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Expected Changes in Fire Damages from Reducing Cigarette Ignition Propensity

Technical Study Group
Cigarette Safety Act of 1984

October 1987

JOHN R. HALL, JR.
National Fire Protection Association

I Mission and Members

The Technical Study Group on Cigarette and Little Cigar Fire Safety was established by Public Law 98-567, the Cigarette Safety Act of 1984, on October 30, 1984. Its mission is to:

"undertake such studies and other activities as it considers necessary and appropriate to determine the technical and commercial feasibility, economic impact, and other consequences of developing cigarettes and little cigars that will have a minimum propensity to ignite upholstered furniture or mattresses. Such activities include identification of the different physical characteristics of cigarettes and little cigars which have an impact on the ignition of upholstered furniture and mattresses, an analysis of the feasibility of altering any pertinent characteristics to reduce ignition propensity, and an analysis of the possible costs and benefits, both to the industry and the public, associated with any such product modification."

Copies of this or any other reports of the Technical Study Group may be obtained from Mr. Colin B. Church, Secretariat, Technical Study Group, Consumer Product Safety Commission, 5401 Westbard Avenue, Washington, D.C., 20207.

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Executive Summary

1. Smoking materials, nearly all of which are cigarettes, are involved in the largest share of fire deaths in the U.S. each year. During 1980-84, smoking-related fires reported to fire departments averaged 281,000 per year, with an associated 1,840 deaths, 4,830 civilian injuries, 2,260-3,790 fire service injuries, and $432 million in direct property damage per year.

2. Smoking-related fire rates relative to the number of cigarettes smoked have been declining during 1980 to 1984 and are expected to continue to decline through at least 1996. Sharp declines in fire rates are associated with recent and projected future changes in the ignitability of upholstered furniture and mattresses/bedding, but declines in smoking-related fires also have occurred and are expected to continue with respect to all other ignited items and properties other than structures.

3. The exclusive use of any of the five tested experimental cigarettes would be expected to reduce these projected losses by sizeable percentages, especially for deaths (relative to number of cigarettes consumed), where even the lowest-impact cigarette would have been expected to reduce deaths by 58% in 1986 (if a change in cigarettes had been implemented prior to that year) and would be expected to reduce deaths by 64% by 1996. The total value of other fire losses (civilian injuries, Version 1 of fire fighter injuries, and direct property damage in 1986 dollars) would have been expected to decline by 41% in 1986 (if a change in cigarettes had been implemented prior to that year) and would be expected to decline by 42% by 1996, again calculated using the experimental cigarette with the smallest impact.

4. Uncertainty exists at several points in these estimates. The greatest points of uncertainty appear to be (a) the models that forecast trends, which are based on only 3-5 years of data and therefore have wide uncertainty limits, and (b) the extension of laboratory tests on experimental cigarettes to fabrics, filling materials, cigarette contact locations, and ignited items other than those tested.

- The brevity of the period used for forecasting and the lack of knowledge as to which factors are driving trends mean great uncertainty in the forecast prediction that smoking-related fires and their losses are likely to continue to decline but also are likely to continue to be major components, in relative and absolute terms, of the U.S. fire problem. Smoking fires could drop to near zero without any change in cigarette design, given that smoking fires have dropped faster during 1980-84 than would have been predicted by the ignitability indexes for the items smoking materials most often ignite. It also is possible that smoking fires could increase dramatically. It is important, therefore, that the conclusions be treated with caution and that actual fire experience involving smoking materials continue to be monitored for agreement with the forecast.
- It is important that any experimental cigarettes considered truly promising for commercial use be tested against a representative range of ignitable items, as discussed in the report, and that a representative range of currently available cigarettes be used to set the baseline. In the absence of such calibration, there is likely to be widespread disagreement over the generalizability of the very limited test results for this analysis.

5. Having noted the seriousness of these uncertainties, it still appears likely that cigarettes can be redesigned to produce large reductions in the smoking fire problem.

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Background and Purpose

The Cigarette Safety Act of 1984 (Public Law 98-567) was passed to create an examination of the technical and economic factors involved in assessing the possibility of changing the propensity of certain specified smoking materials (cigarettes and so-called little cigars) to ignite fires. A Technical Study Group was formed to produce and coordinate the indicated research, in support of an Interagency Committee which has the responsibility of reporting to Congress.

By September 1985, the Technical Study Group had designed and budgeted for a research and analysis program to produce the information required by the Act. Central roles were assigned to the National Bureau of Standards Center for Fire Research (NBS/CFR), which was to coordinate laboratory testing of experimental cigarettes designed for low ignition propensity, and the National Bureau of Standards Center for Applied Mathematics (NBS/CAM), which was to prepare the economic model analyzing costs and benefits of changes in cigarette design.

By March 1986, contracts had been awarded to the National Fire Protection Association (NFPA) and several other technical experts to produce technical inputs to the NBS/CAM. (The other experts were to address such non-fire factors as costs of production, consumer satisfaction with the altered product, changes in health effects, and ripple effects to the agricultural and cigarette production sectors of the economy.) NFPA produced baseline and projected fire losses associated with cigarette fires. This report was delivered in August 1986. The first NFPA report was prepared on the presumption that the NBS/CFR laboratory tests would be converted to ignition-probability form outside the contract. NFPA was awarded a contract, in March 1987, to develop the probabilistic model and input data sources required to perform the conversion. Also, in February 1987, NFPA was awarded a contract to examine the implications of several changes in modeling assumptions so as to determine whether the cost coefficients and forecasting equations could be improved.

This report is intended to be a readable synthesis of the results of the three studies. In addition to bringing them together, this synthesis addresses reviewer comments on the first report by (a) listing assumptions and estimates in concise form, (b) attaching appendixes providing sensitivity analyses and more detailed derivations of key parameters, and (c) explicitly discussing some elements in the measurement of the uncertainty of the estimates.

The purposes of this report, then, are to:

(1) Develop a general model for estimating the relative ignition propensities of different types of cigarettes from suitable laboratory tests of those cigarettes and other necessary data. This model was to provide for testing that could be done and data that could be assembled. Appendix A has the model.
(2) Refine the general model to fit available test data and other Data, and use the results to estimate the relative ignition propensities of up to five experimental cigarettes. This is done in Appendixes B and C.
(3) Calculate historical fire losses due to cigarette and little cigar ignitions, develop models to forecast losses through 1986, and estimate changes in losses if each of the five experimental cigarettes were the only cigarettes in use. This is done in the main body of this report.
(4) Perform sensitivity analyses on the effects of different assumptions on costs of injuries and the handling of unreported fires and on the potential of total fire rates to indicate an overall trend in "carelessness" that might be useful in modeling the cigarette fire problem. These are presented in Appendixes E and F.

Baseline Size of the Cigarette Fire Problem

Overall Size

Table 1 shows the estimated number of smoking material ignitions for 1980-84 (with 1984 being the latest year for which estimates are available), and the associated civilian and fire service deaths and injuries and direct property damage, all for fires reported to fire departments.

These estimates were produced in accordance with a consensus methodology developed by the author and analysts at the National Fire Data Center, U.S. Fire Administration (USFA), Federal Emergency Management Agency, and the U.S. Consumer Product Safety Commission (CPSC). The essential elements of the methodology are as follows:

(1) Each estimate of a number of fire incidents is based on a set of formulas of this form—(total fires reported to the National Fire Incident Reporting System (NFIRS) for which the Form of Heat of Ignition was coded as 30-39, i.e., smoking materials) × [(total fires estimated to have occurred in the U.S., according to the NFPA stratified random sample of U.S. fire departments for fires reported to them)/(total fires reported to NFIRS for which Form of Heat of Ignition was reported)]. (Note that some differences in estimates may result if organizations have performed their own quality control edits on NFIRS, as CPSC has done. These differences tend to be small.)

(2) The formula is applied separately for residential structures, non-residential structures, vehicles, and other properties (principally outdoor brush, grass and trash). Then the subtotals are summed to produce the overall totals.

(3) Similar formulas are separately calculated for civilian deaths, civilian injuries and direct property damage. For fire service deaths, a direct census by NFPA of fire service line-of-duty deaths is used as the source. For fire service injuries, two versions are presented because the consensus of NFPA, USFA, and CPSC analysts does not extend to this measure. Version 1 uses the format of the formula in (1) but without separate calculations by major property class because the NFPA survey does not differentiate fire service fireground injuries by property class. Version 2 is equal to the estimate of civilian injuries times an NFIRS-based ratio of fire service injuries per civilian injury. The author recommends use of Version 1.

(4) The use in (1) of a denominator limited to fires with known form of ignition heat has the effect of proportionally allocating fires with unknown form of ignition heat over all

Table 1. Overview of the 1980-84 Smoking Fire Problem **(National Estimates of Fires Reported to Fire Departments)**

Year	Fires	Civilian Deaths	Fire Fighter Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage
1980	347,000	1,980	4	5,310	4,880	3,030	$498 M
1981	325,000	2,200	5	5,440	4,270	2,450	$447 M
1982	266,000	1,800	5	5,680	3,230	1,900	$430 M
1983	228,000	1,620	1	4,620	3,250	1,940	$373 M
1984	241,000	1,600	0	4,090	3,310	1,970	$410 M

NOTES: Estimates are never expressed to more than three significant places. In this case that means that fires are expressed to the nearest thousand civilian deaths and civilian and fire fighter injuries to the nearest ten, fire fighter deaths to the nearest one, and direct property damage to the nearest million dollars. Dollar figures have not been adjusted for inflation.

the known forms. The percentage increase provided by this allocation ranges from the order of 15% (for residential structure fire incidents) to the order of 100% (for non-residential structure fire civilian deaths). This provides an indication of one of the major sources of uncertainty in those estimates—inability to determine fire cause in the field in many cases.

(5) The use of all smoking materials as a proxy for the cigarettes and small cigars of interest in this analysis is justified by Table 2. Only pipes are clearly outside the domain of the analysis and they account for about 1% of all smoking material fires and associated civilian deaths. Small cigars cannot be separated from other cigars, but the cigar category is small in any case. It is considered likely that the "unspecified other" and "unknown" type smoking materials are nearly all cigarettes. Other damage measures—civilian and fire fighter injuries, property damage—show similar patterns.

Baseline Size of Major Components of Smoking Problem

In order to remove the effects of inflation, the property damage values must be expressed in terms of dollars from a single reference year. Table 3 displays the indexes to convert all property loss figures from the 1980-84 baseline period of 1986 dollars. Table 3 also provides 1980-84 cigarette consumption totals so that total smoking fires can be expressed as rates relative to consumption. This permits the ignition propensity of cigarettes to be forecast separately from the forecasting of cigarette consumption.

Table 4 displays the smoking fire damages of Table 1 in the more specific categories required for forecasting and includes a property damage table in 1986 dollars. Table 4 separates residential structure, nonresidential structure, vehicle and outdoor/other fires as is customary in analyzing

Table 2. Smoking Fire Problem by Type of Smoking Material

A. Fires

Type of Smoking Material	Total Fires	Structure Fires	Vehicle Fires	Other Fires
Cigarette	80.6%	88.7%	89.7%	76.0%
Cigar	0.6%	0.6%	1.1%	0.5%
Pipe	0.3%	0.6%	0.7%	0.1%
Unspecified other type	3.3%	2.8%	2.6%	3.6%
Unknown type	15.2%	7.2%	5.8%	19.8%
TOTAL	100.0%	100.0%	100.0%	100.0%
Estimated 1980-84 Total	1,406,000	410,000	94,000	902,000

B. Civilian Deaths

Type of Smoking Material	Total Fires	Structure Fires	Vehicle Fires	Other Fires
Cigarette	85.6%	85.5%	96.8%	88.2%
Cigar	0.8%	0.8%	0.0%	0.0%
Pipe	1.1%	1.1%	0.0%	0.0%
Unspecified other type	2.1%	2.1%	0.0%	0.0%
Unknown type	10.4%	10.5%	3.2%	11.8%
TOTAL	100.0%	100.0%	100.0%	100.0%
Estimated 1980-84 Total	9,212	9,105	91	15

NOTES: Total fires are expressed to the nearest thousand, total deaths to the nearest one. Totals may not equal the sums of parts because of rounding error.

fires. Within these major categories, the two structure fire classes are further subdivided into those involving initial ignition of (a) upholstered furniture, (b) mattresses or bedding, and (c) all other or unknown materials. The first two material classes accounted for by far the largest shares for which the ignitability of the materials are known to have recent and future trends, reflecting standards (government or industry consensus) designed to reduce ignitability. (Note that some organizations such as CPSC, compute the categories of known materials. If this is done, the upholstered furniture and mattresses/bedding classes increase slightly—for example, 1984 civilian injuries involving upholstered furniture would increase by about 3% — and the other/unknown category would decrease accordingly. Since all fires are being forecast somewhere and the shifts are small, this methodological point has little impact here, although it can have great impact on analyses of other fire problems.)

Table 5 converts the data of Table 4 to the rates required for forecasting — fires per billion cigarettes consumed and losses per thousand fires, by type of loss.

Other Fire-Related Costs

Since any changes in the fire problem produced by the redesign of smoking materials will affect only smoking-related fires, it is estimated that the change in costs for fire department responses will be so low as to be essentially zero. Smoking material fires represent on the order of 10% of all reported fires but less than 3% of all fire department calls. Nearly all of the costs of local fire protection are for personnel and equipment, whose levels are set not on the basis of workload but so as to provide certain levels coverage, typically measured by response times. A small change in the volume of calls would be very unlikely to change the level of resources required to achieve the target coverage.

Table 3. Cigarette Consumption and Price Deflator Indexes Using in Smoking Fire Analysis

Year	Billions of Cigarettes Consumed	Conversion of of Year's Dollars to 1986 Dollars
1980	618.57	1.33
1981	627.70	1.21
1982	624.01	1.14
1983	596.19	1.10
1984	600.23	1.05

SOURCE: [21] The dollar conversion factors are implicit price deflators.

Estimated Size of Smoking Fire Problem Not Reported to Fire Departments

All estimates to this point have addressed solely the impact of smoking material ignitions on fires reported to fire departments. Unreported fires have been the subject of two special studies a decade apart. The more recent may be used to estimate factors to use in scaling up reported fire losses to reflect unreported fires. [1]

Unreported Fires

The most recent study of unreported fires found that in 1984, there were an estimated 925,000 reported fires affecting the property of U.S. households, i.e., their homes, yards, and vehicles, compared to an estimated 24,250,000 unreported fires, for a ratio of 26.2 unreported fires per reported fire. For home structure fires, the figures were 800,000 reported fires and 22,900,000 unreported fires, for a ratio of 28.6 unreported fires per reported fire.

Most unreported fires are cooking-related, however, so it is desirable to develop a ratio specifically for smoking materials. The report states (on page 27) that "4.8% of . . . fire households reported 'smoking materials' as the source of heat." It is not clear in context what base this percentage applies to. If it can be applied to unreported home structure fires, then there would be an estimated 1,137,600 unreported home structure fires due to smoking materials. This is roughly 22.8 times the 1984 figure for reported home structure fires due to smoking materials, computed using the methodology used for Table 1. However, Table 1 also used the NFPA estimate of roughly 600,000 reported home structure fires in 1984, while the unreported fires study used a total of 800,000. Therefore, the ratio needs to be further adjusted to take account of this 4:3 ratio, resulting in a final estimate of 17.1 unreported smoking fires per reported smoking fire (in home structures).

Property Damage in Unreported Fires

Property damage for unreported and reported fires was displayed in terms of a probability distribution over damage categories, with no direct estimate of average damage per fire. The distribution is shown below, both as it appeared in the study (page 32 of [1]) and as transformed to exclude fires with unreported loss:

There are several ways to convert the last two columns to an estimate of the ratio of average losses for reported and unreported fires. Using the lower bound for each range as the loss for that range produces a minimum loss figure of $3,246.33 for reported fires and $7.62 for unreported fires, for a ratio of 426-to-1. Another way is to use the geometric mean of the end points for each range and some corresponding figure for the open-ended upper range of 50,001 and up. Since the geometric means of the closed ranges tend to be on the order of 2-3 times the lower bounds, the average loss figure for the upper range may be

Table 4. Overview of the 1980-84 Smoking Fire Problem, by Major Property Class and Form of Material First Ignited Totals

A. Fires Reported to Fire Departments

Year	Residential Structures: Upholstered Furniture	Residential Structures: Mattresses or Bedding	Residential Structures: Other or Unknown	Non-Residential Structures: Upholstered Furniture	Non-Residential Structures: Mattresses or Bedding	Non-Residential Structures: Other or Unknown	Vehicles	Outdoors or Other	Total
1980	21,800	27,100	28,300	2,300	3,900	20,900	23,600	219,400	347,300
1981	20,600	24,900	25,300	2,000	4,000	18,900	24,500	204,900	325,000
1982	16,000	19,700	20,600	1,900	3,200	15,700	16,600	172,100	265,800
1983	13,200	17,700	18,100	1,300	2,800	13,600	14,500	146,600	227,900
1984	13,200	17,100	19,200	1,300	2,600	13,300	14,900	159,000	240,500

B. Civilian Deaths

Year	Residential Structures: Upholstered Furniture	Residential Structures: Mattresses or Bedding	Residential Structures: Other or Unknown	Non-Residential Structures: Upholstered Furniture	Non-Residential Structures: Mattresses or Bedding	Non-Residential Structures: Other or Unknown	Vehicles	Outdoors or Other	Total
1980	1,047	562	323	3	25	10	15	0	1,984
1981	1,119	619	388	19	23	15	17	5	2,205
1982	938	476	308	5	5	31	31	2	1,797
1983	788	479	308	3	3	17	19	6	1,625
1984	856	386	292	13	20	23	9	1	1,601

C. Civilian Injuries

Year	Residential Structures: Upholstered Furniture	Residential Structures: Mattresses or Bedding	Residential Structures: Other or Unknown	Non-Residential Structures: Upholstered Furniture	Non-Residential Structures: Mattresses or Bedding	Non-Residential Structures: Other or Unknown	Vehicles	Outdoors or Other	Total
1980	1,957	1,617	1,015	57	223	214	158	66	5,307
1981	1,939	1,586	870	62	417	306	155	105	5,439
1982	1,705	1,388	846	106	129	163	231	108	4,676
1983	1,666	1,553	867	27	164	173	132	41	4,623
1984	1,425	1,344	804	53	78	162	150	69	4,086

D. Fire Fighter Injuries (Version 1)

Year	Residential Structures: Upholstered Furniture	Residential Structures: Mattresses or Bedding	Residential Structures: Other or Unknown	Non-Residential Structures: Upholstered Furniture	Non-Residential Structures: Mattresses or Bedding	Non-Residential Structures: Other or Unknown	Vehicles	Outdoors or Other	Total
1980	1,430	1,289	955	40	134	514	147	374	4,883
1981	1,346	1,275	766	64	97	386	58	277	4,270
1982	882	871	812	27	22	319	65	233	3,230
1983	1,016	918	776	54	44	255	74	113	3,250
1984	826	890	1,022	34	64	281	77	111	3,306

NOTE: Fires are expressed to the nearest hundred, damages to the nearest thousand dollars, all other figures to the nearest one.

Table 4. Overview of the 1980-84 Smoking Fire Problem, by Major Property Class and Form of Material First Ignited Totals (continued)

E. Fire Fighter Injuries — Version 2

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1980	1,057	873	548	38	147	141	97	131	3,032
1981	872	714	392	28	188	138	29	90	2,451
1982	699	569	347	61	74	93	30	32	1,904
1983	666	621	347	16	99	104	45	40	1,937
1984	670	632	378	36	52	109	50	47	1,972

F. Direct Property Damage, Not Adjusted for Inflation, in Millions of Dollars

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1980	125.6	91.2	117.1	11.8	6.5	122.3	19.6	4.4	498.4
1981	131.4	92.3	104.8	9.7	4.8	81.3	15.1	8.0	447.4
1982	185.0	78.8	79.3	11.2	3.3	50.6	20.1	1.5	429.8
1983	103.9	86.0	87.5	6.9	7.2	64.7	12.9	3.5	372.5
1984	118.8	85.1	118.2	15.8	4.9	44.8	16.2	6.6	410.4

G. Direct Property Damage in 1986 Dollars, in Millions of Dollars

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1980	167.1	121.2	155.7	15.7	8.7	162.6	26.0	5.8	662.9
1981	158.9	111.7	126.8	11.7	5.8	98.4	18.3	9.6	541.3
1982	210.9	89.9	90.4	12.7	3.8	57.7	22.9	1.7	490.0
1983	114.2	94.6	96.2	7.6	7.9	71.2	14.1	3.8	409.8
1984	124.7	89.3	124.1	16.6	5.1	47.0	17.0	7.0	430.9

NOTE: Fires are expressed to the nearest hundred, damages to the nearest thousand dollars, all other figures are to the nearest one.

estimated as $100,000 or $150,000. If $100,000 is used, one obtains estimated average loss figures of $7,000.55 for reported fires and $26.62 for unreported fires, producing a ratio of 263-to-1. If $150,000 is used, one obtains estimated average loss figures of $9,100.55 for reported fires and $26.62 for unreported fires, producing a ratio of 342-to-1.

Combining these three results with the 17.1 ratio of unreported fires to reported fires produces an estimated range of 4.0-6.5% for the ratio of losses in unreported smoking fires to losses in reported smoking fires. (Here, 0.040 is 17.1/426 and 0.65 is 17.1/263.)

Civilian Injuries in Unreported Fires

There were roughly 9.1 injuries or illnesses in unreported fires for each injury or illness in a reported fire (page 34 of [1]), but there was no distribution of severity provided. Suppose that severities of injuries and illnesses have the same distribution as loss per fire, given that some known non-zero loss occurred. Then the last two columns of the following table would be relevant:

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Table 5. Overview of the 1980-84 Smoking Fire Problem, by Major Property Class and Form of Material First Ignited Rates

A. Fires (Reported to Fire Departments) per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1980	35.2	43.8	45.8	3.8	6.3	33.8	38.8	354.7	561.5
1981	32.8	39.7	40.3	3.2	6.3	30.2	30.2	326.5	517.8
1982	25.7	31.6	33.1	3.1	5.1	25.1	25.1	275.8	426.0
1983	22.2	29.7	30.3	2.2	4.8	22.9	22.9	245.9	382.3
1984	21.9	28.4	31.9	2.2	4.4	22.2	22.2	264.9	400.8

B. Civilian Deaths per Thousand Reported Fires

	Residential Structures			Non-Residential Structures				
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other
1980	48.06	20.73	11.41	1.08	6.53	0.49	0.62	0.00
1981	54.42	24.86	15.33	9.55	5.76	0.80	0.71	0.03
1982	58.51	24.14	14.92	2.73	1.64	1.99	1.88	0.01
1983	59.60	27.04	17.07	2.64	1.22	1.27	1.34	0.04
1984	65.08	22.64	15.25	9.95	7.53	1.74	0.59	0.01

C. Civilian Injuries per Thousand Reported Fires

	Residential Structures			Non-Residential Structures				
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other
1980	89.9	59.7	35.9	24.5	57.4	10.2	6.7	0.3
1981	94.3	63.7	34.4	31.2	105.6	16.1	6.3	0.5
1982	106.4	70.4	41.0	55.8	41.0	10.4	13.9	0.6
1983	126.1	87.6	48.0	20.9	57.9	12.7	9.1	0.3
1984	108.4	78.8	42.0	40.0	29.5	12.1	10.1	0.4

NOTE: Fires are expressed so as to show three significant places to most entries in a table.

The implications of this table are analyzed in the same way as in (2). Using the minimums of the ranges, one obtains a ratio of 248-to-1. Using a figure of $100,000 for the upper range, one obtains a ratio of 67-to-1. Using a figure of $150,000 for the upper range, one obtains a ratio of 87-to-1.

Combining these three results with the 17.1 ratio of unreported fires to reported fires, one obtains a range of 3.7-13.6% for the estimated ratio of injury costs for unreported smoking fires to injury costs for reported smoking fires.

Estimated Cost per Injury in Smoking-Related Fires

The best available cost estimate per injury appears to be that developed by the Economic Analysis group at the U.S. Consumer Product Safety Commission. [16] (See Appendix D.) The CPSC figure of $36,218 per injury is a weighted average of estimates of $62,309 for burn injuries and $21,530 for anoxia injuries. The estimates combine informa-

Table 5. Overview of the 1980-84 Smoking Fire Problem, by Major Property Class and Form of Material First Ignited—Rates (continued)

D. Fire Fighter Injuries (Version 1) per Thousand Reported Fires

	Residential Structures			Non-Residential Structures				
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other
1980	65.7	47.6	33.8	17.1	34.3	24.6	6.2	1.7
1981	65.5	51.2	30.3	32.5	24.5	20.4	2.4	1.4
1982	55.0	44.2	39.3	14.2	6.8	20.4	3.9	1.4
1983	76.9	51.8	43.0	41.2	15.6	18.7	5.1	0.8
1984	62.8	52.2	53.4	25.6	24.2	21.1	5.2	0.7

E. Fire Fighter Injuries (Version 2) per Thousand Reported Fires

	Residential Structures			Non-Residential Structures				
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other
1980	48.5	32.2	19.4	16.2	37.9	6.7	4.1	0.6
1981	42.4	28.7	15.5	14.1	47.5	7.3	1.2	0.4
1982	43.6	28.9	16.8	31.8	23.3	5.9	1.8	0.2
1983	50.4	35.0	19.2	12.5	34.7	7.6	3.1	0.3
1984	50.9	37.0	19.7	26.8	19.7	8.1	3.3	0.3

F. Direct Property Damage (in 1986 Dollars) per Thousand Reported Fires, in Millions of Dollars

	Residential Structures			Non-Residential Structures				
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other
1980	7.67	4.47	5.50	6.68	2.23	7.78	1.10	0.03
1981	7.73	4.49	5.02	5.89	1.48	5.19	0.75	0.05
1982	13.15	4.56	4.38	6.68	1.20	3.69	1.38	0.01
1983	8.65	4.34	5.33	5.80	2.79	5.22	0.97	0.03
1984	9.48	5.24	6.48	12.49	1.93	3.52	1.15	0.04

NOTE: Fires are expressed so as to show three significant places to most entries in a table.

tion from NFIRS and CPSC's National Electronic Injury Surveillance System, a data base on injuries reported to hospital emergency rooms. Pain and suffering estimates, based in part on CPSC analysis of a sample of jury verdict awards, account for more than two-thirds of the cost estimate.

A number of other injury cost estimates also were analyzed, and the results are shown in Appendix E.

Table 6 summarizes the assumptions used in this analysis of the baseline smoking fire problem.

Uncertainty in Estimates

The NFPA survey is statistically designed and so its confidence limits can be calculated. During 1984, for example, the 95% confidence limits for the survey were 1.6% for fires, 7.8% for civilian deaths, 5.2% for civilian injuries, and 3.3% for property damage. The confidence limits for the five-year average therefore would be less than half this wide. (If the confidence limits were the same for years, then the confidence limits for the five-year average would be 0.45 times

Damage Range	Overall Probabilities		Probability Given Known Loss	
	Reported Fires	Unreported Fires	Reported Fires	Unreported Fires
$0	24.5%	57.3%	26.8%	57.7%
$1 – $100	12.2%	37.5%	13.3%	37.8%
101 – $1,000	21.6%	4.2%	23.6%	4.2%
1,991 – $10,000	21.2%	0.3%	23.2%	0.3%
$10,000 – $50,000	8.1%	0.0%	8.9%	0.0%
$50,001 – and up	3.9%	0.0%	4.2%	0.0%
Unknown				

Damage Range	Overall Probabilities		Probability Given Known Loss	
	Reported Fires	Unreported Fires	Reported Fires	Unreported Fires
$0	24.5%	57.3%	–	–
$1 – $100	12.2%	37.5%	18.2%	89.3%
101 – $1,000	21.6%	4.2%	32.2%	10.1%
1,991 – $10,000	21.2%	0.3%	31.7%	0.7%
$10,000 – $50,000	8.1%	0.0%	12.1%	0.0%
$50,001 – and up	3.9%	0.0%	5.8%	0.0%
Unknown	8.6%	0.5%	–	–

the one-year limits, because $0.45 = 1/\sqrt{5}$.)

The other element of the national estimates procedure is the NFIRS sample, which is so large that its statistical sampling error is negligible. However, NFIRS is not a statistically designed sample, so it may have systematic errors, whose magnitudes have never been estimated. For example, even with NFIRS now representing on the order of one-third of all U.S. fires, if the sampling rates were around 20% for rural areas or large cities and higher everywhere else, then an error of 5-10 percentage points in the overall percentage of fires due to smoking materials would be possible, resulting in an error of one-sixth to one-third in the estimated number of smoking fires. This is because cause patterns vary by community size.

As noted earlier, apart from the uncertainty of the sampling procedures, there also is uncertainty because of the need to allocate fires for which the ignition cause was unknown or unreported. The magnitude of the uncertainty is greater for deaths and property damage than for fires and injuries and is less for residential properties than for other properties.

Because of the unknown bias of NFIRS, no objective method exists for quantifying the total uncertainty in the estimates. However, an estimate of one-third for subjective confidence bounds seems reasonable to the author.

Decisions on the handling of unreported fires and the costing of fire injuries also introduce uncertainty, which has been explicitly addressed by sensitivity analyses in Appendix E.

Table 6. Summary of Assumptions in Baseline Analysis

1. The best available estimates of smoking-related fires reported to fire departments (or civilian deaths, civilian injuries, or property damage) are given by combining the NFPA survey-based projections of total fires (or civilian deaths, civilian injuries, or property damage) and NFIRS-based percentages of total fires (or civilian deaths, civilian injuries, or property damage) with known form of ignition heat that involved smoking material ignitions. These calculations are best done separately for residential structure, non-residential structure, vehicle, and outdoor/other fires.

2. The best available estimates of smoking-related fire fighter injuries may be produced by either of two methods: (a) using the formula described in Assumption #1 but without separating the four major property classes, or (b) using the civilian injury estimates developed by the formula described in Assumption #1 and NFIRS-based ratios of fire fighter injuries per civilian injury.

3. The best available estimates of smoking-related fire fighter deaths are provided by an NFPA census.

4. The percentage of smoking-related fires involving ignition sources outside the scope of the Cigarette Safety Act of 1984 is so small that estimates of all smoking material fires may be used without adjustment.

5. Forecasting is best done separately for cigarette consumption, fire rates relative to cigarette consumption, and fire rates (by type of loss), per thousand fires.

6. Smoking-related fires are so small a share of fires and of total fire department calls that changes in their frequency are not expected to change the levels of other fire-related costs, such as fire department costs.

7. Estimates of property damages in unreported home fires are best handled as percentages of damages in reported fires, using the highest value of percentages based on comparisons of (a) average damage per fire in reported and unreported fires and (b) number of reported and unreported fires involving smoking materials in home structures. Estimates of civilian injuries in unreported home fires are best handled as percentages of civilian injuries in reported fires, using the highest value of percentages (to adjust for differences in injury severity) based on comparisons of (a) average damage per fire in reported and non-zero-damage unreported fires and (b) number of reported and unreported fires involving smoking materials in home structures. There are no reliable sources of estimates of civilian deaths in unreported home fires or of unreported fires outside the home. Fire fighter injuries and deaths are assumed not to occur in unreported fires.

8. The best estimate of cost per injury in a smoking-related fire reported to fire departments is $36,218, as developed by the CPSC Economic Analysis group. (See Appendix D.)

Forecasting the Smoking–Fire Problem, Given No Change in Cigarettes

Modeling Assumptions

The forecasting rules were developed, reviewed and revised several times. The final version of the five modeling assumptions used in the study and the reasons for them are as follows:

1. Smoking-related structure fires for 1980-84 are used in a simple regression analysis to fit proportionality relationships between fires per billion cigarettes and the ignitability of material first ignited for four property/material classes—residential upholstered furniture fires, nonresidential upholstered furniture fires, residential mattress and bedding fires, and nonresidential mattress and bedding fires. ("Bedding" includes sheets, mattress pads, blankets and other soft goods in use as bed covers.) The relationships are fit so that an ignitability index of zero predicts zero fires. Also, linear regression relationships are developed to forecast each of the rates of loss per thousand fires.
2. Smoking-related fires for 1982-84 are used to fit linear regression relationships for fires per billion cigarettes as a function of year, for residential fires involving other or unknown materials, nonresidential fires involving other or unknown materials, vehicle fires involving any materials, and outdoor or unknown property fires involving any materials. Linear regression relationships also are developed to forecast each of the rates of loss per thousand fires.
3. The extent of usage, operational status, and loss-reduction effectiveness of detectors are assumed to have stabilized in 1984. After accounting for these factors in 1980-83, loss-per-fire, by major property class and type of loss, is modeled as a linear function of the years of interest.
4. Fire fighter deaths would not be included since they represented 0.16% of civilian deaths in 1980-84, a number less than the round-off error.
5. There will be no significant increases in sprinkler usage or significant changes in fire fighting techniques that would need to be accommodated in the analysis.

A discussion of the rationales for these assumptions follows.

Table 7 displays the ignitability indexes for upholstered furniture, both the total index and the major components which will be used in analyzing experimental cigarettes, both for 1980-84 and for the forecast years of 1986-96. Table 8 displays the ignitability indexes for mattresses (used to fit mattresses and bedding fires). Appendixes A, B, and C derive these indexes from the general model of ignition propensity, as modified to use available data.

Note that bedding fires are grouped with mattress fires and modeled against trends in mattress ignitability. This assumption reflects the judgment of CPSC staff that the reactions of mattresses and bedding to smoking materials are so interconnected that they represent one problem, regardless of how they are coded, and the whole problem may be expected to respond to trends in mattress ignitability. This judgment is consistent with the observed data.

In the first version of the model, it had been expected that smoking fire rates for fires involving items other than upholstered furniture and mattresses/bedding would show no significant upward or downward trend because they involved items whose ignitability had not systematically changed in recent years, as far as was known. Table 5 clearly shows, however, that these fire rates had significant downward trends.

Before settling on assumption #2, which involves a simple regression analysis with no knowledge of the factors driving these trends, a number of possible explanations were considered:

(a) Sizeable reductions in the ignitability of all materials.

This seemed implausible. No theory could be developed to explain a large decline in the ignitability of the components of trash, nor was it deemed likely that the ignitability of grass and brush, which is governed by weather, would appear to decline in the same way as man-made materials.

(b) Significant reductions in the propensity of smokers to carelessly discard smoking materials in situations where fire is likely.

This seemed implausible, given the extremely slight attention given to public fire safety education directed at careless smoking, which is generally considered to be one of the most difficult fire-causing behaviors to change. While there have been shifts in the age and sex distributions of smokers, these changes have been gradual, compared to the rapid 1980-84 decline in smoking fires.

Table 7. Ignitability Indexes for Upholstered Furniture in Use, 1980-84 and 1986-96

	Location of Cigarette and Filling Materials at that Location					
Year	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides	Total
1980	.106	.028	.121	.087	.108	.451
1981	.095	.029	.109	.094	.101	.428
1982	.084	.030	.097	.101	.094	.407
1983	.074	.031	.088	.107	.088	.388
1984	.065	.032	.078	.113	.080	.368
1986	.049	.033	.061	.122	.066	.332
1987	.042	.034	.054	.126	.060	.316
1988	.036	.034	.047	.130	.054	.301
1989	.031	.034	.041	.133	.048	.287
1990	.026	.035	.035	.136	.043	.275
1991	.022	.035	.031	.138	.038	.264
1992	.019	.035	.026	.140	.033	.253
1993	.015	.035	.022	.142	.029	.244
1994	.013	.035	.019	.144	.026	.236
1995	.011	.035	.015	.145	.023	.229
1996	.009	.035	.013	.146	.020	.223

SOURCE: Each column is the sum across the three fabric groups of the products of corresponding values from Table C-5 (ignitability index by fabric type) and Tables C-13 through C-15 (probability by fabric type).

NOTES: The indexes by column reflect the ignitability of the filling materials, the likelihood of the location, and the share of products in use that have or will have those materials at that location. The indexes combine all fabrics for reasons given in Appendix C. The total column is the sum of the other columns. "Untreated cotton" batting includes latex foam and other natural materials. "Any other material" includes polyurethane foam (the material considered representative of the class), treated cotton batting, mixed fibers, and polyester. "Different materials" means the crevice had untreated cotton batting on one side and some other material on the other side. Appendix C, section 3.

At the same time the 1980-84 decline in numbers of fires has occurred across all causes of fires, and this is one of the few factors that could cause such a broad decline. For that reason, an alternative model using the overall fire rate per thousand persons as a measure of carelessness was tested, as indicated in Appendix F. While this approach gave a somewhat better fit, largely due to the addition of another modeling parameter that could be fitted to the data, the approach lacked face validity and is not considered a source of best estimates.

(c) Significant reductions in the ignition propensity of smoking materials in the absence of any legislative requirement.

This seemed implausible, given the laboratory test results that showed no significant variations in the ignition propensities of commercially available cigarettes. If this factor were driving the decline, one would expect to see dramatic and unequivocal inter-product differences in the laboratory. However, a field study, by cigarette type, of share of fires versus market share would help provide more conclusive information on this hypothesis.

(d) Changes in the fire incident data base.

There is no evidence of a systematic national trend of increased under-reporting (or decreased over-reporting) of smoking fires at the level that would be required to sustain a data/methods explanation of changes of this size.

Therefore, no satisfactory explanation could be found. Even if one of these explanations is considered plausible, it does

Table 8. Ignitability Indexes for Mattresses in Use, 1980-84 and 1986-96

Year	Pre-Standard	Post-Standard	Total
1980	.503	.048	.551
1981	.439	.054	.493
1982	.375	.061	.436
1983	.315	.066	.381
1984	.282	.070	.352
1986	.224	.075	.299
1987	.190	.079	.269
1988	.161	.081	.242
1989	.140	.083	.223
1990	.115	.086	.201
1991	.096	.088	.184
1992	.082	.089	.171
1993	.068	.090	.158
1994	.059	.091	.150
1995	.047	.092	.139
1996	.039	.093	.132

SOURCE: The two columns reflect ignitability indexes of 1.000 (pre-Standard) and 0.097 (post-Standard), derived in Appendix C, and shares of mattresses in use, as shown in Table C-16.

not explain why the declines in smoking fires involving upholstered furniture or mattresses track so well with declines in the ignitability of those items. Whatever else is happening, those items should be experiencing even greater declines.

Given this situation, it seemed most reasonable to assume that trends in fires per billion cigarettes consumed involving items other than upholstered furniture, mattresses, or bedding in structures would be driven by the same factors, whatever they are, that are driving fires in general. Here, it became important to note that general trends up to 1982 have been quite different from trends since 1982. Up to 1982, numbers of fires and deaths – whether total or residential structure in particular—have shown a strong long-term trend of decline. For example, from 1980 to 1982, total fires declined 15%, deaths in those fires 7%, residential structure fires 11%, and deaths in those fires 9%. Similar declines occurred in most years of the 1970's, as far as we can tell. From 1982 to 1986, however (and noting a sharp one-year drop in the number of deaths in 1984 that was reversed in 1985), numbers of fires have fallen more slowly and numbers of deaths have been essentially constant. For example, during 1982 to 1986, a period of twice as long as 1980-82, total fires declined 11%, deaths in those fires 3%, residential structure fires 13%, and deaths in those fires 3%. (In 1985, the latest year for which data were available when the modeling decisions were made, the decline per year in fires was even less, and deaths were up slightly over 1982.)

There seemed to be adequate reason to believe that the long term trend may have changed in 1982, and for that reason, all estimates of smoking fire rates and associated rates of loss per thousand fires for these classes of properties and ignited materials were based on the 1982-84 fire experience, rather than the entire 1980-84 period. This has the effect of forecasting a much slower rate of decline in fire rates and a much slower rate of increase in rates of loss per thousand fires than would have been the case if 1980-84 fire experience had been used.

The modeling of trends and effects of detectors (for assumption #3) was incorporated into the forecasts of loss per fire rates. Any loss per fire rate is assumed to reflect a relationship of the following form:

$$(L/F)_t = (L/F)_{no} (1 - P_{det} P_r P_s)$$

where

$(L/F)_t$	= Loss per fire for all fires.
$(L/F)_{no}$	= Loss per fire for all fires where detectors were not present.
P_{det}	= Probability a detector is present.
P_o	= Probability that, given a detector is present, it is operational.
P_s	= Probability that, given an operational detector is present, it saves a unit of loss (a life, an injury, a dollar of damage).

P_o, the probability that a detector, if present, is operational must be inferred indirectly because NFIRS records only the fact of activation, not the operational status. An operational detector may fail to activate if the extent of smoke is too small to require activation. NFIRS has a separate code for this condition, but it appears to be greatly underused, as indicated by significant differences in the reported activation rate as extent of smoke increases. For this analysis, then, P_o was calculated from NFIRS after the exclusion of (i) fires coded as too small to activate the detector, regardless of the actual reported size of the fire, (ii) fires coded as having smoke confined to room of origin and a detector present but not in the room or space of fire origin, and (iii) fires coded as having smoke confined to area of origin and a detector present in the room or space of origin. The values of P_o derived in this manner also are shown in Table 9, as are the values of P_{det}.

P_s, the probability of averting a unit of loss given the presence of an operational detector, could not be computed separately by year or by major property class. When an attempt was made to compute values of P_s by year and separately for residential and non-residential structures, a third to a half of the values fell outside the allowable range of zero to one. The most credible values for deaths and injuries were obtained for residential structures with all years combined:

Table 9. Detector Usage and Performance Factors

Year	Estimated Percentage of Fires with Detector Present: Residential	Non-Residential	Estimated Percentage of Fires Having Detector Present Where Detector Was Operational: Residential	Non-Residential
1980	18	11	76	79
1981	21	12	73	75
1982	24	13	72	76
1983	27	15	69	75
1984	31	16	68	76

SOURCE: All percentages are from the USFA's NFIRS.

NOTES: Percentages of fires with detectors present is given by a ratio, whose numerator includes all fires coded as having detectors, whether in or not in the room or space of fire origin and whether the detector operator or not. The denominator includes all those fires plus all fires coded as having no detector present. Fires coded as having unclassified or unreported detector performance are not included in the calculation.

Percentage operational also is a ratio. The numerator includes fires where the detector operated, in or not in the room or space of fire origin; the denominator includes fires where the detector did or did not operate, in or not in the room or space of fire origin. This calculation is limited to fires where it was considered likely that an operational detector should have operated. Therefore, fires were excluded if (1) they were coded as being too small to require detector operation, regardless of the coded size of extent of flame or smoke damage, (2) they were coded as having a detector outside the room or space of fire origin and smoke damage confined to the room of origin or (3) they were coded as having a detector in the room or space of fire origin and smoke damage confined to the object or area of fire origin.

Severity Measure	Value of P_s
Civilian deaths	0.68
Civilian injuries	0.60
Fire fighter injuries (Version 1)	0.83
Fire fighter injuries (Version 2)	0.60

Note that fire fighter injuries are considered preventable by virtue of earlier detection leading to earlier reporting, leading to smaller fires when the fire department arrives, leading to less dangerous conditions and ultimately fewer injuries.

Valid values of P_s for property damage could not be obtained in most cases because the average damage per fire in homes with detectors was typically higher than for homes without detectors. This phenomenon has been observed before and generally interpreted to mean that detector households have more valuable property than non-detector households. In the absence of some compelling alternative model, capable of producing valid values, the value of P_s was set at zero.

The value selected for P_s for civilian deaths, combined with the indicated value of P_o, produces the roughly 50% decline in civilian deaths attributable to detectors which has been found in other studies. The values of P_s for injuries are much higher than those found in studies using older data (60-83% versus roughly 5%) and not limiting themselves to one cause, while the value for loss is lower (0% versus roughly 22%).

In terms of forecasting, overall home detector usage nationwide leveled off in 1984. In terms of detectors in properties with fires, Table 9 shows detector usage rising in residential and non-residential structures through 1984, while estimated detector operability has been drifting downward, falling less rapidly than usage has risen. For this analysis, it was assumed that detector usage would continue to rise slowly, just enough to balance the downward drift in detector operability, so that the 1984 values of $P_{det} \times P_o$ will hold into the future, separately for residential and non-residential structures. P_s, it was assumed, would remain fixed at the values cited previously.

The simplest way to work this new set of assumptions into the analysis was to forecast using the 1980-84 linear losses per fire that would have occurred if all years had 1984 detector usage and operability, as shown in Table 10. Each of these indexes is given by the ratio of $(1 - P_{det} P_r P_s)$ for the indicated years. As may be seen, the great uncertainty about P_s exerts relatively little impact on those indexes; the indexes for property damage ($P_s = 0$) are little different from the indices for fire fighter injuries, version 2 ($P_s = 0.83$). Small differences, however, can produce measurable effects on forecast losses in the out years.

For consistency, those property/material classes that had their fires estimated using only 1982-84 data also had their losses per fire estimated using only 1982-84 data.

Forecasting Equations and Results of Forecasts

Table 11 gives the forecasting equations that follow from the modeling assumptions developed and stated in the previous section.

Note that losses per fire generally have an upward trend, particularly in those property and material classes that account for the majority of losses. The reasons for these trends are not understood well enough to permit modeling. It has been suggested that some of the changes in materials used in upholstered furniture and mattresses to reduce ignitability will produce higher rates of heat release, or more toxic products, hence more severe fires, if ignition occurs. It was not possible within the scope of this study to model those factors.

Using the equations in Table 11 and the forecasts of materials ignitability from Tables 7 and 8, one obtains detailed forecasts of fires and losses per billion cigarettes consumed, as shown in Table 12. Recombining the Table 12 results by major property class and material first ignited, one obtains the summary forecast of Table 13.

Finally, using the cost per injury values and adjustments for unreported fires derived earlier, one obtains forecasts of total economic impact of smoking fires, as shown in Table 14. Appendix E shows how those figures are changed if alternative assumptions are used on the cost per injury on the effects of unreported fires.

Table 10. Adjustment of 1980-83 Losses to Reflect 1984 Detector Usage and Performance Levels

Severity Measure	Year	Residential	Non-residential
Civilian deaths	1980	.942	.977
	1981	.954	.978
	1982	.966	.985
	1983	.981	.993
Civilian injuries and Fire fighter injuries—Version 2	1980	.949	.980
	1981	.960	.981
	1982	.971	.987
	1983	.983	.994
Fire fighter injuries—Version 1	1980	.927	.971
	1981	.942	.973
	1982	.958	.981
	1983	.975	.992
Direct property damage	1980	1.000	1.000
	1981	1.000	1.000
	1982	1.000	1.000
	1983	1.000	1.000

Uncertainty in Forecasting Equations

Because these equations are based on only three to five years of fire experience, they have a high degree of uncertainty. For example, the fire rate per billion cigarettes in other/unknown materials in residential structures is estimated to drop 0.568 per year, but a 90% confidence range for the regression encompasses both rates of rise and rates of decline more than ten times as great.

One of the best fire-rate fits is obtained for ignitions of mattresses or bedding in residential structures, but even there the 90% confidence range is from a one-third lower rate of decline to a one-third higher rate of decline. The 90% confidence range for upholstered furniture fires per billion cigarettes in residential structures ranges from a rate of decline three times the best estimate to a rate of rise greater than the best estimate rate of decline.

However, errors in forecasting would, in general, change only the level and trend of forecast losses but not the proportional gap between the baseline forecasts and the forecasts with experimental cigarettes. Only if losses did decline sharply without changes in cigarette design would the absolute difference in losses prevented by experimental cigarettes become so small as to make a clear, unequivocal difference in overall conclusions.

The fire rate models for upholstered furniture and for mattresses and bedding are set up to be strictly proportional to the ignitability indexes because this model has more face validity than the general linear model, which would otherwise provide a better fit on strictly statistical grounds. If a general linear model were used, for example, the projected upholstered furniture fires would decline to zero well before 1996 and well before their ignitability indexes declined to zero, which is not plausible.

The estimates used in the study are considered the best attainable with current knowledge, but it is important to be aware that they carry considerable uncertainty. Either the use of a general linear regression model or consideration of the confidence ranges, for example, raises the possibility that (a) important components of the smoking material fire problem may begin to rise significantly, despite continued declines in estimated ignitability or (b) important components of the smoking material fire problems may disappear before 1996 even if nothing is done to alter cigarette construction.

Table 11. Forecasting Equations for Smoking Fires, 1986-96

Severity Measure	Major Property Class	Form of Material First Ignited	Forecasting Equation
Fires per billion cigarettes	Residential structures	Upholstered furniture	68.058 × Ignitability
		Mattresses or bedding	78.354 × Ignitability
		Other or unknown	33.467 − 0.568 × (Year − 1980)
	Non-residential structures	Upholstered furniture	7.168 × Ignitability
		Mattresses or bedding	12.066 × Ignitability
		Other or unknown	27.650 − 1.419 × (Year − 1980)
	Vehicle	All	28.065 − 0.936 × (Year − 1980)
	Outdoors or other	All	278.54 − 5.451 × (Year − 1980)
Civilian deaths per thousand fires	Residential structures	Upholstered furniture	46.20 + 4.62 × (Year − 1980)
		Mattresses or bedding	21.33 + 0.90 × (Year − 1980)
		Other or unknown	14.20 + 0.42 × (Year − 1980)
	Non-residential structures	Upholstered furniture	2.92 + 1.11 × (Year − 1980)
		Mattresses or bedding	4.90 − 0.21 × (Year − 1980)
		Other or unknown	1.99 − 0.11 × (Year − 1980)
	Vehicles	All	3.20 − 0.64 × (Year − 1980)
	Outdoors or other	All	0.027 − 0.002 × (Year − 1980)
Civilian injuries per thousand fires	Residential structures	Upholstered furniture	86.36 + 7.95 × (Year − 1980)
		Mattresses or bedding	56.34 + 6.92 × (Year − 1980)
		Other or unknown	39.69 + 1.10 × (Year − 1980)
	Non-residential structures	Upholstered furniture	29.65 + 2.22 × (Year − 1980)
		Mattresses or bedding	77.35 − 9.95 × (Year − 1980)
		Other or unknown	8.85 + 0.94 × (Year − 1980)
	Vehicles	All	16.74 − 1.91 × (Year − 1980)
	Outdoors or other	All	0.738 − 0.097 × (Year − 1980)

Table 11. Forecasting Equations for Smoking Fires, 1986-96 (Continued)

Severity Measure	Major Property Class	Form of Material First Ignited	Forecasting Equation
Fire fighter injuries per thousand fires (Version 1)	Residential structure	Upholstered furniture	59.16 + 1.73 × (Year – 1980)
		Mattresses or bedding	43.78 + 1.84 × (Year – 1980)
		Other or unknown	20.75 + 7.85 × (Year – 1980)
Fire fighter injuries per thousand fires (Version 2)	Residential structures	Upholstered furniture	42.21 + 1.86 × (Year – 1980)
		Mattresses or bedding	27.55 + 1.98 × (Year – 1980)
		Other or unknown	13.18 + 1.71 × (Year – 1980)
	Non-residential structures	Upholstered furniture	15.93 + 2.06 × (Year – 1980)
		Mattresses or bedding	41.57 – 4.68 × (Year – 1980)
		Other or unknown	3.75 + 1.15 × (Year – 1980)
	Vehicles	All	0.45 + 0.76 × (Year – 1980)
	Outdoors or other	All	0.091 – 0.053 × (Year – 1980)
Direct property damage (in millions of 1986 dollars) per thousand fires)	Residential structures	Upholstered furniture	8.43 + 0.45 × (Year – 1980)
		Mattresses or bedding	4.34 + 0.24 × (Year – 1980)
		Other or unknown	2.25 + 1.05 × (Year – 1980)
	Non-residential structures	Upholstered furniture	5.20 + 1.15 × (Year – 1980)
		Mattresses or bedding	1.78 + 0.07 × (Year – 1980)
		Other or unknown	4.39 – 0.08 × (Year – 1980)
	Vehicle	All	1.52 – 0.12 × (Year – 1980)
		Outdoors or other	0.00

Table 12. Estimated 1986-96 Smoking Fire Problem

A. Fires per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	22.6	23.4	30.1	2.4	3.6	19.1	22.5	245.8	369.5
1987	21.5	21.1	29.5	2.3	3.3	17.7	21.5	240.4	357.2
1988	20.5	19.0	28.9	2.2	2.9	16.3	20.6	234.9	345.3
1989	19.5	17.5	28.4	2.1	2.7	14.9	19.6	229.5	334.1
1990	18.7	15.8	27.8	2.0	2.4	13.5	18.7	224.0	322.8
1991	18.0	14.4	27.2	1.9	2.2	12.0	17.8	218.6	312.1
1992	17.2	13.4	26.7	1.8	2.1	10.6	16.8	213.1	301.7
1993	16.6	12.4	26.1	1.8	1.9	9.2	15.9	207.7	291.5
1994	16.1	11.8	25.5	1.7	1.8	7.8	15.0	202.2	281.8
1995	15.6	10.9	25.0	1.6	1.7	6.4	14.0	196.8	271.9
1996	15.2	10.3	24.4	1.6	1.6	5.0	13.1	191.3	262.5

B. Civilian Fire Deaths per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.67	0.63	0.50	0.02	0.01	0.03	0	0	2.86
1987	1.69	0.58	0.51	0.02	0.01	0.02	0	0	2.84
1988	1.70	0.54	0.51	0.03	0.01	0.02	0	0	2.81
1989	1.71	0.51	0.51	0.03	0.01	0.01	0	0	2.79
1990	1.73	0.48	0.51	0.03	0.01	0.01	0	0	2.77
1991	1.74	0.45	0.51	0.03	0.01	0.01	0	0	2.75
1992	1.75	0.43	0.51	0.03	0	0.01	0	0	2.74
1993	1.76	0.41	0.51	0.03	0	0	0	0	2.73
1994	1.78	0.40	0.51	0.03	0	0	0	0	2.73
1995	1.80	0.38	0.51	0.03	0	0	0	0	2.73
1996	1.82	0.37	0.51	0.03	0	0	0	0	2.74

Table 12. Estimated 1986-96 Smoking Fire Problem (continued)

C. Civilian Fire Injuries per Billion Cigarettes Consumed

Year	Residential Structures: Upholstered Furniture	Residential Structures: Mattresses or Bedding	Residential Structures: Other or Unknown	Non-Residential Structures: Upholstered Furniture	Non-Residential Structures: Mattresses or Bedding	Non-Residential Structures: Other or Unknown	Vehicles	Outdoors or Other	Total
1986	3.03	2.29	1.39	0.10	0.06	0.28	0.12	0.04	7.32
1987	3.05	2.21	1.40	0.10	0.02	0.27	0.07	0.01	7.15
1988	3.07	2.12	1.40	0.10	0	0.27	0.03	0	6.99
1989	3.09	2.07	1.41	0.10	0	0.26	0	0	6.92
1990	3.11	1.98	1.41	0.10	0	0.25	0	0	6.84
1991	3.12	1.91	1.41	0.10	0	0.23	0	0	6.78
1992	3.13	1.87	1.41	0.10	0	0.21	0	0	6.72
1993	3.15	1.81	1.41	0.10	0	0.19	0	0	6.67
1994	3.18	1.80	1.41	0.10	0	0.17	0	0	6.66
1995	3.21	1.74	1.40	0.10	0	0.15	0	0	6.60
1996	3.24	1.73	1.40	0.10	0	0.12	0	0	6.59

D. Fire Fighter Fireground Injuries (Version 1) per Billion Cigarettes Consumed

Year	Residential Structures: Upholstered Furniture	Residential Structures: Mattresses or Bedding	Residential Structures: Other or Unknown	Non-Residential Structures: Upholstered Furniture	Non-Residential Structures: Mattresses or Bedding	Non-Residential Structures: Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.57	1.28	2.04	0.09	0.04	0.41	0.15	0	5.58
1987	1.53	1.19	2.23	0.09	0.02	0.39	0.16	0	5.62
1988	1.50	1.11	2.42	0.09	0.01	0.37	0.16	0	5.65
1989	1.46	1.05	2.59	0.09	0.01	0.34	0.17	0	5.71
1990	1.43	0.98	2.76	0.10	0	0.32	0.17	0	5.75
1991	1.40	0.92	2.92	0.10	0	0.29	0.17	0	5.80
1992	1.38	0.88	3.06	0.10	0	0.26	0.17	0	5.85
1993	1.36	0.84	3.20	0.10	0	0.23	0.17	0	5.90
1994	1.34	0.82	3.33	0.10	0	0.20	0.17	0	5.96
1995	1.33	0.78	3.46	0.11	0	0.17	0.17	0	6.00
1996	1.32	0.76	3.57	0.11	0	0.13	0.17	0	6.05

Table 12. Estimated 1986-96 Smoking Fire Problem (continued)

E. Fire Fighter Injuries (Version 2) per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.21	0.92	0.70	0.07	0.05	0.20	0.11	0.10	3.37
1987	1.19	0.87	0.74	0.07	0.03	0.21	0.12	0.11	3.34
1988	1.17	0.82	0.78	0.07	0.01	0.21	0.13	0.12	3.32
1989	1.15	0.79	0.81	0.07	0	0.21	0.14	0.13	3.31
1990	1.14	0.75	0.84	0.07	0	0.20	0.15	0.14	3.29
1991	1.13	0.71	0.87	0.07	0	0.20	0.16	0.15	3.28
1992	1.11	0.69	0.90	0.07	0	0.19	0.16	0.16	3.27
1993	1.10	0.66	0.92	0.07	0	0.17	0.16	0.17	3.26
1994	1.10	0.65	0.95	0.08	0	0.15	0.17	0.17	3.26
1995	1.09	0.62	0.97	0.08	0	0.13	0.17	0.17	3.24
1996	1.09	0.61	0.99	0.08	0	0.11	0.17	0.18	3.23

F. Direct Property Damage (in Millions of 1986 Dollars) Billion Cigarettes

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	0.25	0.14	0.26	0.03	0.01	0.07	0.02	0.02	0.79
1987	0.25	0.13	0.28	0.03	0.01	0.07	0.02	0.02	0.80
1988	0.25	0.12	0.31	0.03	0.01	0.06	0.01	0.03	0.81
1989	0.24	0.11	0.33	0.03	0.01	0.05	0.01	0.03	0.82
1990	0.24	0.11	0.35	0.03	0.01	0.05	0.01	0.03	0.83
1991	0.24	0.10	0.38	0.03	0.01	0.04	0	0.04	1.84
1992	0.24	0.10	0.40	0.03	0.01	0.04	0	0.04	1.85
1993	0.24	0.09	0.41	0.04	0.01	0.03	0	0.04	1.86
1994	0.24	0.09	0.43	0.04	0.01	0.03	0	0.04	1.87
1995	0.24	0.09	0.45	0.04	0	0.02	0	0.05	1.88
1996	0.24	0.08	0.46	0.04	0	0.02	0	0.05	1.89

Table 13. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage (Millions of 1986 Dollars)
1986	369.5	2.86	7.32	5.58	3.37	0.79
1987	357.2	2.84	7.15	5.62	3.34	0.80
1988	345.3	2.81	6.99	5.65	3.32	0.81
1989	334.1	2.79	6.92	5.71	3.31	0.82
1990	322.8	2.77	6.84	5.75	3.29	0.83
1991	312.1	2.75	6.78	5.80	3.28	0.84
1992	301.7	2.74	6.72	5.85	3.27	0.85
1993	291.5	2.73	6.67	5.90	3.26	0.86
1994	281.8	2.73	6.66	5.96	3.26	0.87
1995	271.9	2.73	6.60	6.00	3.24	0.88
1996	262.5	2.74	6.59	6.05	3.23	0.89

Table 14. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

Injuries Costed by CPSC @ $36,218

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.38 + 2.86Q	1.29 + 2.86Q
1987	1.41 + 2.84Q	1.31 + 2.84Q
1988	1.43 + 2.81Q	1.33 + 2.81Q
1989	1.46 + 2.79Q	1.36 + 2.79Q
1990	1.48 + 2.77Q	1.37 + 2.77Q
1991	1.50 + 2.75Q	1.39 + 2.75Q
1992	1.52 + 2.74Q	1.41 + 2.74Q
1993	1.54 + 2.73Q	1.43 + 2.73Q
1994	1.56 + 2.73Q	1.45 + 2.73Q
1995	1.58 + 2.73Q	1.46 + 2.73Q
1996	1.60 + 2.74Q	1.48 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

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Forecasting the Smoking-Fire Problem, Using New Cigarettes

Modeling Assumptions

A general model was developed whereby laboratory test results on the relative propensity of various cigarettes to ignite major classes of items can be combined with projections of fire experience for those items, to produce baseline projections of fire losses and projections of losses if certain specific cigarettes are used exclusively. The derivation of the general model is given in Appendix A, its modification for use on upholstered furniture and mattresses/bedding is given in Appendix B, and the calculations needed to support the models are given in Appendix C.

Tests were conducted by the National Bureau of Standards (NBS) on 41 experimental cigarettes. Test results suitable for analysis were provided to the author for five of these, code numbered C106, C114, C130, C201, and C202. The same tests were conducted on 12 commercial cigarettes, and compatible test results were provided for three of them, code numbered 1, 2 and 6. [9]

Shown below are the major assumptions used in the analysis, which are developed in more detail in Appendixes A, B, and C.

1. It is possible to identify scaling factors, dependent only on the major class of items being ignited by cigarettes (e.g., upholstered furniture), linking laboratory test results of cigarettes on those items to actual fires. These factors convert ignitions per test in the laboratory to fires per discarded cigarette in the real world and show no changes over time.
2. The probability of a cigarette being discarded on a particular version of an item (e.g., a particular type of upholstered furniture) is the same for every type of cigarette. The probability of a cigarette being discarded in a particular location on a piece of upholstered furniture is the same for all versions of upholstered furniture.
3. All commercially available cigarettes have essentially the same ignition propensity, so results for them can be pooled. A limited number of categories of upholstered furniture fabric, filling material, and location can be used, based on expert judgments as to major differences in expected ignitability and on distinctions that are possible with existing data on shares of items in use. (Test data have verified that the classes selected differ sharply in ignitability, but it has not been possible to establish how much ignitability varies within these categories.)
4. The small number of tests conducted on experimental cigarettes can be used to establish percentage reductions in ignition propensity, by filling material and location, from the baseline values of ignitability, by fabric, filling material, and location, that are developed using a much larger body of test data, as described in detail in Appendix C.
5. NBS test results can be extended to fabric types and locations other than those tested and provide results applicable to mattress/bedding fires as well.
6. No reduction is achieved by use of experimental cigarettes in smoking-related fires involving materials other than upholstered furniture, mattresses, or bedding; involving unknown materials; or involving vehicles or outdoor sites.
7. The probability of cigarette discard on upholstered furniture is the same for arm flat surfaces as for cushion flat surfaces and is the same for arm/cushion crevices as for back/cushion crevices. No other discard location need be considered. Cigarette discards on mattresses are analogous to discards on upholstered furniture flat surfaces. The probability of ignition, given a cigarette discard in a particular location on upholstered furniture, depends only on the furniture characteristics in that location and not on variations elsewhere on the upholstered furniture.

Calculation of Losses

Appendix C converts the laboratory results on the fire experimental cigarettes into revised ignitability indexes for the location/filling material combinations (Tables C-8 through C-12). For each experimental cigarette, the appropriate table may be substituted for Table C-5 (baseline) and combined with the appropriate columns from Tables C-13 through C-15 (probabilities of the fabric and location/filling material combinations) to produce overall ignitability indexes with respect to upholstered furniture (see Table 15).

Tables C-8 through C-12, also provide ignitability indexes for pre-Standard and post-Standard mattresses, which may be substituted for 1.0 and 0.097 (baseline values) and combined with usage share probabilities from Table C-16 to produce overall ignitability indexes for mattresses/bedding (see Table 16).

Table 15. Ignitability Indexes for Upholstered Furniture Versus Baseline and Five Experimental Cigarettes, 1986-96

Year	Baseline	Experimental Cigarettes C106	C114	C130	C201	C202
1986	.332	.020	.061	.081	.014	.027
1987	.316	.019	.055	.073	.012	.024
1988	.301	.017	.049	.066	.011	.021
1989	.287	.016	.044	.060	.009	.018
1990	.275	.015	.039	.054	.008	.016
1991	.264	.014	.035	.049	.007	.014
1992	.253	.013	.031	.044	.006	.012
1993	.244	.012	.028	.040	.005	.010
1994	.236	.011	.025	.036	.004	.009
1995	.229	.011	.022	.033	.004	.008
1996	.223	.010	.020	.030	.003	.007

SOURCE: Tables 7, C-8 through C-12, and C-15.

Forecasts of losses if only a particular experimental cigarette is used may then be calculated in either of two ways. One is to use the substitute ignitability indexes, apply the forecasting equations to them, and thereby repeat the steps shown in Tables 11-14. A quicker and logically equivalent approach is to convert the substitute ignitability indexes to proportions of the baseline ignitability indexes, then use their proportions to directly revise the upholstered furniture and mattress/bedding losses in Table 12, then repeat the steps shown in Tables 13-14.

Using the latter approach and providing the proportions used in doing so, Tables 17-21 give the revised summary forecasts of the smoking fire problem and the ratios of revised to baseline ignitability indexes. (The revised summary forecasts are comparable to the baseline values in Table 13.) Then Tables 22-26 give the revised tables on economic value of the losses. These tables are comparable to Table 14. Tables 22-26 also show these values as percentages of the baseline values. Figures 1 and 2 provide graphical displays of the comparisons between Table 14 and Tables 22-26.

Table 16. Ignitability Indexes for Mattresses/Bedding Versus Baseline and Five Experimental Cigarettes, 1986-96

Year	Baseline	Experimental Cigarettes C106	C114	C130	C201	C202
1986	.299	.302	.084	.116	.017	.035
1987	.269	.030	.074	.105	.015	.029
1988	.242	.029	.066	.094	.012	.025
1989	.223	.027	.060	.087	.011	.022
1990	.201	.026	.053	.079	.009	.018
1991	.184	.025	.047	.072	.007	.015
1992	.171	.024	.043	.067	.006	.013
1993	.158	.023	.039	.062	.005	.010
1994	.150	.023	.036	.059	.005	.009
1995	.139	.022	.033	.055	.004	.007
1996	.132	.022	.031	.052	.003	.006

SOURCE: Tables 8, C-8 through C-12, and C-16.

Table 17. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed, Cigarette C106

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage (Millions of 1986 Dollars)
1986	321.9	0.70	2.27	2.84	1.30	0.40
1987	313.3	0.70	2.20	3.01	1.36	0.42
1988	304.6	0.69	2.14	3.17	1.41	0.44
1989	296.0	0.69	2.10	3.32	1.46	0.45
1990	287.5	0.68	2.09	3.46	1.50	0.47
1991	278.9	0.68	2.07	3.58	1.53	0.49
1992	270.4	0.67	2.05	3.70	1.56	0.50
1993	261.9	0.67	2.03	3.81	1.58	0.51
1994	253.4	0.67	2.01	3.90	1.59	0.53
1995	244.9	0.66	1.98	3.98	1.60	0.54
1996	236.5	0.66	1.95	4.06	1.60	0.55

Year	Estimates as Percentage of Baseline: Upholstered Furniture Fires	Estimates as Percentage of Baseline: Mattress/Bedding Fires
1986	6	11
1987	6	11
1988	6	12
1989	6	12
1990	6	13
1991	5	14
1992	5	14
1993	5	15
1994	5	15
1995	5	16
1996	5	16

SOURCES: Bottom section from Tables 15 and 16; top section from bottom section and Table 13.

Uncertainty in Estimates

The largest points of uncertainty have to do with the generalizability of the results of the very small number of tests conducted. The commercial cigarettes tested may not be representative of all cigarettes. The fabrics tested were selected from the most-ignitable end of the spectrum, and the assumption that reductions in ignitability measured on those fabrics can be generalized to other fabrics may be incorrect.

If, for example, one took the very conservative approach of assuming that reductions should be estimated only for those upholstered furniture fabric classes, filling material classes, and locations that were tested, then the estimated impact would be significantly reduced.

On the other hand, it might be assumed that, because the items tested were the most likely to ignite, then impact on other items would be proportionally greater. This would not significantly increase the reductions, because the estimates for cigarettes C201 and C202 already involve the elimination of nearly all the smoking-material fire problem in upholstered furniture and mattresses/bedding.

Contrary to the assumption in this analysis, items other than upholstered furniture and mattresses/bedding might also show reductions in cigarette fires as a result of these cigarette design changes. This would have limited effect on total losses because such a large share of losses involve first ignition of upholstered furniture or mattresses/bedding.

There is no objective way to quantify these uncertainties with available data. Sensitivity tests on a wider range of cigarettes and versions of upholstered furniture would be highly desirable to confirm the key assumptions in the analysis.

Table 18. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed, Cigarette C114

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage (Millions of 1986 Dollars)
1986	329.7	1.02	3.06	3.27	1.63	0.46
1987	319.9	0.99	2.92	3.39	1.65	0.47
1988	310.4	0.96	2.79	3.51	1.67	0.49
1989	301.0	0.93	2.70	3.62	1.69	0.50
1990	229.7	0.90	2.63	3.72	1.70	0.51
1991	282.5	0.87	2.56	3.81	1.71	0.52
1992	273.5	0.85	2.49	3.90	1.72	0.53
1993	264.5	0.82	2.42	3.98	1.72	0.54
1994	255.6	0.80	2.36	4.06	1.72	0.55
1995	246.8	0.78	2.28	4.12	1.70	0.56
1996	238.0	0.76	2.22	4.17	1.69	0.57

Year	Estimates as Percentage of Baseline: Upholstered Furniture Fires	Estimates as Percentage of Baseline: Mattress/Bedding Fires
1986	18	28
1987	17	28
1988	16	27
1989	15	27
1990	14	26
1991	13	26
1992	12	25
1993	11	25
1994	11	24
1995	10	24
1996	9	23

SOURCES: Bottom section from Tables 15 and 16; top section from bottom section and Table 13.

Table 19. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed, Cigarette C130

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage (Millions of 1986 Dollars)
1986	324.1	1.19	3.51	3.52	1.81	0.49
1987	324.1	1.16	3.36	3.63	1.83	0.51
1988	314.2	1.12	3.22	3.73	1.84	0.52
1989	304.7	1.09	3.14	3.84	1.86	0.53
1990	295.1	1.06	3.06	3.93	1.87	0.54
1991	285.8	1.03	2.99	4.02	1.87	0.55
1992	276.6	1.00	2.92	4.10	1.88	0.56
1993	267.5	0.97	2.84	4.18	1.87	0.57
1994	258.6	0.95	2.79	4.25	1.87	0.58
1995	249.6	0.93	2.71	4.31	1.86	0.59
1996	240.7	0.91	2.65	4.36	1.84	0.60

Year	Estimates as Percentage of Baseline: Upholstered Furniture Fires	Estimates as Percentage of Baseline: Mattress/Bedding Fires
1986	24	39
1987	23	39
1988	22	39
1989	21	39
1990	20	39
1991	19	39
1992	17	39
1993	16	39
1994	15	39
1995	14	40
1996	14	40

SOURCES: Bottom section from Tables 15 and 16; top section from bottom section and Table 13.

Table 20. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed, Cigarette C201

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage (Millions of 1986 Dollars)
1986	320.1	0.64	2.09	2.74	1.23	0.39
1987	311.4	0.63	2.00	2.91	1.28	0.41
1988	302.6	0.62	1.92	3.06	1.33	0.42
1989	294.0	0.61	1.87	3.20	1.37	0.44
1990	285.4	0.60	1.83	3.33	1.40	0.45
1991	276.8	0.59	1.80	3.46	1.43	0.47
1992	268.3	0.58	1.77	3.57	1.45	0.48
1993	259.7	0.57	1.73	3.67	1.47	0.49
1994	251.2	0.56	1.69	3.76	1.48	0.51
1995	242.7	0.55	1.65	3.84	1.48	0.52
1996	234.3	0.55	1.60	3.91	1.47	0.53

Year	Estimates as Percentage of Baseline: Upholstered Furniture Fires	Estimates as Percentage of Baseline: Mattress/Bedding Fires
1986	4	6
1987	4	6
1988	4	5
1989	3	5
1990	3	4
1991	3	4
1992	2	4
1993	2	3
1994	2	3
1995	2	3
1996	2	2

SOURCES: Bottom section from Tables 15 and 16; top section from bottom section and Table 13.

Table 21. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed, Cigarette C202

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries		Direct Property Damage (Millions of 1986 Dollars)
				Version 1	Version 2	
1986	322.7	0.74	2.36	2.89	1.34	0.41
1987	313.6	0.73	2.24	3.03	1.38	0.42
1988	304.6	0.71	2.14	3.17	1.42	0.44
1989	295.7	0.69	2.07	3.30	1.45	0.45
1990	286.8	0.67	2.02	3.42	1.47	0.47
1991	278.0	0.65	1.97	3.53	1.49	0.48
1992	269.3	0.64	1.92	3.64	1.51	0.49
1993	260.6	0.62	1.86	3.73	1.52	0.50
1994	252.0	0.61	1.81	3.81	1.52	0.52
1995	243.3	0.59	1.75	3.88	1.51	0.53
1996	234.8	0.58	1.69	3.94	1.50	0.54

Year	Estimates as Percentage of Baseline	
	Upholstered Furniture Fires	Mattress/Bedding Fires
1986	8	12
1987	8	11
1988	7	10
1989	6	10
1990	6	9
1991	5	8
1992	5	7
1993	4	7
1994	4	6
1995	3	5
1996	3	5

SOURCES: Bottom section from Tables 15 and 16; top section from bottom section and Table 13.

Table 22. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96, Cigarette C106

Injuries Costed by CPSC @ $36,218

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	0.64 + 0.70Q	0.57 + 0.70Q
1987	0.66 + 0.70Q	0.59 + 0.70Q
1988	0.69 + 0.69Q	0.61 + 0.69Q
1989	0.71 + 0.69Q	0.63 + 0.69Q
1990	0.73 + 0.68Q	0.65 + 0.68Q
1991	0.75 + 0.68Q	0.67 + 0.68Q
1992	0.77 + 0.67Q	0.68 + 0.67Q
1993	0.79 + 0.67Q	0.70 + 0.67Q
1994	0.81 + 0.67Q	0.71 + 0.67Q
1995	0.82 + 0.66Q	0.72 + 0.66Q
1996	0.84 + 0.66Q	0.74 + 0.66Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

	Estimates as Percentage of Baseline		
Year	Death	Other Impact (Version 1)	Other Impact (Version 2)
1986	25	54	53
1987	25	54	53
1988	25	54	53
1989	25	54	53
1990	25	55	53
1991	25	55	52
1992	25	55	52
1993	25	55	52
1994	24	55	52
1995	24	55	52
1996	24	55	52

Table 23. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96, Cigarette C114

Injuries Costed by CPSC @ $36,218

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	0.75 + 1.20Q	0.68 + 1.19Q
1987	0.77 + 0.99Q	0.69 + 1.16Q
1988	0.78 + 0.96Q	0.70 + 1.12Q
1989	0.79 + 0.93Q	0.71 + 1.09Q
1990	0.80 + 0.90Q	0.72 + 1.06Q
1991	0.82 + 0.87Q	0.73 + 1.03Q
1992	0.83 + 0.85Q	0.74 + 1.00Q
1993	0.84 + 0.82Q	0.75 + 0.97Q
1994	0.85 + 0.80Q	0.76 + 0.95Q
1995	0.86 + 0.78Q	0.76 + 0.93Q
1996	0.87 + 0.76Q	0.77 + 0.91Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

	Estimates as Percentage of Baseline		
Year	Death	Other Impact (Version 1)	Other Impact (Version 2)
1986	36	54	53
1987	35	54	53
1988	34	54	53
1989	33	54	53
1990	33	55	53
1991	32	55	52
1992	31	55	52
1993	30	55	52
1994	29	55	52
1995	29	55	52
1996	28	55	52

Table 24. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96, Cigarette C130

Injuries Costed by CPSC @ $36,218

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	0.81 + 1.19Q	0.74 + 1.19Q
1987	0.83 + 1.16Q	0.75 + 1.16Q
1988	0.84 + 1.12Q	0.76 + 1.12Q
1989	0.85 + 1.09Q	0.77 + 1.09Q
1990	0.86 + 1.06Q	0.78 + 1.06Q
1991	0.87 + 1.03Q	0.79 + 1.03Q
1992	0.88 + 1.00Q	0.79 + 1.00Q
1993	0.89 + 0.97Q	0.80 + 0.97Q
1994	0.91 + 0.95Q	0.81 + 0.95Q
1995	0.92 + 0.93Q	0.82 + 0.93Q
1996	0.93 + 0.91Q	0.82 + 0.91Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

	Estimates as Percentage of Baseline		
Year	Death	Other Impact (Version 1)	Other Impact (Version 2)
1986	42	59	58
1987	41	59	57
1988	40	59	57
1989	39	58	57
1990	38	58	57
1991	37	58	56
1992	37	58	56
1993	36	58	56
1994	35	58	56
1995	34	58	56
1996	33	58	56

Table 25. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96, Cigarette C201

Injuries Costed by CPSC @ $36,218

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	0.61 + 0.64Q	0.56 + 0.64Q
1987	0.63 + 0.63Q	0.57 + 0.63Q
1988	0.66 + 0.62Q	0.58 + 0.62Q
1989	0.68 + 0.61Q	0.60 + 0.61Q
1990	0.70 + 0.60Q	0.62 + 0.60Q
1991	0.72 + 0.59Q	0.63 + 0.59Q
1992	0.73 + 0.58Q	0.65 + 0.58Q
1993	0.75 + 0.57Q	0.66 + 0.57Q
1994	0.77 + 0.56Q	0.67 + 0.56Q
1995	0.78 + 0.55Q	0.68 + 0.55Q
1996	0.79 + 0.55Q	0.69 + 0.55Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

	Estimates as Percentage of Baseline		
Year	Death	Other Impact (Version 1)	Other Impact (Version 2)
1986	22	44	43
1987	22	45	43
1988	22	46	44
1989	22	47	44
1990	22	47	45
1991	21	48	45
1992	21	48	46
1993	21	49	46
1994	21	49	46
1995	20	50	47
1996	20	50	47

Table 26. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96, Cigarette C202

Injuries Costed by CPSC @ $36,218

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	0.65 + 0.74Q	0.59 + 0.74Q
1987	0.67 + 0.73Q	0.60 + 0.73Q
1988	0.69 + 0.71Q	0.61 + 0.71Q
1989	0.71 + 0.69Q	0.63 + 0.69Q
1990	0.72 + 0.67Q	0.64 + 0.67Q
1991	0.74 + 0.65Q	0.65 + 0.65Q
1992	0.75 + 0.64Q	0.67 + 0.64Q
1993	0.77 + 0.62Q	0.68 + 0.62Q
1994	0.78 + 0.61Q	0.69 + 0.61Q
1995	0.79 + 0.59Q	0.70 + 0.59Q
1996	0.81 + 0.58Q	0.71 + 0.58Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

	Estimates as Percentage of Baseline		
Year	Death	Other Impact (Version 1)	Other Impact (Version 2)
1986	26	47	45
1987	26	48	46
1988	25	48	46
1989	25	48	46
1990	24	49	47
1991	24	49	47
1992	23	50	47
1993	23	50	47
1994	22	50	48
1995	22	50	48
1996	21	51	48

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   John Krasny, National Bureau of Standards
   James Sharman, Consumer Product Safety Commission
   Charles Smith, Consumer Product Safety Commission
   Wayne Stiefel, National Bureau of Standards
2. Other Invited Participants:
   Colin Church, Consumer Product Safety Commission
   Steven Weber, National Bureau of Standards
   Beatrice Harwood, Consumer Product Safety Commission
   Margaret Neily, Consumer Product Safety Commission
   Dale Ray, Consumer Product Safety Commission
   Rosalie Ruegg, National Bureau of Standards
3. Other Participants:
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   John Ottoson, Federal Emergency Agency
   Leonard Rhyne, Lorillard, Inc.
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Appendix A

General Model for Calculation of Relative Ignition Propensities of Different Cigarettes

This model uses actual cigarette fires to weight laboratory results by item class, where item class is a collection of products or other materials in a common form that cigarettes could ignite. These actual fires are taken from a specified historical period (1980-84, the latest five-year period for which data are available), and the same period must be used to estimate other real-world parameters, specifically, the market share structure of cigarettes and the usage share structures for the various products comprising each item class.

The model assumes laboratory test variations that are not variations in the design of products already have been averaged out. The leading example of such a variation is the location of the cigarette on the item. Because ignition propensities may vary significantly by location, this dimension is important enough to be treated explicitly as a refinement of the model, which is feasible if data or estimates are available on the probability of location, given contact between cigarette and item. (Note that this is not the same as the probability of location given ignition.) Laboratory test results by location are also needed.

Definitions of Terms

- i is a benchmark brand or type of cigarette used for modeling. The values of i are assumed to represent the entire cigarette market. Each benchmark brand or type of cigarette is associated with a class of available cigarette types and brands with the understanding that the benchmark cigarette type i represents all the cigarettes in the associated class (e.g., a particular 100 mm brand might represent all 100 mm cigarettes). Every available brand and type is associated with exactly one benchmark type. Let $i = 1, \ldots, n$ be the benchmark type selected from currently available cigarettes. Let i_* be any new experimental type of cigarette, not yet in use, that is to be modeled.

- J is a class of items that could be ignited by cigarettes. The J classes must conform to the class definitions of Form of Material First Ignited as specified in the 1976 edition of the NFPA 901 Standard, *Uniform Coding for Fire Reporting,* as these are the classes used in reporting fires. The values of J may not exhaust all the possible item classes, but it is assumed that the ignition propensities of cigarettes with respect to the J classes used are the ones of interest and may be taken as either representative of all unrepresented item classes or as capturing all the fire losses that would be affected by a change in cigarette design. Let $J = 1, \ldots, r$ be the item classes modeled.

- j_J is a particular benchmark version of the items in item class J. It is a well-defined product suitable for testing. As with the cigarette types, each benchmark version is associated with a larger class of versions of the item and is taken to represent the class (e.g., all velvet-covered, cotton-filled upholstered furniture might be represented by a particular piece). Every currently available version of the item must be associated with exactly one such class. Let $j_J = 1, \ldots, k_J$ be the k_J benchmark version of items in item class J.
- q(i) is a probability distribution giving the market shares of cigarettes in terms of the market shares for the classes associated with cigarette types $i = 1, \ldots, n$.
- $u(j_J)$ is a probability distribution giving the percentage share of items in *use* (not sales) for all items in item class J. Thus, $u(k_J)$ is the percentage share of all J-type items in use that fall into the class associated with item version numbered k_J.
- $R(i,j_J)$ is a ratio that gives the proportion of times that fires occurred in laboratory tests exposing item version j_J to cigarette type i. As noted, if the tests involve variations going beyond the variations in i and j_J, then these variations need to be weighted and averaged to produce $R(i,j_J)$ values that depend only on i and j_J.
- prob(a, b, and c | x, y, z) is a general expression for the probability that a, b, and c occur, given that x, y, and z occur. The use of three defining terms before and after is illustrative only; there can be as many or as few as are required. The vertical bar means "given that."
- B_J is a scaling factor from the laboratory to the real world, defined so that B_J multiplied by $R(i,j_J)$ produces prob(ignition | i, j_J, contact). The assumption implicit in this is that B_J is a function of item class J but not of cigarette type i or item version j_J. In lay terms, the model assumes that

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the specification of a laboratory protocol for exposing items to cigarettes is done in such a way that no cigarette type and no item version is made to look better or worse than it does in real life, relative to every other cigarette type and item version. The protocol is expected to reflect differences in item classes because those differences are so large, but the lesser differences in item version and cigarette type are assumed to have negligible effect.

Summary of Major Assumptions

- As noted above in 1(a), it is assumed that cigarette types can be grouped into classes such that each class is well represented by the benchmark cigarette selected for that class. Similarly, as noted in 1(c), it is assumed that benchmark item versions can be selected and assigned to classes so that each version represents its class and so that the classes, which are non-overlapping, collectively cover all versions of the item.
- As noted above in 1(b), it is assumed that cigarette ignition propensities overall will be validly estimated by a model that assesses cigarette ignition propensities relative to a limited number of item classes.
- As noted above in 1(f), it is assumed that a basis exists for averaging out all laboratory test variations other than those that are variations in the item version and the cigarette type. Thus far, the only significant variation of this type identified is the location of the cigarette on the item, and this is explicitly addressed in the specific applications of the general model.
- As noted above in 1(h), it is assumed that laboratory tests accurately reproduce the ways cigarettes and items come into contact so that no cigarette type or item version is advantaged or disadvantaged in the laboratory. More precisely, it is assumed that prob(ignition | i, j_J, contact)/R(i,j_J) = B_J, a term that is a function of J but not of i or j_J. This is a strong assumption.
- It is assumed that prob(ignition | i, j_J, contact) = q(i) u(j_J). That is, the probability of contact involving a particular cigarette type i is the same for item version j_J as it is for any other item version j_J', and the probability of contact involving a particular item version j_J is the same for cigarette type i as it is for any other cigarette type i'. In lay terms, this is equivalent to saying that carelessness is equally likely for any combination of cigarette type and item version. This is a strong assumption.
- Trends over time are ignored in this model. That is, the relative propensities of different cigarette types to ignite fires are calculated only once and are regarded then as fixed properties of the cigarette types. In theory, one could develop estimates linking, i, j_J, and J so that projections of changes in the use of items of class J could be reflected directly in the weighted ignition propensity terms, but this additional refinement is considered beyond the scope of this project and what we now know how to do. For now, the only terms that are functions of the year being analyzed are the market and usage shares, q(i) and u(j_J).

Derivation of the Model

(a) prob(ignition | contact) =

$$\sum_{j=1}^{r} \text{prob(ignition and J | contact)}$$

By definitions of terms.

(b) prob(ignition | contact) =

$$\sum_{j=1}^{r} \text{prob(ignition and | J, contact) prob(J | contact)}$$

By definitions of terms.

(c) prob(ignition | J, contact) =

$$\sum_{i=1}^{n} \sum_{j_J=1}^{k_J} \text{prob(ignition, i, and } j_J \text{ | J, contact)}$$

By definitions of terms.

(d) prob(ignition | J, contact) =

$$\sum_{i=1}^{n} \sum_{j_J=1}^{k_J} \text{prob(ignition | i, } j_J\text{, J, contact) prob(i and jJ | J, contact)}$$

By definitions of terms.

(e) $$\text{prob(ignition | J, contact)} = \sum_{i=1}^{n} \sum_{j_J=1}^{k_J} B_J \, R(i,j_J) \, q(i) \, u(j_J)$$

By assumptions stated in 2(d) and 2(e).

(f) prob(ignition | J, contact) =

$$\sum_{j=1}^{r} \sum_{i=1}^{n} \sum_{j_J=1}^{k_J} B_J \, R(i,j_J) \, q(i) \, u(j_J) \, \text{prob(J | contact)}$$

By combining 3(b) and 3(e).

(g) prob(ignition | contact) =

$$\sum_{i=1}^{n} q(i) \left[\sum_{J=1}^{r} B_j \, \text{prob (J | contact)} \left\{ \sum_{j_J=1}^{k_J} R(i,j_J) \, u(j_J) \right\} \right]$$

By rearranging terms in 3(f).

(h) prob(ignition | contact) =

$$\sum_{i=1}^{n} q(i) \, \text{prob(ignition | i, contact)}$$

By definitions of terms.

(i) prob(ignition | i, contact) =

$$\sum_{J=1}^{r} B_J \, \text{prob}(J \mid \text{contact}) \left[\sum_{j_J=1}^{k_J} R(i,j_J)\, u(j_J) \right]$$

By using 3(g) and 3(h) to solve for prob(ignition | i, contact).

(j) prob(ignition and J | contact) =

$$B_J \, \text{prob}(J \mid \text{contact}) \left\{ \sum_{i=1}^{n} q(i) \left[\sum_{j_J=1}^{k_J} R(i,j_J)\, u(j_J) \right] \right\}$$

By using 3(f) and 3(a) to solve for prob(ignition and J | contact), then rearranging terms.

(k) B_J =

$$\frac{\text{prob(ignition and } J \mid \text{contact)}}{\text{prob}(J \mid \text{contact}) \left\{ \sum_{i=1}^{n} q(i) \left[\sum_{j_J=1}^{k_J} R(i,j_J)\, u(j_J) \right] \right\}}$$

By solving for B_J in 3(j).

(l) prob(ignition | i, contact) =

$$\sum_{J=1}^{r} \text{prob(ignition and } J \mid \text{contact)} \left\{ \frac{\sum_{j_J=1}^{k_J} R(i,j_J)\, u(j_J)}{\sum_{i=1}^{n} q(i) \left[\sum_{j_J=1}^{k_J} R(i,j_J)\, u(j_J) \right]} \right\}$$

By combining 3(i) and 3(k), then canceling prob(J | contact).

(m) Relative propensity of cigarette type i to ignite fires =

prob(ignition | i, contact)/prob(ignition | contact) =

$$\sum_{J=1}^{r} \text{prob}(J \mid \text{ignition, contact}) \left\{ \frac{\sum_{j_J=1}^{k_J} R(i,j_J)\, u(j_J)}{\sum_{i=1}^{n} q(i) \left[\sum_{j_J=1}^{k_J} R(i,j_J)\, u(j_J) \right]} \right\}$$

By dividing through by prob(ignition | contact), then substituting prob(J | ignition, contact) for prob(ignition and J | contact)/prob(ignition | contact).

(n) Relative propensity of new cigarette type i_* to ignite fires =

$$\sum_{J=1}^{r} \text{prob}(J \mid \text{ignition, contact}) \left\{ \frac{\sum_{j_J=1}^{k_J} R(i_*,j_J)\, u(j_J)}{\sum_{i=1}^{n} q(i) \left[\sum_{j_J=1}^{k_J} R(i,j_J)\, u(j_J) \right]} \right\}$$

(o) Laboratory tests on new cigarette type i_* against item versions $j_J = 1, \ldots, k_J$ are weighted by the relative likelihood of each item version, which produces a weighted sum for the tests of i_* against the entire item class J. This is then compared by ratio to a similar weighted sum for all currently available cigarettes, with the latter calculated as a weighted sum of laboratory tests (weighted by the relative likelihood of each item version) for each commercially available cigarette, each weighted by that cigarette type's market share. The resulting ratio is a measure of new cigarette type i_*'s relative propensity to ignite the items in item class J. Each sure ratio is weighted by that item class's historic share of cigarette fires. Then all weighted ratios are summed to provide the overall relative propensity to cause ignitions for cigarette type i_*. Note that information on i_* is used only in the numerators of the ratios and that no projections on future market share for the new cigarette are required or used.

Formatting of Tests and Data

This model format also dictates a format for the display of laboratory tests and other data. All laboratory test results on cigarette ignitions must be pooled into ratios of the form $R(i,j_J)$. Usage data on items must be organized into proportions of the form $u(j_J)$. And market share information for cigarettes must be organized into proportions of the form q(i).

Sensitivity of Results

This model is at least potentially sensitive to the initial selection of categories for i, j_J, and j, and the selection of benchmark cigarettes and item versions within item classes. The more variation there is in ignition properties between different cigarette types or different item versions, the more desirable it is to have a fine structure of categories, but this may be prevented by the scarcity of data on relative shares of usage, let alone the costliness of testing. One is typically forced to trade off uncertainty in the accuracy of usage proportions against uncertainty in the assignment of a benchmark item as having average properties for its class.

At this time, there is not sufficient laboratory test data to assess these sensitivities quantitatively or to provide guidelines on how fine a structure should be used. In the interim, it is recommended that one use the finest structure possible, consistent with the limitations of available usage data, and that sensitivity tests be conducted on different items within item classes in order to provide a basis for quantifying these uncertainties in future applications.

Appendix B

Derivation of Ignitability Indexes for Smoking Material Ignitions of Upholstered Furniture, 1980-84 and 1986-96

The ignitability indexes for upholstered furniture given in Table 7 were computed so as to be consistent with the modeling format and categorization decisions used in the general model of relative ignition propensities of different cigarette types, as derived in Appendix A. The part of the model in Appendix A that is relevant to the development of ignitability indexes for items is given in expression 3(j) in Appendix A, which leads to the following:

(1) prob(ignition | contact, upholstered furniture) =

$$\frac{\text{prob(ignition and upholstered furniture | contact)}}{\text{prob(upholstered furniture | contact)}} =$$

$$B_f \left\{ \sum_{i=1}^{n} q(i) \left[\sum_{j_f=1}^{k_f} R(i,j_f)\, u(j_f) \right] \right\}$$

where B_f is B_J when J is upholstered furniture;

- $i = 1, \ldots, n$ are the n types of cigarettes;
- $q(i)$ gives the market share cigarette type i;
- $j_f = 1, \ldots, k_f$ are the k_f versions of upholstered furniture;
- $R(i,j_f)$ is the proportion of laboratory tests combining cigarette type i and upholstered furniture version j_f that resulted in ignitions; and
- $u(j_f)$ gives the share of upholstered furniture in use that is of type j_f.

Several assumptions are needed to use this expression as the basis for an ignitability index. First, since Appendix A assumed that B_J, and specifically B_f, the scaling factor that links laboratory results to the real world, is constant over time, it may be dropped from the index. (This means the index will not directly provide the conditional ignition probability given contact with upholstered furniture but will give values proportional to those probabilities.)

Second, one must accommodate the fact that the available test data are not sufficient to provide results from a representative range of cigarettes. Based on tests by the National Bureau of Standards (NBS), the variation of ignition propensity among currently available cigarettes may be so slight that one may safely pool results from all commercially available cigarettes. [12] In that case, n=1 and q(1)=1.

Third, in assumption 2(c) of Appendix A, it was noted that laboratory variations other than cigarette type, item class, and item version were assumed to have been averaged out. In the case of upholstered furniture, the one variation other than those that needs to be explicitly addressed is the location of the cigarette on the upholstered furniture.

The removal of B_f and variations in cigarette type reduces expression (1) to the following:

$$(2) \quad \sum_{j_f=1}^{k_f} R(i_c,j_f)\, u(j_f)$$

where i_c refers to the collective commercially available cigarettes, and other terms are defined as before.

Expansion of expression (2) to explicitly reflect the location where the cigarette is discarded produces the following:

$$(3) \quad \sum_{l=1}^{L} \sum_{j_f=1}^{k_f} \qquad R(i_c,j_f,1)\, u(j_f)\, p\Sigma$$

where $1 = 1, \ldots, L$ are the L locations where discarded is possible;

$R(i_c,j_f,l)$ is the ratio of ignitions to laboratory tests, for all tests involving commercially available cigarettes, location l, and upholstered furniture type j_f;

p(1) is the probability of location 1, that is, the probability that a discarded cigarette (not necessarily one leading to a fire) will land on location 1, with p(1) assumed to be independent of the version of upholstered furniture, j_f; and all other terms are defined as before.

The remainder of the derivation takes advantage of the results from Appendix C regarding the actual values of r and L and how they interact:

(a) There are three classes of fabric to be distinguished. There also are two types of filling material, each of which may be used independently in each of three locations – seats, arms, and backs. Thus there are 2^3 or 8 filling material combinations, producing 24 versions of upholstered furniture.

Expression (3) can therefore be revised to reflect this structure:

$$(4) \quad \sum_{1=1}^{L} \sum_{y=1}^{3} \sum_{z_1=1}^{2} \sum_{z_2=1}^{2} \sum_{z_3=1}^{2} R'(i_c,y,z_1,z_2,z_3,1)\ u'(y,z_1,z_2,z_3)\ p(1)$$

where $R'(i_c,y,z_1,z_2,z_3,1) = R(ic,jf,1)$ and $u'(y,z_1,z_2,z_3) = u(j_f)$, given that j_f is the version of upholstered furniture defined by fabric y, arm filling material z_1, back filling material z_2, and seat filling material z_3.

(b) There are four locations – flat surface of arm, flat surface of seat, crevice formed by arm and seat, and crevice formed by back and seat. However, the two crevices have the same probability of discard and the same performance in the laboratory. This is also true for the two flat surfaces.

(c) Therefore, for each fabric type, there are essentially five location/filling material combinations – flat surface with one or the other filling material (two combinations), crevice with both sides filled with one or the other filling material (two combinations), and crevice with one side filled with one material and the other side filled with the other material. From this vantage point, there are 15 combinations of fabric, filling material and location.

Expression (4) can be restated in terms of these 15 combinations if it can be assumed, as seems reasonable, that the laboratory results for a particular configuration – crevice versus flat and particular fabric and filling materials at that location – is independent of the characteristics of the rest of the upholstered furniture. In that case, one may pool all test results referring to one of the 15 combinations. This allows expression (4) to be recast, as follows:

$$(5) \quad \sum_{y=1}^{3} \sum_{f1=1}^{5} R''(i_c,y,f1)\ u''(y,f1)$$

where y = 1, . . . , 3, represent the three fabric types;

f1 = 1, . . . , 5, represent the five location/filling material combinations;

$R''(i_c,y,f1)$ is the ratio of ignitions to tests for all laboratory tests involving commercially available cigarettes, fabric type y, and filling material/location combination fl; and $u''(y,f1)$ is the probability of fabric type y and filling material/location combination f1.

The formulas for computing $u''(y,f1)$ are based on combining the probability of a version of upholstered furniture and the probability of a location for which that upholstered furniture will have indicated filling materials at that location. The formulas are as follows:

(6) $u''(y,\text{flat with filling material } x) =$

$\text{prob(arm flat)}\ [u'(y,x,1,1)+u'(y,x,1,2)+u'(y,x,2,1)+u'(y,x,2,2)] + \text{prob(seat flat)}\ [u'(y,x,1,1)+u'(y,1,2,x)+u'(y,2,1,x)+u'(y,2,2,x)].$

(7) $u''(y,\text{crevice with filling material } x \text{ on both sides}) =$

$\text{prob(arm/seat crevice)}[u'(y,x,1,x)+u'(y,x,2,x)] + \text{prob(back/seat crevice)}\ [u'(y,1,x,x)+u'(y,2,x,x)].$

(8) $u''(y,\text{crevice with different filling materials on the two sides}) = \text{prob(arm/seat crevice)}$
$[u'(y,1,1,2)+u'(y,2,1,1)+u'(y,1,2,2)+u'(y,2,2,1)] +$
$\text{prob(back/seat crevice)}$
$[u'(y,1,1,2)+u'(y,1,2,1)+u'(y,2,1,2)+u'(y,2,2,1)].$

Careful examination will show that each $u'(y,z_1,z_2,z_3)$ value is weighted once and only once by each of the four location probabilities. The estimation of these four location probabilities is based on a small probabilistic model. Let the key terms be defined as follows:

- Q_1, Q_2 – The probabilities that, given a cigarette is discarded on a piece of upholstered furniture, it comes to rest on a flat surface (Q_1) or a crevice (Q_2), respectively;
- q_1, q_2 – the probabilities that, given that a cigarette has been discarded at location 1 (flat surface) or location 2 (crevice), a fire will result;
- p_1, p_2 – the probabilities that, given fire due to a discarded cigarette on upholstered furniture, it will occur at location 1 or 2;
- r_1, r_2 – the probabilities that fire will occur and it will be at location 1 or 2, respectively, given that a cigarette has been discarded on upholstered furniture;
- x – the probability that a fire will occur, given discard of a cigarette on upholstered furniture; and
- w – a term defined as (q_1/q_2).

Then $q_1 = r_1/Q_1$ and $q_2 = r_2/Q_2$, by definition.

And $r_1 = xp_1$ and $r_2 = xp_2$, again by definition.

So $Q_1 = xp_1/q_1$ and $Q_2 = xp_2/q_2 = xp_2w/q_1$.

Then $Q_1+Q_2 = 1$, so $(xp1+xp_2w)/q_1 = 1$.

So $x_1/q_1 = 1/(p_1+p_2w)$.

And finally $Q_1 = p_1/(p_1+p_2w)$ and $Q_2 = p_2w(p_1+p_2w)$.

Beatrice Harwood of CPSC indicated that data from 1981-82 CPSC in-depth investigations indicate p_1 = .21 and p_2 = .79. The value of w is estimated in Appendix C. Therefore, the probability of discard on an arm flat surface equals the probability of discard on a seat flat surface equals (.105)/(.21+.798w). And the probability of discard on an arm/seat crevice equals the probability of discard on a back/seat crevice equals (.395w)/(.21+.79w).

This completes the derivation of the ignitability index formulas for the baseline case for upholstered furniture. These changes have also altered the formulas developed in the general model for calculating the ignition propensity of different cigarettes. Examine expression 3(n) from Appendix A and revise it as follows:

(a) All commercially available cigarettes are considered the same, so n=1 and q(1)=1.

(b) Isolate the expression in braces for J=1 (upholstered furniture).

(c) For J=1, note that the numerator and denominator expressions have been changed:

$$\sum_{j_1=1}^{k_1} R(i,j_1)\, u(j_1) \text{ has been replaced by } \sum_{y=1}^{3} \sum_{f1=}^{5} R''(i,y,fl)\, u''(y,f1).$$

Therefore, the revised expression within the braces for J=1 is:

$$(9) \quad \frac{\sum_{y=1}^{3} \sum_{f1=1}^{5} R''(i_*,y,f1)\, u''(y,f1)}{\sum_{y=1}^{3} \sum_{f1=1}^{5} R''(i_c,y,f1)\, u''(y,f1)}$$

The other J class to be explicitly modeled is mattresses/bedding. In Appendix C, it is noted that there are no tests of experimental cigarettes on mattresses and bedding, but it is possible to model mattresses and bedding as flat surface location ignitions of upholstered furniture. All are modeled as fabric type 1 (cellulosics excluding prints, because this was the only fabric type tested with experimental cigarettes. Those mattresses not complying with the mattress ignitability standard are modeled as filling material type 1 (untreated cotton batting), while those complying with the standard are modeled as filling material type 2 (all other materials).

This means that, for mattresses and bedding, expression (2) becomes:

(10) $R''(i_c$,1,flat/filling material 1) prob(pre-Standard) +

$R''(i_c$,1,flat/filling material 2) prob(post-Standard),

where prob(pre-Standard) and prob(post-Standard) represent shares of products in use (and are given in Appendix C).

Relabel $R'(i_c$,1,flat/filling material x) as $R''(i_c$,1,flat-x) for short.

Then expression (9) for mattresses and bedding is given as follows:

$$(11) \quad \frac{R''(i_*,1,\text{flat-1})\ \text{prob(pre-Standard)} + R''(1_*,1,\text{flat-2})\ \text{prob(post-Standard)}}{R''(i_c,1,\text{flat-1})\ \text{prob(pre-Standard)} + R''(1_c,1,\text{flat-2})\ \text{prob(post-Standard)}}$$

This completes the derivation of the needed formulas for analysis. Expressions (5) and (10) provide the ignitability indexes, which are converted to fire rates per billion cigarettes by a scaling factor that is estimated by linear regression of the 1980-84 fire rates against the 1980-84 ignitability indexes (but fixing the regression so that an index of zero predicts a fire rate of zero). Then expressions (9) and (11) provide the formulas for modifiers that can be used to produce ignitability indexes appropriate for a new cigarette type i* rather than the commercially available cigarettes.

Appendix C
Ignition Propensity Calculations for Commercially Available and Experimental Cigarettes Applied to Upholstered Furniture and Mattress/Bedding

To produce projections of the smoking-material fire problem if new cigarettes are used, it is necessary to address the major classes of fires ignited by cigarettes and the data available on them. Upholstered furniture and mattresses/bedding account for roughly four-fifths of all deaths, three-fourths of all civilian injuries, and one-half the property damage and fire fighter injuries in smoking-material fires. Therefore, an analysis confined to those fires, which is necessary because of the absence of adequate data on other major item classes, is acceptable. Because the analysis of mattress/ bedding fires is partly based on the upholstered furniture data, the latter will be analyzed first.

The model in Appendix A, as revised in Appendix B, requires that all upholstered furniture test data be grouped into representative classes defined by fabric type, location on the upholstered furniture, and filling materials at those locations. These classes should be chiefly distinguished by differences in relative ignitability and must be classes for which one can estimate, on a year-by-year basis, the shares of upholstered furniture in use having those fabric and filling material combinations. This grouping exercise was done in stages.

Calculating Baseline Upholstered Furniture Ignitability Parameters

(a) First, a table showing estimated qualitative differences in ignitability as a function of fabric, filling material, and location of contact between cigarette and furniture, was developed by James Sharman and Margaret Neily of the U.S. Consumer Product Safety Commission and John Krasny of the National Bureau of Standards. This is shown in Table C-1.

(b) There was some discussion of how this table compared to an ideal categorization. It was noted that, of the filling materials grouped in the "other" class, polyester was the least ignitable and therefore the filling material that would be most appropriate to isolate as a third class. Also, there was some discussion of the extent to which ignitability may be a function of the weight of the fabric. This had been excluded from the bases used for categorizing because it was recognized that no data or basis for estimating existed with respect to relative usage as a function of fabric weight. Finally, there was some discussion of the possibility that ignitability might be a very sensitive physical property that varies widely as a function of many material properties, including random variations in production quality and even ambient environmental conditions such as humidity. [11]

The key modelling assumption involved here is that any parameters not explicitly addressed are effectively averaged out in the testing process. The accuracy of this assumption can only be tested through extensive sensitivity tests. Such testing has not been done and would be needed to assure that any test protocol would be designed to assure the averaging out of all factors that are not explicitly addressed. Because this has not been tested, there is some uncertainty, whose magnitude cannot be quantified with available data, in the data used for this analysis.

In a more sophisticated version of the model, one would test a finer gradation of classes of upholstered furniture, which would imply a much larger regimen of laboratory tests (which could therefore cost more). (It also would likely overwhelm the obtainable data on usage shares of product versions.) One way of inferring test results without having to conduct tests on all product versions would be sequential sampling. Suppose products could be arranged monotonically by those characteristics related to ignitability. Then if one product version were tested and found resistant to ignition by all cigarette types, then that would be sufficient to dictate that similar results would be found if any less ignitable product version were tested. Conversely, if one product version were tested and found susceptible to ignition by all cigarette types, then that would be sufficient to dictate that similar results would be found if any more ignitable product version were tested.

(c) The second stage was that the initial classification given in Table C-1 was collapsed into a smaller number of categories based on identical or similar patterns, as shown in Table C-2. At this point, available test data were assembled and organized according to this categorization. See Table C-3 for a display of the test data used.

Data also were obtained from the UFAC Voluntary Action

Table C-1. First-Stage Table of Upholstered Furniture Classes With Estimated Ignitability

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
1. Cellulosic Velvet or Corduroy	I	?	I	I	I
2. Cellulosic or Jacquard	I	I	I	?	I
3. Cellulosic Flock	I	?	I	?	I
4. Cellulosic Dobby	I	?	I	?	I
5. Cellulosic Print	I	?	I	?	I
6. Thermoplastic Velvet or Corduroy	?	N	?	N	?
7. Thermoplastic Jacquard	?	N	?	N	?
8. Thermoplastic Flock	I	N	I	N	I
9. Thermoplastic Dobby	I	N	I	N	I
10. Thermoplastic Print	I	N	I	N	I
11. Vinyl	N	N	N	N	N

NOTES: I – Would be expected to ignite, given contact with lighted cigarette.
? – Not sure whether it would ignite, given contact with lighted cigarette.
N – Would be expected not to ignite, given contact with lighted cigarette.

"Any other material" includes polyurethane foam (the material considered representative of the class), treated cotton batting, mixed fibers, and polyester. "Untreated cotton batting" includes latex foam and other natural materials. "Different materials" means the crevice has untreated cotton batting on one side and some other material on the other side.

Program Chair Test, published by Guilford Laboratories, Inc. in July 1979 [20]. These data were not used because the results differed so sharply from the other tests. (For example there were no ignitions in 16 tests on flat surfaces, untreated cotton batting filling, with fabric group 1.) While this divergence of results provides a useful cautionary note on the uncertainty of these calculations it is believed the excluded results were anomalous and would produce best estimates.

Table C-2. Second-Stage Table of Upholstered Furniture Classes With Estimated Ignitability

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
1. Cellulosic Velvet, Corduroy, Jacquard, Flock, Dobby	I	I or ?	I	I or ?	I
2a. Thermoplastic Velvet, Corduroy or Jacquard	?	N	?	N	?
2b. Cellulosic or Thermoplastic Print, or Thermoplastic Flock or Dobby	?	N	I	N	I
3. Vinyl	N	N	N	N	N

NOTES: I – Would be expected to ignite, given contact with lighted cigarette.
? – Not sure whether it would ignite, given contact with lighted cigarette.
N – Would be expected not to ignite, given contact with lighted cigarette.

Test results on the 400 chair tests conducted by Gordon H. Damant in California were not systematically included because they were not available in time for inclusion. However, they do provide the one test of fabric group 2a, crevice with other material in both sides; this test produced an ignition. [4] Also, results of six tests by Emil Braun and others at NBS were provided late in the project but were considered unlikely to change the results and so were not included. [2]

Table C-4 summarizes the results of the test data from Table C-3.

(d) At this point, it was determined that usage share information could not be developed separately for fabric classes 2a and 2b (see [18], provided in full at the end of this appendix). Therefore, after consulting with two of the developers of the original categorization, the author obtained agreement to combine the two classes.

There were still four entries for which the basic test data provided no tests. Three were for vinyl fabrics; these were all set to zero in accordance with the uniform pattern of tests involving vinyl fabrics and the estimates of the developers of the original categorization. The fourth was for the fabric class combining classes 2a and 2b and for crevices involving other materials on both sides. This was set at 1.000 in accordance with the one test done by Damant, cited in point #2; this also appears generally consistent with the much larger number of tests involving the same filling material and location for fabric class 1.

The result of all these decisions is shown on Table C-5, which provides the baseline $R''(i_c,y,fl)$ values required for expression (5) in Appendix B.

(e) Test results can be greatly affected if the cigarette is in contact with the welt cord, given that the furniture has welt cord, because some welt cord is of a type that reduces ignitability. However, it is estimated that in the baseline period used for model calibration (1980-84), such ignition-reducing welt cord was in use in at most 5% of all upholstered furniture in use. Furthermore, the likelihood of a cigarette falling onto the welt cord further reduces the effect of this scenario on the overall calculation. Therefore, welt cords were ignored.

Table C-3. Test Data on Ignitability of Upholstered Furniture

		Location of Cigarette and Filling Materials at that Location				
		Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
1.	Cellulosic	(3/3)	(86/327)	(–)	(149/192)	(2/3)
	Velvet,	(–)	(3/30)	(–)	(10/58)	(1/3)
	Corduroy,	(–)	(–)	(–)	(–)	(–)
	Jacquard,	(14.25/16)	(0/16)	(15.92/16)	(2.25/24)	(–)
	Flock	(–)	(0/6)	(–)	(0/12)	(–)
	Dobby					
2a.	Thermoplastic	(0/3)	(3/155)	(–)	(10/84)	(0/3)
	Velvet,	(–)	(0/42)	(–)	(2/108)	(–)
	Corduroy or	(–)	(–)	(–)	(–)	(–)
	Jacquard	(–)	(0/6)	(–)	(2/12)	(–)
2b.	Cellulosic	(1/16)	(33/286)	(–)	(64/216)	(3/3)
	or Thermoplastic	(–)	(3/48)	(–)	(22/114)	(3/3)
	Print, or	(8/24)	(0/12)	(–)	(–)	(7/12)
	Thermoplastic	(–)	(–)	(–)	(–)	(–)
	Flock or	(–)	(0/15)	(–)	(8/30)	(–)
	Dobby					
3.	Vinyl	(–)	(0/12)	(–)	(0/6)	(–)
		(–)	(–)	(–)	(–)	(–)
		(–)	(–)	(–)	(–)	(–)
		(–)	(–)	(–)	(–)	(–)

NOTES: Each row represents a different data source. Tests in row 4 have had numbers of tests and ignitions divided by 12 because it is the only test series in which tests were run for different cigarettes (12 types) and it was felt these results would overly dominate the results unless they were reduced in this way.

SOURCES:Row 1 [7], Row 2 [5], Row 3 [13], Row 4 [12], Row 5 [6].

(f) There is a question as to whether the decking material of upholstered furniture is ever the first location ignited. The group's view was that even when cigarettes fall to the decking material, they ignite the cushions first, so this scenario does not alter the location probabilities.

(g) Laboratory tests have been conducted on 12 different currently available cigarettes. However, the conditions of the test required the identities of the cigarettes to be concealed. Therefore, it is not possible to assign those 12 cigarettes as benchmarks to classes and assess market shares for the classes. Also, the results showed sufficiently little variation that the pooling of the results is plausible.

At the same time, the tests showed only slight variations in ignition propensity among the 12 cigarettes. Therefore, these test results are roughly consistent with the idea that any currently available cigarette can be used to represent all current cigarettes, which is what must be done to obtain results using currently available data.

Calculating Baseline Mattress/Bedding Ignitability Parameters

(a) A field test was done by CPSC [3] that compared the involvement of pre-Standard and post-Standard mattresses in actual fires. It found post-Standard mattresses accounted for 15% of the fires in a field study running from December 1981 through August 1983. Another CPSC study [14] estimated the percentage of mattresses in use that were post-Standard mattresses for each year, 1980-83. An estimate of the average percentage of mattresses in use that were post-Standard mattresses during the 21-month field study, then,

Table C-4. Estimated Ignitability Based on Test Data, Four Fabric Classes of Upholstered Furniture

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
1. Cellulosics Except Prints	0.908	0.235	0.995	0.564	0.500
2a. Thermoplastic Velvet, Corduroy or Jacquard	0.000	0.015	No Data	0.069	0.000
2b. Cellulosic or Thermoplastic Flock or Dobby	0.300	0.100	No Data	0.261	0.722
3. Vinyl	No Data	0.000	No Data	0.000	No Data

would be (1/21) (1981 percentage) + (12/21) (1982 percentage) + (8/21) (1983 percentage). This estimate is 64.5%.

Suppose the ignitability index for pre-Standard mattresses is set equal to 1, the index for post-Standard mattresses is set equal to x, the total number of mattresses in use during the period is X, and the total number of mattress/bedding fires in the period is Y. Then the rate of fires per mattress will be (0.15Y)/(0.64X) for post-Standard mattresses and (0.85Y)/(0.355X) for pre-Standard mattresses. Each such rate should have the same proportionality to the corresponding ignitability index. Therefore:

$$\frac{x}{1} = \frac{(0.15Y)/0.645X)}{(0.85Y)/(0.355X)} = 0.097$$

The ignitability indexes of 0.097 and 1 substitute for the R" values required in expression (11) of Appendix B.

Calculating Location Probabilities for Upholstered Furniture

In Appendix B, formulas were developed for the probabilities of location of cigarette discards on upholstered furniture, as follows.

prob(arm flat) = prob(cushion flat) = (.105)/(.21 + .79w); and

prob(arm/cushion crevice) = prob(back/cushion crevice) = (.395w)/(.21 + .79w);

where w was defined as the ratio between the probability that fire will result, given discard on a flat surface, and the probability that fire will result, given discard in a crevice. This ratio can be estimated by the ratio between the percentage of tests on flat surfaces that cause ignition and the percentage of tests in crevices that cause ignition. Using Table C-3 and combining all test results into the two indicated classes, one obtains an estimate of 0.436 for w. Therefore, the probabilities are as follows:

prob(arm flat) = prob(cushion flat) = .19

prob(arm/cushion crevice) = prob(back/cushion crevice) = .31

Calculating Ignition Parameters of Upholstered Furniture and Mattresses/Bedding, for Experimental Cigarettes

(a) Laboratory tests using the same fabric types and the same number of tests on each combination of locations and filling materials and conducted on five experimental cigarettes and three commercially available cigarettes were made available for this analysis [9]. In accordance with the earlier discussion, results on the three commercially available cigarettes were pooled. Table C-6 displays these results.

(b) The test results shown in Table C-6 form a very narrow

Table C-5. Final Table of Relative Ignitability Based on Test Data, Three Fabric Classes of Upholstered Furniture

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
1. Cellulosics Except Prints	0.908	0.235	0.995	0.564	0.500
2. Cellulosics Prints and Thermoplastics Except Vinyl	0.273	0.069	1.000*	0.191	0.619
3. Vinyl	0.000**	0.000	0.000**	0.000**	0.000

*Based on one test by Gordon H. Damant [4].

**Estimated as equal to values for other locations and filling materials when combined with vinyl fabric; no direct test results.

Table C-6. Test Results on Experimental vs. Commercially Available Cigarettes

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
Cigarette Type					
C106	1/15	0/5	No Data	0/5	No Data
C114	4/15	1/5	No Data	0/5	No Data
C130	5/15	2/5	No Data	0/5	No Data
C201	1/15	0/5	No Data	0/5	No Data
C202	2/15	0/5	No Data	0/5	No Data
Commercially Available #1, 2, and 6	39/45	15/15	No Data	9/15	No Data

NOTE: All tests were from fabric class of cellulosics excluding cellulosic prints.

data base from which to calculate changes in ignition propensity. One way to make use of other tests is to use these results, not directly, but to adjust the more broadly based ignitability parameters of the previous two sections. Table C-7 converts Table C-6 to a set of multipliers for this purpose.

(c) It is also necessary to develop multipliers in the cases where no data has been provided. This is done with two assumptions:

(i) **The multipliers for fabric class 1 would also apply to fabric classes 2 and 3.** Fabric class 1 is the most

Table C-7. Ignitability Indexes for Cigarette C106

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
Cigarette Type					
C106	.077	.200	.077	.000	.077
C114	.308	.200	.308	.000	.308
C130	.384	.400	.384	.000	.384
C201	.077	.000	.077	.000	.077
C202	.153	.000	.153	.000	.153

*These are also used for mattress/bedding estimates.

SOURCE: Each entry is given by the corresponding entry from Table C-6 divided by the "commercially available cigarettes" entry from Table C-6, same column.

Table C-8. Ignitability Indexes for Cigarette C106

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
A. **Upholstered Furniture**					
1. Cellulosics Except Prints	.070	.047	.077	.000	.039
2. Cellulosics Prints and Thermoplastics Except Vinyl	.013	.014	.231	.000	.143
3. Vinyl	.000	.000	.000	.000	.000
B. **Mattresses and Bedding**					
	Pre-Standard mattresses		**Post-Standard mattresses**		
	.077		.019		

Table C-9. Ignitability Indexes for Cigarette C114

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
A. Upholstered Furniture					
1. Cellulosics Except Prints	.280	.047	.306	.000	.154
2. Cellulosics Prints and Thermoplastics Except Vinyl	.084	.014	.308	.000	.191
3. Vinyl	.000	.000	.000	.000	.000

B. Mattresses and Bedding

Pre-Standard mattresses	Post-Standard mattresses
.308	.019

ignitable of the three. It is therefore plausible to estimate that the reduction in ignitability in fabric classes 2 and 3 would be proportionally as great or greater. That is, for example, if fabric class 1, flat surface with untreated cotton batting filling, was 3.33 times as likely to be ignited by baseline cigarettes as fabric class 2, flat surface with untreated cotton batting filling (based on Table C-5), then the ratio between the two fabric classes, given that same location and filling material, would be at least 3.33 or more if experimental cigarettes were used.

(ii) **The multipliers for flat surfaces with untreated cotton batting filling are the best estimates of multipliers for the untested locations of crevices with untreated cotton batting on one or both sides.** This produces a less dramatic reduction attributed to experimental cigarettes than would the case if all crevices were given the same multipliers. It is, in that sense, a conservative assumption. It also appears plausible in that the crevices with untreated cotton batting seem, in Table C-5, to have ignitability indexes closer to those for flat surfaces with untreated cotton batting than to crevices without untreated cotton batting.

(d) Tables C-8 through C-12 thereby combine Table C-7 with Table C-5 and the mattress/bedding ignitability indexes to produce ignitability indexes for upholstered furniture and mattresses/bedding, for each of the five experimental cigarettes.

Probabilities of Upholstered Furniture Fabric, Location, and Filling Materials Combinations, By Year

Chuck Smith of CPSC developed estimates for 1980-86 of the shares of upholstered furniture in use that fell into 32 classes, defined by (a) four fabric classes– cellulosic prints (coded P), cellulosics other than prints (coded HC), thermoplastics other than vinyl (coded T), and vinyls (coded V), (b) backs filled with untreated cotton batting (coded NRB) or with other materials (coded SRB), (c) arms filled with untreated cotton batting (coded NRA) or with other materials (coded NRS) or with other materials (coded SRS) (see end of this Appendix).

In accordance with the grouping in Tables C-2 and C-5, cellulosic prints need to be grouped with thermoplastics. Also, these usage shares need to be combined with the location probabilities (given in section 3 of this appendix) and expressions (6)-(8) from Appendix B to produce usage share probabilities for the three fabric classes and the five

Table C-10. Ignitability Indexes for Cigarette C130

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
A. Upholstered Furniture					
1. Cellulosics Except Prints	.349	.094	.382	.000	.192
2. Cellulosics Prints and Thermoplastics Except Vinyl	.105	.028	.384	.000	.238
3. Vinyl	.000	.000	.000	.000	.000
B. Mattresses and Bedding					
	Pre-Standard mattresses		**Post-Standard mattresses**		
	.384		.039		

combinations of location and filling material. Tables C-13 through C-15 provide the resulting probabilities for each of the three fabric classes.

Usage Shares of Mattresses

Analysts at CPSC have estimated the usage shares of pre-Standard and post-Standard mattresses for 1980-83 [14], 1985 [17], and 1986-96 [19]. These are given in Table C-16.

Table C-11. Ignitability Indexes for Cigarette C201

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
A. Upholstered Furniture					
1. Cellulosics Except Prints	.070	.000	.077	.000	.039
2. Cellulosics Prints and Thermoplastics Except Vinyl	.021	.000	.077	.000	.048
3. Vinyl	.000	.000	.000	.000	.000

B. Mattresses and Bedding

Pre-Standard mattresses	Post-Standard mattresses
.077	.000

Table C-12. Ignitability Indexes for Cigarette C202

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
A. Upholstered Furniture					
1. Cellulosics Except Prints	.139	.000	.152	.000	.077
2. Cellulosics Prints and Thermoplastics Except Vinyl	.042	.000	.153	.000	.095
3. Vinyl	.000	.000	.000	.000	.000
B. Mattresses and Bedding					
	Pre-Standard mattresses		**Post-Standard mattresses**		
	.153		.000		

Table C-13. Probabilities of Upholstered Furniture by Location and Filling Material Combination, Cellulosics Except Prints, 1980-84 and 1986-96

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Untreated Any other material, flat surface	cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
1980	10.1	9.0	8.6	10.7	11.6
1981	9.0	9.0	7.8	11.1	10.7
1982	7.9	9.0	7.1	11.4	9.8
1983	7.0	9.0	6.5	11.6	8.9
1984	6.1	8.9	5.8	11.7	8.1
1986	4.5	8.6	4.7	11.8	6.4
1987	3.8	8.4	4.2	11.8	5.6
1988	3.3	8.2	3.7	11.7	4.9
1989	2.7	8.0	3.3	11.6	4.3
1990	2.3	7.8	2.9	11.6	3.7
1991	1.9	7.7	2.5	11.5	3.1
1992	1.6	7.5	2.2	11.3	2.6
1993	1.3	7.3	1.9	11.2	2.2
1994	1.0	7.2	1.6	11.1	1.9
1995	0.8	7.1	1.3	11.0	1.5
1996	0.7	6.9	1.2	10.9	1.3

SOURCE: Tables at end of appendix and location probabilities driven in Appendix C, section 3.

Table C-14. Probabilities of Upholstered Furniture by Location and Filling Material Combination, Cellulosic Prints and Thermoplastics Except Vinyls, 1980-84 and 1986-96

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
1980	5.3	10.0	3.6	13.8	8.1
1981	4.9	11.7	3.1	16.7	7.7
1982	4.5	13.3	2.7	19.4	7.3
1983	4.1	14.7	2.4	21.8	6.9
1984	3.7	16.1	2.0	24.3	6.5
1986	3.0	19.0	1.4	29.2	5.5
1987	2.7	20.2	1.2	31.4	5.1
1988	2.5	21.4	1.0	33.4	4.7
1989	2.2	22.5	0.8	35.3	4.3
1990	2.0	23.4	0.7	37.0	3.9
1991	1.8	24.3	0.5	38.6	3.6
1992	1.6	25.1	0.4	40.0	3.3
1993	1.4	25.9	0.3	41.3	3.0
1994	1.3	26.5	0.3	42.4	2.7
1995	1.1	27.0	0.2	43.3	2.5
1996	1.0	27.5	0.2	44.1	2.3

SOURCE: Tables at end of Appendix and location probabilities driven in Appendix C, section 3.

Table C-15. Probabilities of Upholstered Furniture by Location and Filling Material Combination, Vinyls, 1980-84 and 1986-96

	Location of Cigarette and Filling Materials at that Location				
	Untreated cotton batting, flat surface	Any other material, flat surface	Untreated cotton batting, both sides of crevice	Other material, both sides of crevice	Different materials on crevice sides
1980	1.2	2.3	0.5	3.1	1.6
1981	1.1	2.3	0.5	3.1	1.5
1982	1.0	2.3	0.4	3.2	1.4
1983	0.9	2.3	0.4	3.2	1.3
1984	0.9	2.3	0.3	3.2	1.2
1986	0.7	2.2	0.3	3.2	1.0
1987	0.6	2.2	0.2	3.2	0.9
1988	0.6	2.1	0.2	3.1	0.9
1989	0.5	2.1	0.2	3.1	0.8
1990	0.4	2.0	0.1	3.0	0.7
1991	0.4	2.0	0.1	3.0	0.6
1992	0.3	1.9	0.1	2.9	0.5
1993	0.3	1.9	0.1	2.9	0.4
1994	0.2	1.8	0.1	2.8	0.4
1995	0.2	1.8	0.1	2.7	0.3
1996	0.2	1.7	0.0	2.7	0.3

SOURCE: Tables at end of Appendix and location probabilities driven in Appendix C, section 3.

Table C-16. Usage Share Percentages for Pre- and Post-Standard Mattresses, 1980-84 and 1986-96

	Pre-Standard mattresses	Post-standard mattresses
1980	50.3	49.7
1981	43.9	56.1
1982	37.5	62.5
1983	31.5	68.5
1984	28.2	71.8
1986	22.4	77.6
1987	19.0	81.0
1988	16.1	83.9
1989	14.0	86.0
1990	11.5	88.5
1991	9.6	90.4
1992	8.2	91.8
1993	6.8	93.2
1994	5.9	94.1
1995	4.7	95.3
1996	3.9	96.1

SOURCE: 1980-83 [14], 1984 [17], 1986-96 [19]

U.S. CONSUMER PRODUCT SAFETY COMMISSION

WASHINGTON, D.C. 20207

May 11, 1987

Dr. John R. Hall, Jr.
Director, Fire Analysis Division
National Fire Protection Association
Executive Office: Batterymarch Park
Quincy, MA 02269

Re: Order #CPSC87-114800

Dear Dr. Hall:

As a result of discussions held at NBS on April 14, you decided to group upholstery fabrics into four groups, according to suspected cigarette ignition resistance. These groups were: A. Cellulosic velvets, corduroys, jacquards, flocks and dobbies; B. Thermoplastic Velvets, corduroys, and jaquards; C. Cellulosic prints and thermoplastic prints, flocks and dobbies, and; D. Vinyl or coated fabrics. I was asked to make estimates of the proportion of furniture pieces in use in the years 1980 through 1984 that were covered with each of the four fabric groups, by ignition-resistance of filling materials in arms, backs and seats. I provided such estimates for thermoplastic fabrics, cotton prints, and heavier cotton fabrics in an April 3 letter.

Although I noted that historical data on usage of some specific types of fabrics were lacking, we had some indication on April 14 that an official with the furniture industry might be able to provide information, at least for use of vinyl fabrics. Unfortunately, this lead did not provide adequate information; contacts with others were not helpful. Coated fabrics are an item reported in the Census of Manufactures (under "items consumed, by kind"), so I was able to estimate vinyl coated fabrics use.

Because of data limitations, I have provided calculations in which fabrics are grouped by heavier cellulosics, cotton prints, vinyls, and thermoplastics (other than coated fabrics). The implications of the data limitations are that I could not group thermoplastic prints, flocks, and dobbies with cotton prints in group C. However, analysis of CPSC chair test data reveals that projections of furniture ignitability might be more accurate if these thermoplastic fabrics were grouped with the other thermoplastics in group B.

I have attached printouts showing ignition percentages for fabrics grouped into the categories selected by Jim Sharman, John Krasny, and Margaret Neilly (as they reported in a March 18 letter to you). The tests were performed over the more smolder resistant filling materials that have been used in the past several years; according to my estimates, the less smolder-resistant materials will be present in smaller percentages of furniture pieces as the years pass.

The chair test data show that thermoplastic prints and flocks had no ignitions on the seat cushions and 13% of the cigarettes tested in crevice locations ignited. This is closer to the performance of the thermoplastic fabrics in group B than to cotton prints (12% ignited on seats, 32% ignited in crevices). No thermoplastic dobbies reportedly were tested; however, since dobbies are generally heavier than prints, and the ignition-resistance of thermoplastic fabrics generally increases with weight, they may be expected to be at least as resistant as thermoplastic prints.

In addition to the chair test analysis, I have attached the estimates and projections of fabric and filling material combinations found in households from 1975 to 2000. I have included a key for the variable names. Please call me if you have questions about these calculations, or other matters.

Sincerely,

Chuck Smith

Chuck Smith
Directorate for
Economic Analysis

Attachments

NOTE: This document has not been reviewed or accepted by the Commission.
Initial CS Date 5/11/87

KEY TO FABRIC/FILLING MATERIAL VARIABLES

Smolder-Resistant filling materials are considered to be urethane foam, polyester, FR-treated cotton batting, mixed fiber batting.

Non-smolder-Resistant filling materials are considered to be untreated cotton batting and other natural fibers, and latex foam.

With the exception of MMINUSE, which estimates/projects the number of upholstered furniture pieces in use in a given year, all variables refer to the proportion of pieces in use that have certain fabric and filling material characteristics.

The first six variables after MMINUSE are for fabrics:

PCTCF = Proportion of pieces covered with cellulosic fabrics
PCTCPRT = ... with printed cellulosic fabrics
PCTCNOPT = ... with non-print cellulosic fabrics
PCTTF = ... with thermoplastic fabrics (including vinyl)
PCTVINYL = ... with vinyl or coated fabrics
PCTTFIB = ... with thermoplastic fiber fabrics (not incl. vinyl)

The last two variables are for the proportion of pieces with boxed-edge welt cord; WELT refers to all welt cord, HCWELT refers to the presence of heat-conducting welt cord.

The other variables refer to combinations of back or arm materials and seat filling materials, and (except for the first eight) fabrics.

The last three letters refer to the seat cushion filling material: ---SRS refers to seats with Smolder-Resistant materials
---NRS refers to Non-Resistant materials.

The letters before the seat designation refer to the back or arm material: SRB--- refers to backs with Smolder-Resistant materials
NRB--- refers to backs with Non-Resistant materials.
SRA--- refers to arms with Smolder-Resistant materials
NRA--- refers to arms with Non-Resistant materials.

If present, the first one or two letters refer to fabric:

C------ = cellulosic;
P------ = cotton prints;
HC------ = non-print cellulosic;
T------ = thermoplastic (including vinyl);
V------ = vinyl or coated;
TF------ = thermoplastic fiber (not including vinyl)

TIME	MMINUSE	PCTCF	PCTCPRT	PCTCNOPT	PCTTF	PCTVINYL	PCTTFIB	SRBSRS	SRBNRS	NRBSRS	NRBNRS	SRASRS	SRANRS
1975	271.0	0.772668	0.131764	0.640904	0.227332	0.0707601	0.080199	0.264143	0.161950	0.0125834	0.363515	0.133603	0.0649803
1976	276.7	0.754373	0.133216	0.621156	0.245627	0.0761222	0.099368	0.307690	0.159180	0.0128966	0.322143	0.164348	0.0664257
1977	283.7	0.730529	0.134716	0.595812	0.269471	0.0816814	0.124434	0.358233	0.153268	0.0129676	0.281740	0.202240	0.0662444
1978	290.8	0.703714	0.136128	0.567586	0.296286	0.0867400	0.152662	0.413353	0.143893	0.0128511	0.244777	0.250971	0.0637914
1979	299.8	0.673322	0.137578	0.535744	0.326678	0.0917[illegible]	0.184813	0.471232	0.133848	0.0125624	0.209431	0.307266	0.0610764
1980	308.6	0.642690	0.138931	0.503759	0.357310	0.0927220	0.220706	0.526374	0.123243	0.0122677	0.178059	0.368019	0.0578037
1981	314.7	0.614147	0.140874	0.473273	0.385853	0.06[illegible]8348	0.257674	0.573617	0.113864	0.0120922	0.151872	0.423864	0.0549731
1982	320.1	0.587273	0.142709	0.444564	0.412727	0.0877163	0.291862	0.617851	0.104686	0.0119494	0.128470	0.476754	0.0520935

TIME	NRASRS	NRANRS	CSRBSRS	CSRBNRS	CNRBSRS	CNRBNRS	PSRBSRS	PSRBNRS	PNRBSRS	PNRBNRS	HCSRBSRS	HCSRBNRS	HCNRBSRS
1975	0.340932	0.460485	0.183220	0.125373	0.155142	0.308933	0.035378	0.0212663	0.0277756	0.0473440	0.147842	0.104106	0.127367
1976	0.354330	0.414897	0.207455	0.121557	0.153433	0.271928	0.042100	0.0210471	0.0280752	0.0419943	0.165355	0.100510	0.125358
1977	0.362751	0.368764	0.230959	0.115268	0.148021	0.236282	0.049905	0.0203790	0.0276796	0.0367531	0.181054	0.094889	0.120341
1978	0.360335	0.324902	0.252487	0.107129	0.140028	0.204070	0.058397	0.0191865	0.0265986	0.0319455	0.194090	0.087943	0.113429
1979	0.349511	0.282147	0.271550	0.098353	0.129894	0.173525	0.067337	0.0179093	0.0249855	0.0273464	0.204213	0.080444	0.104908
1980	0.330765	0.243412	0.287027	0.089482	0.119570	0.146611	0.075865	0.0165389	0.0232640	0.0232625	0.211161	0.072943	0.096306
1981	0.310484	0.210679	0.297953	0.081596	0.110365	0.124232	0.083922	0.0153430	0.0217547	0.0198540	0.214031	0.066253	0.088610
1982	0.290172	0.180981	0.307770	0.073928	0.101243	0.104332	0.091487	0.0141702	0.0202442	0.0168071	0.216283	0.059758	0.080999

TIME	HCNRBNRS	TSRBSRS	TSRBNRS	TNRBSRS	TNRBNRS	VSRBSRS	VSRBNRS	VNRBSRS	VNRBNRS	CSRASRS	CSRANRS	CNRASRS	CNRANRS
1975	0.055544	0.080923	0.0365768	0.0552500	0.0545825	0.0304851	0.0095996	0.000829945	0.0126377	0.091152	0.0488091	0.247211	0.385497
1976	0.069015	0.100235	0.0376228	0.0575543	0.0502146	0.0359161	0.0100843	0.000881543	0.0113775	0.108676	0.0490014	0.252212	0.344484
1977	0.066781	0.127275	0.0380004	0.0587374	0.0454587	0.0422632	0.0102860	0.000906489	0.0101721	0.127103	0.0478671	0.251876	0.303683
1978	0.093114	0.160866	0.0367632	0.0579500	0.0407067	0.0491320	0.0100328	0.000908373	0.0089828	0.147680	0.0454590	0.244824	0.265751
1979	0.117440	0.199682	0.0354951	0.0555952	0.0359058	0.0563428	0.0097321	0.000892752	0.0078180	0.168697	0.0427277	0.232770	0.229128
1980	0.112109	0.239348	0.0337612	0.0527528	0.0314488	0.0598597	0.0092364	0.000872375	0.0068074	0.189271	0.0397604	0.217360	0.196298
1981	0.109174	0.275663	0.0322673	0.0502829	0.0276397	0.0592571	0.0087274	0.000857334	0.0059760	0.206157	0.0371010	0.202194	0.168694
1982	0.107612	0.310081	0.0307576	0.0477503	0.0241381	0.0593273	0.0082200	0.000845320	0.0052531	0.221971	0.0344406	0.187074	0.143787

TIME	PSRASRS	PSRANRS	PNRASRS	PNRANRS	HCSRASRS	HCSRANRS	HCNRASRS	HCNRANRS	TSRASRS	TSRANRS	TNRASRS	TNRANRS	VSRASRS
1975	0.017998	0.00857638	0.0451557	0.0600339	0.073154	0.0402327	0.202055	0.325463	0.042451	0.0161712	0.093722	0.0749881	0.0163270
1976	0.022696	0.00885762	0.0474789	0.0541838	0.085980	0.0401438	0.204733	0.290300	0.055672	0.0174242	0.102118	0.0704133	0.0200538
1977	0.028483	0.00890450	0.0491015	0.0482276	0.098621	0.0389626	0.202774	0.255455	0.075137	0.0183773	0.110875	0.0650819	0.0246741
1978	0.035896	0.00861006	0.0490960	0.0425257	0.111784	0.0368489	0.195728	0.223226	0.103291	0.0183324	0.115512	0.0591506	0.0305825
1979	0.044461	0.00828425	0.0478703	0.0369630	0.124236	0.0344435	0.184900	0.192165	0.138569	0.0183486	0.116741	0.0530189	0.0374010
1980	0.053694	0.00787266	0.0454481	0.0319158	0.135577	0.0318877	0.171912	0.164382	0.178748	0.0180433	0.113405	0.0471143	0.0416145
1981	0.062911	0.00753445	0.0427786	0.0276500	0.143246	0.0295665	0.159416	0.141044	0.217707	0.0178721	0.108290	0.0419846	0.0419371
1982	0.071643	0.00718724	0.0401001	0.0237779	0.150328	0.0272533	0.146974	0.120009	0.254783	0.0176530	0.103098	0.0371941	0.0429449

TIME	VSRANRS	VNRASRS	VNRANRS	TFSRBSRS	TFSRBNRS	TFNRBSRS	TFNRBNRS	TFSRASRS	TFSRANRS	TFNRASRS	TFNRANRS	WELT	HCWELT
1975	0.00491981	0.0321958	0.0173175	0.050438	0.0269772	0.0544201	0.0419448	0.026124	0.0112514	0.0615259	0.0576706	0.750000	0.000000
1976	0.00531108	0.0346066	0.0161506	0.064319	0.0275386	0.0566727	0.038[illegible]372	0.035618	0.0121131	0.0675113	0.0542626	0.750000	0.000000
1977	0.00554367	0.0365492	0.0149144	0.085012	0.0277144	0.0578309	0.0352867	0.050463	0.0128336	0.0743262	0.0501674	0.750000	0.000000
1978	0.00549429	0.0371391	0.0135241	0.111734	0.0267304	0.0570416	0.0317240	0.072709	0.0128381	0.0783725	0.0456265	0.750000	0.000000
1979	0.00542969	0.0367568	0.0121137	0.143339	0.0257630	0.0547025	0.0280878	0.101168	0.0129189	0.0799844	0.0409053	0.750000	0.000000
1980	0.00521837	0.0350727	0.0108164	0.179488	0.0245248	0.0518805	0.0246414	0.137134	0.0128250	0.0783320	0.0362979	0.750000	0.000000
1981	0.00496791	0.0332030	0.0097267	0.216406	0.0235399	0.0494256	0.0216637	0.175770	0.0129042	0.0750868	0.0322578	0.750000	0.000000
1982	0.00472296	0.0313068	0.0087417	0.250754	0.0225376	0.0469050	0.0188851	0.211838	0.0129300	0.0717909	0.0284524	0.750000	0.000000

TIME	MMINUSE	PCTCF	PCTCPRT	PCTCNOPT	PCTTF	PCTVINYL	PCTTFIB	SRBSRS	SRBNRS	NRBSRS	NRBNRS
1983	322.6	0.563524	0.144299	0.419225	0.436476	0.0857595	0.322095	0.657132	0.0958378	0.0118875	0.109258
1984	327.8	0.539497	0.145946	0.393551	0.460503	0.0831818	0.353099	0.696177	0.0865713	0.0117291	0.091656
1985	335.3	0.515896	0.149231	0.366666	0.484104	0.0800895	0.383838	0.734013	0.0773205	0.0114963	0.075656
1986	339.6	0.495227	0.152073	0.343154	0.504773	0.0773174	0.410839	0.766967	0.0690870	0.0113799	0.062247
1987	343.9	0.476383	0.154795	0.321588	0.523617	0.0743065	0.435731	0.796647	0.0615062	0.0112664	0.050925
1988	348.3	0.458909	0.157402	0.301507	0.541091	0.0712518	0.458906	0.823828	0.0543891	0.0111525	0.041121
1989	352.2	0.442825	0.159895	0.282930	0.557175	0.0681034	0.480443	0.848599	0.0477495	0.0110571	0.032801
1990	356.5	0.428712	0.162196	0.266516	0.571288	0.0649734	0.499512	0.869928	0.0419316	0.0108426	0.026178
1991	361.0	0.416227	0.164346	0.251881	0.583773	0.0619446	0.516529	0.888501	0.0367819	0.0106033	0.020769
1992	365.4	0.404912	0.166366	0.238547	0.595088	0.0590038	0.532022	0.905141	0.0320925	0.0103517	0.016213
1993	369.5	0.394858	0.168238	0.226620	0.605142	0.0563302	0.545867	0.919744	0.0279445	0.0100931	0.012329
1994	373.7	0.386390	0.169928	0.216462	0.613610	0.0537945	0.557656	0.931807	0.0244686	0.0098394	0.009345
1995	377.9	0.379222	0.171442	0.207780	0.620778	0.0514845	0.567 22	0.941885	0.0215395	0.0095700	0.007005
1996	382.2	0.372938	0.172836	0.200102	0.627062	0.0494532	0.576593	0.950581	0.0189717	0.0090801	0.005092
1997	386.5	0.368078	0.174036	0.194041	0.631922	0.0476274	0.583542	0.957166	0.0170178	0.0085643	0.003789
1998	391.4	0.364083	0.175072	0.189011	0.635917	0.0461523	0.589290	0.962508	0.0154123	0.0080353	0.002784

TIME	SRASRS	SRANRS	NRASRS	NRANRS	CSRBSRS	CSRBNRS	CNRBSRS	CNRBNRS	PSRBSRS	PSRBNRS	PNRBSRS
1983	0.523198	0.0488072	0.271785	0.156210	0.315746	0.0668737	0.0927789	0.0881258	0.098208	0.0130179	0.0187691
1984	0.570754	0.0452070	0.251095	0.132944	0.322728	0.0595881	0.0837382	0.0734424	0.104968	0.0118065	0.0171611
1985	0.617853	0.0414644	0.229243	0.111440	0.328790	0.0524097	0.0745220	0.0601741	0.113187	0.0106096	0.0155102
1986	0.659228	0.0380925	0.209507	0.093172	0.333825	0.0460362	0.0662555	0.0491102	0.120332	0.0095430	0.0140241
1987	0.697339	0.0348857	0.190296	0.077480	0.337786	0.0402496	0.0584879	0.0398591	0.126936	0.0085589	0.0126044
1988	0.732816	0.0318121	0.171736	0.063636	0.341011	0.0348577	0.0511457	0.0318944	0.133103	0.0076334	0.0112502
1989	0.765802	0.0288716	0.153705	0.051622	0.343522	0.0298880	0.0442023	0.0252124	0.138847	0.0067687	0.0099531
1990	0.794936	0.0261913	0.137007	0.041865	0.345168	0.0256030	0.0379982	0.0199436	0.143957	0.0060079	0.0087727
1991	0.820855	0.0237631	0.121643	0.033740	0.346227	0.0218552	0.0324612	0.0156833	0.148558	0.0053333	0.0077060
1992	0.844455	0.0215111	0.107283	0.026751	0.346913	0.0184770	0.0273952	0.0121268	0.152779	0.0047172	0.0067184
1993	0.865422	0.0194850	0.094345	0.020749	0.347328	0.0155093	0.0229163	0.0091046	0.156585	0.0041722	0.0058411
1994	0.883239	0.0177508	0.082983	0.016027	0.347347	0.0130659	0.0191592	0.0068180	0.159877	0.0037138	0.0050896
1995	0.898413	0.0162472	0.073073	0.012267	0.347158	0.0110431	0.0159744	0.0050466	0.162736	0.0033262	0.0044421
1996	0.911648	0.0149110	0.064314	0.009126	0.346874	0.0092746	0.0131813	0.0036086	0.165287	0.0029874	0.0038767
1997	0.922009	0.0138615	0.057206	0.006924	0.346431	0.0079695	0.0110269	0.0026500	0.167367	0.0027285	0.0034278
1998	0.930502	0.0129729	0.051321	0.005205	0.345981	0.0069106	0.0092752	0.0019158	0.169122	0.0025144	0.0030568

TIME	PNRBNRS	HCSRBSRS	HCSRBNRS	HCNRBSRS	HCNRBNRS	TSRBSRS	TSRBNRS	TNRBSRS	TNRBNRS	VSRBSRS	VSRBNRS
1983	0.0143048	0.217538	0.0538558	0.0740097	0.105529	0.341386	0.0289641	0.0449932	0.0211325	0.0593743	0.00772972
1984	0.0120105	0.217760	0.0477816	0.0665771	0.100928	0.373449	0.0269832	0.0418569	0.0182139	0.0589651	0.00715400
1985	0.0099236	0.215603	0.0418001	0.0590118	0.096149	0.405222	0.0249108	0.0384890	0.0154818	0.0582315	0.00652798
1986	0.0081742	0.213493	0.0364932	0.0522314	0.091854	0.433142	0.0230508	0.0354434	0.0131367	0.0575161	0.00596464
1987	0.0066957	0.210850	0.0316907	0.0458835	0.087006	0.458861	0.0212566	0.0324339	0.0110656	0.0565609	0.00539696
1988	0.0054146	0.207908	0.0272243	0.0398955	0.080897	0.482817	0.0195314	0.0295167	0.0092261	0.0554798	0.00483600
1989	0.0043267	0.204676	0.0231193	0.0342492	0.074211	0.505077	0.0178615	0.0266477	0.0075890	0.0542638	0.00428590
1990	0.0034589	0.201211	0.0195951	0.0292255	0.067903	0.524760	0.0163286	0.0239643	0.0062342	0.0529462	0.00376685
1991	0.0027494	0.197670	0.0165219	0.0247552	0.061659	0.542273	0.0149267	0.0214869	0.0050860	0.0515619	0.00328879
1992	0.0021507	0.194134	0.0137599	0.0206768	0.055059	0.558227	0.0136155	0.0191582	0.0040866	0.0501763	0.00283416
1993	0.0016401	0.190743	0.0113371	0.0170752	0.049432	0.572416	0.0124353	0.0170661	0.0032242	0.0488509	0.00243334
1994	0.0012470	0.187470	0.0093521	0.0140695	0.042845	0.584459	0.0114027	0.0152211	0.0025267	0.0475213	0.00207266
1995	0.0009378	0.184422	0.0077169	0.0115324	0.036188	0.594727	0.0104964	0.0135963	0.0019585	0.0462643	0.00175637
1996	0.0006852	0.181587	0.0062873	0.0093046	0.032579	0.603707	0.0096971	0.0121745	0.0014830	0.0451270	0.00148688
1997	0.0005124	0.179064	0.0052409	0.0075990	0.027833	0.610735	0.0090483	0.0110000	0.0011394	0.0440710	0.00125451
1998	0.0003783	0.176859	0.0043962	0.0062184	0.022468	0.616527	0.0085018	0.0100206	0.0008680	0.0431894	0.00107372

TIME	VNRBSRS	VNRBNRS	CSRASRS	CSRANRS	CNRASRS	CNRANRS	PSRASRS	PSRANRS	PNRASRS	PNRANRS
1983	0.000839997	0.00465001	0.235151	0.0317931	0.173405	0.123175	0.079312	0.00676390	0.0376766	0.0205469
1984	0.000827880	0.00412415	0.248121	0.0289515	0.158375	0.104049	0.087212	0.00629698	0.0349284	0.0175085
1985	0.000810543	0.00355442	0.260579	0.0260478	0.142762	0.086507	0.096647	0.00582497	0.0320613	0.0146974
1986	0.000801446	0.00311186	0.271412	0.0234377	0.128696	0.071681	0.104900	0.00539844	0.0294663	0.0123084
1987	0.000792576	0.00268246	0.281077	0.0209980	0.115223	0.059085	0.112620	0.00499139	0.0269300	0.0102534
1988	0.000783701	0.00231278	0.289858	0.0186821	0.102323	0.048045	0.119890	0.00460013	0.0244725	0.0084386
1989	0.000776147	0.00195979	0.297800	0.0164968	0.089947	0.038581	0.126729	0.00422488	0.0220796	0.0068618
1990	0.000757013	0.00163618	0.304528	0.0145437	0.078660	0.030985	0.132886	0.00388092	0.0198512	0.0055779
1991	0.000735515	0.00136461	0.310297	0.0127931	0.068411	0.024726	0.138477	0.00356863	0.0177940	0.0045068
1992	0.000712635	0.00111056	0.315412	0.0111911	0.058914	0.019395	0.143640	0.00327794	0.0158644	0.0035833
1993	0.000705800	0.00091086	0.319838	0.0097627	0.050422	0.014835	0.148307	0.00301642	0.0141252	0.0027900
1994	0.000698927	0.00073475	0.323417	0.0085651	0.043104	0.011305	0.152383	0.00279175	0.0125895	0.0021638
1995	0.000692207	0.00058488	0.326342	0.0075454	0.036803	0.008532	0.155937	0.00259624	0.0112454	0.0016632
1996	0.000685455	0.00046009	0.328823	0.0066420	0.031243	0.006231	0.159107	0.00242309	0.0100609	0.0012456
1997	0.000678854	0.00035222	0.330633	0.0059562	0.026833	0.004654	0.161703	0.00228674	0.0090954	0.0009509
1998	0.000671367	0.00027534	0.332053	0.0053828	0.023211	0.003436	0.163890	0.00217045	0.0082913	0.0007195

TIME	HCSRASRS	HCSRANRS	HCNRASRS	HCNRANRS	TSRASRS	TSRANRS	TNRASRS	TNRANRS	VSRASRS	VSRANRS	VNRASRS
1983	0.155839	0.0250292	0.135729	0.102628	0.288047	0.0170140	0.0983793	0.0330350	0.0438195	0.00447118	0.0295685
1984	0.160909	0.0226545	0.123447	0.086540	0.322633	0.0162555	0.0927194	0.0288958	0.0444275	0.00416904	0.0274841
1985	0.163933	0.0202228	0.110701	0.071810	0.357273	0.0154167	0.0864815	0.0249324	0.0448243	0.00383716	0.0251903
1986	0.166512	0.0180393	0.099230	0.059373	0.387816	0.0146548	0.0808117	0.0214911	0.0451361	0.00353681	0.0231121
1987	0.168457	0.0160066	0.088293	0.048831	0.416261	0.0138877	0.0750732	0.0183951	0.0452337	0.00323184	0.0210002
1988	0.169968	0.0140819	0.077851	0.039607	0.442958	0.0131300	0.0694129	0.0155904	0.0452043	0.00292822	0.0189051
1989	0.171071	0.0122719	0.067868	0.031719	0.468002	0.0123748	0.0637573	0.0130410	0.0450417	0.00262789	0.0168220
1990	0.171641	0.0106598	0.058808	0.025407	0.490409	0.0116505	0.0583480	0.0108803	0.0447388	0.00234188	0.0148371
1991	0.171821	0.0092245	0.050617	0.020219	0.510557	0.0109700	0.0532321	0.0090135	0.0443172	0.00207533	0.0129790
1992	0.171772	0.0079132	0.043050	0.015812	0.529043	0.0103199	0.0483687	0.0073557	0.0438528	0.00182095	0.0112109
1993	0.171531	0.0067463	0.036297	0.012045	0.545584	0.0097223	0.0439223	0.0059135	0.0433651	0.00159405	0.0096249
1994	0.171034	0.0057733	0.030514	0.009141	0.559823	0.0091857	0.0398791	0.0047225	0.0428077	0.00138793	0.0081830
1995	0.170405	0.0049492	0.025557	0.006869	0.572071	0.0087018	0.0362706	0.0037346	0.0422402	0.00120531	0.0069062
1996	0.169716	0.0042189	0.021182	0.004985	0.582826	0.0082690	0.0330717	0.0028954	0.0417067	0.00104843	0.0058022
1997	0.168930	0.0036694	0.017738	0.003704	0.591376	0.0079053	0.0303722	0.0022692	0.0411717	0.00091264	0.0048513
1998	0.168163	0.0032124	0.014919	0.002717	0.598449	0.0075901	0.0281097	0.0017686	0.0407169	0.00080425	0.0040882

TIME	VNRANRS	TFSRBSRS	TFSRBNRS	TFNRBSRS	TFNRBNRS	TFSRASRS	TFSRANRS	TFNRASRS	TFNRANRS	WELT	HCWELT
1983	0.00790031	0.282011	0.0212344	0.0441532	0.0164825	0.244228	0.0125428	0.0688109	0.0251347	0.743335	0.000000
1984	0.00710118	0.314484	0.0198292	0.0410290	0.0140898	0.278205	0.0120865	0.0652353	0.0217946	0.724741	0.000000
1985	0.00623770	0.346991	0.0183829	0.0376784	0.0119273	0.312449	0.0115795	0.0612912	0.0186947	0.699717	0.031740
1986	0.00553248	0.375626	0.0170862	0.0346419	0.0100219	0.342680	0.0111180	0.0576996	0.0159586	0.679352	0.060127
1987	0.00484076	0.402300	0.0158597	0.0316413	0.0083832	0.371028	0.0106559	0.0540730	0.0135543	0.663111	0.091463
1988	0.00421413	0.427337	0.0146954	0.0287330	0.0069133	0.397753	0.0102018	0.0505078	0.0113763	0.647235	0.122059
1989	0.00361181	0.450813	0.0135756	0.0258716	0.0056292	0.422960	0.0097469	0.0469353	0.0094292	0.639336	0.158635
1990	0.00305561	0.471814	0.0125618	0.0232073	0.0045980	0.445670	0.0093087	0.0435109	0.0078246	0.631924	0.193736
1991	0.00257303	0.490711	0.0116379	0.0207514	0.0037214	0.466240	0.0088947	0.0402531	0.0064405	0.625097	0.227655
1992	0.00211919	0.508051	0.0107813	0.0184455	0.0029761	0.485191	0.0084990	0.0371578	0.0052365	0.618804	0.260470
1993	0.00174605	0.523566	0.0100019	0.0163603	0.0023134	0.502219	0.0081282	0.0342973	0.0041674	0.613147	0.291795
1994	0.00141583	0.536938	0.0093300	0.0145222	0.0017919	0.517015	0.0077978	0.0316960	0.0033066	0.608314	0.321351
1995	0.00113276	0.548462	0.0087400	0.0129041	0.0013736	0.529831	0.0074965	0.0293644	0.0026019	0.604197	0.348833
1996	0.00089584	0.558580	0.0082102	0.0114890	0.0010229	0.541119	0.0072206	0.0272695	0.0019995	0.600717	0.374750
1997	0.00069181	0.566664	0.0077938	0.0103211	0.0007872	0.550204	0.0069927	0.0255209	0.0015774	0.598070	0.398268
1998	0.00054290	0.573337	0.0074280	0.0093493	0.0005927	0.557732	0.0067859	0.0240215	0.0012257	0.596127	0.419611

SAS 10:37 WEDNESDAY, MAY 6, 1987 4

TIME	MMINUSE	PCTCF	PCTCPRT	PCTCNOPT	PCTTF	PCTVINYL	PCTTFIB	SRBSRS	SRBNRS	NRBSRS	NRBNRS	SRASRS
1999	395.7	0.360788	0.175984	0.184804	0.639212	0.0448244	0.594041	0.966781	0.0141012	0.00751301	0.00203225	0.937486
2000	400.0	0.357953	0.176795	0.181158	0.642048	0.0436950	0.598125	0.970506	0.0129665	0.00693850	0.00138095	0.943519

TIME	SRANRS	NRASRS	NRANRS	CSRBSRS	CSRBNRS	CNRBSRS	CNRBNRS	PSRBSRS	PSRBNRS	PNRBSRS	PNRBNRS
1999	0.0122409	0.0463955	0.00387748	0.345488	0.00605698	0.00787014	0.00137307	0.170608	0.00234019	0.00275791	0.000278207
2000	0.0116012	0.0421461	0.00273390	0.345097	0.00531661	0.00663636	0.00090299	0.171918	0.00218962	0.00249562	0.000191351

TIME	HCSRBSRS	HCSRBNRS	HCNRBSRS	HCNRBNRS	TSRBSRS	TSRBNRS	TNRBSRS	TNRBNRS	VSRBSRS	VSRBNRS
1999	0.174880	0.00371679	0.00511224	0.0172615	0.621293	0.00804421	0.00921563	0.000659174	0.0423821	0.000912824
2000	0.173178	0.00312699	0.00414074	0.0133478	0.625409	0.00764994	0.00851019	0.000477961	0.0417007	0.000776129

TIME	VNRBSRS	VNRBNRS	CSRASRS	CSRANRS	CNRASRS	CNRANRS	PSRASRS	PSRANRS	PNRASRS	PNRANRS
1999	0.000665072	0.000204563	0.333154	0.00491814	0.0202106	0.00250587	0.165748	0.00207510	0.00762033	0.000541033
2000	0.000658912	0.000144246	0.334118	0.00451046	0.0176195	0.00170418	0.167374	0.00199198	0.00704226	0.000387137

TIME	HCSRASRS	HCSRANRS	HCNRASRS	HCNRANRS	TSRASRS	TSRANRS	TNRASRS	TNRANRS	VSRASRS	VSRANRS	VNRASRS
1999	0.167406	0.00284304	0.0125903	0.00196484	0.604332	0.00732272	0.0261848	0.00137161	0.0402825	0.00070869	0.00342599
2000	0.166745	0.00251848	0.0105773	0.00131704	0.609400	0.00709074	0.0245266	0.00102972	0.0399200	0.00062731	0.00285591

TIME	VNRANRS	TFSRBSRS	TFSRBNRS	TFNRBSRS	TFNRBNRS	TFSRASRS	TFSRANRS	TFNRASRS	TFNRANRS	WELT	HCWELT
1999	0.000407141	0.578910	0.00713139	0.00855056	0.000454612	0.56405	0.00661403	0.0227588	0.000964469	0.594678	0.438807
2000	0.000291785	0.583709	0.00687381	0.00785128	0.000333715	0.56948	0.00646343	0.0216706	0.000737936	0.593665	0.456302

Figure 1. Projected Fire Loss Rates (Excluding Deaths) per Billion Cigarettes Consumed, 1986-96

Baseline vs. Five Experimental Cigarettes

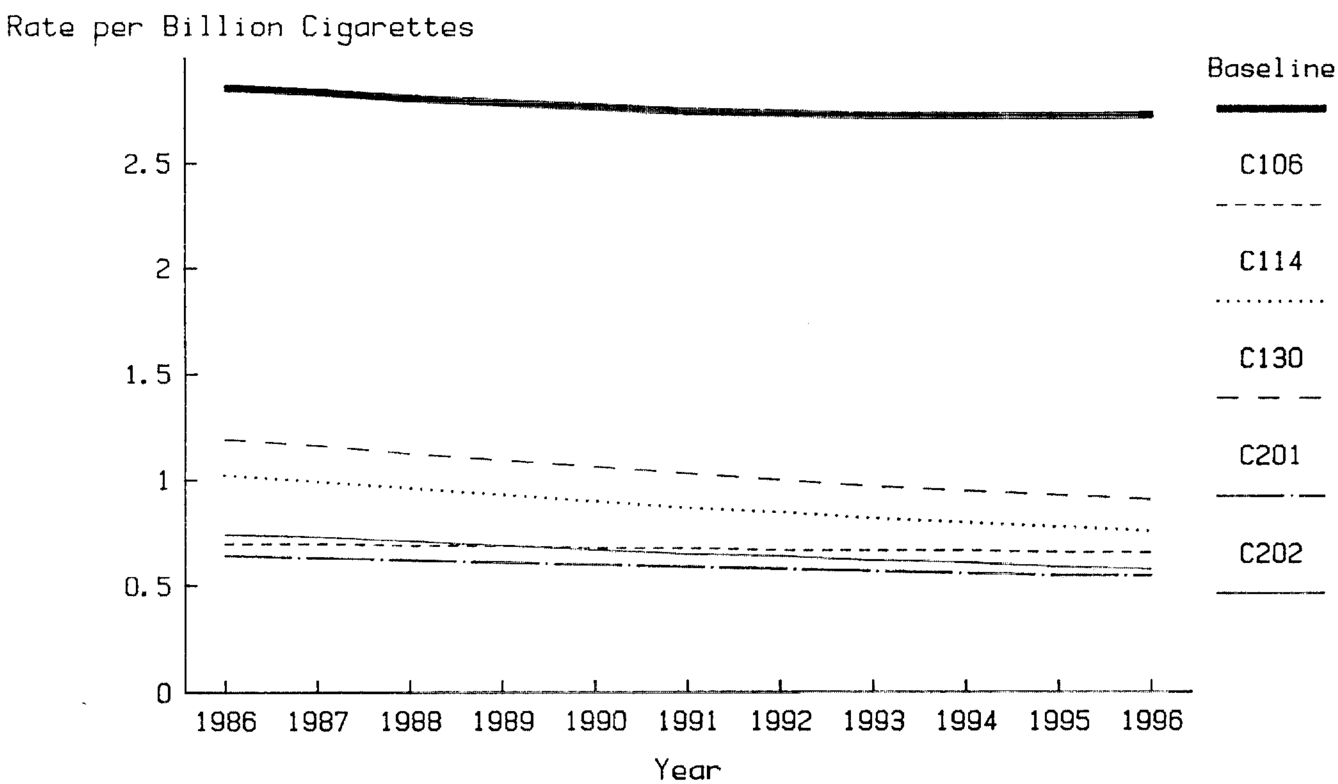
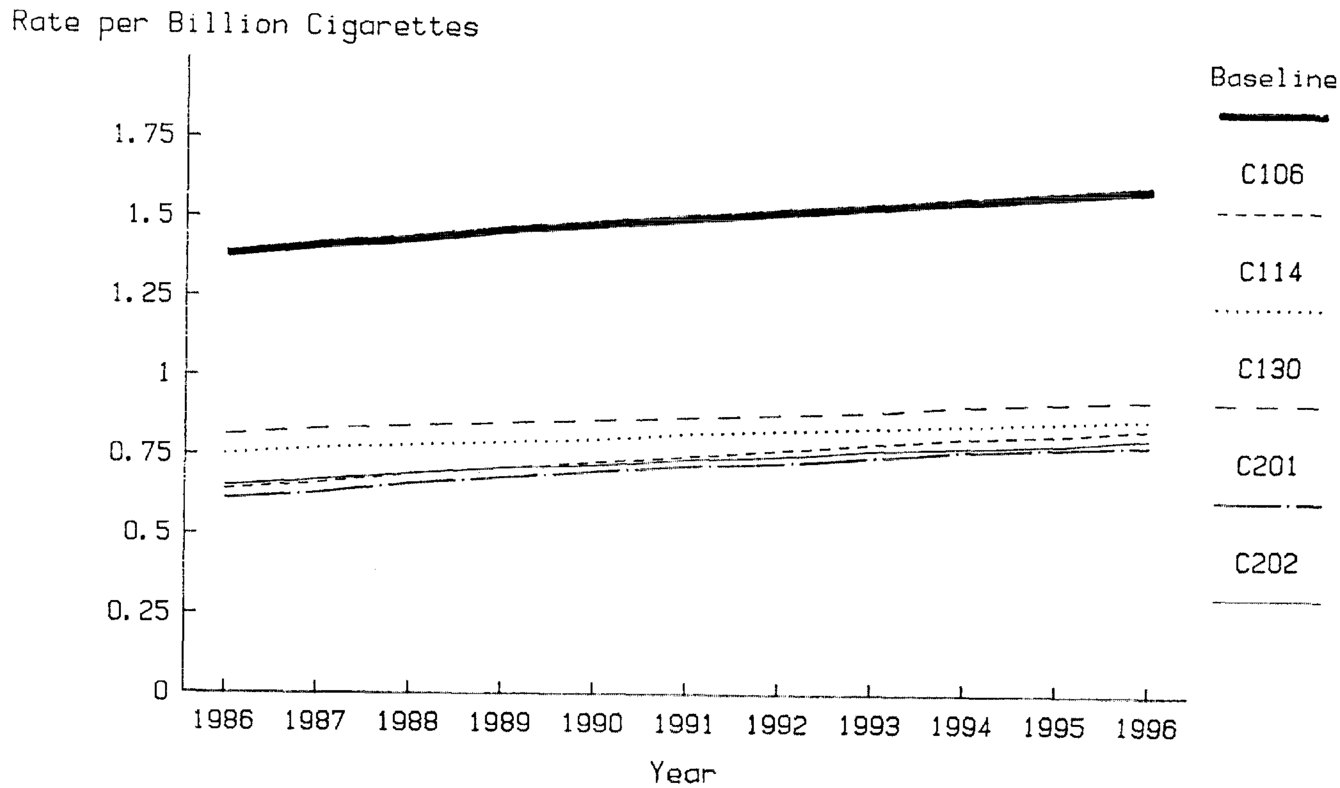


Figure 2. Projected Civilian Fire Death Rates per Billion Cigarettes Consumed, 1986-96
Baseline vs. Five Experimental Cigarettes



Note: Uses Version 1 of fire fighter injury estimates.

Appendix D

Derivation of CPSC Estimate of Average Cost Per Fire Injury

Note: This appendix consists entirely of the text of a CPSC memorandum, which has not been re-edited for format or style consistency with the rest of this report. Also, the memorandum develops a number of results that are not used in this report. Only a $36,218 average cost per injury figure and the data and analyses used to produce it are used in this report.

UNITED STATES GOVERNMENT
M E M O R A N D U M

U.S. CONSUMER PRODUCT
SAFETY COMMISSION
WASHINGTON, D.C. 20207

May 12, 1987

To : James F. Hoebel, EX-P
Thru : Paul H. Rubin, AED, Economic Analysis
From : Dale R. Ray, ECCP
Subject: Costs of Smoking-Related Fires

We have developed some preliminary estimates of the costs of accidental cigarette-ignition fires involving upholstered furniture and mattresses and bedding. These estimates are based on the latest available (1984 NFIRS) data on injuries, deaths and property damage. 1985 and 1986 data from CPSC's Injury Cost Model were used to estimate average costs for thermal burns and anoxia, the two most common kinds of fire-related serious injuries; the injury cost estimates, given in 1986 dollars to achieve consistency with other data being considered in the Cigarette Safety Act cost/benefit study, were applied to the 1984 frequency data to approximate total injury costs.

Injuries

Table D-1 shows estimated numbers of civilian and firefighter injuries associated with Cigarette-ignition fires involving upholstered furniture and mattresses and bedding, and estimated costs to the public of those injuries. The Injury Costs Model provides average costs for hospital emergency-room-treated injuries from CPSC's National Electronic Injury Surveillance System (NEISS). Weighted average costs, including pain and suffering, of $62,309 and $21,530 for thermal burns and anoxia respectively were calculated from the NEISS data.[1] A combined weighted average cost figure of $36,218 (based on an estimated 1,055 cases from NEISS in 1985 and 1986)[2] was applied to NFPA frequency estimates to arrive at total estimated costs of about $177 million. A maximum estimate of firefighter injuries[3] was allocated between the two product groups in proportion to estimated civilian injuries.

Deaths

NFPA's estimates of cigarette-ignition-related civilian deaths total 1,600 for 1984. Excluding outdoor (vehicular, etc.) and other non-upholstered furniture bedding fires, and proportionally allocating fires in which the material first ignited was unknown, 933 fatalities are estimated to have resulted from cigarette-ignition upholstered furniture fires in 1984; 437 deaths resulted from cigarette-ignition mattress or bedding fires. Although the value to society of these lost lives may be controversial, a statistical value of life can be assigned for the purpose of evaluating risk-reduction alternatives; omitting these values would seriously impair the utility of any results obtained from a cost-benefit analysis. Values ranging from a few hundred thousand to several million dollars per life have been discussed in the relevant literature; we have used $1

[1] *The pain and suffering costs components are based on a sample of jury verdict awards for all types of injuries. The nominal average figure for burns is $26,180; however, a study on burn injury costs conducted for CPSC suggests that the pain and suffering factor for burns is probably understated by a factor of up to three. The average pain and suffering value (69% of the total average cost) was therefore tripled to arrive at the $62,309 figure. This essentially raises the total injury cost estimate by half.*

[2] *This assumes the distribution of injuries is the same in NEISS as in the NFPA. The NEISS estimate is based on a small number of actual cases (21). NFIRS data would provide a much larger and more reliable base for estimating total injury costs. The cost estimates will be refined as further study of the NFIRS data suggests.*

[3] *J. Hall, NFPA, "Expected Changes in Fire Damages from Reducing Cigarette Ignition Propensity," August 29, 1986.*

Table D-1: Costs of Smoking-related Fire Injuries Involving Upholstered Furniture and Mattresses and Bedding, 1984[1]

	Upholstered Furniture		Mattresses & Bedding	
	Residential	Non-residential	Residential	Non-residential
# Injuries:[2]				
Civilian	1461	56	1378	83
Firefighter	862	37	928	70
Total	2323	93	2306	153
Total cost ($mil)[3]	$84.13	$3.37	$83.52	$5.54
Combined Total Injury Cost = $176.56 million				

SOURCE: CPSC/Economic Analysis, using NFPA and CPSC/Epidemiology data and CPSC Injury Cost Model

NOTES: 1) All figures in 1986 dollars; "bedding" includes sheets, pillows, blankets, comforters and similar items.
2) NFPA injury frequency estimates based on NFIRS data for material first ignited; unknowns allocated proportionally; outdoor (e.g., trash, vehicular) fires excluded; NFIRS may underestimate injury frequency somewhat; firefighter injuries per NFPA maximum estimate method.
3) Assumes that all injuries are comprised of thermal burns and anoxia, and that the NFIRS injury distribution is about the same as in NEISS; includes substantial subjective component for pain and suffering; combined weighted average = $36,218 per injury.

million and $ 2 million in a variety of recent analyses. If we assign a $1 million value to each death, then the cost of the 1,370 deaths involved here would be $1.370 billion; at $2 million each, the cost would be $2.740 billion. This represents by far the largest component of smoking-fire accident costs to the public. It also provides the bulk of the basis for evaluating potential fire-risk reduction benefits of alternative safety activities.

Property Damage

Upholstered furniture and mattress/bedding fires involve substantial property damage as well as human losses. Property losses represent an important component of total smoking fire costs, and are greater, in dollar value, than the estimated costs of the injuries discussed above. Using the same allocation method with fires as with injuries and deaths, we estimate that in 1984 about $143.8 million in property losses resulted from upholstered furniture smoking fires, and that about $96.0 million in property loss resulted from cigarette ignitions of mattresses and bedding, for a total, in 1986 dollars, of about $240 million. About 9% ($22 million) of this total involves non-residential fires.

Total Accident Costs

From the information above, we can add up the three cost components of smoking fires involving upholstered furniture and mattresses and bedding. For 1984, the aggregate cost (adjusted to 1986 dollars) of smoking fires is estimated to be $1.164 billion for upholstered furniture and $622 million for mattresses and bedding, or about $1.79 billion altogether. Using the $2 million figure for deaths yields a total cost of about $3.16 billion.

Fire safety improvements in cigarettes may also affect fires other than those described here (e.g., vehicular, trash, or forest fires, or fires involving carpets or other home furnishings). Using the same procedures as above, the cost of these other fires is estimated at about $517 million (or $752 million at $2 million per death) for 1984 (in 1986 dollars). We have no information on the extent to which such fires would approximately be included in calculations of potential smoking fire risk reduction benefits. Counting some may be appropriate; counting them all would probably overstate the likely benefits of cigarette fire-safety improvements.

The aggregate costs of cigarette-ignition fires can be viewed in a few ways. For example, the 1984 estimates of injuries, deaths and property damage can be expressed in the following terms:

Total Cost = $1.786 billion (@ $1 million per death)

a. Cost per principally-involved product unit:

Upholstered Furniture (@ 328 million units in use in 1984) = $3.55
Mattresses/Bedding (@ 210 million units in use in 1984) = $2.96
Note: Cost per pre-flammability-standard mattress (N = 60 million) = $10.37[4]

[4]*Assuming that virtually all mattress fires are distributed only among pre-standard units.*

b. Cost per smoker (@ 50 million smokers):

Upholstered Furniture	=	23.28
Mattresses/Bedding	=	$12.44
Total		$35.72

c. Cost per thousand cigarettes (@ 600 billion units):

Upholstered Furniture	=	1.94
Mattresses/Bedding	=	$1.04
Total		$2.98

(= about six cents per pack, or about three-tenths of a cent per cigarette)

At $2 million per death, the 1984 costs would be $6.39 per furniture piece, $5.04 per mattress, $63.12 per smoker, and about 10½ cents per pack of cigarettes. These figures, of course, are averages and do not account for risk differences among kinds of furniture and bedding products, among smokers (e.g., socioeconomic factors), or among cigarettes. They do, however, illustrate the rough magnitude of the smoking-fire hazard.

Present Value of Accident Costs

The practice of smoking carries with it a stream of expected annual costs just as do individual products like cigarettes, furniture or mattresses. To account for society's time preference, streams of expected future costs are discounted to establish their present value (since one would, other things being equal, presumably prefer to incur the cost of an accident later rather than sooner, the later cost is lower in present value than an immediate cost; thus, adding all future years' costs (or benefits) without discounting would overstate the expected value). The present value of the expected costs of smoking fires forms the basis for estimating the expected benefits of safety measures that could reduce future fire losses.

The expected value of future costs is equal to the sum of the discounted costs for each year. If the $35.72 per smoker annual cost were constant during the foreseeable future, then discounting the steady stream of costs at 5% over a typical 35-year lifetime of smoking would yield the following estimate of lifetime smoking-fire costs:

Year	Discount Factor (5%)	Cost per Smoker ($35.72 × discount factor)
1	1.000	$ 35.72
2	.952	34.01
3	.907	32.40
4	.864	30.86
.	.	.
.	.	.
35-year Total		$614.08

The risk, however, may be expected to decline in the future (e.g., as less-ignition-prone furniture and bedding come into increasingly widespread use). Smoking is also expected to decrease. Thus, the expected present value of future accident costs would probably be lower than under the constant-cost assumption. Using information from the NFPA cigarette safety contract report (J. Hall, 1986) for mattresses, CPSC's ignitability and casualty estimates (C. Smith, 1987) for upholstered furniture, and NBS' projections on future cigarette consumption, we have projected deaths, injuries and

Table D-2. Projected Costs of Cigarette-Ignition Fires Involving Upholstered Furniture and Mattresses and Bedding 1986-1995 (Millions of 1986 dollars)

Year	Death	Injury	Property Damage	Total
1986	1294	164	239	1697
1987	1229	155	229	1613
1988	1171	147	220	1538
1989	1124	141	211	1476
1990	1070	134	204	1408
1991	1024	128	195	1347
1992	980	123	188	1291
1993	935	117	179	1231
1994	897	113	174	1184
1995	856	107	168	1131

NOTES: All figures to nearest million; death and injury frequency projections rounded to nearest one; deaths valued @ $1 million each, injuries @ $36,218 each; $2 million death value would yield total cost of $1.987 billion in 1995.

SOURCE: CPSC/Economics, based on NFPA (J. Hall, 1986), NBS (R. Ruegg 1987), CPSC/Epidemiology (B. Harwood, 1986-87) and CPSC/Economics (C. Smith, 1987) information.

property damage in order to estimate year-by-year future costs (see appendix for methodology). Cost estimates are then multiplied by the appropriate discount factors so that a sum of discounted values may be calculated. Table D-2 shows a partial compilation of the costs of projected future cigarette-ignition fires involving upholstered furniture and mattresses and bedding. This corresponds to the years of data in Table 10 of the Hall/NFPA report. As expected, the total costs of smoking-related fire deaths, injuries and property damage decline gradually over the next decade, though costs of over $1.1 billion (in 1986 dollars, and using $1 million per death) would still be incurred by the public in 1995.

The costs above can be expressed in terms of the present value of the fire costs of smoking. This value can be roughly estimated from the 1986-1995 data in the Hall/NFPA report by projecting the present value for the remainder of a typical 35-year smoking period using the same proportion as in the constant-risk-assumption case noted above. This procedure yields the following estimate of the present value per smoker (assuming that the number of smokers declines each year in proportion to the projected decline in cigarette consumption):

Year	PV per smoker($)
1986	34.92
1987	32.40
1988	30.06
1989	28.09
1990	26.10
1991	24.39
1992	22.82
1993	21.30
1994	20.09
1995	18.80
10-year Subtotal	258.97

Decreasing cost in remaining years of typical 35-year smoking period assumed to be proportional to decrease in constant-annual-cost PV;

Extrapolation factor to project to 35-year PV = 2.120;

Total PV = $258.97 × 2.120 = $549.02

This $549 figure illustrates the effect of recent safety improvements in upholstered furniture and mattresses (compared to the $614 present value figure in the hypothetical constant-risk case). As $2 million per death, the 35-year present value would be $966.44.

A similar approach may be used to estimate the present value of cigarette-ignition fire-accident costs per unit of upholstered furniture or mattresses and bedding products. Since these goods have relatively well-known expected service lives, this cost can be readily calculated and by adding the projected cost components—death, injury and property damage—for each year and summing their discounted values over the service life period (see Appendix Tables D-3 and D-4). Assuming an average useful product life of 15 years each, ignoring furniture reupholstering and mattress renovating, and again discounting at 5%, the expected per-unit lifetime fire costs would be about $30 per item of upholstered furniture and $19 per mattress, independent of their relative use in among households (or $54 and $32, respectively, if the $2 million death figure is used). The fire data do not allow us to assess the relative incidence of fire in smoking and non-smoking households; the per unit cost would be higher to the extend that cigarette-ignition fires are confined to smoking households.

What the foregoing analysis suggests is that the cost of a piece of upholstered furniture or a mattress involves more than its retail purchase price. Consumers are paying an average of about $30-54 more over the life of a piece of upholstered furniture, or about $19-32 more per mattress, in expected costs of smoking-related fires (these figures overstate the fire cost for new, relatively safer furniture and mattresses, and understate the cost for old, relatively less safe items). The burden of this cost, of course, falls on all consumers: smokers are not the only victims of smoking fires. Similarly, the kinds of potential remedies that have been pursued to address this hazard – changes in the ignition propensity of furniture and mattresses – would affect all

Table D-3. Smoking Fire Costs: Present Value per Piece of Upholstered Furniture in Use

Year	Est. Cost ($mil)	Est. # in use (mil)	Cost/Unit ($)	PV($,@5%)
1986	1112	340	3.27	3.25
1987	1075	344	3.12	2.97
1988	1044	348	3.00	2.72
1989	1012	352	2.88	2.48
1990	980	357	2.74	2.26
1991	947	361	2.62	2.06
1992	915	365	2.51	1.87
1993	881	369	2.39	1.70
1994	850	374	2.27	1.54
1995	818	378	2.16	1.39
Subtotal				22.24

Extrapolation factor: for full 15-year estimate, constant-cost extrapolation factor = 1.34434; Total 15-year PV = $22.24 × 1.34434 = $29.90

NOTES: All figures in 1986 dollars; estimated average product life = 15 years; undiscounted costs are equal to the sum of estimated deaths @$1 million each, estimated injuries @$36,218 each, and estimated property damage, all to nearest million dollars; costs based on CPSC ignitability and death estimates. Assigning $2 million death cost would yield total per-unit PV of $53.90

Table D-4. Smoking Fire Costs: Present Value per Mattress in Use

Year	Est. Cost ($mil)	Est. # in use (mil)	Cost/Unit ($)	PV($,@5%)
1986	586	223	2.63	2.63
1987	538	230	2.34	2.23
1988	494	236	2.09	1.90
1989	464	245	1.90	1.64
1990	428	252	1.70	1.40
1991	400	261	1.53	1.20
1992	376	269	1.40	1.04
1993	350	278	1.26	.89
1994	334	288	1.16	.78
1995	314	297	1.06	.65
Subtotal				14.36

Extrapolation factor: for full 15-year estimate, constant-cost extrapolation factor = 1.34431; Total 15-year PV = $14.36 × 1.34431 = $19.30

NOTES: All figures in 1986 dollars; estimated average product life = 15 years; undiscounted costs are equal to the sum of estimated deaths @$1 million each, estimated injuries @$36,218 each, and estimated property damage, all to nearest million dollars; costs based on Hall/NFPA death, injury and property damage rates. Assigning $2 million death cost would yield total per-unit PV of $32.44.

consumers. It might, therefore, be worth to spending up to $30-54 per piece in use to eliminate the total risk associated with all upholstered furniture in an economically efficient manner; spending up to $19-32 per unit to eliminate the hazard associated almost exclusively with pre-flammability-standard mattresses may also be economically efficient, assuming that post-standard units present virtually no cigarette-ignition risk (it should be noted that these figures do not suggest efficient levels of safety investment for new furniture and mattresses, which are already, on the average, more cigarette-ignition resistant). Alternatively, it might be worth spending 6-10 cents per pack of cigarettes to eliminate the combined risk. Correspondingly lower figures would accompany measures that reduce but do not eliminate the risk, e.g., a 20%—effective remedy might be worth up to about 1-2 cents per pack of cigarettes.

Consumer Knowledge and Consumers' Surplus

The measurement of potential changes in "consumers' surplus" associated with regulatory alternatives has engendered discussion recently among the CPSC staff and others, particularly regarding the cost-benefit work on cigarette safety. Briefly stated, consumers' surplus is the aggregate dollar value consumers place on a product over an above the level of expenditures on that product; this assumes a downward-sloping demand curve, and implies that most people would be willing to pay something more than the market price for the product.

The expected costs of unknown or misunderstood product hazards, however, can essentially be considered the same as additions to the product's price; these constitute decreases in the real level of consumers' surplus associated with the product. In the case of cigarettes, two kinds of potential risks—fire and smoking-related disease—are involved. To the extent that these risks are known and understood, their costs are excluded from the consumers' surplus associated with cigarette consumption. If consumers had perfect information, all accident costs would just be part of the cost of smoking, and would not affect consumers' surplus. We know of no studies in this area of risk awareness; it seems, however, that consumers, while unable to evaluate loss probabilities precisely, are generally aware that smoking may be addictive and have adverse health effects and that carelessly discarded cigarettes may ignite upholstered furniture and bedding. We therefore consider the bulk (though perhaps not all) of the expected $1.8 billion annual fire-accident costs and the bulk of health care costs associated with cigarette consumption to be separate from the consumers' surplus associated with smoking; in such a case, projected changes in expected fire or health costs as a result of changes in cigarettes would not affect consumers' surplus. This is essentially the approach of the cost-benefit study on cigarette safety, in which possible changes in fire and health risks are counted separately from possible changes in consumers' surplus resulting from satisfaction- or price-related changes in cigarette consumption.

Appendix

Estimation of Deaths, Injuries and Property Damage from Smoking Fires

The Hall/NFPA cigarette safety report of August 29, 1986 contains tables which are comprised of historical data on smoking fires (Table 4) and projected rates of such fires (per billion cigarettes consumed, Table 10). Information from these tables was lifted or modified for use in the estimation of costs and projected incidence of fires, deaths, injuries and property damage.

1984 composite smoking-fire loss estimates were obtained by combining the residential and non-residential estimates from Table 4, allocating the unknown-material categories proportionally with the known groups; overall unknowns for fires, deaths and civilian injuries were provided by B. Harwood, CPSC/Epidemiology, and firefighter injuries (Hall version 1) were allocated in the same proportions as civilian injuries. Outdoor fires (trash, vehicular, forest, etc.) were excluded.

Example: Civilian Deaths, 1984

a. Residential structures

Upholstered Furniture	Mattresses/ Bedding	Other Unknown
856	386	292

Unknowns = 103, or 35.3% of 292; Proportional allocation yields

62	28
918	414

b. Non-residential structures

13	20	23

+unknowns @ 35.3% of 23 = 8, proportionally allocated

2	3
15	23

c. Total = 933 + 437 = 1370

These totals are used to establish the death component of the 1984 fire cost estimate.

Projections of future losses for mattresses and bedding were made for 1986-95 using Hall's rates per billion cigarettes (allocating unknowns and excluding outdoor fires as above) and NBS' projections of yearly cigarette consumption (see Table D-5).

Example: Civilian Deaths, 1986 (mattresses/bedding)

a. Residential structures

Mattresses/Bedding	Other/Unknown
0.627/billion × 583 billion = 366	0.503/billion × Unknown proportion = 35.3%; × Mattress proportion = (26/103) = 27.18%; × 583 billion = 28

b. Non-residential structures

.013/billion × 583 billion = 8	.025/billion × Unknown proportion = 35.3% × Mattress proportion = (3/8) = 37.5% × 583 billion = 2

c. Total = 366 + 28 + 8 + 2 = 404

Table D-5. Estimated Cigarette Consumption and Numbers of Smokers, 1986-95

Year	Est. Cigarette Consumption (billions)	Estimated number of Smokers (millions)
1986	582.84	48.6
1987	568.62	47.4
1988	557.22	46.4
1989	545.14	45.4
1990	532.39	44.4
1991	519.54	43.3
1992	506.23	42.2
1993	492.90	41.1
1994	479.23	39.9
1995	465.58	38.8

SOURCE: NBS/Center for Applied Mathematics estimates for cigarette consumption, except 1986 (Maxwell Report figure); CPSC/Economic Analysis estimates for numbers of smokers.

NOTE: Estimated number of smokers assumed to decrease in proportion to consumption decrease; consumption index based on 1984 levels of 600 billion cigarettes and 50 million smokers.

These totals are used to establish the death component of the 1986 fire cost estimate.

Estimates of the number of deaths from residential cigarette-ignition-related upholstered furniture fires through the year 2000 were recently made by CPSC/Economics (C. Smith memo of 2/17/87). The upper end of the range for the year 2000 was 750 deaths, assuming no change in smoking behavior of cigarette consumption. This upper estimate was proportionally adjusted, per NFPA 1984 data, to project total civilian deaths (residential and non-residential) for the years 1984 through 2000, assuming a steady reduction each year from the 1984 level of 933 total deaths, to a year-2000 level of 800 total deaths. Injuries and property damage, using the 1984 data as a baseline, were treated similarly. The resulting estimates are significantly lower than those which would correspond to the ignitability rates mentioned in the Hall/NFPA report; CPSC's ignitability estimates are believed to account for changes in furniture construction and numbers of deaths per fire more accurately than any previously available. The numbers were than adjusted to reflect the projected decreases in cigarette consumption provided by NBS.

The per-unit present value of the costs of upholstered furniture and mattress and bedding fires, based on the foregoing procedure, was discounted at 5%. The following tables illustrate the yearly and discounted costs per product unit. Since only data through 1995 are available for all components of the calculations, the total 15-year discounted cost was extrapolated assuming that the remaining years' values would be proportionally the same as in a dummy case in which the annual costs are constant; any resulting error is believed to be insignificant.

Appendix E

Sensitivity Analysis – Variations in Estimated Average Cost per Injury and Impact of Unreported Fires

The estimated cost of injuries has been the subject of limited work in the past:

1. A 1976 survey that analyzed the indirect losses associated with fire produced some useful results.[15] The authors found medical care costs per fire involving injury to be $1,217.50. (Based on the declining purchasing power of the dollar, this would be equivalent to roughly $2,500 in 1986.) Costs of missing work, which was often but not always due to injury, averaged $397.63 per fire involving such costs, which would be equivalent to about $750 in 1986. Allowing for other indirect costs that might include some side-effects of injuries, the total would be on the order of $3,500 to $4,000 in 1986 dollars. This also represents about one-third of all indirect costs, which in turn were estimated to add 10% to direct property damage.
2. Calculations based on direct costs of injuries or illnesses, like these in #1, generally have been superceded in recent years by cost values based on the willingness-to-pay concept, which involves inferences from past safety-related purchase decisions. In unpublished risk analysis work at the National Bureau of Standards, the Center for Fire Research used a value of $20,000 per injury, with a range of $10,000 to $40,000.
3. Specialists in burn care treatment have developed some data specifically on costs of burn care treatment, with reported costs for the worst cases ranging at least as high as hundreds of thousands of dollars. However, these figures focus on burns requiring hospitalization and so do not address either minor burns or illnesses involving smoke or gas inhalation. If account is taken of the small percentage of smoking-related fire injuries fitting the profile of burn cases covered by the burn-care cost figures, the figures cited in #2 are consistent and can still be validly used.

   For example, one of the few published references to the cost of burn care cited a study of 420 burn center admissions for emergency and acute burns, of which 19 had charges in the highest range of $100,000 to $500,000.[8] This means 4.5% had charges in that range. For 1984 residential structure smoking fire related injuries to civilians, only 30.8% of those injuries involved any burns and transport to any facility, let alone a burn center. The most serious burns therefore would add at most $1,400-$6,900 to the average cost per injury (depending on where in the range of $100,000–$500,000 the average of those 19 injuries fell).

If it is further assumed that any burn reaching a burn center would involve burns to either multiple body parts of at least to the head or neck, then only 14.5% of 1984 injuries qualify, and the add-on is reduced to at most $650-$3,260. If one could separate burn centers from other treatment facilities, the add-on would drop more. All the other injuries not covered in the add-on will tend to involve lower costs, usually much lower costs. Considering all these analyses as background, then, the estimated cost per injury was tested for four values—$10,000, $20,000, and $40,000 (the range cited above) and $36,218, the value estimated by Dale Ray of CPSC (see Appendix D). The CPSC estimate was based on the most thorough analysis yet done of fire injury costs and so was considered to give the best estimates. Among other refinements, it explicitly addressed the cost of pain and suffering, which is addressed only implicitly by the willingness-to-pay estimates.

Independently, the effects of unreported fires were tested at three levels – no effect, a low estimated effect of 3.7% added to injuries and 4.0% added to property damaged, and a high estimated effect of 13.6% added to injuries and 6.5% added to property damage. The high estimate was considered to give the best estimate, because it converted loss values, expressed as ranges, to some type of averages, rather than using lower bounds exclusively.

There were therefore a total of 12 analyses, each also showing results for both versions of the fire fighter injury estimate. The best estimate was included in the text as Table 14 and is reproduced here as Table E-1. The other estimates are shown in tables numbered E-2 through E-12.

The contract also called for use of an injury cost estimate based on data collected in a recent study by the U.S. Department of Health and Human Services (HHS), if the data proved suitable for such use. Unfortunately, in several conversations with one of the participants in that study, it was learned that (1) most of the cases studied probably did not record cost-related data, (2) those that did probably have that information in a format not readily amenable to analysis, and (3) the data itself could not be located in a form that covered all participating facilities or that was coded

Table E-1. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96 (Also Table 14 in Text)

Injuries Costed by CPSC @ *$36,218*

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.38 + 2.86Q	1.29 + 2.86Q
1987	1.41 + 2.84Q	1.31 + 2.84Q
1988	1.43 + 2.81Q	1.33 + 2.81Q
1989	1.46 + 2.79Q	1.36 + 2.79Q
1990	1.48 + 2.77Q	1.37 + 2.77Q
1991	1.50 + 2.75Q	1.39 + 2.75Q
1992	1.52 + 2.74Q	1.41 + 2.74Q
1993	1.54 + 2.73Q	1.43 + 2.73Q
1994	1.56 + 2.73Q	1.45 + 2.73Q
1995	1.58 + 2.73Q	1.46 + 2.73Q
1996	1.60 + 2.74Q	1.48 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-2. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

Injuries Costed by CPSC @ *$36,218*

Includes Unreported Fires Adding 3.7% to Injuries and 4.0% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.32 + 2.86Q	1.23 + 2.86Q
1987	1.34 + 2.84Q	1.26 + 2.84Q
1988	1.36 + 2.81Q	1.27 + 2.81Q
1989	1.39 + 2.79Q	1.30 + 2.79Q
1990	1.41 + 2.77Q	1.32 + 2.77Q
1991	1.43 + 2.75Q	1.34 + 2.75Q
1992	1.45 + 2.74Q	1.35 + 2.74Q
1993	1.47 + 2.73Q	1.37 + 2.73Q
1994	1.49 + 2.73Q	1.39 + 2.73Q
1995	1.51 + 2.73Q	1.40 + 2.73Q
1996	1.53 + 2.74Q	1.42 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

for computer manipulation. Given these findings, it was concluded that no analysis using injury cost values from the HHS study was possible.

Table E-4 shows the highest figures of all the tables. Of all the variations, however, none appears to be as significant as the question of what value to assign to a statistical death. It appears likely that the fatality component will continue to dominate total loss, no matter which of the modeling variations examined are ultimately adopted. Also, property damage consistently dominates the costs estimated for injuries, even with the higher values of injury costs.

The conclusion of these analyses are that these variations are not of major significance to the overall conclusion of this study and that greatest attention should be paid to the effect of cigarette redesign on fire fatalities.

Table E-3. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

Injuries Costed by CPSC @ *$36,218*

No Adjustment for Unreported Fires

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.27 + 2.86Q	1.19 + 2.86Q
1987	1.29 + 2.84Q	1.21 + 2.84Q
1988	1.31 + 2.81Q	1.23 + 2.81Q
1989	1.34 + 2.79Q	1.25 + 2.79Q
1990	1.36 + 2.77Q	1.37 + 2.77Q
1991	1.38 + 2.75Q	1.28 + 2.75Q
1992	1.40 + 2.74Q	1.30 + 2.74Q
1993	1.41 + 2.73Q	1.32 + 2.73Q
1994	1.43 + 2.73Q	1.34 + 2.73Q
1995	1.45 + 2.73Q	1.35 + 2.73Q
1996	1.47 + 2.74Q	1.37 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-4. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

Injuries @ *$40,000*

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.44 + 2.86Q	1.34 + 2.86Q
1987	1.46 + 2.84Q	1.36 + 2.84Q
1988	1.48 + 2.81Q	1.38 + 2.81Q
1989	1.51 + 2.79Q	1.40 + 2.79Q
1990	1.53 + 2.77Q	1.42 + 2.77Q
1991	1.55 + 2.75Q	1.44 + 2.75Q
1992	1.57 + 2.74Q	1.46 + 2.74Q
1993	1.59 + 2.73Q	1.47 + 2.73Q
1994	1.61 + 2.73Q	1.49 + 2.73Q
1995	1.63 + 2.73Q	1.51 + 2.73Q
1996	1.65 + 2.74Q	1.52 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-5. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

Injuries @ *$40,000*

Includes Unreported Fires Adding 3.7% to Injuries and 4.0% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.37 + 2.86Q	1.28 + 2.86Q
1987	1.39 + 2.84Q	1.30 + 2.84Q
1988	1.41 + 2.81Q	1.32 + 2.81Q
1989	1.44 + 2.79Q	1.34 + 2.79Q
1990	1.46 + 2.77Q	1.36 + 2.77Q
1991	1.48 + 2.75Q	1.37 + 2.75Q
1992	1.50 + 2.74Q	1.39 + 2.74Q
1993	1.52 + 2.73Q	1.41 + 2.73Q
1994	1.54 + 2.73Q	1.43 + 2.73Q
1995	1.56 + 2.73Q	1.44 + 2.73Q
1996	1.58 + 2.74Q	1.46 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-6. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

Injuries @ *$40,000*

No Adjustment for Unreported Fires

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.32 + 2.86Q	1.23 + 2.86Q
1987	1.34 + 2.84Q	1.25 + 2.84Q
1988	1.36 + 2.81Q	1.27 + 2.81Q
1989	1.38 + 2.79Q	1.29 + 2.79Q
1990	1.40 + 2.77Q	1.30 + 2.77Q
1991	1.42 + 2.75Q	1.32 + 2.75Q
1992	1.44 + 2.74Q	1.34 + 2.74Q
1993	1.46 + 2.73Q	1.36 + 2.73Q
1994	1.48 + 2.73Q	1.37 + 2.73Q
1995	1.50 + 2.73Q	1.39 + 2.73Q
1996	1.52 + 2.74Q	1.40 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-7. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

[redacted]

Injuries *@* ***$20,000***

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.15 + 2.86Q	1.10 + 2.86Q
1987	1.17 + 2.84Q	1.12 + 2.84Q
1988	1.20 + 2.81Q	1.14 + 2.81Q
1989	1.22 + 2.79Q	1.17 + 2.79Q
1990	1.24 + 2.77Q	1.19 + 2.77Q
1991	1.27 + 2.75Q	1.21 + 2.75Q
1992	1.29 + 2.74Q	1.23 + 2.74Q
1993	1.31 + 2.73Q	1.25 + 2.73Q
1994	1.33 + 2.73Q	1.27 + 2.73Q
1995	1.34 + 2.73Q	1.28 + 2.73Q
1996	1.36 + 2.74Q	1.30 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-8. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

[redacted]

Injuries *@* ***$20,000***

Includes Unreported Fires Adding 3.7% to Injuries and 4.0% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.10 + 2.86Q	1.05 + 2.86Q
1987	1.13 + 2.84Q	1.08 + 2.84Q
1988	1.15 + 2.81Q	1.10 + 2.81Q
1989	1.18 + 2.79Q	1.13 + 2.79Q
1990	1.20 + 2.77Q	1.15 + 2.77Q
1991	1.22 + 2.75Q	1.17 + 2.75Q
1992	1.24 + 2.74Q	1.19 + 2.74Q
1993	1.26 + 2.73Q	1.20 + 2.73Q
1994	1.28 + 2.73Q	1.22 + 2.73Q
1995	1.29 + 2.73Q	1.24 + 2.73Q
1996	1.31 + 2.74Q	1.25 + 2.74Q

NOTE: Note: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-9. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

Injuries @ *$20,000*

No Adjustment for Unreported Fires

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.06 + 2.86Q	1.01 + 2.86Q
1987	1.08 + 2.84Q	1.04 + 2.84Q
1988	1.11 + 2.81Q	1.06 + 2.81Q
1989	1.13 + 2.79Q	1.08 + 2.79Q
1990	1.15 + 2.77Q	1.10 + 2.77Q
1991	1.17 + 2.75Q	1.12 + 2.75Q
1992	1.19 + 2.74Q	1.14 + 2.74Q
1993	1.21 + 2.73Q	1.16 + 2.73Q
1994	1.23 + 2.73Q	1.18 + 2.73Q
1995	1.25 + 2.73Q	1.19 + 2.73Q
1996	1.26 + 2.74Q	1.21 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-10. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

Injuries @ *$10,000*

Includes Unreported Fires Adding 13.6% to Injuries and 6.5% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.00 + 2.86Q	0.97 + 2.86Q
1987	1.03 + 2.84Q	1.00 + 2.84Q
1988	1.05 + 2.81Q	1.03 + 2.81Q
1989	1.08 + 2.79Q	1.05 + 2.79Q
1990	1.10 + 2.77Q	1.07 + 2.77Q
1991	1.12 + 2.75Q	1.09 + 2.75Q
1992	1.14 + 2.74Q	1.12 + 2.74Q
1993	1.16 + 2.73Q	1.13 + 2.73Q
1994	1.18 + 2.73Q	1.15 + 2.73Q
1995	1.20 + 2.73Q	1.17 + 2.73Q
1996	1.22 + 2.74Q	1.19 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-11. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

[illegible]

Injuries @ *$10,000*

Includes Unreported Fires Adding 3.7% to Injuries and 4.0% to Property Damage

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	0.97 + 2.86Q	0.94 + 2.86Q
1987	0.99 + 2.84Q	0.97 + 2.84Q
1988	1.02 + 2.81Q	0.99 + 2.81Q
1989	1.04 + 2.79Q	1.02 + 2.79Q
1990	1.07 + 2.77Q	1.04 + 2.77Q
1991	1.09 + 2.75Q	1.06 + 2.75Q
1992	1.11 + 2.74Q	1.08 + 2.74Q
1993	1.13 + 2.73Q	1.10 + 2.73Q
1994	1.15 + 2.73Q	1.12 + 2.73Q
1995	1.16 + 2.73Q	1.14 + 2.73Q
1996	1.18 + 2.74Q	1.15 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table E-12. Summary of Estimated Economic Value of Losses in Smoking Fires per Billion Cigarettes Consumed, 1986-96

[illegible]

Injuries @ *$10,000*

No Adjustment for Unreported Fires

Economic Value of Fire Losses (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	0.93 + 2.86Q	0.91 + 2.86Q
1987	0.96 + 2.84Q	0.93 + 2.84Q
1988	0.98 + 2.81Q	0.96 + 2.81Q
1989	1.00 + 2.79Q	0.98 + 2.79Q
1990	1.03 + 2.77Q	1.00 + 2.77Q
1991	1.05 + 2.75Q	1.02 + 2.75Q
1992	1.07 + 2.74Q	1.04 + 2.74Q
1993	1.08 + 2.73Q	1.06 + 2.73Q
1994	1.10 + 2.73Q	1.08 + 2.73Q
1995	1.12 + 2.73Q	1.09 + 2.73Q
1996	1.14 + 2.74Q	1.11 + 2.74Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Appendix F

Sensitivity Analysis Forecasting Model Using "Carelessness" Index[1]

The intent of this sensitivity analysis was to identify an index that would reflect trends in the general propensity of the U.S. population to commit acts or oversights that lead to fires, labelled a "carelessness index" for short. The hypothesis was that explicit modeling of such an index would further isolate those trends that are specific to cigarettes and the items they ignite.

As proposed, the particular index used here was total fires per 1,000 persons. The index was arbitrarily set equal to 1 for 1984, then calculated for the 1980-83, as follows:

Year	Total Fires per Thousand Persons	Carelessness Index
1980	13.2	1.333
1981	12.6	1.273
1982	11.0	1.111
1983	9.9	1.000
1984	9.9	1.000

It was further determined that the index should be set equal to 1 for 1986-96 because the index appears to have levelled off in 1983-84 (and in 1985, not shown, when it also would have been 1.000). Thus a projection based on the three most recent years would be for a constant index into the future.

In general, the fit of the forecasting line to the data was better than the original when the carelessness index was used, with notable exception of residential mattress/bedding fires, where the original equation fit much better.

In three of the four equations based on the year (not on an ignitability index), use of the carelessness index produced a prediction of increasing fires in future years, as contrasted to the old forecasting equations which predicted decreasing fires across the board.

Although the statistical fit of this new approach was better, there were serious face validity problems that were identified in discussions of this concept with other fire statistics experts. These problems are briefly summarized below. They are regarded as sufficiently serious that this approach was not judged to provide an improvement to the original analysis. The problems are as follows:

1. Roughly one-fourth of total fires involve incendiary or suspicious origins. They are not accidental and should not be used in an index claiming to represent carelessness.
2. Total fires are dominated by outdoor trash, grass, brush, and tree fires. While this fact does subordinate the influence of products and systems, it elevates the influence of weather patterns and so, even if accidental fires were isolated, trends in total accidental fires may not be dominated by trends in behavior.
3. Public education programs of recent years have focused on home fires. It might be expected, therefore, that trends in carelessness would be different for home fires than for fires in general, if the differential emphasis has produced a differential impact.
4. It is premature to conclude that carelessness, public fire consciousness, or total fires per 1,000 persons have levelled off simply on the basis of a three-year plateau. Examination of pre-1980 data shows a fair amount of fluctuation, with starts and stops, within a long-term downward trend. Therefore, projection of a level remains counter-intuitive to many.

The tables that follow include those tables from the 1986 final report for which the use of the index results in changes. The original numbering of the original tables has been preserved. Tables F-1 gives the original projection formulas from Table 9 of the 1986 report, while Table F-1a gives the revised formulas for fire rates using the carelessness index.

The original three-page Table 10, which presented the projected loss rates per billion cigarettes, is presented as Table F-2 along with Table F-2a which gives the revised loss

[1] *This analysis was performed using first-round values of the ignitability indexes for upholstered furniture, not the final values given in the main section of the report. Because this approach ultimately was deemed to be innappropriate, based on flaws in its fundamental assumptions, it was not considered necessary or useful to revise it to correspond to the updated basic model. Also, the changes in the basic model were comparatively small, so the effects of using the "carelessness index" as described here probably would be much the same if updated.*

Table F-1. Forecasting Equations for Smoking Fires, 1986-96, Without Carelessness Index (Table 9 From 1986 Report)

Severity Measure	Major Property Class	Form of Material First Ignited	Forecasting Equation
Fires per billion cigarettes	Residential structures	Upholstered furniture	61.032 × Ignitability
		Mattresses or bedding	78.354 × Ignitability
		Other or unknown	33.467 − 0.568 × (Year−1980)
	Non-residential structures	Upholstered furniture	6.395 × Ignitability
		Mattresses or bedding	12.650 × Ignitability
		Other or unknown	27.650 −1.419 × (Year−1980)
	Vehicle	All	28.065 −0.936 × (Year−1980)
	Outdoors or other	All	278.54 −5.451 × (Year−1980)
Civilian deaths per thousand fires	Residential structures	Upholstered furniture	46.20 + 4.62 × (Year−1980)
		Mattresses or bedding	21.33 + 0.90 × (Year−1980)
		Other or unknown	14.20 + 0.42 × (Year−1980)
	Non-residential structures	Upholstered furniture	2.92 + 1.11 × (Year−1980)
		Mattresses or bedding	4.90 −0.21 × (Year−1980)
		Other or unknown	1.99 − 0.11 × (Year−1980)
	Vehicles	All	3.20 − 0.64 × (Year−1980)
	Outdoors or other	All	0.027 − 0.002 × (Year−1980)
Civilian injuries per thousand fires	Residential structures	Upholstered furniture	86.36 + 7.95 × (Year−1980)
		Mattresses or bedding	56.34 + 6.92 × (Year−1980)
		or unknown	39.69 + 1.10 × (Year−1980)
	Non-residential structures	Upholstered furniture	29.65 + 2.22 × (Year−1980)
		Mattresses or bedding	77.35 − 9.95 × (Year−1980)
		Other or unknown	8.85 + 0.94 × (Year−1980)
	Vehicle	All	16.74 − 1.91 × (Year−1980)
	Outdoors or other	All	0.738 − 0.097 × (Year−1980)
Fire fighter injuries per thousand fires (Version 1)	Residential structure	Upholstered furniture	59.16 + 1.73 × (Year−1980)
		Mattresses or bedding	43.78 + 1.84 × (Year−1980)
		Other or unknown	20.75 + 7.85 × (Year−1980)
	Non-residential	Upholstered furniture	20.27 + 2.73 × (Year−1980)
		Mattresses or bedding	26.02 − 2.66 × (Year−1980)
		Other or unknown	18.29 + 0.53 × (Year−1980)
	Vehicle	All	2.83 + 0.63 × (Year−1980)
	Outdoors or other	All	1.922 + 0.328 × (Year−1980)

rates reflecting the carelessness index. Table F-3 is the original Table 11 and gives the original summary totals of loss rates. Table F-3a gives the revised totals reflecting the carelessness index. And Table F-3b gives the totals if the carelessness index is applied to all cases except residential mattress/bedding fires. Table F-3b is essentially a summary based on the best fitting forecasting curves thus far identified for all cases. The results in Tables F-3a and F-3b are quite close.

If projections for 1986-96 are summed without consideration of present value discounting, it may be seen that use of the carelessness index produces a large net increase in

Table F-1. Forecasting Equations for Smoking Fires, 1986-96, Without Carelessness Index (Table 9 From 1986 Report) (Continued)

Severity Measure	Major Property Class	Form of Material First Ignited	Forecasting Equation
Fire fighter injuries per thousand fires (Version 2)	Residential structures	Upholstered furniture	42.21 + 1.86 × (Year−1980)
		Mattresses or bedding	27.55 + 1.98 × (Year−1980)
		Other or unknown	13.18 + 1.71 × (Year−1980)
	Non-residential structures	Upholstered furniture	15.93 + 2.06 × (Year−1980)
		Mattresses or bedding	41.57 + 4.68 × (Year−1980)
		Other or unknown	3.75 + 1.15 × (Year−1980)
	Vehicles	All	0.45 + 0.76 × (Year−1980)
	Outdoors or other	All	0.091 + 0.053 × (Year−1980)
Direct property damage (in millions of 1986 dollars) per thousand fires	Residential structures	Upholstered furniture	8.43 + 0.45 × (Year−1980)
		Mattresses or bedding	4.34 + 0.24 × (Year−1980)
		Other or unknown	2.25 + 1.05 × (Year−1980)
	Non-residential structures	Upholstered furniture	5.20 + 1.15 × (Year−1980)
		Mattresses or bedding	1.78 + 0.07 × (Year−1980)
		Other or unknown	4.39 − 0.08 × (Year−1980)
	Vehicle	All	1.52 − 0.12 × (Year−1980)
	Outdoors or other	All	0.00

total fires (46.7% for Table F-3a, 47.2% for Table F-3b). Projections for 1986 are 14.8-15.5% higher, but the trend is increasing rather than decreasing, so projections for 1996 are 90.5-91.0% higher. Most of this is due to the projection of an increasing rather than a decreasing trend in outdoor cigarette fires, which represent the largest total.

However, projected civilian deaths for the 11-year period are virtually unchanged (down 0.9% for Table F-3a, up 1.1% for Table F-3b), and this is the dominant component in projected loss.

Civilian deaths are projected to increase rather than decrease in 1986-96 but from a much lower estimated

Table F-1a. Forecasting Equations for Smoking Fires, 1986-96, Including Effects of Careless Index

Severity Measure	Major Property Class	Form of Material First Ignited	Forecasting Equation
Fires per billion cigarettes	Residential structures	Upholstered furniture	52.462 × Ignitability
		Mattresses or bedding	69.352 × Ignitability
		Other or unknown	29.608 × 1.055 × (Year−1980)
	Non-residential structures	Upholstered furniture	5.508 × Ignitability
		Mattresses or bedding	10.130 × Ignitability
		Other or unknown	22.758 − 0.195 × (Year−1980)
	Vehicle	All	23.950 + 0.430 × (Year−1980)
	Outdoors or other	All	244.683 + 8.330 × (Year−1980)

Table F-2. Estimated 1986-96 Smoking Fire Problem, Without Carelessness Index
(Table 10 From 1986 Report)

A. Fires per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	22.3	23.4	30.1	2.3	3.6	19.1	22.5	245.8	369.2
1987	21.2	21.1	29.5	2.2	3.3	17.7	21.5	240.4	356.9
1988	20.2	19.0	28.9	2.1	2.9	16.3	20.6	234.9	344.9
1989	19.2	17.5	28.4	2.0	2.7	14.9	19.6	229.5	333.8
1990	18.4	15.8	27.8	1.9	2.4	13.5	18.7	224.0	322.5
1991	17.6	14.4	27.2	1.9	2.2	12.0	17.8	218.6	311.7
1992	17.0	13.4	26.7	1.8	2.1	10.6	16.8	213.1	301.4
1993	16.4	12.4	26.1	1.7	1.9	9.2	15.9	207.7	291.2
1994	15.9	11.8	25.5	1.7	1.8	7.8	15.0	202.2	281.6
1995	15.4	10.9	25.0	1.6	1.7	6.4	14.0	196.8	271.7
1996	15.0	10.3	24.4	1.6	1.6	5.0	13.1	191.3	262.3

B. Civilian Fire Deaths per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.651	0.627	0.503	0.022	0.013	0.025	0	0.004	2.845
1987	1.668	0.583	0.506	0.024	0.011	0.021	0	0.003	2.816
1988	1.680	0.542	0.508	0.025	0.009	0.018	0	0.003	2.784
1989	1.688	0.515	0.510	0.026	0.008	0.014	0	0.002	2.763
1990	1.697	0.478	0.512	0.027	0.007	0.012	0	0.002	2.734
1991	1.711	0.451	0.513	0.028	0.006	0.009	0	0.001	2.718
1992	1.724	0.431	0.513	0.029	0.005	0.007	0	0.001	2.710
1993	1.738	0.410	0.513	0.030	0.004	0.005	0	0	2.699
1994	1.759	0.399	0.513	0.031	0.004	0.003	0	0	2.709
1995	1.776	0.380	0.512	0.031	0.003	0.002	0	0	2.704
1996	1.803	0.370	0.510	0.032	0.002	0.001	0	0	2.720

starting point in 1986, so the curves with and without the carelessness index look like mirror images of each other in projected loss.

Civilian injuries also are up only slightly (3.7% on Table F-3a, 7.0% on Table F-3b), while fire fighter injuries are up significantly (18.0-28.7% on Table F-3A, 20.0-30.2% on Table F-3b, depending on the use of version 1 or 2 to compute fire fighter injuries). Property damage projections also are up significantly (25.3% on Table F-3a, 26.7% on Table F-3b).

Tables F-4a and F-4b provide the total economic impact corresponding to Tables F-3a and F-3b, respectively. Tables F-4a and F-4b are comparable to Table F-4, which corresponds to Table 12 of the 1986 report.

Table F-2. Estimated 1986-96 Smoking Fire Problem, Without Carelessness Index
(Table 10 from 1986 Report) (Continued)

C. Civilian Fire Injuries per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	2.995	2.293	1.391	0.101	0.064	0.278	0.119	0.038	7.279
1987	3.017	2.209	1.397	0.101	0.025	0.274	0.073	0.014	7.110
1988	3.030	2.118	1.402	0.100	0	0.267	0.031	0	6.949
1989	3.037	2.073	1.406	0.100	0	0.258	0	0	6.874
1990	3.048	1.978	1.408	0.100	0	0.246	0	0	6.780
1991	3.067	1.910	1.409	0.100	0	0.232	0	0	6.718
1992	3.085	1.868	1.409	0.100	0	0.214	0	0	7.676
1993	3.104	1.812	1.408	0.100	0	0.194	0	0	7.618
1994	3.138	1.801	1.405	0.101	0	0.172	0	0	7.617
1995	3.163	1.745	1.402	0.101	0	0.146	0	0	7.617
1996	3.207	1.728	1.396	0.102	0	0.118	0	0	7.553

D. Fire Fighter Fireground Injuries (Version 1) per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.553	1.285	2.040	0.086	0.036	0.411	0.148	0	5.558
1987	1.513	1.195	2.233	0.088	0.024	0.390	0.155	0	5.597
1988	1.474	0.110	2.417	0.089	0.014	0.367	0.161	0	5.632
1989	1.436	0.055	2.592	0.090	0.006	0.343	0.166	0	5.688
1990	1.404	0.980	2.758	0.091	0	0.318	0.170	0	5.721
1991	1.379	0.923	2.915	0.093	0	0.290	0.173	0	5.774
1992	1.356	0.883	3.064	0.094	0	0.262	0.174	0	5.832
1993	1.335	0.839	3.203	0.095	0	0.232	0.175	0	5.879
1994	1.323	0.818	3.334	0.097	0	0.200	0.174	0	5.945
1995	1.308	0.778	3.455	0.099	0	0.167	0.172	0	5.979
1996	1.303	0.758	3.568	0.101	0	0.132	0.168	0	6.030

Table F-2. Estimated 1986-96 Smoking Fire Problem, Including Carelessness Index (Table 10 From 1986 Report) (Continued)

E. Fire Fighter Fireground Injuries (Version 2) per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.192	0.818	0.704	0.066	0.049	0.203	0.113	0.101	3.352
1987	1.173	0.773	0.742	0.068	0.029	0.209	0.125	0.111	3.328
1988	1.153	0.728	0.777	0.069	0.012	0.210	0.135	0.121	3.300
1989	1.133	0.702	0.810	0.069	0	0.209	0.144	0.131	3.289
1990	1.117	0.746	0.841	0.070	0	0.205	0.151	0.139	3.269
1991	1.105	0.711	0.871	0.071	0	0.197	0.157	0.148	3.260
1992	1.094	0.688	0.898	0.072	0	0.186	0.162	0.155	3.255
1993	1.085	0.660	0.924	0.073	0	0.172	0.165	0.162	3.241
1994	1.083	0.650	0.947	0.074	0	0.154	0.167	0.169	3.243
1995	1.078	0.624	0.969	0.076	0	0.133	0.167	0.175	3.222
1996	1.080	0.613	0.988	0.077	0	0.109	0.166	0.180	3.213

F. Direct Property Damage (in Millions of 1986 Dollars) per Billion Cigarettes

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	0.249	0.135	0.257	0.028	0.008	0.075	0.018	0.019	0.789
1987	0.246	0.127	0.283	0.030	0.007	0.068	0.015	0.023	0.798
1988	0.244	0.118	0.308	0.031	0.007	0.061	0.012	0.026	0.806
1989	0.240	0.113	0.331	0.031	0.007	0.054	0.009	0.030	0.816
1990	0.238	0.106	0.354	0.032	0.006	0.048	0.007	0.033	0.823
1991	0.237	0.100	0.375	0.033	0.006	0.042	0.004	0.036	0.833
1992	0.235	0.096	0.395	0.034	0.005	0.036	0.002	0.038	0.843
1993	0.234	0.092	0.414	0.035	0.005	0.031	0	0.041	0.852
1994	0.234	0.090	0.432	0.036	0.005	0.025	0	0.043	0.866
1995	0.234	0.086	0.449	0.036	0.005	0.020	0	0.045	0.875
1996	0.235	0.084	0.464	0.037	0.005	0.015	0	0.047	0.888

Table F-2a. Esitmated 1986-96 Smoking Fire Problem, Including Carelessness Index (Continued)

A. Fires per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	19.2	20.7	35.9	2.0	3.0	21.6	26.5	294.7	423.7
1987	18.3	18.7	37.0	1.9	2.7	21.4	27.0	303.0	429.9
1988	17.4	16.8	38.1	1.8	2.5	21.2	27.4	311.3	436.4
1989	16.5	16.5	39.1	1.7	2.3	21.0	27.8	319.7	443.6
1990	15.8	13.9	40.2	1.7	2.0	20.8	28.3	328.0	450.6
1991	15.2	12.8	41.2	1.6	1.9	20.6	28.7	336.3	458.2
1992	14.6	11,8	42,3	1.5	1.7	20.4	29.1	344.6	466.2
1993	14.1	11.0	43.3	1.5	1.6	20.2	29.5	353.0	474.2
1994	13.6	10.4	44.4	1.4	1.5	20.0	30.0	361.3	482.7
1995	13.2	9.6	45.4	1.4	1.4	19.8	30.4	396.6	491.0
1996	12.9	9.2	46.5	1.4	1.3	19.6	30.8	378.0	499.7

B. Civilian Fire Deaths per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.419	0.555	0.601	0.019	0.011	0.028	0	0.005	2.638
1987	1.434	0.516	0.634	0.020	0.009	0.026	0	0.004	2.644
1988	1.444	0.479	0.699	0.021	0.008	0.023	0	0.004	2.648
1989	1.451	0.456	0.704	0.022	0.007	0.020	0	0.003	2.662
1990	1.459	0.423	0.739	0.023	0.006	0.018	0	0.002	2.671
1991	1.471	0.399	0.776	0.024	0.005	0.015	0	0.002	2.692
1992	1.482	0.382	0.814	0.025	0.004	0.013	0	0.001	2.721
1993	1.494	0.362	0.852	0.026	0.003	0.010	0	0.001	2.749
1994	1.512	0.354	0.892	0.026	0.003	0.008	0	0	2.795
1995	1.526	0.336	0.932	0.027	0.002	0.006	0	0	2.831
1996	1.550	0.328	0.973	0.028	0.002	0.004	0	0	2.884

Table F-2a. Esitmated 1986-96 Smoking Fire Problem, Including Carelessness Index (Continued)

C. Civilian Fire Injuries per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	2.575	2.030	1.663	0.087	0.053	0.313	0.141	0.046	6.908
1987	2.593	1.955	1.753	0.087	0.021	0.331	0.092	0.018	6.849
1988	2.605	1.875	1.845	0.086	0.	0.348	0.041	0	6.799
1989	2.610	1.835	1.939	0.086	0	0.364	0	0	6.834
1990	2.620	1.750	2.035	0.086	0	0.380	0	0	6.872
1991	2.636	1.691	2.134	0.086	0	0.396	0	0	6.943
1992	2.652	1.653	2.235	0.086	0	0.412	0	0	7.038
1993	2.668	1.603	2.339	0.086	0	0.427	0	0	7.124
1994	2.697	1.594	2.444	0.087	0	0.442	0	0	7.264
1995	2.719	1.544	2.552	0.087	0	0.456	0	0	7.359
1996	2.757	1.530	2.663	0.088	0	0.470	0	0	7.508

D. Fire Fighter Fireground Injuries (Version 1) per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.335	1.137	2.439	0.074	0.031	0.464	0.175	0	5.653
1987	1.301	1.057	2.801	0.075	0.012	0.471	0.195	0	5.920
1988	1.267	0.982	3.179	0.077	0.005	0.478	0.215	0	6.210
1989	1.235	0.934	3.574	0.078	0	0.484	0.236	0	6.545
1990	1.207	0.867	3.986	0.079	0	0.491	0.257	0	6.887
1991	1.185	0.817	4.414	0.080	0	0.497	0.279	0	7.273
1992	1.165	0.781	4.859	0.081	0	0.503	0.301	0	7.691
1993	1.148	0.742	5.320	0.082	0	0.509	0.324	0	8.126
1994	1.137	0.724	5.798	0.084	0	0.515	0.348	0	8.606
1995	1.125	0.688	6.293	0.085	0	0.520	0.372	0	9.083
1996	1.120	0.671	6.804	0.087	0	0.526	0.397	0	9.604

Table F-2a. Esitmated 1986-96 Smoking Fire Problem, Including Carelessness Index (Continued)

E. Fire Fighter Fireground Injuries (Version 2) per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	1.024	0.818	0.842	0.057	0.041	0.229	0.133	0.121	3.266
1987	1.008	0.773	0.930	0.058	0.024	0.252	0.156	0.140	3.341
1988	0.991	0.728	1.022	0.059	0.010	0.274	0.179	0.161	3.424
1989	0.974	0.702	1.117	0.060	0	0.295	0.204	0.182	3.533
1990	0.960	0.660	1.216	0.061	0	0.316	0.228	0.204	3.645
1991	0.950	0.630	1.318	0.061	0	0.337	0.254	0.227	3.777
1992	0.941	0.609	1.424	0.062	0	0.357	0.280	0.251	3.924
1993	0.933	0.584	1.534	0.063	0	0.377	0.306	0.276	4.073
1994	0.931	0.575	1.647	0.064	0	0.396	0.334	0.302	4.248
1995	0.926	0.552	1.764	0.065	0	0.415	0.362	0.328	4.412
1996	0.928	0.542	1.884	0.066	0	0.433	0.390	0.356	4.601

F. Direct Property Damage (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

	Residential Structures			Non-Residential Structures					
Year	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Upholstered Furniture	Mattresses or Bedding	Other or Unknown	Vehicles	Outdoors or Other	Total
1986	0.214	0.120	0.307	0.024	0.007	0.084	0.022	0.023	0.800
1987	0.212	0.112	0.355	0.025	0.006	0.082	0.019	0.029	0.839
1988	0.209	0.105	0.405	0.026	0.006	0.079	0.016	0.035	0.881
1989	0.206	0.100	0.457	0.027	0.005	0.077	0.013	0.041	0.927
1990	0.205	0.094	0.511	0.028	0.005	0.074	0.010	0.048	0.974
1991	0.203	0.089	0.568	0.028	0.005	0.072	0.007	0.055	1.027
1992	0.202	0.085	0.627	0.029	0.005	0.070	0.003	0.062	1.083
1993	0.201	0.081	0.688	0.030	0.004	0.067	0	0.069	1.142
1994	0.201	0.080	0.751	0.031	0.004	0.065	0	0.077	1.210
1995	0.201	0.076	0.817	0.031	0.004	0.063	0	0.085	1.278
1996	0.202	0.075	0.885	0.032	0.004	0.061	0	0.094	1.352

Table F-3. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed, Including Carelessness Index (Table 11 from 1986 Report)

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage (Millions of 1986 Dollars)
1986	369.2	2.845	7.279	5.558	3.352	0.789
1987	356.9	2.816	7.110	5.597	3.328	0.788
1988	344.9	2.784	6.949	5.632	3.300	0.806
1989	333.8	2.763	6.874	5.688	3.289	0.816
1990	322.5	2.734	6.780	5.721	3.269	0.823
1991	311.7	2.718	6.718	5.774	3.260	0.833
1992	301.4	2.710	6.676	5.832	3.255	0.843
1993	291.2	2.699	6.618	5.879	3.241	0.852
1994	281.6	2.709	6.617	5.945	3.243	0.866
1995	271.7	2.704	6.557	5.979	3.220	0.875
1996	262.3	2.720	6.553	6.030	3.213	0.888

Table F-3a. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed, Including Carelessness Index

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage (Millions of 1986 Dollars)
1986	423.7	2.638	6.908	5.653	3.266	0.800
1987	429.9	2.644	6.849	6.920	3.341	0.839
1988	436.4	2.648	6.799	6.210	3.424	0.881
1989	443.6	2.662	6.834	6.545	3.533	0.927
1990	450.6	2.671	6.872	6.887	3.645	0.974
1991	458.2	2.692	6.943	7.273	3.777	1.027
1992	466.2	2.721	7.038	7.691	3.924	1.083
1993	474.2	2.749	7.124	8.126	4.073	1.142
1994	482.7	2.795	7.264	8.606	4.248	1.210
1995	491.0	2.831	7.359	9.083	4.412	1.278
1996	499.7	2.884	7.508	9.604	4.601	1.352

Table F-3b. Summary of Estimated 1986-96 Smoking Fire Problem per Billion Cigarettes Consumed, Including of Carelessness Index, Except for Residential Mattress/Bedding Fires

Year	Fires	Civilian Deaths	Civilian Injuries	Fire Fighter Injuries Version 1	Fire Fighter Injuries Version 2	Direct Property Damage (Millions of 1986 Dollars)
1986	426.4	2.710	7.171	5.801	3.372	0.816
1987	432.3	2.711	7.103	6.057	3.442	0.854
1988	438.6	2.710	7.043	6.337	3.519	0.894
1989	445.6	2.721	7.072	6.666	3.624	0.940
1990	452.4	2.726	7.099	6.999	3.731	0.987
1991	459.9	2.744	7.163	7.379	3.859	1.038
1992	467.7	2.770	7.253	7.793	4.003	1.094
1993	475.6	2.796	7.332	8.222	4.149	1.152
1994	484.0	2.841	7.471	8.699	4.323	1.220
1995	492.2	2.874	7.560	9.173	4.484	1.288
1996	500.9	2.927	7.707	9.691	4.671	1.361

Table F-4. Summary of Estimated Total Economic Impact of Smoking Fires per Billion Cigarettes Consumed, 1986-96, Including Carelessness Index (Table 12 from 1986 Report)

Injuries @ *$20,000*

No Adjustment for Unreported Fires

Total Economic Impact (in Millions of 1986 Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.051 + 2.638Q	1.003 + 2.638Q
1987	1.094 + 2.644Q	1.043 + 2.644Q
1988	1.141 + 2.648Q	1.085 + 2.648Q
1989	1.195 + 2.662Q	1.134 + 2.662Q
1990	1.249 + 2.671Q	1.184 + 2.671Q
1991	1.311 + 2.692Q	1.241 + 2.692Q
1992	1.378 + 2.721Q	1.302 + 2.721Q
1993	1.447 + 2.749Q	1.366 + 2.749Q
1994	1.527 + 2.795Q	1.440 + 2.795Q
1995	1.607 + 2.831Q	1.513 + 2.831Q
1996	1.694 + 2.884Q	1.594 + 2.884Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table F-4a. Summary of Estimated Total Economic Impact of Smoking Fires per Billion Cigarettes Consumed, 1986-96, Including Carelessness Index

Injuries @ *$20,000*

No Adjustment for Unreported Fires

Total Economic Impact (in Millions of Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.046 + 2.845Q	1.002 + 2.845Q
1987	1.052 + 2.816Q	1.007 + 2.816Q
1988	1.058 + 2.784Q	1.011 + 2.784Q
1989	1.067 + 2.763Q	1.019 + 2.763Q
1990	1.073 + 2.734Q	1.024 + 2.734Q
1991	1.083 + 2.718Q	1.033 + 2.718Q
1992	1.093 + 2.710Q	1.042 + 2.710Q
1993	1.102 + 2.699Q	1.049 + 2.699Q
1994	1.117 + 2.709Q	1.063 + 2.709Q
1995	1.126 + 2.704Q	1.071 + 2.704Q
1996	1.140 + 2.720Q	1.083 + 2.720Q

NOTE: Note. Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

Table F-4b. Summary of Estimated Total Economic Impact of Smoking Fires per Billion Cigarettes Consumed, 1986-96, Including Carelessness Index Except for Residential Mattress/Bedding Fires

Injuries @ *$20,000*

No Adjustment for Unreported Fires

Total Economic Impact (in Millions of Dollars) per Billion Cigarettes Consumed

Year	Using Version 1 for Fire Fighter Injuries	Using Version 2 for Fire Fighter Injuries
1986	1.075 + 2.710Q	1.027 + 2.710Q
1987	1.117 + 2.711Q	1.065 + 2.711Q
1988	1.162 + 2.710Q	1.105 + 2.710Q
1989	1.215 + 2.721Q	1.154 + 2.721Q
1990	1.269 + 2.726Q	1.204 + 2.726Q
1991	1.329 + 2.744Q	1.258 + 2.744Q
1992	1.395 + 2.770Q	1.319 + 2.770Q
1993	1.463 + 2.796Q	1.382 + 2.796Q
1994	1.543 + 2.841Q	1.456 + 2.941Q
1995	1.623 + 2.874Q	1.529 + 2.874Q
1996	1.709 + 2.927Q	1.609 + 2.927Q

NOTE: Q is the value in millions of dollars per life saved, which was not to be calculated as part of this study.

* U.S. GOVERNMENT PRINTING OFFICE : 1987 O - 193-850 QL 3

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