meters to reduce their fire safety requirements. (They are separate buildings for purposes of the building code, though from the outside six such "buildings" under the same roof might appear to be one building to anyone but a code expert.)

The estimate of 13.2 percent shown in Table 4-2 from the Hanscomb study for fire protection in high-rise apartment buildings therefore was used for the 60 percent of apartments thought to require the highest level of fire protection. This estimate includes

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14 Canadian Mortgage and Housing Corporation Report on Housing Construction, 1991-1992, Table 28, p. 34, "Apartment Completions by Size of Structure," 1991, and special computer printout provided by Paddy Fuller, of CMHC.

only the active and passive elements defined in the Hanscomb study; no separate estimate was made for the building's electrical or mechanical systems.[15]

Although low-rise apartment buildings do not require use of sprinkler systems, they still have more fire protection requirements than for single family dwellings. Table 4-2 showed that passive protection for high-rise apartment buildings was 5.3 percent of the cost. In addition, there are detection systems and possibly other features. Note that the cost per square meter in a low rise is different than a high-rise. Percentages can be affected by changing the denominator (base) as well as the numerator (costs of fire protection). We estimated 8 percent of cost as fire protection for this portion of apartment construction. It is about midway between the percentages used for single family homes and for high-rise apartments. This category needs further analysis.

As another point of information, two major hotel chains in the U.S. estimate that their costs of fire protection for medium rise hotels was 5-7 percent excluding passive protection. Hotels have similar requirements to new apartment highrises. The estimated 8 percent (Table 4-2) for a concrete apartment building is only slightly higher than the hotel estimate; the percentage would be expected to be lower for hotels because they tend to have more expensive architecture and construction.

Other Residential Construction—A problem with the residential construction data is that almost 50 percent of new residential construction value is reported in the "other" category. It is too large to ignore. On closer examination, with the aid of a special computer run by the Investment and Capital Stock Division of Statistics Canada, about

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15 There is an implicit assumption being made here for lack of data: the percent of the structural cost estimated for active and passive fire protection —what the NRC/Hanscomb study estimated —is applied to the total value of the construction, which includes the value of the buildings' mechanical and electrical systems as well as the cost of the structure. The Hanscomb study did not estimate the percent of a buildings' systems that are attributable to fire safety. Since we don't know what that percentage is, we did not make any adjustment here, and left the implicit assumption. The percent of built-in systems that can be attributed to fire safety is another area for further study.

$0.74B of the $15.7B "other" category is "mobile homes" and "cottages," and the rest is the cost of major improvements and alterations to existing residential structures, which are not subdivided by type of structure. (That is how they are obtained by Statistics Canada, which produces the *Cost of Construction in Canada* annual report.)

We will assume that the cost of alterations and improvements are distributed between apartments and single family dwellings roughly 1:2, based on residential construction in the period 1966-1971, 20-25 years ago, but with a small bias toward single family homes on the grounds because they are built less sturdily than apartments and require more repairs. (It would be better to straightforwardly collect data on the mix of actual renovations with respect to the categories of large apartment buildings, smaller apartments, and single family dwellings.)

We treat the mobile home and cottage categories as single family dwellings; i.e, we assume 2 percent for fire safety. Mobile homes have more fire safety built into them since 1974, when U.S. mobile homes regulations increased fire safety requirements. Cottages are vacation homes; some are built to the same standard as other single family homes and some more flimsy, but the construction volume is small relative to other residential construction and not worth a special study for present purposes.

Overall Estimate for Residences — The overall result, shown in Table 4-3, is that about $1.5B worth of fire safety is built into residences, which is 4.7 percent of the new residential construction. These estimates of built-in fire protection include the active fire protection as well as passive fire protection.

If the percentages used by Meade were used, the total would be $0.8B. The main differences between our estimate and Meade's stem from a) the higher estimated cost of fire protection in apartment buildings based on the NRC study, and b) the percentage of residential construction that is for apartments. Note in particular that the estimated amount of renovation of apartment buildings over four storeys is a large contributor to the total; if renovations involve fewer apartment buildings, or if fire protection costs associated with renovated apartment buildings are lower, then the overall estimate could be as much as $0.3B lower. On the other hand, some alterations to the existing building stock are made as a result of retrofit legislation (e.g., Ontario Fire Code 9.5 and 9.6). These alternatives may be 100 percent for fire protection, and so would increase the percentage of retrofit alterations attributable to fire safety.

Commercial Construction

The previously mentioned NRC/Hanscomb Consultants study compared a baseline 6-storey commercial office building constructed of concrete, with no fire protection added, to the same building with passive and active fire protection. The finding was that the built-in fire protection increased the cost of the building by 4.3 percent. This split into 1.5 percent passive protection and 2.9 percent active protection. The same building built of steel would have had 11.4 percent built-in fire protection.

Small low-rise commercial buildings may have less than the amount of active protection estimated for the six-story commercial office building used as the prototype in the NRC/Hanscomb study. Taking out the sprinkler systems could reduce the built-in protection costs to 3-4 percent.

On the other hand, some of the high-rise commercial market uses steel construction. The percent of commercial office construction that used steel during 1991-1993 was about 42 percent for 2-6 story buildings, 5 percent for 7-10 stories, and 17 percent for 11-15 stories.[16] But the dollar volume of new construction is not disaggregated by the number of stories in "Construction in Canada."[17] We therefore

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16 Conversation with Canadian Steel Construction Council, July 1994.

17 If there is a source from which new commercial construction by number of stories can be obtained, the estimate for commercial and industrial construction can be refined.

made the following assumptions: suppose 50 percent of new commercial construction is low-rise, and does not require sprinklering. About 40 percent of this low-rise construction is steel and close to 60 percent is concrete. We assume wood commercial buildings are a very small part of the total — under 5 percent). The cost of fire protection in concrete low-rise office buildings is estimated at 3 percent (1.5 passive and 1.5 active, excluding sprinklers). The cost of fire protection in steel low-rises is estimated at 6.5 percent (5 percent passive and 1.5 percent active protection). Then the low-rise prevention factor =

.6 (concrete) x .03 (fire protection) + .4 (steel) x .065 (protection) = .044.

For the other 50 percent of office building construction, which is high-rise, assume 20 percent is steel, 80 percent concrete. Then the high-rise prevention factor =

.8 (concrete) x .043 (protection) + .2 (steel) x .114 (protection) = .057.

Combining, .5 x .044 (low-rise) + .5 (high-rise) x .057 = .0505 (overall fire protection factor for commercial construction.) We round this to 5.0 percent, higher than the 4.3 percent test case but lower and more conservative than the 9–12 percent estimate used in earlier U.S. studies.

Industrial, Institutional, and Other Building Construction

We did not find any analysis of fire protection in industrial or other types of properties as there was for commercial properties.

Industrial buildings vary greatly, and probably have a larger percentage of these costs spent on fire safety than commercial buildings because of their lower base cost per square meter (they often are more shed-like.) Because the commercial estimate was so much less than the U.S. estimate, we will use an estimate of 6 percent for industrial properties, slightly above the 5 percent estimate for commercial, but less than the 9-12 percent used in the U.S. studies.[18]

No special study was undertaken for institutions and "other" structures; we used the percentages estimated by Meade and Hall. It is questionable in the U.S. estimate why institutions (e.g. schools, jails, hospitals, nursing homes) have lower fire protection percentages than industrial and commercial properties. Many institutions are low-rise but have high life safety risk. This needs further consideration.

Table 4-3 shows all of the percentages used by the U.S. studies and this study when applied to the 1991 cost of construction.

Engineering Construction

Table 4-4 shows that the annual "engineering construction" costs — the costs of structures other than buildings — are very large, about 60 percent of the construction investment in buildings.[19] Table 4-4 includes repairs with new construction, whereas Table 4-3 was just new construction.

The major headings in Table 4-4 are unchanged from the source reports, but the subcategories under each main heading are those Statistics Canada construction subcategories for which some portion seemed reasonable to allocate to fire safety. All of the other construction subcategories, for which fire protection seemed a minor consideration, were grouped into subcategories labeled "all other" in the table. More

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18 A noted U.S. fire protection engineer, Richard Kraus, independently estimated that 6-10 percent was a good approximation for fire protection costs of modern storage occupancies like warehouses and many industrial facilities are warehouse-like, and have warehouses. He estimated 7 percent for average costs of protection of factories, including sprinkler systems, ventilation, drainage, fire curtains and other features. This is another rationale for using at least 6 percent, but a separate in-depth study is warranted to get a better estimate.

19 Source: "Construction in Canada, 1991 - 1992," Statistics Canada.

TABLE 4-4. ESTIMATED COST OF FIRE PROTECITON IN "ENGINEERING CONSTRUCTION" (New Construction and Repairs — 1991)				
	Construction Costs ($ Millions)		**Estimated Percent for Fire Safety**	**Estimated Dollars for Fire Safety ($ Millions)**
MARINE CONSTRUCTION	553.5			
Docks		262.3	5.0	13
Other Marine Construction		43.3	1.0	nil
All Others		247.8		
ROAD, HIGHWAY, RUNWAY	6334.2		0.1	6
WATERWORKS & SEWAGE	2659.6			
Water Mains & Hydrants		799.4	20 (10–30)	160 (80–240)
Pumping Stations		292.1	10 (5–15)	29 (15–44)
Storage Tanks		26.8	1	nil
All Others		1541.3	---	---
DAMS & IRRIGATION	398.8	---	---	
ELECTRIC POWER CONSTRUCTION	6859.0			
Generating Plants		3965.8	1 (.6–1.5)	40 (24–60)
All Others (Power Transmission & Distribution lines)		2893.2	0.1	3
RAILWAY, TELEPHONE, TELEGRAPH	3134.9	---	---	---
GAS & OIL FACILITIES	9628.6			
Gas Mains & Services		619.5	5 (1–20)	31 (6–124)
Oil & Gas Pumping Stations		78.0	3 (1–5)	2 (1–4)
Oil & Gas Storage Tanks		72.8	2 (1–5)	2 (1–4)
Oil Piplines		121.8	---	---
Gas Pipelines		1787.4	1 (0–5)	18 (0–126)
Oil & Gas Wells		5018.2	0.1 (0–1)	5 (0–50)
Oil Refineries		926.0	10 (9–11)	93 (83–102)
Natural Gas Processing Plants		1004.9	3.5 (3–4)	35 (30–40)
OTHER ENGINEERING CONSTRUCTION	3685.7			
Tunnels & Subways		34.7	0.5	0.2
Mine Shaft and Below Surface		1160.5	1.0	11.6
All Others		2491.1		
TOTAL	33254.2			$440 ($270–830M)

protection features, or whether some of the categories assumed to have fire protection features are defined differently than might be expected from their titles. The report does not define the categories in detail.

Three categories of engineering construction seemed most relevant to consider in detail: waterworks, electric power, and gas and oil facilities.

Waterworks — \$2.6B was spent on waterworks and sewage in 1991, of which \$0.8B was water mains and fire hydrants. Fire flow requirements often are a major factor in sizing water mains and associated pumping, especially in smaller communities. The cost of using larger pipe and pumps than are needed for drinking water and sanitation can be attributed to fire protection. Of course the cost of hydrants attached to mains are 100 percent for fire protection.

An expert in water systems said that the fire-related costs tend to be approximately 10 percent for a large municipal water system and 30 percent for a small municipal system.[20], [21] A large city needs large pumps and mains just to distribute water to households and businesses, and only in the outlying fingers of the network does fireflow affect sizing and costs. We assumed 50 percent of the new waterworks were in small cities and 50 percent in large cities, and so estimated $(10 + 30) \div 2 = 20$ percent. The percentage to be applied could be better apportioned if the percent of waterworks in construction was known by size of city.

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20 Michael Loundon, consulting engineer, Watersystems, private communication with Jeffrey Stern (TriData), September 1994.

21 Another point of information: about 10 percent of the income from sale of water by the Peterborough, Ontario Utilities Commission was explicitly for fir eprotecton, in addition to charges for water to residential and commercial occupancies that implicitly include fire protection, too. Of course revenues do not necessarily track investment, and this is just one utility, but it is suggestive of the order of magnitude.

We further assumed that half of the investment in pumping stations was water (vs. sewage), so the percentage of the total category is 5–15 percent instead of 10–30 percent. For storage tanks, we assumed they were all for water, but that the size and hence cost of water storage tanks is not highly dependent on fire requirements; we assumed 1 percent was for fire safety. (It is a small category anyhow).

The previously cited Quebec study of total fire costs allocated 20–25 percent of the cost of water systems in larger cities and 25–33 percent in smaller cities to fire protection, which is generally consistent with the former estimate for small cities but higher for large cities. However the Quebec study included maintenance.

It would be a relatively straightforward engineering cost analysis to estimate the fire protection contribution of the water supply in greater depth. The key is to estimate the cost of increasing water capacity by a factor of 2–4 over what it would be without fire protection considerations. One still has to lay a pipe in the ground, but for fire requirements it is a larger pipe (and a larger trench).

As a note of caution, one must make sure that the water supply estimates are not double counted both here in construction and again in estimates of the cost of local fire services. We assumed the maintenance and operation of the water system is there, and the capital cost is here.

Electric Power — Generating plants and power transmission lines have to consider fire safety in their design. The question is, what is done extra, beyond the design needed to prevent shocks and power interruptions?

An insurer's risk analysis of a major electric power company in the U.S. in 1994 identified the need for fire protection systems (detectors and sprinklers) to protect boiler units, a computerized burner management system, and other miscellaneous plant equipment. The computerized burner management system is a modern control system for production that also offers more fire safety; it probably would not have been purchased as soon if not also needed for safety.

Depending on what part of the burner management is included, the fire safety costs were \$15–30M out of about \$2–2.5B in generating plant investment, not counting passive protection features and fire safety built-in previously. The estimate therefore is 0.6–1.5 percent. Electric utilities also work closely with fire departments to shut power off to structures involved in fires, handle downed power lines, and many other ways that can be counted under built-in costs of equipment and operations, rather than here. The equipment included in the category "Power Transmission and Distribution Lines" needs to be considered more closely. We included essentially just a marker of 0.1 percent assuming some equipment had some fire protection.

Gas and Oil Facilities —The oil and gas industries generally do an excellent job in fire safety protection, but do not like to publicize it to avoid raising public fears. (People actually are more at risk at home than in a refinery.)

Fire safety is a major design consideration in gas processing plants and oil refineries. Fire protection also requires extra land for spacing of petroleum product storage tanks and various manufacturing processes. (Land costs are not included in the construction cost in Table 4–4, but the cost of extra land should be considered in estimating the percent of built-in fire protection.) Pipelines often are rerouted for safety to avoid populated areas, which adds to their cost. There often are berms placed around plant components, many sensors to monitor conditions, and often deluge systems and other active fire protection. Drainage ditches and storage ponds are used to catch spills and prevent or mitigate fires.

Some of the above safeguards are for environmental protection as well as fire safety, but much of the intensity of care given to these features stems from fire safety concerns. However, there is a major question as to what fraction of dual use protection features to consider as fire protection costs.

For example, about 20 percent of the cost of gas pipelines goes to special coatings, cathodic protection, and special attention to the fill used in pipeline ditches all to prevent leaks. Much attention also is given to monitoring pipelines for leaks with gas detectors, and with overflights by planes and helicopters looking for breaks, discolored vegetation, and potential problems. Special requirements must be met for pipelines as they cross roads or railroad tracks. One can argue that virtually all of the 20 percent for leak protection and the attendant operation costs might be spent anyhow just to protect the investment in product if the gas being pumped was inert instead of flammable. However, because of public perception of the danger of gas explosion, and the occasional reality, the gas industry is assiduous in protecting pipelines, probably beyond what it might be with an inert gas. We will conservatively estimate the fire safety portion of the investment as only 1 percent out of the 20 percent, with a range of (0-5). The cost of patrolling pipelines should be accounted for under operations, discussed in Chapter 5.

We assumed that there is much more fire safety concern about gas mains than pipelines, because the mains are located where the population is located. We assumed 5 percent of their cost is for fire safety. The industry tends to argue that they would spend virtually the same to avoid loss of product and protect their investment in the infrastructure, but the level of care given to the engineering and construction is very likely higher than it would be with a non-explosive product.

Oil pipelines are assumed here to have no fire safety costs; environmental spills is the prime concern if a pipeline breaks, rather than a fire in virtually all cases.[22]

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22 Floods in 1994 in the Houston, Texas Ship Channel broke an oil pipeline and caused fires in the river, but the fires were seen as almost helpful in burning up the spilled product to lessen pollution damage. Some pipelines deliver products like gasoline; further study is needed to identify any special fire safety built in.

Gas pumping stations are often remotely situated, and hence less critical for fire safety; about 1-5 percent is estimated for leak detectors, emergency shutdown equipment, and enclosures around turbines; without analysis we estimate the same for oil pumping stations.

In gas processing plants, foam firefighting systems are often used. One gas industry estimate was that about $500,000 was spent for fire protection (foam, detectors, emergency cutoffs, etc.) in a facility that cost $12-20M, i.e., about 3-4 percent.

Gas and oil wells were said to have virtually no fire protection, though this category may include some ancillary processing and storage facilities; we estimated 0.1 percent as a marker.

Oil and gas storage tanks have little or no fire protection built in, but are limited in size and well spaced especially for fire safety. We estimated that the extra land costs were 1-5 percent of the construction cost. (The *Construction in Canada* statistics do not include land costs, but, in consultation with one industry expert, we estimated land costs at 10 percent of the storage facility cost, with half of the land going to extra spacing between tanks.)

Meade and Hall had estimated the fire safety cost of industrial facilities of all types at 9-12 percent. A new estimate by a highly experienced consultant to the petroleum industry estimated that 9-11 percent of petroleum plant costs went to fire protection.[23]

The various estimates for the oil and gas industry are summarized in Table 4-4. Overall we estimated 1-5 percent for fire safety in the oil and gas industry, with a best estimate of under $200M or 2 percent. Estimates of fire safety in the oil and gas

23 Richard Kraus, petroleum safety consultant, private communication, August 1994.

industries deserve a separate mini-study because they involve very large numbers. If the fire safety costs average 5 percent overall, instead of 2 percent, that would add another $0.3B to the national estimate. If they are closer to 1 percent, that would lower the estimate by $0.1B.

Other Engineering Categories — Docks are highly vulnerable to fire, and we assumed passive or active fire protection for them at 5 percent. Mines have crucial fire safety concerns, and must have sensors and/or fire protection. We estimated one percent. (Someone suggested estimating the cost of the canaries.) Roads and highways have to be wide enough for fire apparatus, and need turnaround space. Roads for emergency vehicles at airports must consider fire protection, too. We estimated 0.1 percent for roads.

Engineering Total — With the above assumptions, the cost of fire safety in structures other than buildings was estimated as $0.4B with a range of $.3B–.8B. Most of the estimate comes from waterworks, electric generating plants and the oil and gas industry.

Building Repairs

Though "repairs" are defined as minor improvements and generally do not require plans review or inspections, some portion of them should be allocated to fire protection. Repairs to chimneys or fireplaces, electrical systems, alarm systems, and holes in walls contribute to fire safety. However, many minor repairs to homes such as new roofs, siding, doors, and floors, have essentially no fire safety component. We assumed that repairs are more often made to features that do not have fire protection than to fire protection-related features, and so we used percentages for repairs that are much less than the percentages for new construction. We therefore estimate the contribution to fire safety as 1 percent of repairs to residences, 1 percent for structures other than buildings, and 2 percent for other buildings. These numbers need further examination. Industrial repairs are estimated at 2 percent (at least twice as likely to involve a fire safety component as a repair to a residence) because of far reaching building codes; this may be on the low side.

The estimated fire safety contribution of repairs to buildings in 1991-1992 is $0.15B, as shown in Table 4-5. Repairs to engineering construction were included in Table 4-4.

TABLE 4-5. ESTIMATED FIRE PROTECTION COSTS ATTRIBUTABLE TO BUILDING REPAIRS (1991)

	Repair Costs ($ Millions)	Estimated Percentage	Fire Protection Costs ($ Millions)
Residential	$3864.2	1.0%	$ 38.6
Industrial	1091.1	2.0%	21.8
Commercial	2197.0	2.0%	43.9
Institutional	1489.3	2.0%	29.8
Other	704.3	2.0%	14.1
TOTAL	$9345.0	1.6%	$ 148.0

Trend in Cost of Fire Protection in Buildings

Table 4-6 shows the cost of construction and the estimated cost of built-in fire protection costs for 1982-1993. In the decade from 1982 to 1991, construction costs increased 40 percent in 1991 dollars, while built-in fire protection costs increased by only 14 percent. The difference comes from the change in the mix of construction. More single family homes were built, with less fire protection required. Note, however, that

TABLE 4-6. TREND IN COST OF FIRE PROTECTION IN NEW BUILDINGS (1982 - 1993)

Year	***1993***	***1992***	***1991***	***1990***	***1989***	***1988***	***1987***	***1986***	***1985***	***1984***	***1983***	***1982***
1. Construction Costs	61315	59948	60901	70047	71238	63885	57908	47427	41459	31412	30753	28844
2. Costs Adj. ($1991)	59340	59059	60901	73974	78862	74239	70000	59853	54501	42902	43853	43489
3. New Const. ($1991)	50422	50182	51747	62856	67009	63081	59479	50857	46310	36454	37622	36953
4. Built-in Fire Prot Cost ($1991)	2415	2450	2552	3157	3298	3125	2923	2471	2265	1791	1816	2038
5. Percentage Built-in Costs	4.79%	4.88%	4.93%	5.02%	4.92%	4.95%	4.92%	4.86%	4.89%	4.91%	4.87%	5.51%

SOURCE: The *Construction Costs in Canada* report gives the cost of new construction and repairs separately for the latest three years (1981-1993) but only the combined amount (new construction plus repairs) for 1982-1990. Line 1 in this table is the total construction cost (new and repairs). Line 2 is the total converted into constant 1991 dollars. Line 3 is an estimate of the new construction cost (total construction less repairs), computed as 15.03 percent less than the total construction cost; the 15.03 percent was the average cost of repairs for 1990-1993. Line 4 is the estimated cost of built-in fire protection, in 1991 dollars using the percentages of fire safety costs for each property category from Table 4-3, and the actual expenditures by property category for each year. Line 5 is the resulting percentage of built-in fire protection as a function of new construction. This table could be revised with actual repair costs for each year, but the trend should be reasonably accurate, and this was a faster approximation. Since code requirements change over time, the percentages of built-in fire safety for 1991 would ideally be estimated separately for each year, but that was beyond the scope here, and beyond the estimation techniques, too.

1982 was the end of an era. Since 1983, built-in fire protection costs have trended downward more slowly.

Construction costs are amortized over the life of mortgages, and the expenditures for built-in fire protection in a given year are actually the amortized annual principal plus interest cost of the fire protection built-in over many years — but that is a more complex and not necessarily more revealing viewpoint.

Maintenance of Fire Protection Features

Maintenance of passive fire protection (e.g., repairing walls, doors) is largely covered by the estimates for repairs and renovation discussed above. The maintenance estimates in this section are for active fire protection systems (e.g., sprinklers, detectors, smoke control).

Whereas the annual cost of built-in fire protection is based on new construction, the cost of maintaining fire protection gets applied to all buildings with fire protection, old as well as new. It is a significant industry. ***As more buildings have active fire protection systems, the total annual cost of fire protection maintenance also goes up.***

The fire service, as part of routine annual inspections, does some checking of the fire protection systems in buildings. This cost is not counted here, because the costs of fire protection personnel are covered under fire service costs and should not be double counted.

Many commercial buildings rely on outside contractors to test and maintain their fire protection features. Large hotels may require as much as $40,000 a year for tests and maintenance of fire protection, according to representatives of major chains.

However, there is little information on how much maintenance is being done in most occupancy types, in part for fear of liability when not enough maintenance is paid for.

Maintenance Unit Costs —The NRC/Hanscomb Consultants study of apartment and commercial buildings included estimates of maintenance costs for fire protection in each building.[24] Table 4-7 gives some key examples.

Commercial and Institutional Maintenance —There were 377.5 million square meters of "commercial sector" floor space in Canada in 1991.[25] This included commercial and institutional properties, as follows:

	Square Meters (Millions)
warehouses	25
hotels and restaurants	21
office buildings	114
stores (retail and wholesale)	80
theaters and recreation	22
religious buildings	9
hospitals	24
schools	50
universities and colleges	17
other institutions	17
	378

The average age of most of these properties classes ranged from 10.5 to 13.5 years. Religious buildings averaged 26.3 years, schools and universities 19 years. There was a surge in investment in office buildings and stores in the last decade. Thus a large

24 NRC/Hanscomb Consultants, Phase I. Commercial Building, Op. cit, Section E.

25 Historical Estimates of Commercial Floor Space, 1992 Database Update, Prepared for Efficiency and Alternative Energy Branch, National Resources Canada, Contract Serial No. EMR-MMD-93-0118, Iutometrica Limited, March 2, 1994.

TABLE 4-7. MAINTENANCE OF FIRE PROTECTION – OFFICE BUILDINGS	
Type of Maintenance	Cost
Maintenance of local alarms	$0.3 per m^2
"Local alarms" are single-station smoke detectors. This assumed replacement after a recommended life of 5–7 years; yearly inspections; and detector coverage of 40 m^2 per detector. A 5700 m^2 building was estimated to require 430 smoke alarms.	
Maintenance of thermal detectors	$0.2 per m^2
Assumed life of 8–10 years.	
Maintenance of smoke detectors	$0.5 per m^2
Assumed 8–10 year life. Smoke detectors are attached to central alarm systems.	
Maintenance of sprinkler systems	
Based on one annual inspection of all heads.	
— in a light hazards system:	$0.2 per m^2
— in an ordinary hazard system:	0.3 per m^2
Maintenance of standpipe pump set	$150 per unit
Inspect and test pump and controls.	
Maintenance of Standpipe (FCAH)	$0.1 per m^2
Inspect for hose and test extinguishers.	
Maintenance of mechanical smoke controls or stair pressurization systems	$90 per fan per shaft
Inspection and lubrication of fans (one fan per shaft.)	$40 per damper per floor

Estimates from NRC/Hanscomb study, op. cit, Section E.

part of the office space is covered by relatively recent codes. We estimated, with NRC Fire Research Laboratory assistance, the levels of protection shown in Table 4-8. A conservative assumption was made that the space in the building had either detectors or sprinklers but not both (though some properties do have both.)

TABLE 4-8. ESTIMATED FIRE PROTECTION COVERAGE OF COMMERCIAL AND INSTITUTIONAL FLOOR SPACE

	Percent of Floor Space Covered by:	
Type of Property	**Detectors**	**Sprinklers**
Office Space	25%	50%
Stores	25%	50%
Hospitals	60%	30%
Hotels and Restaurants	60%	30%
Schools and Universities	50%	10%
Theaters and Recreation	30%	10%
All Others	10%	10%

For detector maintenance, we will use an average of \$.3 per m^2 for all properties, rather than estimate the mix of different types of detector by individual property type (thermal detectors at \$.2, local alarms at \$.3, smoke detectors at \$.5 per m^2.) Note that these maintenance rates include inspecting and maintaining the central alarm system as well as the individual detector.

For sprinklers, much of the "commercial sector" is light hazard. The Hanscomb study estimated maintenance as \$.2 per m^2 (vs. \$.3 per m^2 for maintenance of sprinklers protecting ordinary hazards.) Buildings with mechanical smoke control or stair pressurization would average another \$.05-0.1 per m^2 (it depends more on average height and number of shafts and floors than on square meters, but it roughly averages .05-.1). We estimate maintenance at an average of \$.25 per sprinklered square meter for all categories.

We also assume that all commercial sector floor space has extinguishers, and half the space is protected by standpipes. To be conservative, we assume that the maintenance cost is three-quarters of what Hanscomb estimated (3/4 x $.1 per m^2) on the assumption that much commercial sector space is left to the fire service to inspect.

Based on the above assumptions, we estimate maintenance costs as shown in Table 4-9.

TABLE 4-9. MAINTENANCE OF FIRE PROTECTION IN COMMERCIAL AND INSTITUTIONAL PROPERTIES

Maintenance of Detectors and Sprinklers	Million Square Meters	Detector Maintenance	*Sprinkler Maintenance*	*Total*
Office space	114 x	[(.25 x .3) +	(.5 x .25)] =	$22.8
Stores	80 x	[(.25 x .3) +	(.5 x .25)] =	16.0
Hospital	24 x	[(.6 x .3) +	(.3 x .25)] =	6.1
Hotels and restaurants	21 x	[(.6 x .3) +	(.3 x .25)] =	5.4
Schools and universities	17 x	[(.4 x .3) +	(.1 x .25)] =	2.5
Theaters and Recreation	22 x	[(.3 x .3) +	(.1 x .25)] =	2.5
Other	100 x	[(.1 x .3) +	(.1 x .25)] =	5.5
			SUBTOTAL	$ 61M
Maintenance of Extinguishers and Standpipes		$.075 per m^2 x 378 =		$28M
			TOTAL	$89M

Maintenance of Other Types of Structures —The above maintenance estimates do not include homes, apartment buildings, industrial occupancies, other building construction, or non-building structures.

We estimated replacement and maintenance of smoke alarms in existing residences earlier in this chapter (Table 4-1) at $45-57M, or about $51M average.

We could not find a published estimate of the square feet of other types of occupancies. As a very gross approach, we can scale the maintenance of these other occupancies using the ratio of (A) new construction of high-rise apartments, industrial and other buildings to (B) commercial and institutional construction (assuming this ratio is representative of all existing space in each category.)

	\$6000M	Apartment New Construction
	2550	Industrial Construction
	2506	Other Construction
(A) =	\$11B	
	\$11239M	Commercial Construction
	4335	Institutional Construction
(B) =	\$16B	

$$\left(\frac{A}{B} = .7\right) x \ \$89M = \$61M$$

A better estimate could be obtained by estimating the percentage of fire protection investment that is in active systems in each type of occupancy, and ratioing the maintenance based just on the investment in active systems. Better yet, the ratio would be developed using data from 20-30 years of investment.

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Total Building Maintenance Estimate —The above estimates for maintenance of building fire protection features were \$89M for commercial and institutional properties, \$61M for other buildings, and \$51M for residential smoke alarms, which sum to \$.20B. This is about 8 percent of the estimated cost of the annual built-in fire protection bill, but is maintenance not of that new construction but rather of all the previous generations of built-in protection.

Alternative Building Maintenance Estimate —An alternative approach to estimating maintenance costs of fire protection systems in buildings is to consider the maintenance costs as a percent of the investment in fire protection systems.

Using data from the NRC/Hanscomb study, the ratio of maintenance of light hazard sprinkler systems to the cost of the systems per square meter protected is:

$$\frac{.2}{12.3} = 1.6\%$$

For an ordinary hazard, it is: $$\frac{.3}{15.6} = 1.9\%$$

At present, the sprinkler market is roughly $300M per year, based on an estimate from the Canadian Automatic Sprinkler Association. Sprinkler requirements and construction have increased over 20 years. Assume in current dollars that sprinklers were installed at a rate of $200M a year for 20 years, or $4B total investment. (Some sprinklers have been around for 100 years, but most of the installation has been in the last 10-20 years.) Then $4B x (1.6-1.9) = $.064-.076B, or about $.07B.

Likewise, the ratio for alarm systems is:

$$\frac{\$\,1,300}{\$35,400} = 3.7\%$$

Alarm systems have more maintenance than sprinklers, and often have false alarm problems. The current market is about $250M per year. Assume that alarm systems were installed at an average percent value rate of $150M for 30 years, or $4.5B. Then .037 x $4.5B = $.17B.

The commercial and institutional floor space in 1991 was 377.5 million square meters. If 20 percent of this space is in high-rises or large structures with a smoke exhaust fan, then there are .2 x 377.5 = 76 million square meters with fans. A typical 10-story office building equivalent has 5,700 square meters. Then there are about 13,000 buildings with pressurized systems. Assuming 4 shafts per building, $360 + 40 x 10 x 4 = $2,000 per building per year, or $.026B.

Summing the pieces, this approach yields $.27B, which may be somewhat on the high side if the above estimates of the level of protection are high. This estimate is in the ballpark of the $.2B estimated by the approach in the preceding section! They both have the Hanscomb estimates for maintenance per square meter and per shaft as a starting point, but then use radically different assumptions to arrive at the same order of magnitude.

Maintenance of Engineering Construction — Maintenance is needed for fire protection of engineering construction as it is for building systems, from the deluge systems on docks to foam systems in refineries. Maintenance of water supply systems is included in municipal fire protection and not here. It was beyond the scope here to delve into this engineering maintenance, but we did consider a special case: the oil and gas industry.

In the natural gas industry a great deal of effort is expended on checking for leaks throughout the distribution system, but especially the network of gas mains leading to customers, where the fear and hazard of explosions and fires are greatest. While much of field operations to check for leaks would be undertaken for an inert gas system, there is extra incentive to be careful in the oil and gas industries because of the liability issue and because explosions can shut down parts of the distribution system for longer times than do leaks of inert gas. A natural gas leak or petroleum product has to be responded to immediately.

One estimate was that 20 percent of the cost of field operations of gas distribution companies goes to patrolling, checking for leaks, and repairs and maintenance related to leaks.[26] The pipeline companies also are required to check for leaks on a regular basis. The gas industry in Canada has revenues of $6.9B from customers in 1993. Of this, $2.9B is residential, $1.8B is commercial, and $2.2B is industrial.[27] The cost of the gas is about 40 percent of their bill, corporate overhead and profit about 30 percent, and the remainder (30 percent) operating costs. About $4.7B goes to Residential and Commercial Properties. Assume two-thirds of operating costs is in non-rural areas, where inspections are more frequent and more important. If 20 percent of the operating costs go to field inspections, leak checking, repairs, corrosion control and other hazard reduction measures, and one-quarter to one-half of that is attributed to fire safety concerns versus steps to identify distribution network problems, then $4.7B x .3 x 2/3 x .20 x (.25–.5) = $47–74M. This seems high, even without the petroleum industry contribution added. Some sources in the Canadian gas industry thought this was high, and that perhaps one percent of operations might be closer, or .01 x .3 x $4.7B = $14M.

By a second approach, there are about 15,100 employees in gas distribution companies in Canada.[28] About 70 percent are involved in field operations. If 20 percent of field operations are involved with inspections, and one-quarter to one-half of that allocated to safety, then 5–10% x 15,100 = 750–1500 employee years are involved. Assuming $60,000 per employee fully loaded, then $45–90M is attributable to fire safety operations.

Thus we estimated $.01–.09B for fire safety-related maintenance in the gas industry. We will assume a range of $.02–.1B for all fire- and explosion-related fire safety maintenance per year for the oil and gas industry, and other engineering construction — a very soft figure.

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26 Phil Runge, American Gas Association, November 1994.

27 Canadian Gas Facts, 1993.

28 Canadian Gas Facts, 1993.

Comparison with U.S./Meade Study — Fire protection maintenance was estimated by the Meade study to be U.S. $6.5B for the United States. That included estimates for maintaining fire protection systems, and also the cost of industrial fire brigades and the cost of training programs for occupational fire protection and fire safety. Several industries reported that fire protection maintenance and training was 0.5–2 percent of their manufacturing costs. Manufacturing costs were estimated at 25 percent of revenues for manufacturing, mining and trade corporations, which yielded a range of $3.4B–13.6B. To this was added an estimate for non-manufacturing sector of 25 percent of the manufacturing sector's cost, for a total of $4.3–16.6B. Meade chose $6.5B as his "best estimate." All of the above numbers are U.S. dollars.

Scaling Meade's estimate to Canada by population yields $0.86B in Canadian dollars, much larger than the $.2B estimated earlier for maintenance of fire protection systems, but it includes industrial fire brigades and training of employees in fire safety, which we deal with elsewhere. If one quarter to one half of Meade's estimate is maintenance of fire protection systems, or $.2–.4B, the order of magnitude of the estimates is the same despite radically different approaches in making them.

Alternatively, we can use Meade's approach but Canadian data. Manufacturing industries GDP for Canada was $92.2B at 1986 prices in 1993. Using Meade's formula, (.005–.02) x .25 x $92.20 = $.11B–.46B. Increasing by 25 percent for non-manufacturing industries, this yield $.14B. Mining and petroleum would add at least another (.005–.02) x .25 x $20B = $.025–.1B, for a total of $.14B–.56B.[29] Again, recall that Meade includes fire brigades and training costs in "fire maintenance," so only one quarter to one half should be counted, or a range $.04–.28B.

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[29] Based on Table 1., Gross Domestic Product at Factor Cost by Industry, from publication Cat No. 15-001, Statistics Canada.

Best Estimate and Range — Our best estimate of the maintenance of fire protection in buildings was $0.2B, and for engineering construction .02–.1B. We therefore will estimate maintenance at $.2–.3B, with a best estimate of $0.25B.

Overall Estimate

Table 4–10 shows that the total estimated cost of built-in fire protection for all structures is $3.3B. The fire protection of buildings dominates the estimate. But note that the estimate for engineered construction is larger than that for insurance overhead given in a later chapter.

TABLE 4–10. ESTIMATED COST OF FIRE PROTECTION IN STRUCTURES — 1991

	Best Estimate	Range
1. Building Construction (new)	$2.4B	$2.2–2.6
2. Engineered Construction (new & repair)	.5	.3–.8
3. Building Construction (repair)	.15	.1–.2
4. Maintenance	.25	.2–.3
TOTAL	$3.3B	$2.8–3.9B

Recommendations

1. ***Extend the methodology used in the NRC/Hanscomb study for commercial office and high-rise residential buildings to single family dwellings, heavy industry, and other occupancy categories that comprise the largest dollar categories of construction each year.***

2. *A study is needed to estimate the cost of fire safety added to the built-in systems in a building (mechanical, electrical, etc.), or to exclude the costs of those systems from the total construction cost.*

3. *Improve estimates of commercial office building fire safety by estimating the reduction in passive protection for steel commercial structures that are not high-rises; the reduction in active protection for low-rise commercial vs. high-rise commercial; and the proportion of commercial buildings that are high-rises (and thus subject to the most stringent fire protection features).* If more than 50 percent of commercial construction dollars are high-rises and/or if the proportion of steel structures is higher than estimated above, then the built-in costs of fire protection would be higher than estimated here for commercial and residential properties.

4. *Identify the approximate distribution of commercial buildings by height, and how the cost varies with the height for the base building and fire protection.* The NRC/Hanscomb study can be the starting point.

5. *Refine the estimates of fire protection and its maintenance in engineered construction.* Especially important to revisit are the oil, gas, and electrical power industries.

6. *Undertake engineering analysis of the impact of fire safety consideration on the cost of water/supply construction for a) large cities, b) small cities and rural areas.* Also needed is an estimate of the percent of water supply construction costs that are for large vs. small cities.

CHAPTER 5. COST OF FIRE SAFETY BUILT INTO EQUIPMENT, VEHICLES, GOODS, AND OPERATIONS

This chapter briefly discusses the fire safety built into the equipment, goods, and vehicles used by businesses and residents, and the cost of business operations caused by fire safety concerns. This whole chapter should be the subject of a special study.

Cost of Fire Safety in Equipment, Furnishings, Consumer Products and Vehicles

From very large equipment to small household products, fire safety is built into much of the equipment and products used by everyone.

Some features of equipment are solely for fire safety. For example, the tipover switch in portable space heaters cuts off the heater if it accidentally gets knocked over. This was built into heaters because of the large numbers of portable space heater fires that were occurring. Humidifiers and many other devices with motors have controls to cut them off when they start to overheat. School buses, pickup trucks, and ambulances all had their fuel tanks redesigned in recent years to make the vehicles more fire safe when they are involved in an accident, after rashes of fires involving these types of vehicles. Particular makes of cars have had major fire problems and had to be redesigned also.

All electrical products and electrical wiring have to be designed to prevent shocks and prevent fires. The design often applies to both hazards. It is hard to apportion the costs between the two causes, but some part of it is attributable to fire safety.

Color TVs were considered fire safety hazards and so were some brands of coffee makers, and they had to be redesigned. Cigarette lighters have been totally redesigned and are required to be child-resistant now.

We would not attribute to fire safety the features of equipment that are necessary to keep the equipment operating as it heats up. For example, computers have to be designed to dissipate heat to avoid damaging their sensitive electronics. Heat can affect the operation of stereos and much other equipment well before it starts a fire. We would not count that as built-in fire protection.

Industrial and commercial equipment also must be designed with fire safety in mind, and often have features specifically for fire safety. The telephone companies spend large amounts protecting the cables that interconnect their equipment and the equipment itself to avoid fires that not only cause direct loss but often enormous indirect losses from all the other businesses dependent on telephone service.

A huge amount of effort goes into the design of military installations and equipment to make sure they are resistant to fires and explosions, both accidental and resulting from an attack. Fire safety on board ships, planes, and tanks are among their key design features if they are to survive in combat. No independent estimate has been made of this cost.

Every civilian plane, vehicle, and train has fire safety designed into it. This includes the materials used in aircraft cabins and seats; the brake systems on trains, which have been a significant fire safety hazard in the past; automatic fire control systems in aircraft engines; and so on. This has not been estimated separately.

Virtually all flammable liquids have to be stored in special containers and then often in metal cabinets to reduce fire risk. It would be much cheaper if they could be stored in thin plastic containers such as used for drinking water, or if the flammable liquid containers could be stacked outside of metal cabinets.

Every paint spraying and welding shop not only has to have built-in fire protection features, but the equipment and procedures and processes have to be designed for fire safety too. Many drilling or processes require cooling to avoid starting fires. Many processes involving flammable materials such as paper making and paint production require special design of equipment that doesn't cause sparks, doesn't overheat.

Furnishings in hotels, hospitals, prisons, and other occupancies have to meet fire safety standards required by fire codes. Upholstered furniture, rugs, drapes all have flame resistant standards for non-residential use, and more and more items sold to the general public have fire resistance built into them. While some materials such as wool are naturally fire resistant others are not.

Whole families of plastics have been designed that are fire resistant.

In addition to the added cost of the materials and equipment for fire safety, there is also a large industry for testing materials and equipment to see if they meet fire safety standards and resistance to other hazards such as shocks. The Canadian Standards Association, the Underwriters Laboratories of Canada and many other organizations get much of their budget from such testing. (This is counted under miscellaneous costs.)

Cost Estimates —The cost of fire safety built into equipment, furnishings and products in Canada should be quite similar to that in the U.S., since both nations use similar products and equipment, and generally have similar safety principles. Both nations also use a great deal of products imported from abroad, and they must not only meet our standards, but often have even more stringent standards of their own. The consumer pays for the built-in fire safety in the price of product and services.

No one has a good estimate for the total cost of fire protection built into equipment and products. It is the most nebulous part of the total cost of fire at present, and requires a major study of its many components. A very rough estimate of the cost of built-in fire protection was made by Meade (1991) for the total cost of fire in the United States. Meade estimated that the price premium paid for fire grade design of products used in "Industrial Equipment" and "Information Processing and Related Equipment" ranged from 20 percent to 20 times the cost of a non-fire rated product. He estimated that 30 percent was a reasonable overall factor for fire-grade design, applied to 40 percent of the above categories of equipment, which gave an estimate of $18B for the U.S. This assumes that electrical codes are fire-related. To this, he added $2.5B in fire retardants added to products. Hall (1992) thought these estimates were high, and were based on interviews with the most fire-safety conscious representatives of industry, but did not provide alternative estimates. They also implicitly include as fire safety costs much that could be considered as needed for electrical (shock) safety. Meade's estimate may be high by a factor of 2-10.

If Meade's estimates are scaled to Canadian dollars and population, and if we discount half of his estimate for a lower bound, then the estimate is (.5 - 1) x .1064 x 1.33 x $20.5B = $1.5-2.9B. We will use $2.0B as a best estimate.

Because the estimate was a very rough estimate and seems high, we will assume that it includes the fire safety built into cost of military equipment, bases, and transportation systems, but it should be noted that these are significant contributors when making a new estimate at a later time.

Cost of Fire Safe Operations and Training

None of the previous studies of the total cost of fire have considered all of the costs of operations and training attributable to fire safety in addition to the costs of fire safety built into products. The cost of manufacturing something without attention to fire safety versus the cost of how it is done with fire safety in mind would represent the incremental cost from fire safety considerations. The petroleum and natural gas industries spend enormous amounts of time and money in preventing fires not only by building safety into structures and equipment and in checking for leakage, as discussed in the previous chapter, but also in safety procedures for their personnel.

Many industrial processes involving flammable materials have to be conducted in smaller quantities for fire safety, causing diseconomies of scale. The handling of liquid sodium, phosphorus, and even gasoline are examples. The transportation of flammable products is restricted by types of carrier, quantity and packaging, which increases the price to the consumer. The size of gasoline and gas storage tanks are limited by safety concerns (and hence have less economies of scale than they otherwise would.)

There are many person-hours spent on fire drills in businesses and institutions. Additional time is spent by workers evacuating buildings in response to false alarms. Interviews with Canadian occupational safety specialists suggest that a typical office worker probably spends a half-hour on one fire evacuation drill each year and another half hour to one hour disrupted by a false alarm. A small number of employees (perhaps 1 in 10) are designated as floor wardens or members of emergency response teams, and may have 4-6 hours of safety training per year. Thus office workers may average 1.5-2 hours per year on fire safety concerns.

Non-trivial amounts of money also are spent training industrial employees on fire safety — how to prevent fires and what to do if a fire occurs. This may range from basic ideas about escape to sophisticated risk management and loss prevention concepts. Virtually every major hotel chain requires fire safety training for its employees on how to help the guests evacuate and how to extinguish small fires. Guards monitor industrial and office buildings for fire safety as well as to deter crime. Gas distribution company personnel typically spend one day every three years on annual safety refreshers (or 2 hours per year). Gas transmission company personnel typically attend a one week safety course every 5 years, or an average of 8 hours per year, including a disaster drill. In the auto industry there may be a half-hour per employee per year spent in class on fire safety and another 1-2 hours for hands-on fire extinguisher training. Members of in-house fire/or emergency response teams may receive 8 hours per year, but comprise less than one percent of the workforce.[1]

To show how the numbers can add up, assume that 10 million of the 13 million workers in Canada are in offices, manufacturing, or other industry (exclude transportation, farming and some others) and assume that each spend 1.5-2 hours a year on fire safety drills, fire safety training, or other fire safety-related concerns, or that their efficiency is reduced by up to two hours because of fire safety constraints. For some workers it be will vastly more than this, and for some it is nil. Assume an average loaded wage (benefits, overhead, etc.) of $20 an hour for this time. Then 10M x (1-2) x $20 = $200-400M a year would be spent on fire safety operations and training.

Meade included fire safety training, fire brigades, and worker time spent on fire safety as part of his estimates of fire protection maintenance. His "fire maintenance" estimate scaled to Canada was shown to be $.87B in Chapter 3. Of that, we estimated maintenance of fire protection systems at $0.2B, leaving $.67B as his estimate for fire safety training, fire brigades, and effect on operations.

We will estimate the range for the cost of fire-safe operations and training at $0.2-0.4B, with a best estimate of $.3B.

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1 Based on interviews with the Industrial Fire Safety Association — Labour Canada, Fire and Property Protection Branch, and safety officials in several industries.

Overall Estimate

The cost of fire safety built into equipment was estimated at \$1.5-2.9B, with a best estimate of \$2.0B. The cost of fire safety training and time spent on processes and operations because of fire safety concerns is estimated at another \$.2-.4B, with a best estimate of \$.3B.

The overall estimate is then \$2.3B, with a range of \$1.7-3.3B.

Recommendations

1. *Undertake a series of mini-studies to estimate the cost of fire safety for different types of products.* Those mentioned above are a starting point. The studies should consider: fire safety of transportation; fire safety of industrial processes; fire safety of consumer products; and fire safety of active building systems (electrical, mechanical, heating and air conditioning). (The latter costs would be added to the built-in fire protection of structures.)

2. *Undertake a study of the cost of fire safety built into military equipment.* This should include vehicles, ships, planes, weapons, and bases (other than personnel, fire departments, and buildings, which are accounted for elsewhere).

3. *Undertake a sample survey of at least 100-200 people in office settings and industry to determine the staff time spent on fire safety.* They might be asked how often they have fire drills, how often are there false alarms, what fire safety training they have, and any other aspects of their time spent on fire safety-related issues.

4. *Survey industrial safety managers on the time spent on fire safety issues in their industry.* A survey of company safety representatives might be undertaken through

the membership of the Canadian Industrial Safety Association. They can be queried on training given to employees and any special constraints or expenses for fire safety of operations and transportation.

CHAPTER 6. INSURANCE OVERHEAD

Another significant part of the total cost of fire is the cost of providing fire insurance — the cost paid by the public for insurance less what is returned to the public in payments for insured losses.

Simply put, insurance works as follows: households and businesses pay insurance premiums on a regular basis to protect themselves from large losses from fire and other hazards. Insurance companies invest much of the premiums and make money on the investments. They also use part of the premiums to pay for their overhead and profits.

In some years insurance payouts are a larger percentage of premiums than in other years. This may occur when actual losses exceed expected losses and premiums were set at too low a rate, or when premiums are held down by regulation or competition. Both of these situations have existed over the past several years, and as a result, the portion of insurance premiums attributable to overhead and profits is much lower than it was a decade ago. Nevertheless, whether the insurance companies make money or not, the public pays premiums that include overhead as part of the cost of fire protection.

The costs to the public for having fire insurance protection is at least the difference between the premiums paid and the payout. One might also argue that there is an opportunity cost that should be added for the earnings foregone on the part of premiums not returned as payouts, or that are returned with a delay. However, the opportunity cost will be ignored here, since one generally does not compute the opportunity costs for medical expenses or other costs of fire protection.

Unbundling Fire Insurance

Most homeowner household polices and business insurance in Canada are "multi-peril" (or "multi-hazard"). They cover fire, theft, wind damage and many other hazards. Canada's national insurance industry organizations told our researchers that estimates were not readily available for the portion of premiums attributable to fire insurance, nor was an estimate of the total payout for fire-related losses.[2] What is available and published annually is the ratio of premiums to payouts for property losses of all types. If one makes the assumption that the overhead and profits attributable to fire insurance are generally similar to those of property insurance taken as a whole, then one can use the ratio of total property loss premiums to total losses as a surrogate for the ratio of fire premiums to fire losses. Using this ratio, one can scale up fire losses to estimate fire premiums, and then compute the difference between premiums and payouts for fire insurance. That is the approach used here and by several other studies of total cost of fire protection (Quebec, Meade, Hall).

The assumption that the ratio for fire premiums is similar to the ratio for all types of property losses is reasonable. The Insurance Bureau of Canada reported that over 80 percent of commercial property losses and about one-third of residential property losses were attributable to fire. (Residential policies include loss from crime, unlike commercial policies, and crime accounts for about a third of the payouts.)

Insured versus Uninsured Losses, and Direct versus Indirect Losses

Using the above method, the cost of insurance overhead preferably should be computed from insured losses, not from total losses, which include insured and uninsured losses. The insured losses here should include indirect as well as direct losses.

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2 Conversations with Insurance Bureau of Canada, Insurers Advisory Organization (IAO), and Fire Underwriters.

As discussed earlier, a few provinces are reporting primarily insured direct losses (data received from insurance companies) in their direct dollar loss, while most others report a mixture of fire department and insurance company data, and some just fire department data (see Table 2-5). Estimates of the uninsured losses were on the order of 5-10 percent of the insured loss. Some and perhaps much of that loss is reported by fire departments. On the other hand, much of the fire department losses are underestimated by an average of 25 percent.

Direct losses excluding woodlands losses were estimated at $1.55B in Chapter 2. Indirect losses were estimated at $.1-.4B in Chapter 7. Assuming that 5-10 percent of the direct and indirect loss is uninsured, then insured fire losses are about ($1.65-1.95B) x (.9-.95) = $1.5-1.85B.

It would be much preferable to obtain an estimate directly from the insurance industry of the ratio between direct and indirect fire loss payouts, or better yet the dollars paid out for the two different categories. Surely this information exists in individual insurance companies, though we could not find a source for the entire industry. Alternatively, a sample of claims could be examined to estimate indirect losses.

Overhead Estimate

Data on the insurance payouts and premiums for all property losses for 1992 are shown in Table 6-1. The first two data columns in Table 6-1 are from *Canadian Underwriter* Magazine, June 1993. The June issue each year contains the annual summary of premium and loss data provided by The Insurance Bureau of Canada. The third and fourth columns were computed from the first two.

TABLE 6-1. INSURANCE PREMIUMS AND PAYOUTS — ALL RISKS (1992)				
	Earned Premiums	Loss Payouts	Premiums ÷ Payouts	Payouts ÷ Premiums
Commercial Lines	$1.95B	$1.6B	1.22	.82
Personal Property Lines (Households)	$2.70B	$1.96B	1.38	.73
TOTAL	$4.65B	$3.56B	1.30	.77

Now, if payouts ÷ premiums is .77, then the overhead portion of premiums is (1-.77) = .23 (i.e., 23 percent).

The insured fire loss for 1991 was estimated above at $1.5-1.85B. Assume that about 10 percent of the loss was deductible or not allowed. Then the estimated fire-related premiums were
($1.5-1.85B) insured losses x 1.3 (premiums/payouts) x .9 = $1.76-2.16B, and the fire-related insurance overhead was .23 x ($1.76-2.16B) = $.4-.5B. The degrees of underreporting of losses, the estimated indirect losses, and the deductibles are relatively soft numbers, so we will be conservative and estimate insurance overhead for 1991 at $.4B, with a range of $.4-.5B.

Trends

There has been a major change in the premium/payout ratio over the last decade. Whereas payouts used to be about 50 percent of premiums, they are now closer to 75 percent. This means that the part of the total cost of fire attributable to insurance overhead has decreased significantly. Competition, regulation, large spot losses, and high overall losses probably are major factors in the change in the ratio.

Consider the insurance overhead for the five years 1988-1992, rather than just 1991. Property loss premiums over this period totaled $21.8B, and payouts $15.4B.

Then the premium/payout ratio was 1.41, the payout/premium ratio was .707, and the overhead/premium was .293. The five-year unadjusted average fire loss was $1.23B (nearly the same as the $1.24B loss in 1991). Then the five-year average annual fire-related premiums would be $2.1–2.6B, and the overhead portion was $.6–.8B, much higher than the .4–.5 range estimated for 1991 above.

Furthermore, even the high five-year average was lower than the average for the whole decade: A rule of thumb for the industry was said by IAO to be 22–35 percent for the retained portion of premiums, or 65–78 percent for the payout. The commercial lines had weak performance in 1991. If this rule of thumb is true, then the longer term premium to payout ratio must be 1.28–1.54.

The unadjusted average loss over the decade 1982–1991 was $1.28B. With the same assumption as above, the insurance overhead would have been $.7–.10B; that is, over the past decade the insurance overhead could have been almost double what it was in the early 90s.

Recommendations

1. ***Undertake a small study of the direct losses paid for fires, and the approximate ratio between indirect and direct losses paid for fires.*** This study can be undertaken by the insurance industry or independently. A sample of fire victims from the commercial, industrial, and residential sector should be surveyed to tally how much was paid by insurance companies for each fire, divided into direct and indirect losses. This victim study also could determine the percent of the losses that were insured, the magnitude of indirect losses, and the amount deducted or unallowed. This is one of the high priority studies to consider.

CHAPTER 7. INDIRECT LOSSES FROM FIRE

The aftermath of almost every fire results in additional time lost and out-of-pocket expenses above the value of the property damaged in the fire. Indirect losses range from the cost of living in motels or using temporary office space while homes and offices get repaired, to losses that can go into the millions of dollars from business interruption.[1]

Indirect Losses For Businesses

Indirect costs of fires experienced by businesses include renting office space or equipment for the short-term while one's office or plant is being repaired or rebuilt; restoring computer files; paying salaries while people are not producing; demolition costs; loss of goodwill, records and other factors affecting sales; loss of drive-in business, loss of rent from tenants; and many other costs. Indirect costs can go on for weeks, months or even a year for major facilities. There also may be losses of clients and business because people do not know you are still operating, principals of the business are involved in spending time restoring the business rather than marketing, records are lost, key employees leave, etc. Typical fire insurance or multi-peril policies include coverage for some indirect losses, but rarely would they cover all of the indirect losses, especially the more intangible ones.

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1 The term "business interruption" costs sometimes includes the variety of costs needed to keep a business going after a fire occurs, and sometimes only the loss of business or loss of profits not later made up when the business opens again (if it does reopen).

A particularly disastrous type of loss is loss of market share. One well known example followed a major fire in the Phillips petrochemical plant outside of Houston, Texas. The company was said to have lost hundreds of millions of dollars of business because it produced a large share of the world's supply of a particular type of plastic, and other businesses successfully took over some of their clientele on a long-term basis when that plant could not meet the demand while they were rebuilding.

At the national level, losses to one business in Canada may be made up by other businesses in Canada unless the business is lost to companies in other nations (which was in part the case with the Phillips plant).

A fire in Alberta that resulted in a $50 Million loss in a plant involved in oil shale extraction was claimed (in court) to have led to $1 Billion in business interruption and loss. Alberta has had three fires of that magnitude over the past 20 years. Having one or two fires per decade of that magnitude leads to an amortized annual business interruption loss of $.1 -.2B average per year — and that is one province.

The loss of business and plant shutdowns for weeks or even months can devastate the economy of a "company town" or any community in which a significant amount of the jobs and money flow from the damaged industry. (That also suggests that strong fire protection measures should be taken to protect hazards that affect the well-being of the whole community.)

A small town (pop. 1200) in Saskatchewan suffered a fire loss to a farm implement dealer that was a key industry of the town. The fire caused the loss of 23 jobs, with half of those people and their families leaving town. Other businesses in town lost revenue from people who no longer came to visit the dealership, plus the loss of expenditures by the dealership and its employees. Some of the people who left town abandoned mortgages, which together with the loss of the dealership account and reduced business caused a local bank office to close, with a loss of three more jobs. The fire started a chain of events that could lead to the death of the town.[2]

Some types of business interruption involve not only the business that has the fire but other businesses dependent on it. Perhaps the most common examples are fires involving electric utilities or telephone companies. Large numbers of workers may be sent home from many industries when utilities fail. Some of the business lost is not really lost but rather deferred demand that builds up and gets met when the utility operation is restored. However, there often are losses to hourly workers who are not covered when their company closes when electricity or phone service fails. When telephones go down, carry out pizza parlors lose irreplaceable business. Stock brokers may or may not have real losses. But there are "frictional losses," as the economists say; not all the business lost is made up.

Fires also can bring business to a community, reducing losses at the community level. Insurance expenditures may flow into a community to buy materials and services to restore properties that have fires, and create a net positive income flow to the community as a result of a fire. Fires also can eliminate a non-productive property. Extreme examples are war time damage such as suffered by Germany and Japan, requiring their industry to rebuild more efficiently, and more than make up for the damage over the long run. Arson for fraud is often stimulated by the desire to eliminate a failing business.

Fires often have the effect of redistributing wealth rather than necessarily causing a net loss at the national level. But the costs and interruptions are almost always ones that people involved would prefer not having had to pay, so the indirect losses can be taken as a social indicator of the costs of the fire, even if they do not net out as large as they may seem.

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2 From *Saskatchewan —Fire Loss and Prevention Strategy,*" Appendix A, pp. A3-A4, FCB, March 1993.

Estimates of Indirect Business Losses — One approach to estimate indirect losses to business is that used in the 1993 revised estimate of the total cost of fire in the U.S., by Dr. John Hall of NFPA. He looked in detail at 109 fires in firms in the "highly protected risk portion of the insurance industry," and for which information on indirect losses was available in the NFPA database. From this sample he estimated the percentages in Table 7-1.[3]

TABLE 7-1. INDIRECT NON-RESIDENTIAL LOSS AS PERCENTAGE OF DIRECT FIRE LOSS (HALL, NFPA, 1991)

Manufacturing and Industrial Properties	65 percent
Public Assembly, Education, Stores, Offices	25 percent
Storage, Special Structure, Residential	10 percent
Vehicle and Outdoor Properties	0 percent[4]

Another view of indirect losses comes from data of the Insurance Bureau of Canada, which showed that the ratio of Business Interruption premiums to Property Damage premiums in 1992 was about .07. If premiums reflect actual losses, then Business Interruption losses paid by insurance companies are about 7 percent of direct business losses.[5] Property losses here included losses from fire, water, wind, hail, vandalism, and some other causes. Since fire losses comprised 82 percent of commercial property losses (in 1992), they should dominate, and the ratio of business interruption loss to direct losses for fires alone should be fairly close to the ratio for all types of losses. However, business interruptions do not include all indirect losses, nor are all business interruptions paid by insurance companies so the 7 percent is a lower bound.

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3 Hall (1991) op. cit, p.3

4 The zero loss here is somewhat questionable and may have resulted from the small sample used, in which there were no or few vehicle fires, since loaner vehicles or rental cars are often allowed for damaged vehicles, and are an indirect cost. Also, Hall did not distinguish lost business with business interruption expenses, but that did not affect his evaluation.

5 Private Communication, Tom Logie, Insurance Bureau of Canada, June 1994. For 1992, Business Interruption Premiums ÷ Commercial Property Damage Premiums = \$13M/\$190M = .07.

An experienced member of the Insurance Adjusters Association of Canada agreed that the insured business interruption was a lower bound to total business interruption costs.[6] He has found that the indirect costs to other businesses affected by a fire in business "A" are often of the same order of magnitude as the business interruption loss of business "A" itself. Often the secondary business interruption losses are not insured, and not recorded by insurance companies. (To save money, many businesses today are insuring for only a limited amount of extended costs.) Overall, the adjuster's opinion was that indirect losses from a business fire probably averaged about 10–15 percent of the direct loss, not 7 percent.

We also received data from a very small sample (12) of non-residential structural fires in Ontario that were part of a previously discussed sample of 100 structural fires. Two of these fires had indirect losses reported; the rest had either zero indirect loss or no information on the indirect loss. Depending on how the latter cases are treated, the indirect losses were 8.6–25.0 percent of the direct loss.[7] A similarly small sample of 17 fires from Manitoba yielded a range of 6.3 to 8.4 percent.[8] Combining the two sources, the indirect loss was 7-15 percent.

Using the Hall percentages in Table 7–1, the Canadian non-residential indirect business loss for 1991 would be $164M. Using the adjuster's estimate of 10–15 percent of non-residential loss yields $68–102M. To these estimates we add $50–100M per year for the amortized indirect losses from the few very large fires (1–3 per decade) that have very large indirect losses. We therefore estimate the range of indirect losses from non-residential structure fires as $.12–.26B,and the best estimate as $.2B.

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6 Conversation with Glen Gibson, Adjusters Canada, June 1994.

7 Mini-study undertaken by Mary Prencipe, Ontario Fire Marshal Office, October 1994.

8 Mini-study undertaken by Louise Hornbeck, Manitoba Fire Commissioner's Office, October 1994.

Indirect Losses For Residences

For most residential fires, the indirect losses tend to be small relative to the cost of the fire. Most residential fires do not totally destroy a home. Occupants must leave long enough for smoke to be cleared out, windows boarded up, stairs at least temporarily repaired, etc. Often this requires several days in a motel, or with friends or relatives. If a car is damaged, then a rental car may be needed. But in the majority of fires in homes, people tend to occupy the non-damaged parts of the home within a short time after the fire.

An experienced Canadian adjuster estimated that indirect losses from residential fires probably ran no more than about 5 percent of direct losses.[9] The Insurance Bureau of Canada actuaries and a highly experienced U.S. insurance agent and others agreed that residential indirect losses were proportionately less than commercial indirect losses, on the order of 1-5 percent.

Hall (1991) estimated that indirect losses from residential fires were approximately 10 percent of direct losses, based on his analysis of a 1980 USFA report on indirect costs of residential fires.[10]

To get some actual data on indirect losses, the Ontario Fire Marshals' office drew a sample of 100 fires for which they had insurance adjusters reports. [11] Of these 100 fires, 82 were residential fires, mostly detached dwellings, and small multi-unit dwellings. Of the 82 fires, 30 had an indirect loss specifically reported. The rest had a blank, and it

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9 Private communication, Glen Gibson, Adjusters Canada, June 1994.

10 Michael J. Munson and James C. Ohr, *Indirect Costs of Residential Fires*, FA-6, Federal Emergency Management Agency, Washington, DC, April 1980. (This study was undertaken under the direction of the author of the present report.)

11 Mary Prencipe of the Ontario Fire Marshal's Office kindly drew the sample for this mini-analysis in October 1994.

was unclear whether these should be considered as having zero indirect loss or no information on the indirect loss (the insurance companies are not asked to report indirect losses to the provincial commissioner, and therefore are not given any guidelines for doing so, at least in Ontario). If only the fires with some reported indirect loss are considered, the indirect losses amounted to 4.2 percent of direct. If all of the fires were considered, the indirect losses would be 3.5 percent, for a range of 3.5–4.2 percent.

A second mini-study was undertaken by the Manitoba Fire Commissioner's Office.[12] Again a sample of 100 fires was drawn from fires for which insurance adjusters reports had been submitted. Of the 100 fires, 83 were in residential properties. Of these 83, 36 had the indirect loss specifically reported, and the rest had a blank. Following the same procedure as above, the indirect loss was 3.7–4.5 percent, quite similar to the Ontario data.

Based on the above data, we estimate the range of indirect residential losses as 4–10 percent, and thus (.04–.1) x residential direct loss = $28–56M for 1991, with a best estimate of 4 percent, rounded to $30M.

Other Indirect Costs

Legal Costs — While Canada has not yet become as litigious as the U.S., the number of law suits involving fires is reportedly increasing. At least one nationally known attorney in Canada now is specializing in nothing but fire-related lawsuits, and has written a book on fire-related litigation that is likely to stimulate more litigation as well as being a harbinger of it. Several law firms in Quebec have about one-third of their business associated with fire-related suits.

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12 Louise Hornbeck, Manitoba Fire Commissioner's Office.

Legal expenses connected to fire protection exist both in preparing for the eventuality of fires and dealing with the aftermath of a fire. Businesses have to plan for their potential liability, and many have at least partial coverage for liability arising from fires as part of their comprehensive insurance coverage. Attorneys for firms that purchase products likely to be involved in fires must also help these firms plan courses of action to lower their liability. Hotels, petrochemical manufacturers, electrical equipment manufacturers, heating equipment manufacturers, and many others know that their product or services will be involved in fire sooner or later, and are spending considerable amounts of money with attorneys to plan for that eventuality, in addition to spending money to reduce the likelihood of their product or service being involved in a fire.

Once a fire occurs, especially where there are injuries or significant business interruption, there may be lawsuits. In the U.S., lawsuits involving high-rise fires and hotel fires can run into the hundreds of millions of dollars. The largest fires can involve billions of dollars of claims and tens of millions of dollars in attorneys fees. Much also is spent on expert testimony. Litigation costs have not exploded in Canada as they have in the U.S., but it may be coming.

We found no source that could yield even an order of magnitude estimate of litigation associated with fires in Canada today. Commercial liability insurance mostly deals with warranties, pollution, and non-fire liability. Alberta's previously mentioned $50M fire involving tar sands oil extrication led to a $650M lawsuit. There is an expectation of 2-3 of these large loss fires per 20 years in Alberta alone. Canadian lawyers tend to work on hourly fees rather than taking cases on a contingency basis. We estimate $5-20M average per year for legal fees relating to fire safety. As in some other places in this report, the estimate is a marker for entering a refined estimate in the future.

Environmental Impact of Fires and Fire Protection — There can be major damage to the environment from a fire. Only in the last decade are these damages being fully recognized, and there is no good way yet to make overall estimates, though anecdotes suggest that the economic impacts can be large from even a few fires that damage the environment.

Environmental damage can be caused by polluting the atmosphere with the products of combustion of the fire, or polluting the ground or water supply with the run-off of chemicals from a fire, often from water sprayed on the fire. Sometimes one type of environmental damage is accepted to prevent even larger damage from another impact: in Dayton, Ohio, a large Sherwin-Williams paint warehouse was allowed to burn to the ground with over $30M (U.S.) loss rather than applying water to the fire that would have produced a run-off that would have contaminated much of the water supply of the City of Dayton. The atmospheric pollution from what was burning was deemed minor compared to the potential damage of the runoff. The other extreme was the Basle, Switzerland chemical plant fire in which run-off of pesticides and products of combustion went into the Rhine River and destroyed all life in it for 500 miles — an enormous environmental disaster.

Fire protection systems themselves may have caused major environmental damage: halon, widely used to protect electronic equipment rooms and in many military applications, has proven to be extremely damaging to the ozone layer of the environment and has been banned from production. The release of halon is thought to have contributed to the a hole in the ozone layer that has been thought to have increased the incidence of skin cancer and to cause other effects that are almost incalculable. There also is an enormous cost being borne by converting existing fire protection systems from halon to other substances, which should be reflected in the fire protection equipment market discussed as part of the built-in fire protection systems. (A question for the future is what portion of the fire protection market can be attributed to conversion of systems rather than installation of new systems?)

Even the first order estimate of environmental impact would require its own study. This should include the added health risks to firefighters as well as civilians.

Tax Losses or Gains — Part of the indirect costs of fires is the loss of tax revenues when businesses are interrupted, or buildings are destroyed. The extent to which there is a net loss depends on how much of the business gets picked up by other suppliers, and whether new properties or valued added by repair to damaged property leads to more valuable properties that pay higher tax rates in the long run. At the national level, there may not be much tax loss as a result of fire, but at the province or local level, there can be huge displacements if businesses are rebuilt elsewhere, or businesses out of the province or local community pick up the demand. Whether there is a net tax loss or gain as a result of fires is a subject for future studies.

Overall Estimate

The indirect loss estimates are summarized in Table 7-2. These are probably conservative estimates, and include nothing for environmental impacts of fire or tax losses, nor for other indirect losses not discussed here. The best estimate is $0.3B per year.

TABLE 7-2. INDIRECT FIRE LOSSES

	Best Estimate ($B)	Range ($B)
Non-residential	$ .2B	$.12-.26B
Residential	.03	.02-.06
Other (including legal costs and settlements)	.05	0-.1
TOTAL	$.3B	$.1-.4B

Recommendations

1. *Estimates for indirect losses should be obtained from insurance company sources for a representative sample of residential and non-residential fires.* Alternatively, as discussed earlier, a sample of residential and non-residential victims can be drawn to identify the same information.

2. *A survey of a sample of businesses with fire losses should be conducted to identify their total losses, insured and uninsured.*

3. *Further research is needed to estimate the magnitude of indirect fire losses from environmental impacts, tax losses, and legal costs.*

CHAPTER 8. DEATHS AND INJURIES

The total cost of fire can be stated as the sum of all of the above economic costs, with the human cost in terms of injuries and deaths treated as separate numbers. But in many cost-effectiveness studies, a dollar value is attributed to each injury and death to make the various losses commensurable to compute a total cost. Many people find it odious to put a dollar value on an injury or death, and life valuations can be quite arbitrary. But if for no other reason than this has been done in many other studies of national problems, and also has been part of the total cost of fire cited for the United States, we include estimates of the costs of fires, injuries, and deaths in this section.

Conceptual Issues

Injuries — Fire-related injuries vary from the minor smoke inhalation or burned finger cases to the most serious, painful injuries that can be imagined, in which a large percent of the body or the face or hands are severely burned. Fire-related injuries often are disfiguring. Fire injuries to children have not infrequently caused families to break up over the guilt involved and the difficulties of raising a disfigured, handicapped child. The medical costs of restorative operations can be staggering.

Injuries to firefighters as well as civilians should be considered. Unreported injuries as well as reported ones should be considered.

There are major differences in how various economists and others have viewed the costs of injuries and deaths. Injury costs at a minimum are the medical costs of treating the injury. More broadly, they have been taken to include lost wages, and a cost for the pain and suffering of the injury, or what someone would pay not to have the injury. These non-tangible costs are often established by looking at court awards involving litigation, which tend to be inflated by concepts of punishment and by jury feelings about the deep pockets of corporations who are often the ones sued.

Deaths —The economic value of a person killed in a fire can be estimated in terms of future earnings, taking expected life into account, plus the medical treatment of the injury and the cost of the funeral. Another approach is to place the same value on all individuals regardless of their economic history and age. It is simpler and less befuddling to the users of these statistics if a constant amount is used per death (and per injury) rather than trying to get into details with each individual casualty. It also seems somehow more tasteful.

U.S. vs. Canada Estimates —Should there be a different value placed on a Canadian injury or death compared to one in the U.S.? The medical cost of treating an injury in Canada generally is much less than in the U.S., because of the differences in the medical care system and medical insurance, and the different amounts and results of litigation. Much of the "cost of injury" in U.S. studies is the intangible amount attributed to the suffering rather than the medical cost. While the costs of treating a particular severe burn injury can easily get into the tens of thousands of dollars, or even hundreds of thousands, most injuries from fire don't require that level of treatment.

For purposes of comparing the cost of Canada's fire-related deaths and injuries to the cost of other social problems in Canada, it seemed useful to consider the costs of injuries used in other Canadian studies, especially automobile injuries, which have received much attention though the average automobile accident injury may not cost the same as the average fire injury. On the other hand, it also is desirable and likely that the Canadian costs will be compared to those of the U.S., and it seems inappropriate to have the comparison biased by different values put on a Canadian life versus a U.S. life.

It happens that there may be a simple way out of this dilemma: the range of estimates of injuries and deaths used in different Canadian studies is broader than the range used in the studies of the total cost of fire in the U.S. We therefore will use the same values for deaths and injuries used in the NFPA/Hall study in computing the cost of the deaths and injuries in Canada. The tables below show the ranges that result from using estimates from different sources.

Cost Estimates

Medical Costs of Injuries — There do not seem to be any previous complete estimates of the total "economic" cost of Canadian fire injuries. The only estimate we found was the in-hospital cost of severe fire burns. There do not appear to have not been any estimates of the costs of an average injury from a fire. But there is some information from which one can develop a minimum estimate. Even though the medical cost will turn out to be a small part of the ascribed cost of the pain and suffering and lost work time from an injury, the medical cost represents a less arguable minimum and is of some interest.

Data gathered by the Ontario Ministry of Health in 1989 found that 51 hospitalized burn victims from residential fires had an average in-hospital bill of $25,800 excluding physician billings, aftercare, etc. They totaled $1.3M. The total lifetime care cost at present worth would easily be much more than these figures, certainly over double.[13]

The burn ward of one hospital in Saskatchewan averaged 90 patients per year from fires, at a cost of $1.3M per year for 1989-1991, or $14,400 per patient.[14] A

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13 Letter from Maris Gailitis, Ontario Ministry of Health, to Mary Prencipe, Office of the Fire Marshal, Ontario, December 12, 1991.

14 "Saskatchewan — Fire Loss and Prevention Strategy", Appendix A, P. A5, FCB March 1993.

broader based study of all fire-related injuries requiring acute care hospitalization in Ontario for FY 1992-1993 found the following:

TABLE 8-1. HOSPITAL COST OF ACUTE CARE FOR FIRE-RELATED INJURIES (Ontario, FY 92-93)

	No. of Cases	No. of Days	Total Cost	Cost Per Case
Diagnosis - Burns (ICD 940-949)	347	5054	$4,931,553	$12,700
Other Diagnoses	187	1616	785,463	4,200
TOTAL	534	6670	$5,177,016	$9,700

Notes:

These figures include all hospitalizations for which an E-code in the range #890-899 (Accidents Caused by Fire and Flames) was recorded. A distinction is made between cases where the most responsible diagnoses were "burns" (ICD9 940-949) and "Other Diagnoses." The most frequent occurrences in the "Other" category were: ICD9 987.8 (Toxic effect of other gases, fumes or vapours: other): 46 cases; and ICD9 987.9 (Toxic effect... unspecified): 52 cases). It was not possible to identify diagnoses connected with "respiratory distress."[15]

In Ontario, the health care system reported for a recent year a total cost of $4.8B for patient hospitalization and another $3.8B for physician billing. About half of the physician billing is for hospital care and that is split about 50-50 between in-patient and out-patient care. So the fire-related inpatient charges are about another 50 percent of the hospital charges. To that must be added a series of out-patient or private office visits for follow-up care.

Ontario had 1800 fire injuries reported to its Fire Commissioner in 1991, but the hospital system had only 534 cases related to fires (some of those may be repeat visits

15 Letter from Maris Galaitis, Ontario Ministry of Health, to Jeffrey Stern, TriData, November 24, 1994.

for injuries in fires prior to 1991, but that number should be small). Thus at least 1300 people were treated as outpatients, and possibly twice that many if people injured in fire not reported to the fire service were counted. Out-patient emergency room treatment averages about $500 per patient. Office visits can be $50–60 or more for emergency cases and consultations. Assuming half the fire victims are first treated in an emergency room, and that they and others have 2–3 office visits for their injury, then there is a medical cost of at least $600–1,000 per non-hospital case, and possibly more when medicines, bandages, etc., are factored in.

Assuming that the Ontario experience is typical nationally, we make the following lower-bound estimates for medical costs: of the 3,476 injuries to civilians and firefighters in 1991, about one-third require hospitalization, with a bill averaging $15,000 for in-hospital care, or $17M. The other injuries reported plus unreported injuries, total about 5,000, and may average $1000 per patient. The hospitalized patients generally require extensive follow-up visits, too. So the total medical cost is perhaps $25–30M. Since there are many charges absorbed by hospitals in Canada and not allocated fully to the higher users of equipment and services, which burn patients surely are, the true cost is probably substantially higher than this —perhaps closer to $50M per year.

We did not add into the medical cost above an estimate for the medical costs of the 388 people who died, at least some of whom would have received intensive medical care before succumbing.

Table 8–2 shows the fire-related deaths and injuries reported for 1991 and the 10-year average for the decade ending 1991. Included are civilians and firefighters.

TABLE 8-2. FIRE DEATHS AND INJURIES IN CANADA		
	10-Year Average (1982 - 1991)	1991
Deaths	555	388
Injuries	3,856	3,476

Table 8-3 shows the estimated cost of fire deaths and injuries using valuations from the NFPA/Hall study, and the costs of deaths and injuries estimated from two viewpoints in a Quebec study of auto accidents. The higher value in the Quebec study is essentially how much people say they would pay to save a life. The lower value is essentially what has been paid out in auto accident lawsuits in Canada.[16] These costs may be interpreted as including medical costs and funeral expenses and associated legal expenses, since they are so high relative to just the medical costs.

TABLE 8-3. ESTIMATED COST PER LIFE AND INJURY				
	Deaths		Injuries	
	U.S.$	Canadian $	U.S. $	Canadian $
NFPA/Hall Study[17]	$1.5M (1987 dollars)	$2.4M (1991 dollars)	$35,000 (1987 dollars)	$56,000 (1991 dollars)
Quebec Study[18]				
S.A.A.Q. "economic" method		$.425M		$22,400
S.A.A.Q. "statistical" method		$3.560M		$77,000

16 As noted earlier, the relative severity of vehicle accident injuries compared to fire injuries was not examined here.

17 We used the Canadian Price Index ratio for 1987 to 1991, 126.2/104.4, and 1.33 Canadian dollars per U.S. dollars, to scale Hall's 1987 data to Canada for 1991.

18 Bertrand Bordeleau, Évaluation des Coûts de l'insécurité routière au Quebec. Société de l'Assurance automobile du Québec, juin 1992. Cited in Economic Cost of Fire, Government of Quebec, Nov. 1993.

Using the approach selected by Hall, and with dollars converted to Canadian 1991 dollars, the costs are as shown in Table 8-4.[19]

TABLE 8-4. ESTIMATED COST OF REPORTED INJURIES AND DEATHS			
	Injuries	Deaths	Total Cost
1991	$.20B	$.93	$1.1B
10-Year Average	$.22B	1.33	$1.6B

Unreported Injuries —A 1984 survey in the U.S. found that there were 9 civilian fire injuries for every one reported.[20] Most of the unreported injuries, however, were minor, adding 4-14 percent to the cost of reported injuries. An earlier study circa 1973 had found that about half the fire injuries that caused lost time from work were not reported.[21] We are not aware of a similar study for Canada. Deaths should be close to 100 percent reported and no adjustment is made for their unreporting. We suggest adding 10 percent to the direct costs of injuries to cover unreported injuries. Another approach to the unreported injuries is to assume their severity is like the non-hospitalized reported injuries, which is what was assumed in estimating medical costs.

Total Cost —With 10 percent added for underreporting, the best estimate of the cost of fire-related injuries and deaths is $1.2B for 1991. If the range of costs per death

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19 A newer U.S. study discovered late in the present study is "Estimating the Costs to Society of Smoking Fire Injuries," Ted Miller, et al, National Public Services Research Institute report to Consumer Product Safety Commission, June 1993, CPSC-C-93-1118. It found that the cost of a fatal fire injury was $2.7M U.S., a hospitalized fire injury $76K, and a more minor injury, $15K. Only 2 percent of the cost of an injury was medical treatment; 77 percent was pain and suffering, 20 percent loss of productivity and 19 percent legal costs. Scaling up the $50M Canadian estimate for medical costs associated with fires in 1991, assuming they were 2 percent of total costs, the total cost would be about $2B, higher than the estimates above.

20 1984 National Sample Survey of Unreported Residential Fires, Final Technical Report, Contract No. C-83-1239, U.S. Consumer Product Safety Commission, June 1985.

21 Survey on unreported fires undertaken for Center for Fire Research, National Bureau of Standards, Gaithersburg, Maryland, circa 1973.

and injury from the Quebec auto accident study were used, the estimate would be $0.2 - $1.6B. If only medical and funeral expenses were considered, the estimate would be much lower, about $.05-.08B.

Trends —The number of fire deaths in Canada and the fire death rate per capita had been high for decades but dropped rather sharply in just the past 2-3 years. It is not clear whether this is a short term statistical fluctuation or reflective of a significant change in trend. We therefore also present in Table 8-3 the ten-year average estimate, as well as the latest year.

Recommendations

1. ***A once in 10 year survey of Canadian households' fire experience should be undertaken to help estimate the unreported injury part of the fire problem, as well as the unreported losses.***

2. ***A special study of the cost of fire-related injuries should be made, to provide a better estimate of the minimum cost of injuries.*** The existing data for in-hospital treatment for burn injuries needs to be supplemented by a study of in-hospital, follow-up, and physician billing for all types of fire-related injuries, major and minor, burns and smoke inhalation and other fire-related injuries.

CHAPTER 9. MISCELLANEOUS COSTS

There are a variety of miscellaneous costs which were not explicitly estimated above in this study.

National and Provincial Fire-related Organizations — In addition to the National Defense fire protection costs, there are other organizations, within the NRC itself (such as the Fire Research Laboratory, and part of the Codes Centre), a portion of other code-making and research agencies, Provincial Fire Offices (excluding their budget for local departments and for forest fires), Underwriters Laboratories of Canada, the Canadian Association of Fire Chiefs, IAFF locals budgets, and others. Meade estimated standards activity alone at \$0.2B (U.S.) in the U.S. We estimate these costs for Canada at \$.04-.07B.

Disaster Recovery — Meade estimated that in addition to fire safety built into structures, there was a major cost for preparing for fire disasters. This includes extinguishing systems built for computer rooms, preparation for backup systems, fire-proof safes and file cabinets, backup files and systems, etc. While some of this may be counted in the fire protection built into equipment and operations and the indirect costs of fire, Meade identified \$0.6B (U.S.) for this category, which proportionately would be \$.08B (Canadian).

Overall — There may well be some categories of costs we omitted. A rough additional estimate for these miscellaneous costs is \$.04-.15B. We will use \$.1B as a best estimate here.

CHAPTER 10. SUMMING UP

The total cost of fire in Canada is the summation of the components discussed above. The totals and ranges from each chapter are presented in Table 10-1. Our best estimate for 1991, the base year used in this study, is that the total cost of fire was over $11B, with a range of $9-14B. Initial indications are that there were higher losses and more construction in 1993, and perhaps a 10 percent higher overall estimate.[1] The year 1991 seems to have been a local minimum versus the late 80s or mid-90s.

The largest component in the total cost of fire is the cost of fire protection built into structures. That merits highest priority for additional analysis to improve the estimate. The fire protection built into equipment and operations is the second largest, but also the least well estimated cost component. It has the most uncertainty, and merits a separate study to take a second look at even the order of magnitude of the estimate .

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1 Add another $.8-1.8B if the fulltime equivalent cost was used for the value of the volunteer fire service.

TABLE 10-1. TOTAL COST OF FIRE — 1991		
	$ Billions	
	Best Estimate	**Range**
Direct Fire Loss	1.7	1.5-1.8
Fire Services	2.3	2.1-2.6[2]
Fire Protection in Structures	3.3	2.8-3.9
Fire Protection in Equipment, Vehicles, and Operations	2.3	1.7-3.3
Insurance Overhead	.4	.4-.5
Indirect Losses	.3	.1-.4
Human Losses	1.2	.2-1.6
Miscellaneous	.1	.04-.15
TOTAL	$11.6	$8.8-14.3

As a point of comparison, it is useful to consider what the total estimate for Canada would be if one simply scaled estimates made for the U.S. without the deaths or injuries component. One can then add in the cost of the Canadian estimates of deaths and injuries. Another comparison is to extrapolate the estimate made by Quebec, though Quebec's study explicitly stated that it deleted some of the major components of the U.S. estimate because of the lack of a good way to estimate them. The scaled up Quebec estimate of $1.29B (without human losses added in) therefore represents a lower bound. These approaches are summarized in Table 10-2.

2 Add another $.8-1.8B if the full-time equivalent cost was used for the value of the volunteer fire service.

TABLE 10-2. CANADIAN ESTIMATES EXTRAPOLATED FROM U.S. AND QUEBEC ESTIMATES			
	Hall/NFPA	Meade/NIST	Quebec Method
Without Human Losses	$10.7B	$11.8B	$5.2B
Human Losses (Canadian Estimates)	1.6	1.6	1.6
TOTAL	$12.3B	$13.4B	$6.9B

In computing the comparison figures in Table 10-2, the attributed cost of volunteer fire departments was excluded from the Hall and Meade totals as not relevant to Canada's practice. The base Hall estimate (without the attributed cost of the volunteers' time) was then $78B and the Meade total $85B in U.S. dollars.

In this study, the total cost of fire was estimated to be in the range $8.8-14.3B (Canadian dollars). The range obtained by extrapolating the other studies is $6.9-13.4B. Despite the uncertainty in estimating the many piece parts, there is little question that the total cost of fire to Canada is of the order of $10-11B, which makes it a nationally important problem, one that probably is underestimated in its total impact on society.

Follow-on Research Needed

Many recommendations were given in the preceding chapters for specific research needed to refine the estimate of the total cost of fire.

The weakest part of the total estimate of the cost of fire is the cost of fire protection built into equipment, vehicles and operations. It is clearly a large number, but whether it is on the order of $2.3B as scaled from the very rough U.S. estimate, or one-tenth of that, or larger, is unclear. That and some of the other key areas needing further study are listed in Table 10-3. They are rated on a difficulty scale of 1 to 3, with 1 being the easiest (least time to undertake) and 3 the most difficult, in roughly priority order.

TABLE 10-3. HIGHEST PRIORITY FOLLOW-ON STUDIES			
Further Studies Needed	**Dollars at Issue**	**Difficulty Level**	**Comments**
1. Cost of Fire Safety Built into Consumer Products and Vehicles.	$2B	3	The problem is the diversity of equipment. Several categories to focus on are: upholstered furniture, mattresses, plastics, electronics, flammable liquid containers, vehicles.
2. Cost of Fire Safety Built into Building Systems	1B	2	Electrical and heating systems.
3. Cost of Fire Safety Built into Industrial Processes	1B	3	Diversity of industry makes this a challenge.
4. Indirect Losses for Residences and Businesses	.3-1B	1	Can be obtained using a sample of insurance companies and a sample of victims.
5. Underreporting of Fire Departments to Provinces	.1-.2B	1	Survey of a sample of fire departments.
6. Unreported Fires and Their Losses	.1-.5B	2	National survey of a sample of households.
7. Cost of Fire Safety in Detached Dwellings	.2-.4B	2	The largest category of construction with the worst estimate of built-in safety. Important to focus on what is required, and how small relative to other nations.
8. Second Cut at Proportions of Water Supply Attributable to Fire Safety Needs	.1-.5B	2	Need to review the design considerations for large vs. small communities, and identify the proportion of new construction in each.
9. Review of Oil and Industry Capital Investment in Fire Safety	.1-1B	2	Discussion with fire protection engineers in the industry.
10. Analysis of Gas Industry Expenditures on Leak Safety	.1-.2B	1	Further discussion with industry.
11. Sales of Fire Protection Equipment	.3B	1	Further discussion with Canadian manufacturers.

12. Military Investment in Fire Safety (Equipment)	?	2	Discussions with military contractors.
13. Hanscomb-type Study of Built-in Fire Protection for Major Property Classes (other than office and apartment buildings)	.3-.5B	3	Studies for highrise residential and typical office buildings exist. Need extension to other property classes.
14. Estimate of Volunteer Fire Service Expenditures	.2B	1	Sample of budgets from several hundred fire departments because their variance is so large that small samples do not suffice.
15. Further analysis of the medical costs of fire injuries	$.1B	1	Doctor costs, including office visits and all minor as well as major injuries need to be considered.

Note to Readers: *The Fire Research Laboratory of the National Research Council would greatly appreciate receiving improved quantitative or qualitative information on any of the estimates here. The NRC also welcomes the identification of additional costs of the fire problem that were not addressed here.*

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In addition, see the references in the footnotes throughout the text.