FIRE SEVERITY AND RESPONSE DISTANCE: INITIAL FINDINGS

EDWARD IGNALL, KENNETH L. RIDER, RICHARD URBACH

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PREFACE

This study was conducted for the Fire Department of New York City by the New York City-Rand Institute, as part of its research into the deployment of fire resources. The research, which was conducted in the early 1970s, was documented in preliminary form in 1973. It addresses an important topic--severity of fire damage versus distance traveled by fire companies--that has seen little work in the United States in the succeeding years.

Minor inconsistencies persist in the original computations which would have been corrected, had sufficient time and money been available. For example, one set of regressions uses the average of the distances traveled to a fire by the first engine to arrive and the first ladder to arrive; the other set uses the shorter of the two distances. These minor flaws aside, the report can claim the positive contribution of finding statistically significant coefficients in regressions of a measure of physical damage from fire against fire-engine response distance.

SUMMARY

Rational decisions about the number of fire companies a community should have require reliable estimates of how much fire losses would change if the number of companies were changed. Such estimates are not now available. One building block in their development is a relationship between the distance the responding companies travel (which is determined by the number and location of companies) and physical damage (which determines dollar losses). We report our initial findings on the damage-response distance relationship, using data from over 100,000 structural fires in New York City in 1968-1970.

We divide these fires into "types" according to building construction and occupancy, when and how the alarm was received, and the fire cause: These factors determine how fast fires would grow and how advanced they would be when discovered. Consequently, controlling for them is very helpful in isolating the effect of distance traveled on damage.

We develop several damage measures. They are based on the qualitative assessments, by the battalion chief, of the damage to the building and to its contents (none, light, medium, or heavy); whether the fire extended beyond the room of origin; and measures of fire-fighting effort--e.g., the number of hose lines used. Some of these measures correlate positively with response distance for a large majority of incident types.

We then regress some of these damage measures against response distance, using both linear and logit models. We find some statistically significant slopes. They are the first such found in the United States, probably a result of the large sample size and our dividing fires into types. We also see differences among fire types.

Typical of our results are the following: The estimated fraction of fires that were serious (precisely--where more than 15 percent of the contents are in effect destroyed) at the moment of dispatch ranged from 3 percent to 27 percent. This fraction was typically 10 percent smaller for alarms reported by telephone than for those reported from

alarm boxes, for comparable occupancies at the same time of day. For commercial buildings, the estimated fraction serious at dispatch was also smaller during the day than in the evening or night, again by about 10 percent. The estimated fraction serious when fire companies arrived increased with response distance in 9 out of 10 cases examined. In non-fireproof and frame structures, the fraction serious at fire company arrival typically increased by about 5 percent for each one mile increase in response distance.

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CONTENTS

I. INTRODUCTION

Recent local government budget crises have drawn increased attention to the problem of establishing a rational level of public expenditures, including those for fire protection. What is needed, in order to do cost-benefit analyses of fire protection levels, is a way to predict the fire losses* that will result from a given level. Unfortunately, for the most part the required relationships have not been developed. In particular, it is not yet known how sensitive fire losses are to the number and manning of fire companies. Since these factors account for an overwhelming proportion of a typical city's fire protection budget, this information would be very helpful to those attempting to make rational fire protection decisions.

Consider the problem of choosing the number of fire companies to assign to a given community, assuming that the number of firefighters per company is fixed. This choice determines the distance from each possible fire location in the community to the closest fire company, to the second closest fire company, and so forth. Adding companies will reduce some of these distances and will thus reduce financial loss from fire. The reduction in response distance and time can quickly be estimated in a rough way from the "square root law"[(1)] and other simple formulas.[(2)] More precise and time consuming estimates, requiring detail about individual incident locations, are also possible.[(3-5)] The key missing link in predicting fire loss, given the number of companies, is the lack of a relationship between fire loss and the speed with which fire companies get to the scene of a fire.†

This relationship is difficult to obtain because factors other than response time probably have a larger effect on fire loss. Such factors include the length of the delay in discovering and reporting

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*Human morbidity and mortality, direct financial loss to property, and indirect losses (lost business, etc.).

†This missing link similarly hampers evaluation of other methods for reducing response time--installing fire detectors, speeding up dispatch office operations, etc.

the fire, the size and number of door and window openings, and so forth. (For example, investigations of large fires often reveal delays of over 30 minutes in discovering and reporting fires.) Thus data on a large number of fires are essential for obtaining a reliable relationship between loss and response time.

This need for a large sample creates other problems. Accurate dollar damage figures would require extensive follow-up, weeks or even months after each fire. Collecting these data is then administratively difficult. Furthermore, thorny questions of definition arise. Should replacement cost or depreciated value of the damaged property be used? Are insurance payments a suitable substitute?

A possible substitute for dollar damage is a measure of physical damage. Examples include number of square feet burned and whether the fire spread beyond the room of origin. Physical measures of fire damage can be estimated accurately in a routine way by fire officers at the scene.* They should be more consistently and closely related to dollar damage than response time is. Thus, associating a physical damage measure with dollar damage should be possible with a relatively small number of incidents.

The work described in this report was, to our knowledge, the first in the United States to study the relationship between physical damage and response distance. For 115,000 structural fires in New York City in 1968-1970, we compare various physical damage measures to an estimate of the distance† traveled by the first arriving fire companies.

We control for some of the "other factors" by making this comparison separately for fires at different times of day (discovery delays may be larger late at night), in different types of buildings, reported in different ways (discovery delays may be larger for incidents reported from street alarm boxes), and having different causes (explosions imply more damage). These controls were chosen because they

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*See Ref. 6, Chapter 2.

†Response distances were not recorded in New York City in these years: We estimated them from the map coordinates of the fire scene (the alarm box nearest the fire) and the coordinates of the first arriving engine or ladder.

could be obtained easily and because we saw them as essential to establishing valid and useful relationships between damage and response distance. A naive approach that did not try to separate the effects of these other factors might fail to discover a response distance relation.

Consider the following example. A crowded part of the city has poor Spanish speaking residents and many fire companies per square mile. Because of language difficulties and lack of telephones, most fires are reported by alarm box, introducing a delay in comparison with telephone reporting. In consequence, a larger proportion of fires are serious than would be with telephone reporting. This part of the city may have both shorter response distances and higher average damage per fire than a richer, less densely populated area. We would not believe that faster response could make things worse, but we might (mistakenly) conclude that response distances did not matter.

A second reason for separating the effects is to gain information that could help a community allocate fire companies. For example, frame buildings burn faster than fireproof ones. This suggests that, all other things being equal, a community would want more companies per square mile in an area where frame construction predominates than in one where fireproof construction is the norm. If we are able to determine the relationship between fire damage and response distance for these two types of buildings, we can hope to determine how many more fire companies should be assigned to the first region than to the second.

The above discussion bypasses the possibility of using a cross section of data from many cities, and associating total fire losses in each with the number of companies it has (or a proxy therefor). This approach has been tried by MacGillivray et al. and Getz.[7,8] It requires "control variables" also. For example, MacGillivray et al. included per capita income, the fraction of houses built before 1939, the fraction of buildings that were manufacturing establishments, and so forth. We have reservations about the findings in these two studies, particularly because the control variables chosen do not capture distance (and other notions) in physical terms. Consequently, we feel that validation with studies that associate response distance and/or time with losses on an incident-by-incident basis is essential.

Other work on this subject includes a study by the New York City-Rand Institute staff in which we found that response distance tends to be slightly larger at fatal fires than at otherwise similar non-fatal incidents.[9] Some progress has been made in Great Britain by Hogg and others on developing a direct relationship between fire losses and response time.[10] Hogg has also related a physical damage measure--the proportion of fires that spread beyond the room of origin--to response time using a group of about 50,000 fires.[11] Miller and Rappaport correlated dollar damage with response time (and transformations of it--e.g., the logarithm of response time) for 529 structural fires in Wichita, Kansas, in 1974.[12] They found correlation coefficients that were near zero and (not what one would expect) negative.

The approach that we have used may be helpful in emergency services other than fire. For example, the planning of emergency ambulance service would presumably be improved if a reliable association of mortality and morbidity with the time to get to the scene and the time to return to a hospital were available.

II. MEASURING FIRE DAMAGE

We were constrained in our choice of fire damage measures by the data recorded by the battalion chief at each fire. Possible choices, with the range of outcomes recordable by the chief and the weights we assigned to each, are given in Table 1. We have included measures of the firefighting effort by the Fire Department in part because we felt that they were more reliably recorded than direct damage measures.

Table 1

FIRE DAMAGE MEASURES AND WEIGHTS

Category	Abbreviation	Weights
Damage to contents	Contents I	0 if none or light, 1 if medium or heavy.
	Contents II	0 if none or light, 0 if medium with no extension, 1 if medium with extension, 1 if heavy.
	Contents III	0 if none, .08 if light, .33 if medium, .75 if heavy.[a]
Damage to building	Building I	Weighted as Contents I.
	Building III	Weighted as Contents III.
Extension	Extension	0 if none, 1 if extended beyond room of origin.
Number of companies working	Working	
Time	Time	Chief's time at fire (minutes) × number of companies working.
Severity index	Index	2.33 × Contents III + 4.67 × Building III + Extension + .2 × Time.
Hose lines used	Hoses	0 if out before arrival, 1 if booster or hydrant stream, 2 if one engine stream, 3 if two or three engine streams, 4 if four or more streams.

[a]These weights come from the suggested definitions of light, medium, and heavy damage: light being up to 15 percent, medium being up to 50 percent, and heavy being beyond 50 percent.

We calculated correlation coefficients between each of the 10 severity measures in Table 1 and response distance, for 24 different "types" of fire. The types are determined by time of day (day, evening, late night), fire cause (explosive or not), whether it was reported by box or by phone, and whether the building was commercial or residential.

To see which measures are better, we calculated the following for each: (a) the number of fire types where the correlation between the severity measure and response distance is positive and statistically significant at the 5 percent level, and (b) the number of fire types where the correlation is negative. Good measures ought to have few negative coefficients and many significant positive ones. The results presented in Table 2 show that the first five measures (damage to building or to contents) and the last (hose lines) produce many positive correlations and the other four do not. (The worst among the latter four is whether or not the fire extended. This measure is the one that worked well in Great Britain.[11])

Table 2

SIGNS OF CORRELATION BETWEEN SEVERITY MEASURES AND DISTANCE

	Number of the 24 Correlation Coefficients That Were:	
Measure	Positive and Statistically Significant	Negative
Contents I	14	3
Contents II	10	3
Contents III	12	3
Building I	13	5
Building III	16	1
Index	5	12
Extension	3	16
Working	7	8
Time	5	13
Hoses	17	2

III. STATISTICAL SEVERITY MODELS

Our statistical models were developed in the following spirit. We divided a large set of fires into classes, depending upon response distance. We then found the fraction of the fires in each distance class that were severe. For example, the first measure in Table 1 labels a fire severe only if damage to the building's contents is judged medium or heavy by the chief. This fraction was plotted, with the hope that the plots would suggest a form for the relationship between the chance that the fire is severe and response distance.

If number of square feet burned or similar detailed information on fire damage were available, a statistical model could be based on a physical model of fire spread.* However, such detail was not available routinely in New York City.

A linear relationship would be the simplest model to use. Writing p(d) for the proportion of severe fires when response distance is d, the linear model is:

$$p(d) = a + bd . \tag{1}$$

Regression can be used to estimate the parameters a and b, which can be given the following interpretations: a can be thought of as the proportion of fires that are severe at the instant the fire companies leave their houses, and b is the rate at which the proportion severe grows with distance from the house. Presumably, both a and b would be positive.

One difficulty with relationship (1) is that if b is positive, substituting a large value of d on the right-hand side of (1) will make the left-hand side bigger than 1. However, p(d), being a proportion, cannot be bigger than 1. This difficulty may not arise in practice, if the values of d that make the left-hand side bigger than 1 are larger than we would ever see in the city--for example, 20 miles

*See Chapter 7 of Ref. 13 for a discussion of fire spread models based on physical considerations.

or more. On the other hand, it is troubling to begin with a model that has this kind of possibility built into it. Another difficulty could occur if the estimated value of a or b were negative.

Difficulties of this kind can be avoided by the use of a "logit" model:

$$p(d) = \frac{1}{1 + e^{-(\alpha + \beta d)}} . \qquad (2)$$

The right-hand side is then constrained to be between 0 and 1, regardless of the signs of α and β and the size of d. The relationship (2) looks inconvenient, but a simple transformation makes it linear. The idea is to solve (2) for $\alpha + \beta d$, and the result is:

$$\log (p(d)/(1 - p(d))) = \alpha + \beta d . \qquad (3)$$

As with Eq. (1), regression can be used to estimate α and β, which are more or less like a and b: The proportion severe when companies leave their houses is $e^{\alpha}/(1 + e^{\alpha})$ and β is a growth rate. The form of the logit model (Eq. (2)) is contrasted with that of the linear model (Eq. (1)) in Fig. 1.

Either model can be used when the severity measure is not a fraction. The logit model would be appropriate only when the severity measure can vary between 0 and 1 (for example, if the "hose lines used" measure were rescaled to divide each weight by 4, so that 4 or more hose lines gave severity of 1). In this case, the difficulty with the linear model discussed above does not arise.

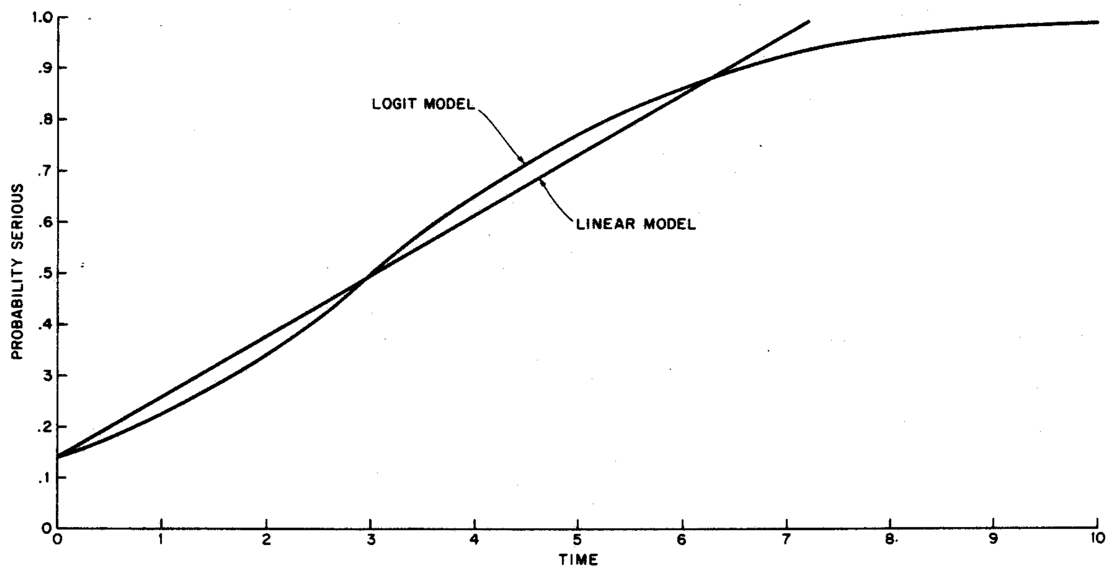

Fig. 1—Comparison of linear and logit models

IV. RESULTS

In this section we present plots of severity versus response distance for 24 types of incidents and the results of fitting the linear model (1) and the logit models (2) to data from New York City.

PLOTS OF FIRE SEVERITY VERSUS RESPONSE DISTANCE

We made many plots of severity versus distance. Some are given in Figs. 2-5. Three definitions of severity were used: damage to building (Building III), damage to contents (Contents III), and number of hose lines used.* The first important observation from the results is that the three severity measures behave more or less alike. For example, the drop in severity when distance goes to more than 1.5 miles is seen for all three definitions in Fig. 2. The second observation is that the severity appears to increase with distance. The rate of increase may be small and it is not steady, but it seems to be there. These observations need statistical support, and the regression results presented later give that support. They indicate the degree of confidence we can have that what we seem to see is real, rather than the result of chance or a prejudiced eye.

As mentioned in Sec. III, one reason for making plots is that they may be helpful in choosing an appropriate model. However (and this is our third observation), they do not clearly favor either of the models discussed there, nor do they suggest any other models. It appears that the growth in severity with distance is so slow that the data we have are not sufficient for choosing among the models.

REGRESSIONS

Logit Model

We give here the results of regressions that estimated the

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*In these plots, weights on hose lines were: .01, out before arrival; .1, booster or hydrant stream; .2, one engine stream; .5, two or three streams; .9, four or more streams.

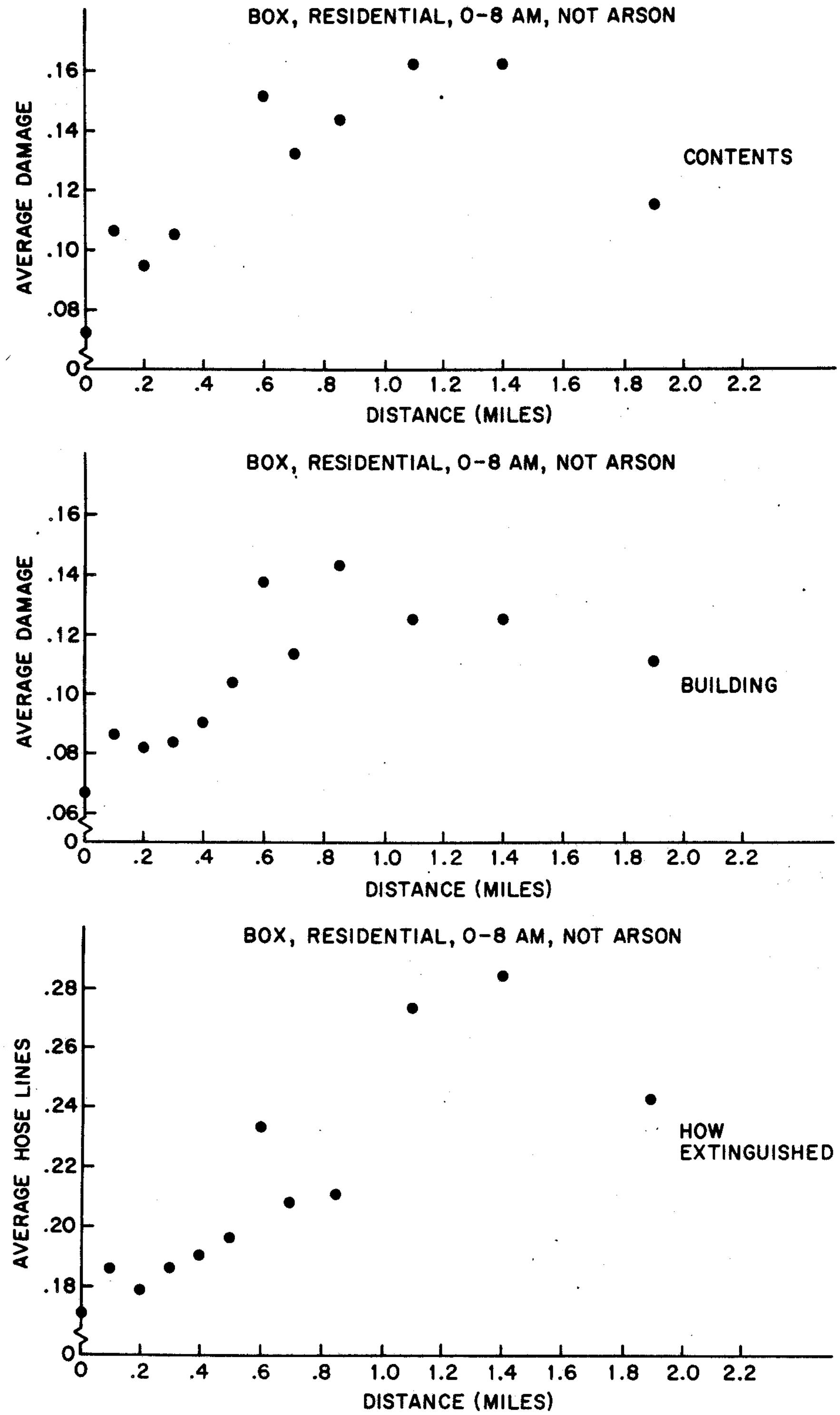

Fig. 2—Fire severity versus response distance: residential fires (reported by box 0-8 AM)

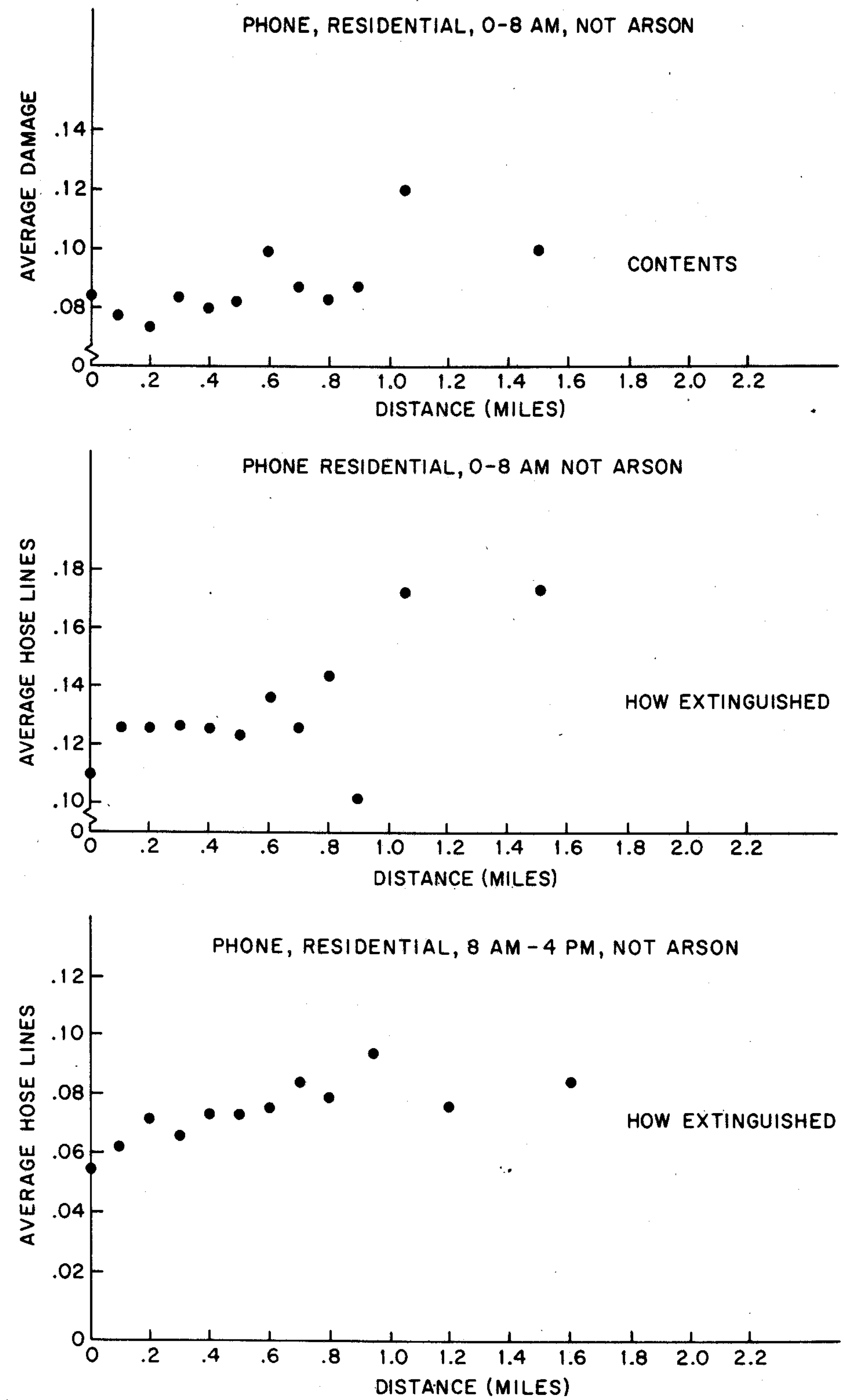

Fig. 3—Fire severity versus response distance: residential fires (reported by phone)

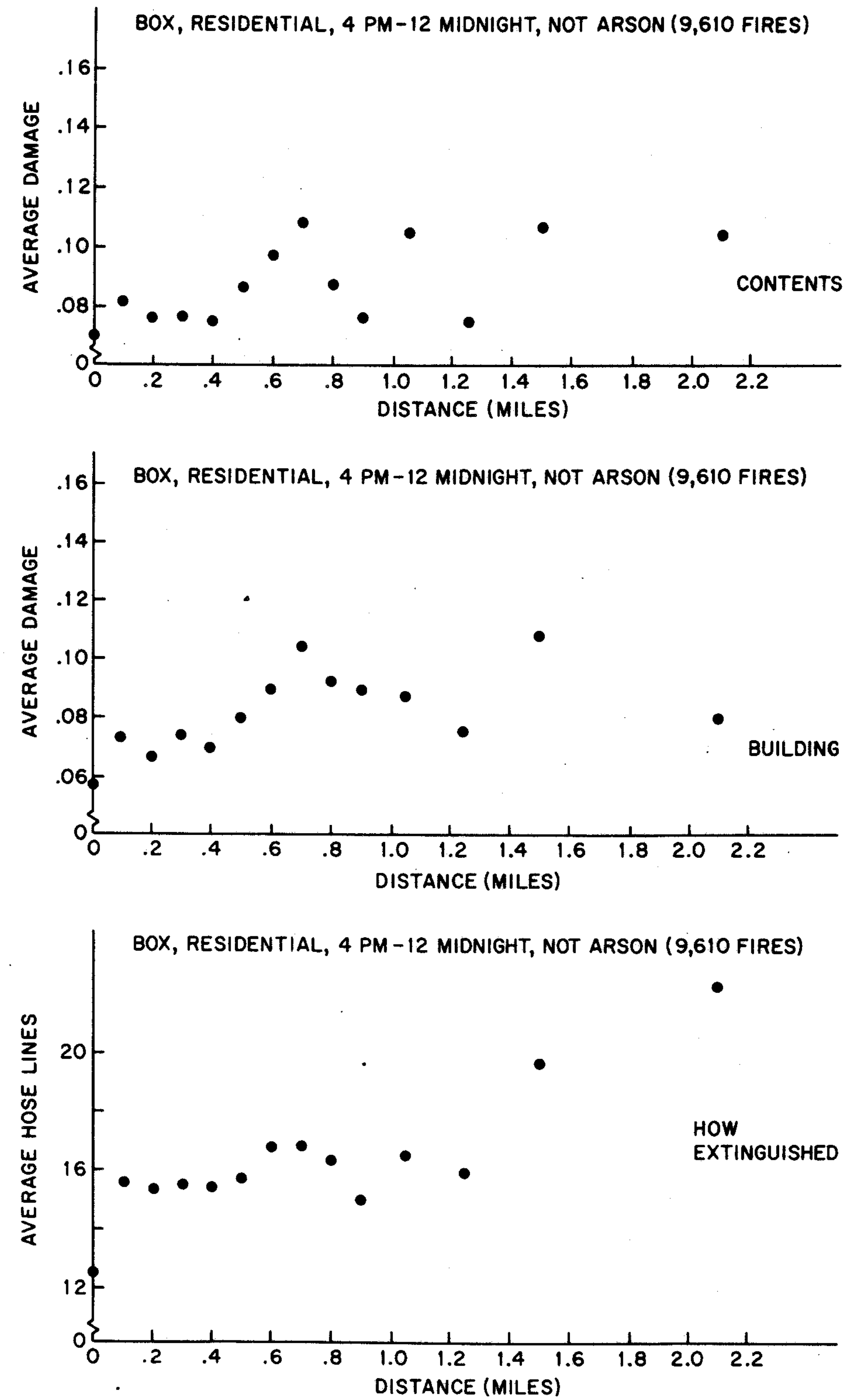

Fig. 4—Fire severity versus response distance: residential fires (reported by box 4 PM-midnight)

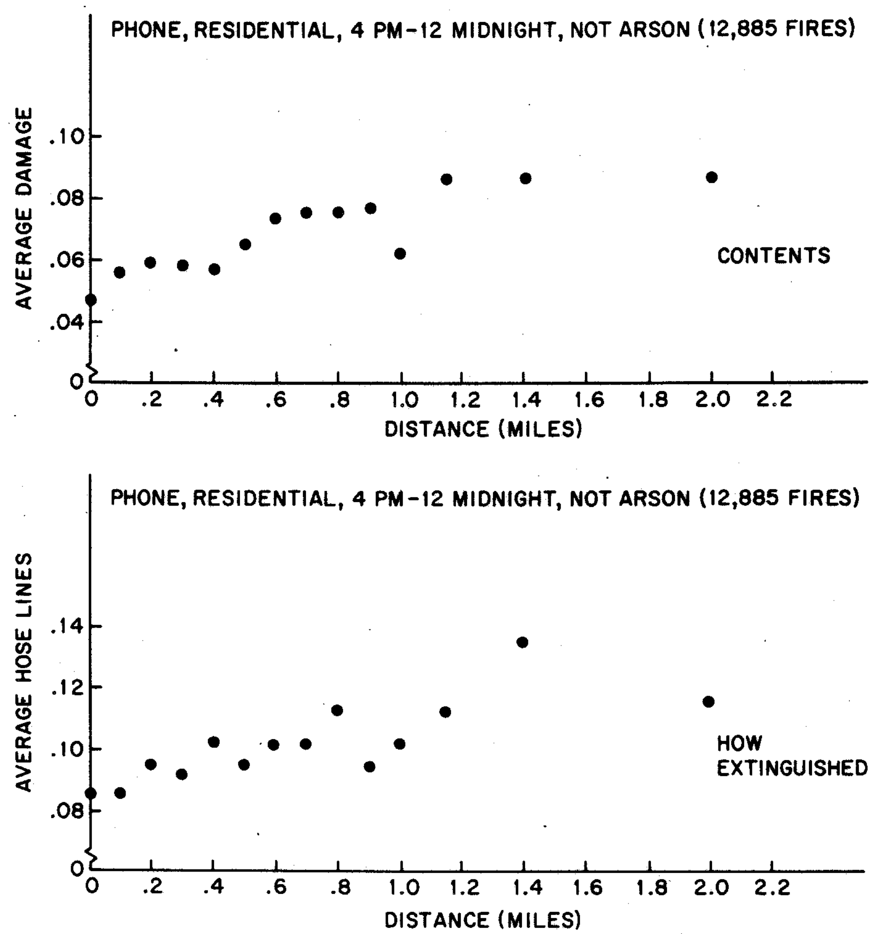

Fig. 5— Fire severity versus response distance: residential fires (reported by phone 4 PM-midnight)

parameters of the logit model (Eq. (2)) for ten types of incidents defined as follows:

- Fires in *private dwellings* reported by alarm *box* that started in *kitchens* and similar often used places (P-K-Box);
- Fires in *private dwellings* reported by alarm *box* that started in *basements* and other little used places (P-B-Box);
- Fires in *commercial buildings* reported by *box* between the hours of *4:00 PM and 8:00 AM* that started in *often used places* (C-K-Box-4-8);
- Fires in *commercial buildings* reported by *box* that started in *little used places* (C-B-Box-4-8);

- Fires in *commercial buildings* reported by *box* between *8:00 AM and 4:00 PM* (C-Box-8-4);
- The same five classes as listed above for telephone alarms rather than box alarms.

The set of fires that were examined were those occurring in structures in Brooklyn in 1968-1970 with reported causes of careless smoking, malfunctioning electrical appliances, and faulty wiring. In addition, the following types of fires were *excluded*:

- Fires in fireproof or fire-protected structures;
- Fires in which sprinklers were used; and
- Fires extinguished before arrival of the firefighters.

The following protocol was used for the regressions:

- A serious fire is one where the damage to the *contents* of the building was judged medium or heavy.
- Response distance is defined as the *minimum* of the distance from the alarm box to the station of the first arriving engine and distance from the box to the station of the first arriving ladder.
- Distance was measured in half-mile increments and there were 5 distance classes: 0-.5 miles; .5-1.0 miles; 1.0-1.5 miles; 1.5-2.0 miles; and more than 2 miles. For each fire in the first class, the independent regression variable d is .25; in the second, .75; in the third, 1.25; in the fourth, 1.75; and in the fifth, 2.50.

Plots of the data and some regression lines are given in Figs. 6-7. Table 3 gives the estimated values of β in Eq. (2) for the ten classes.

The estimated slope for commercial building incidents originating in often used areas reported by box between 4 PM and 8 AM is statistically significant at the 2 percent level and two other slopes are significant at the 10 percent level.* If we believed all the slopes

*We use t tests. They are not really appropriate because, for example, we would expect one coefficient in the ten to be significant at the 10 percent level. For truly conclusive rather suggestive results, multiple comparison methods are needed.

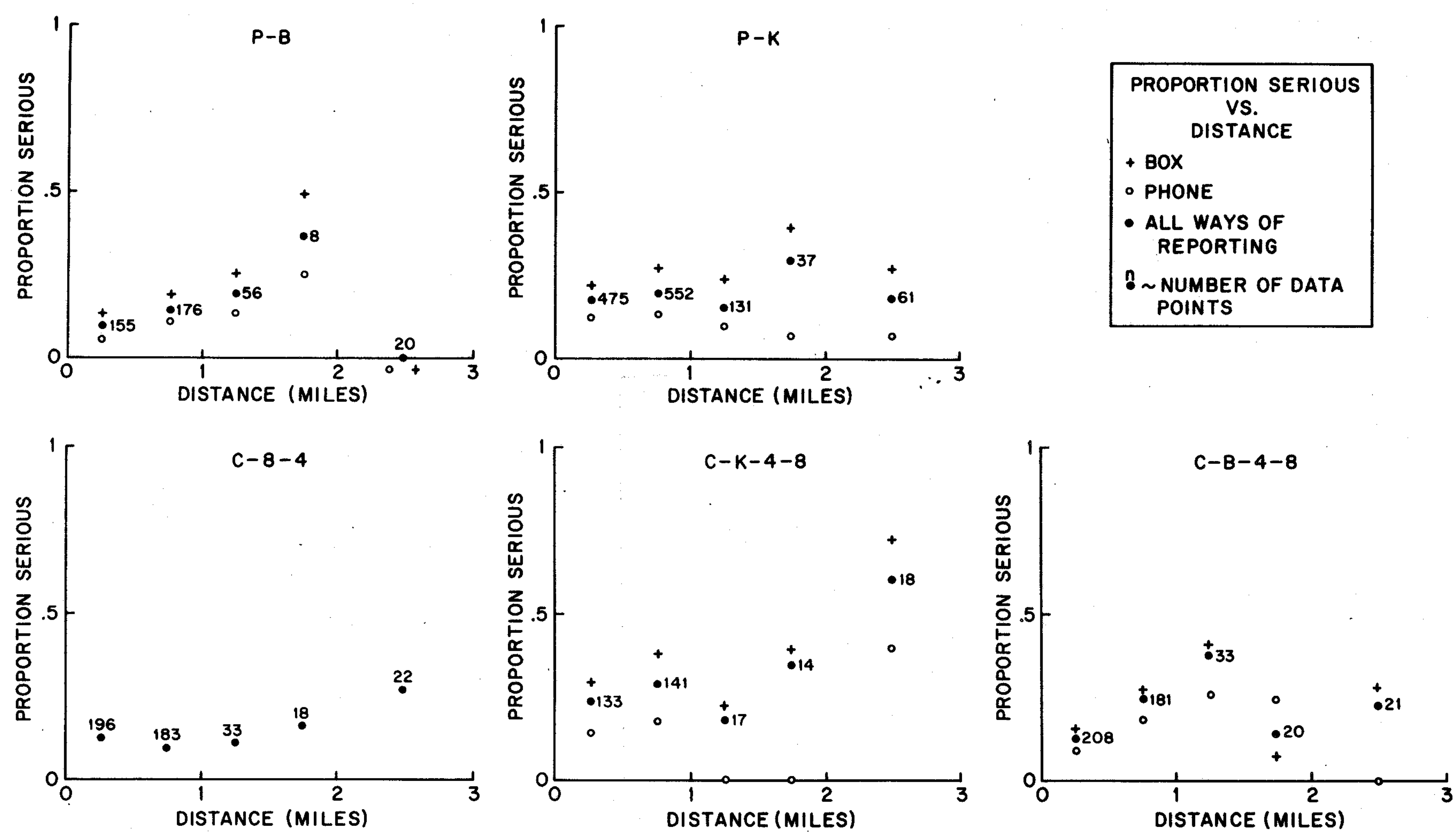

Fig. 6—Brooklyn 1968-1970, non-fireproof and frame

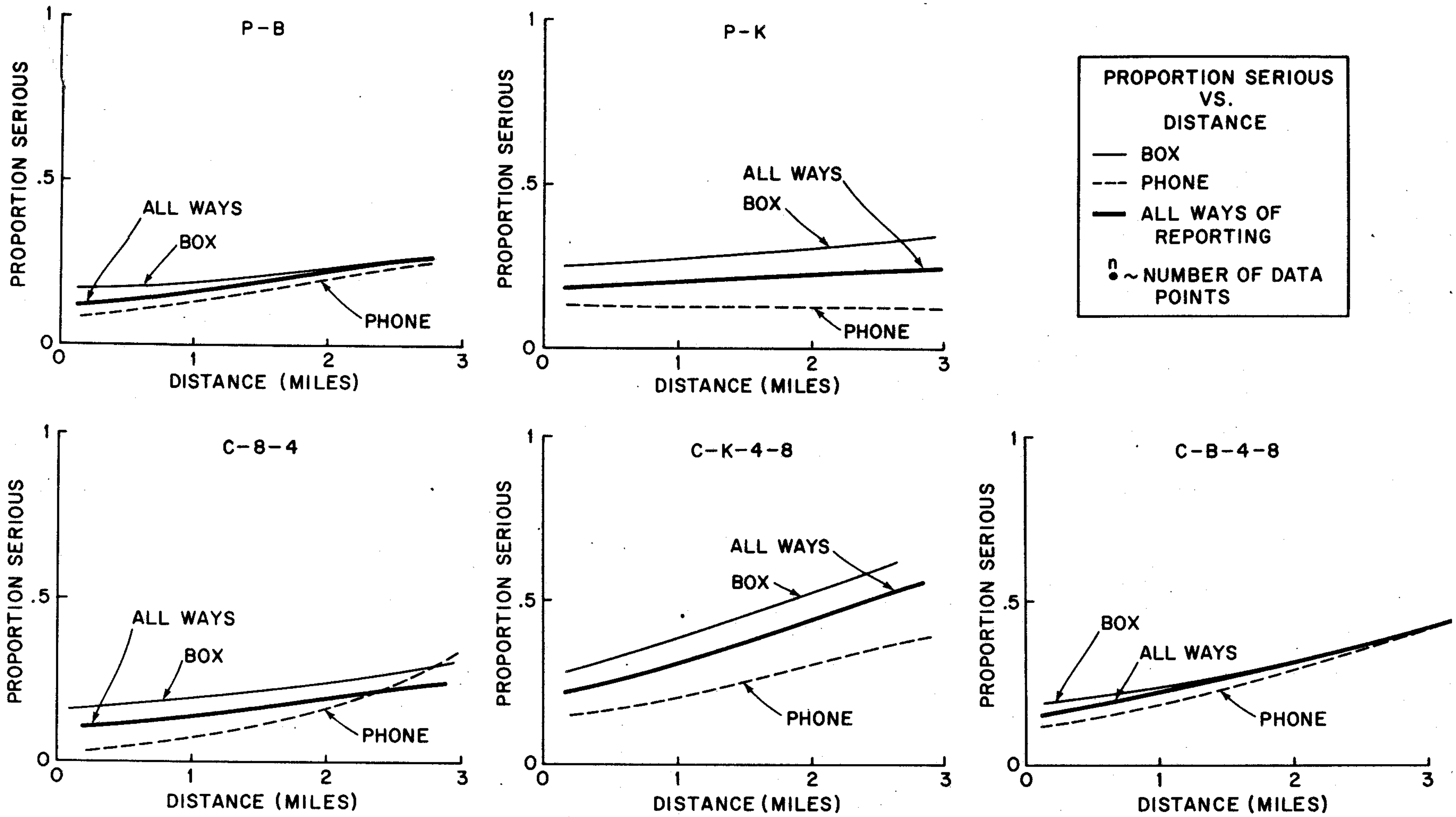

Fig. 7—Logit regressions—response distance versus proportion serious (Brooklyn 1968-1970, non-fireproof and frame)

Table 3

ESTIMATED SLOPES OF CURVES RELATING LOGIT OF PROPORTION SERIOUS TO RESPONSE DISTANCE

(Standard deviations in parentheses)

Building Type	Time	Area	Box		Phone	
Commercial	8 AM-4 PM	All	.29	(.22)	.88*	(.49)
	4 PM-8 AM	Little used	.37*	(.23)	.57	(.43)
		Often used	.56**	(.25)	.52	(.40)
Private dwelling	All hours	Little used	.20	(.37)	.47	(.41)
		Often used	.15	(.16)	-.08	(.24)

NOTES: *Significant at the 10 percent level, ** significant at the 2 percent level.

were the same, 9 of 10 estimates being positive would more or less confirm the positive sign of the common slope. (Using the sign test, even though it is not quite appropriate here, 9 successes in 10 trials rejects the hypothesis that p(success) = .5.) While there are differences among the estimates, no difference is statistically significant, as we have noted. Further, the estimates are not that different from one another and there is no clear pattern. If we rank the ten estimated slopes, those for private dwellings are fifth, eighth, ninth, and tenth. Perhaps, therefore, the fires in commercial buildings grow faster than those in private buildings. (This possible difference between commercial buildings and private dwellings is statistically significant at the 5 percent level by the Mann-Whitney-Wilcoxon test, and not significant by the Wald-Wolfowitz runs test.)

Now let us turn to the estimates of the intercept, α, from Eq. (2) or equivalently, to $e^{\alpha}/(1 + e^{\alpha})$, the estimated proportion serious when d = 0. The latter is tabulated in Table 4.

Subject to the statistical variability of these estimates we observe that:

1. More of the box alarms are serious at the time of dispatch than phone alarms. This holds for all 5 cases, considered

Table 4

ESTIMATED PROPORTION OF FIRES THAT ARE SERIOUS AT THE TIME FIRE COMPANIES ARE DISPATCHED

Building Type	Time	Area	Box	Phone
Commercial	8 AM-4 PM	All	.157	.035
	4 PM-8 AM	Little used	.187	.114
		Often used	.271	.136
Private dwelling	All hours	Little used	.163	.087
		Often used	.235	.132

NOTE: The standard deviation of each of these estimates is about .050.

pairwise. In addition, the smallest of the 5 box estimates is larger than the biggest of 5 phone estimates.

2. More of the fires in often used areas are serious at the time of dispatch than fires in little used areas. This holds for all 4 cases, considered pairwise.
3. More of the night and evening fires are serious at the time of dispatch than daytime fires. For commercial building fires reported by box alarms, the day estimate is lower than the night estimates for the two areas of origin. The same holds for commercial fires reported by phone.
4. Overall, the estimated values of the proportion serious when companies are dispatched for private dwellings are similar to those for commercial buildings.

Observation 2 is at first glance counter-intuitive, since it indicates that discovery is delayed more for fires in commonly occupied areas. The difficulty may be one of the precise definition of kitchen-like and basement-like areas. Or the effect may be real: Perhaps fires occur in basements when people are there; or chiefs may have different standards for identifying medium or heavy damage in basements compared with kitchens.

Linear Model

We give here the results of regressions that estimated the parameters of the linear model (Eq. (1)) for 24 types of incidents, with damage to building (Building III) as the severity measure.* *Response distance* is the average of first arriving engine and first arriving ladder distance.

The set of fires examined below were those occurring in structures, excluding food-on-the-stove fires, fires in vacant buildings, and fires in fireproof buildings. (Other statistical analysis of food-on-the-stove fires and fires in fireproof buildings revealed no relationship between severity and response distance.)

The 24 incident types were defined by three *times of day* (0-8; 8-16; 16-24); two *occupancies* (multiple dwelling; commercial); whether *box* or *telephone* alarms; and two *causes* (arson, explosion, careless smoking, faulty wiring, etc.). Fires in private dwellings yielded inconclusive regressions. Tables 5 and 6 give slope and intercept estimates.

As with the logit regressions, the usual t tests are not really appropriate; nevertheless, some of the individual slope estimates are statistically significant. If we believed all the slopes were the same, 20 out of 24 estimates being positive would confirm the positive sign of the common slope. Subject to the statistical variability of our estimates we see that:

1. Fires reported by box are more severe when reported than are those reported by telephone. (Each of the 12 box alarm intercepts is larger than the corresponding telephone alarm intercept.)
2. Fires reported by box typically grow faster than those reported by telephone. (For 9 of the 12 pairs, the box slope is larger.)
3. Fires in commercial buildings are more severe when reported than those in multiple dwellings. (There are 12 pairs: 3

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*Contents III and Hose Lines gave similar results.

Table 5

ESTIMATED SLOPE OF DAMAGE TO BUILDING VERSUS RESPONSE DISTANCE (MILES), LINEAR RELATIONSHIP

Time	Cause	Occupancy	How Reported: Box	How Reported: Phone
0000-0759	Malicious	MD	.077	.007
		Comm.	.057	.019
	Other	MD	.015	.005
		Comm.	.039	.035
0800-1559	Malicious	MD	-0	.043
		Comm.	-.025	.003
	Other	MD	-.001	.008
		Comm.	.054	.032
1600-2359	Malicious	MD	+0	-.005
		Comm.	.077	.017
	Other	MD	.007	.003
		Comm.	.062	.035

NOTE: The standard deviations range from .002 to .060.

times of day, 2 causes, 2 methods of reporting. For every one, the commercial intercept is larger than the corresponding multiple dwelling intercept.)

4. Fires in commercial buildings typically grow faster than those in multiple dwellings. (For 9 of 12 pairs, commercial slope is larger.)

Other Regressions

The results reported above are the ones we see as most interesting. They are only part of those we obtained. We fitted regressions for fireproof structures and found insignificant slopes. We tried other combinations of control variables. We also fitted logit models under the assumption that $p(d)$ reached a maximum value of $A < 1$, and estimated A as well as α and β.

Table 6

ESTIMATED INTERCEPTS

(Average damage at the time companies are dispatched)

Time	Cause	Occupancy	How Reported: Box	How Reported: Phone
0000-0759	Malicious	MD	.090	.078
		Comm.	.170	.124
	Other	MD	.073	.059
		Comm.	.148	.102
0800-1559	Malicious	MD	.115	.062
		Comm.	.143	.112
	Other	MD	.076	.055
		Comm.	.091	.057
1600-2359	Malicious	MD	.098	.079
		Comm.	.140	.083
	Other	MD	.063	.051
		Comm.	.100	.070

V. CONCLUSION

How much is a minute of response time worth? The statistical variability of our estimates relating physical damage to distance indicates that it depends on occupancy, construction, and other factors, and that even for a single class of incidents, a reliable answer is out of the question at this time. Nevertheless, it appears that on the average for structural fires, a minute of response time is probably worth around \$100-\$10,000.

Assuming a response speed of 30 mph (2 minutes per mile) (and disregarding the nonlinearity of time with distance for short distances[(2)]), \$50,000 as the value of the typical structure and contents, and .040 as the typical slope (increase in fraction damaged per mile) from Table 5, we get 50,000 × (1/2) × .040 = \$1000. By comparison, Hogg estimated the value of a minute of response time in Great Britain in 1973 at about \$25 to \$250 for dwellings and \$2500 for industrial-commercial buildings.[(10)*]

Making rational fire protection choices requires valid and reliable relationships between those choices and fire loss. Estimates of the value of response time that meet these needs require further research, both on the relationship of physical damage to response distance and/or time and on the relationship of dollar losses to physical damage.

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*Presuming that one pound is worth approximately \$2.50.

REFERENCES

1. P. Kolesar and E. Blum, "Square Root Laws for Fire Engine Response Distances," *Management Science, 19,* 1368-1378, August 1973.

2. P. Kolesar, W. Walker, and J. Hausner, "Determining the Relation Between Fire Engine Travel Times and Travel Distances in New York City," *Operations Research, 23,* 4, 614-627, May 1975.

3. G. M. Carter, *Simulation Model of Fire Department Operations: Program Description,* The New York City-Rand Institute, R-1188/2-HUD/NYC, December 1974.

4. P. Dormont, J. Hausner, and W. Walker, *Firehouse Site Evaluation Model: Description and User's Manual,* The New York City-Rand Institute, R-1618/2-HUD, June 1975.

5. *Fire Station Location Package: Chief Executive's Report, Fire Chief's Report, Project Leader's Guide, Project Operations Guide,* Public Technology, Inc., Washington, D.C., 1974.

6. P. Schaenman, J. Hall, A. Schainblatt, J. Swartz, M. Karter, *Measuring Local Fire Prptections: Some Potential Improvements*, The Urban Institute and NFPA, April 1976.

7. L. MacGillivray, et al., *Evaluating the Organization of Service Delivery: Fire,* Technical Report of Phases I and IIA: Research Triangle Institute, ICMA and NFPA, n.d.

8. M. Getz, *Production in the Public Sector: A Case Study of the Urban Fire Service,* Department of Economics, Vanderbilt University, August 1976.

9. H. Corman, E. Ignall, K. Rider, A. Stevenson, "Fire Casualties and Their Relation to Fire Company Response Distance and Demographic Factors," *Fire Technology, 12,* 3, 193-203, August 1976.

10. J. Hogg, "Losses in Relation to the Fire Brigade's Attendance Times," Report 5/73, Home Office, Scientific Advisory Branch, London, 1973.

11. J. Hogg, "A Model of Fire Spread," Report 2/71, Home Office, Scientific Advisory Branch, London, March 1971.

12. R. E. Miller and A. Rappaport, "On the Relationship Between Fire Department Response Times and Damages," ORSA/TIMS National Meeting, November 1977 (mimeo, Wichita State University).

13. A. J. Swersey, E. J. Ignall, et al., *Fire Protection and Local Government: An Evaluation of Policy Related Research,* The New York City-Rand Institute, R-1813-NSF, September 1975.