

STUDY OF VEHICLE FIRE CASUALTIES AND FIRE BRIGADE RESPONSE TIMES

Technical Note
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By
ENTEC

Home Office
Fire and Emergency Planning Department
Horseferry House
Dean Ryle Street
London, SW1P 2AW

Technical Note Issued By:
F Izoldi
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Reviewed By:
Michael S. Wright
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TECHNICAL NOTE RELEASE SHEET

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Fire and Emergency Planning Department
Horseferry House
Dean Ryle Street
London, SW1P 2AW

Main Contributors

F Izoldi
M S Wright

Technical Note Issued by:
F Izoldi

Technical Note Reviewed by:
M S Wright

17 Angel Gate, City Road, London, EC1V 2SH, England.
Tel: (+44) (0) 171278 8338. Fax: (+044) (0) 171 833 9090.

CONTENTS

- 1 INTRODUCTION
- 2 RISK OF FATALITY FROM VEHICLE FIRES
 - 2.1 *Number and Causes of Fatal Fires*
 - 2.2 *Individual Risk of Fatality*
- 3 INFLUENCE OF FIRE BRIGADE RESPONSE TIMES AND RISK OF FATALITIES
- 4 HOW MIGHT A CHANGE IN FIRE BRIGADE RESPONSE TIME AFFECT THE RATE OF FATALITY IN VEHICLE FIRES?
- 5 DOES THE FREQUENT OF ABNORMAL FIRE DEVELOPMENT THWART RESCUE?
- 6 DOES THE STATISTICAL RELATIONSHIP HOLD FOR ALL AREAS IN THE UK?
 - 6.1 *Introduction*
 - 6.2 *Does Fire Discovery / Reporting Times Affect the Rate of Fatalities?*
 - 6.3 *Does Location of Vehicle fires Affect Fire Discovery / Reporting Times and the Rate of Fatalities?*
- 7 FIRE RESEARCH INTO VEHICLE FIRES AND CASE STUDIES
 - 7.1 *Car Fire Research*
 - 7.2 *Table 25: Vehicle fires Case Studies*
- 8 CONCLUSIONS

1. INTRODUCTION

This technical note reviews the fires in vehicles involving casualties (i.e. fatalities, non-fatalities and rescues by the fire brigade) to address two issues:

1. To what extent do vehicle fires pose a risk to life?
2. To what extent can the risk to life posed by vehicle fires be reduced by an emergency response by the fire brigade?

These issues have been examined by analysing data obtained from the Home Office statistics on casualties from vehicle fires (FDRI reports) attended by local authority fire brigades in the UK for the years 1994 to 1997.

In particular, we have:

- calculated the rate of fatality in accidental vehicle fires and compared this rate with criteria relating to what is and is not viewed to be a negligible risk of fatality,
- developed a statistical model of the relationship between fire brigade response times and the probability of fatal injury in vehicle fires,
- examined how the relationship between fire brigade response time and probability of fatality varies geographically.

Next, we have identified a number of case studies on vehicle fires to provide qualitative evidence on the possibility of emergency responses averting vehicle fire fatalities.

Finally, we have reviewed research into the rate of fire development in vehicle fires as a final source of information on the possibility of successfully rescuing persons involved in vehicle fires.

2. RISK OF FATALITY FROM VEHICLE FIRES

2.1 Number and Causes of Fatal fires

The data provided by the Home Office show a total of 2,337 fires involving 3,265 casualties (i.e. fatal, non-fatal and rescued persons) for the 4 year period (1994 to 1997), as shown in Table 1:

Table 1: Causes of Vehicle fires Resulting in Casualties in the UK (1994 - 1997)

Causes of Vehicle FIRE	Vehicle fires		Overall Casualties	
	No.	%	No.	%
Accidental	1,891	81.0	2,728	84.0
Malicious	213	9.0	253	7.5
Deliberate	127	5.4	138	4.0
Doubtful	37	1.6	49	1.5
Not known	69	3.0	97	3.0
Total	2,337	100	3,265	100

Accidental vehicle fires were responsible for over 80% of all vehicle fires and casualties (i.e. 1,981 and 2,728, respectively). The Home Office statistics give a total of about 70,000 vehicle fires per year between 1994 and 1997. Therefore, vehicle fires involving casualties account for only 1% of all vehicle fires in the UK.

In the case of accidental car fires, fire casualties are reported in about 1.6% of all accidental car fires. Table 2 below shows the breakdown of the causes of those vehicle fires resulting in casualties:

Table 2: Fire Casualties from Vehicle fires (1994 - 1997)

Causes of Vehicle fires	Overall Fatalities		Overall Non-Fatalities		Overall Rescues		Overall Casualties	
	No.	%	No.	%	No.	%	No.	%
Accidental	215	64.0	2430	85.8	83	86.5	2,728	84%
<i>Collision</i>	189		1127		64			
<i>Equip. Fault</i>	10		931		12			
<i>Suicide</i>	1		0		0			
<i>Others</i>	15		372		7			
Malicious	2	0.6	243	8.6	8	8.3	253	7.5%
<i>Suicide</i>	1		0		0			
<i>Bombs</i>	0		11		0			
<i>Others</i>	1		232		8			
Deliberate	65	19.3	73	2.5	0	0	138	4%
<i>Suicide</i>	30		20					
<i>Unknown</i>	35		47					
<i>Others</i>	0		6					
Doubtful	13	3.9	33	1.1	3	3.1	49	1.5%
<i>Suicide</i>	2		0		0			
<i>Others</i>	11		30		3			
Not known	41	12.2	54	2.0	2	2.1	97	3%
<i>Suicide</i>	2		0		0			
<i>Others</i>	39		54		2			
Total	336	100	2,833	100	96	100	3,265	100

Table 2 shows that of the 336 fatalities, 215 (i.e. 64%) were caused by accidental vehicle fires and 36 (i.e. 10.7%) by suicides, mostly (i.e. 30) resulting from deliberate vehicle fires. The causes of other fatal fires were doubtful or unknown in most cases.

There were only 2 fatalities (i.e. 0.6%) from 213 malicious vehicle fires involving casualties (see Table 1), thus suggesting that these tend to present a low risk to life relative to accidental vehicle fires, namely less than 1% of all car fire fatalities. Indeed, with about 40,000 malicious car fires per year, the likelihood of fatality per malicious car fire is about 1 in 80,000.

However, care should be taken when considering malicious vehicle fires, given that there were 8 reported rescues, the only instance where the number of rescues exceed the number of fatalities.

Deliberate vehicle fires were responsible for 65 fatalities (i.e. 19.3% of all car fire fatalities), 30 of which resulting from suicides (i.e. 9%), with no rescues reported. This may suggest that deliberate vehicle fires involve a certain degree of preparation by the perpetrators, thus negating any chance of a fire brigade rescue.

2.2 Individual Risk of Fatality

The individual risk of fatality is the risk experienced by a single individual in a given time period. In order to calculate the individual risk of fatality from vehicle fires, it is necessary to know the number of vehicle users in the UK. The exact figure is unknown, as it comprises the total number of people making use of vehicles in the UK, either as a passenger or as a driver.

However, the latest data from the Driver and Vehicle Licensing Agency in the UK (i.e. December 1997) register approximately 25.9 million licensed vehicles in the UK. In addition, it is reasonable to assume that the vast majority of the population either drives or rides as a passenger in private or public vehicles.

Therefore, the annual total number of vehicle users in the UK is in the range of 25.9 million (i.e. total number of licensed vehicles in the UK) to 56 million (i.e. approximate UK population), probably closer to the latter.

Therefore, the annual individual risk of fatality in the UK for accidental vehicle fires is calculated using the total number of accidental vehicle fire fatalities (i.e. 215) averaged over the 4-year period. The calculation has been completed twice, once for a population of 25.9 million and once for a population of 56 million i.e.:

- Individual Risk of Fatality (25.9 million): 2.1×10^{-6} per year,
- Individual Risk of Fatality (56 million): 1.0×10^{-6} per year.

If it is accepted that there are about 56 million car users in the UK, the lower individual risk estimate of 1.0×10^{-6} per year (1 in 1,000,000 per year per person) is probably the best estimate for the general population, although the risk will vary from individual to individual, depending on the level of car use.

When considering the fatalities resulting from all causes of vehicle fires, the annual individual risk of fatality is approximately 50% greater than for the accidental vehicle fires, as shown below:

- Individual Risk of Fatality (Drivers): 3.2×10^{-6} per year,
- Individual Risk of Fatality (General Population): 1.5×10^{-6} per year.

To place the individual risk of fatality from vehicle fires in context, the individual risk of fatality for all types of road accidents is currently about 57×10^{-6} per year (i.e. 1 in 17,500 per year). An individual risk of fatality of 1 in a million per year is commonly regarded to be negligible by UK regulators, whereas a risk of 1 in a hundred thousand per year is considered to be tolerable.

Therefore, the annual individual risk of fatality from accidental vehicle fires for the general population and drivers is just above the level considered negligible, but still very tolerable. In addition, vehicle fires account for only a fraction of the of fatalities from all road traffic accidents (i.e. 57×10^{-6} per year), namely 1.0% of all road traffic fatalities.

3. INFLUENCE OF FIRE BRIGADE RESPONSE TIMES AND RISK OF FATALITIES

A statistical model of the relationship between response times and fatality rates has been developed by calculating the probability of fatality per vehicle fire casualty for 5 “bands” of fire brigade response time, grouped in 5 minute intervals, namely:

- 0 to 5 minutes,
- 6 to 10 minutes,
- 11 to 15 minutes,
- 16 to 20 minutes and
- greater than 20 minutes.

The number of casualties experienced within those response time bands are summarised in Table 3:

Table 3: Vehicle Fire Casualties x Response Time (1994 - 1997)

Response Times (mins)	Overall Fatalities		Overall Non-Fatalities		Overall Rescues		Overall Casualties	
	No	%	No	%	No	%	No	%
0-5	77	23	964	34	31	32	1,072	33
6 -10	162	48	1,336	47	52	54	1,550	47
11 - 15	69	21	424	15	12	13	505	16
16 - 20	20	6	86	3	1	1	107	3
> 20	8	2	23	1	0	0	31	1
Total	336	100	2,833	100	96	100	3,265	100

Table 3 shows that, the majority of fires were attended within 10 minutes and that 86% of rescues were also carried out within this same period. In addition, there were 77 fatalities out of 1,072 casualties (i.e. 7%) for fires attended within 5 minutes, compared with 8 fatalities out of 31 casualties (i.e. 26%) for fires attended in over 20 minutes, an increase of 460%.

This suggests that there is a relationship between fire brigade response times and the risk of fatality in vehicle fires. In order to investigate this relationship, the data were then analysed considering the fatalities within their respective response time interval, so to obtain the probability of a fatality per vehicle fire, given that a casualty was reported.

This is illustrated in Table 4 for all vehicle fires involving casualties, Table 5 for accidental vehicle fires involving casualties and Table 6 for vehicle fires other than accidental and deliberate:

Table 4: Vehicle Fire Casualties within Response Time Bands (1994 - 1997): All Vehicle fires Involving Casualties

Response Times (mins)	Fatalities (all vehicle fires)	Casualties (all vehicle fires)	Percentage of Casualties Fatally Injured (all vehicle fires)
	No.	No.	%
0 - 5	77	1,072	7.2
6 - 10	162	1,550	10.5
11 - 15	69	505	13.7
16 - 20	20	107	18.7
> 20	8	31	25.8
Total	336	3,265	-

Table 5: Vehicle Fire Casualties within Response Time Bands (1994 - 1997): Accidental Vehicle fires Involving Casualties

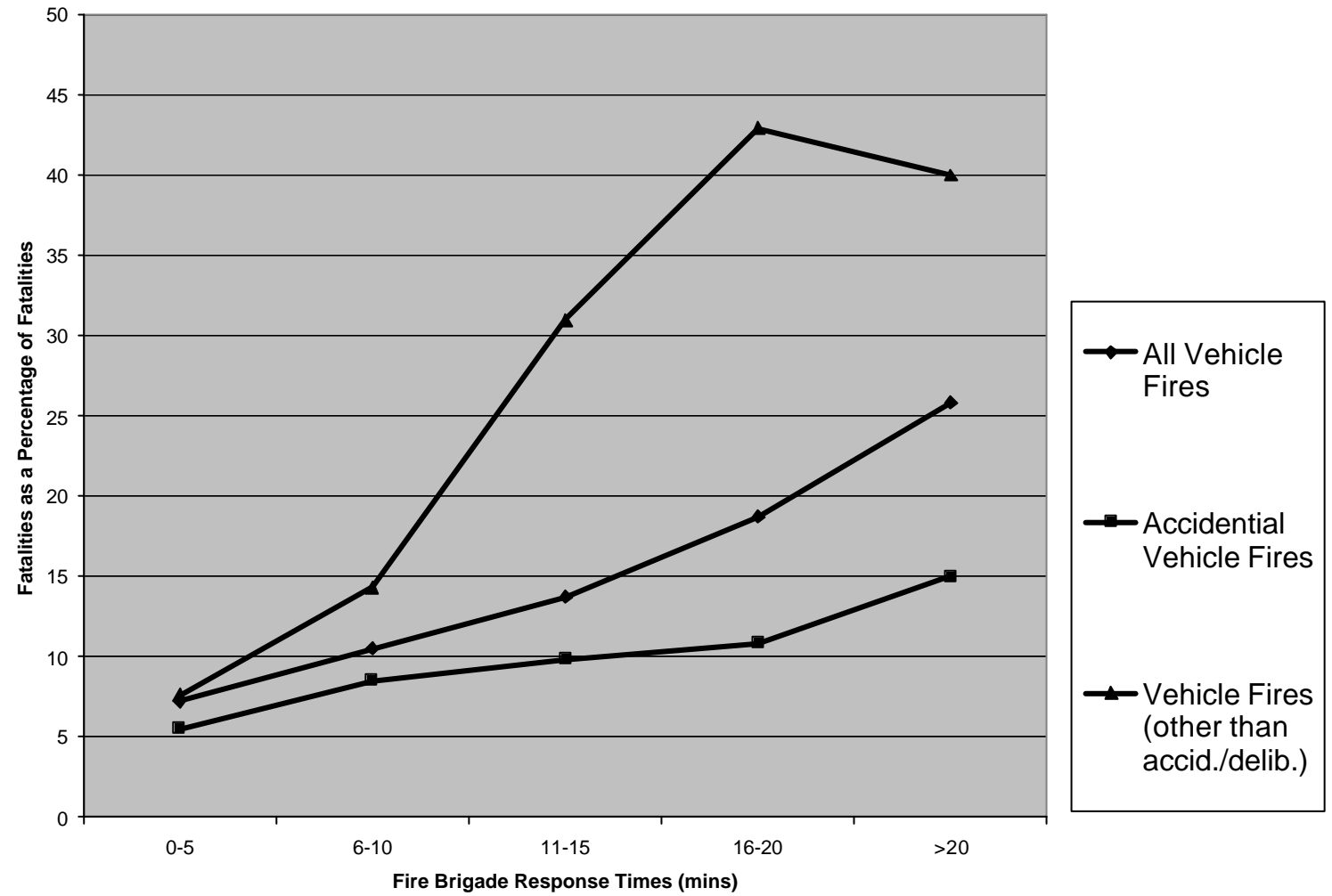
Response Times (mins)	Fatalities (accidental vehicle fires)	Casualties (accidental vehicle fires)	Percentage of Casualties Fatally Injured (accidental vehicle fires)
	No.	No.	%
0 - 5	47	856	5.5
6 - 10	112	1,319	8.5
11 - 15	43	440	9.8
16 - 20	10	93	10.8
> 20	3	20	15.0
Total	215	2,728	-

Table 6: Vehicle Fire Casualties within Response Time Bands (1994 - 1997): Vehicle fires, Other than Accidental and Deliberate, Involving Casualties

Response Times (mins)	Fatalities (other than accid./delib. Vehicle fires)	Casualties (other than accid./delib. vehicle fires)	Percentage of Casualties Fatally Injured (other than accid./delib. vehicle fires)
	No.	No.	%
0 - 5	13	170	7.6
6 - 10	25	175	14.3
11 - 15	13	42	31.0
16 - 20	3	7	42.9
> 20	2	5	40.0
Total	56	399	-

The tables show that the fatality rate in vehicle fires (fatalities as a percentage of casualties) increases almost linearly with response times, as illustrated in Figure 1. The position of the curves for accidental vehicle fires and other fires are very different, suggesting that the rate of fatality is lower for accidental fires and that there is a greater opportunity to rescue casualties from accidental vehicle fires.

Figure 1: Fatality Rates According to Response Times



The impact that response times have on the fatality rate can be illustrated by calculating the growth in fatality rate that would result in an increase from 0-5 to 11-15 minutes in the response time, as shown in Table 7 :

Table 7: Illustration of Changes in Fatality Rates for Increased Response Time (1994 - 1997)

Response Times (mins)	Percentage of Casualties Fatally Injured (all vehicle fires)		Percentage of Casualties Fatally Injured (accidental vehicle fires)		Percentage of Casualties Fatally Injured (other than accid./delib. vehicle fires)	
	Rate	%	Rate	%	Rate	%
0-5	1 in 14	7.2	1 in 18	5.5	1 in 14	7.6
11-15	1 in 7.5	13.7	1 in 10	9.8	1 in 3	31
Growth	90%		78%		300%	

Table 7 shows a 90% growth in the fatality rate for all vehicle fires involving casualties when the response time is increased from 0-5 to 11- 15 minutes, i.e. from a 1 in 14 chance of fatality (7.2%) to 1 in 7.5 (13.7%), respectively

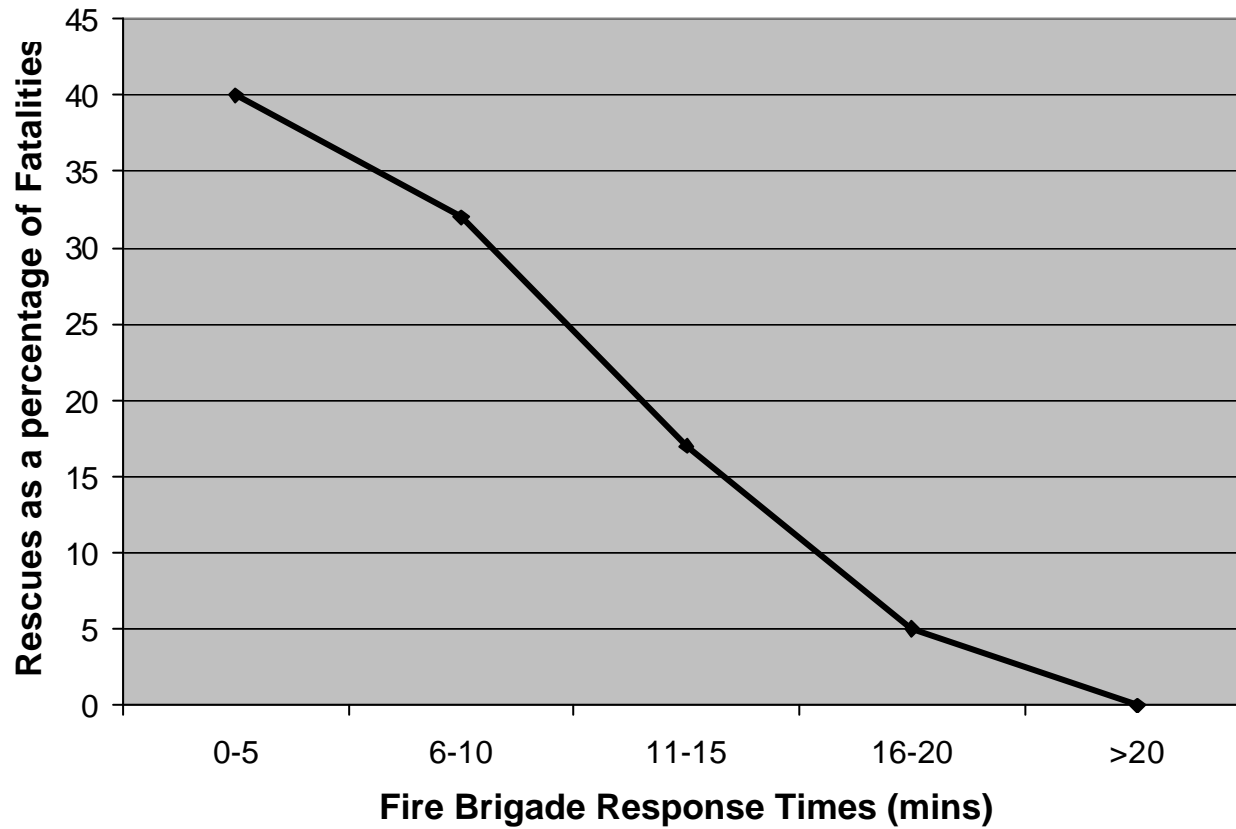
For accidental vehicle fires, the fatality rate increases by 78% (from 5.5% to 9.8%), whereas for vehicle fires other than accidental and deliberate there is a 300% increase. The relationship between the fatality rate and fire brigade response times may also be analysed by looking into the ratio of rescues to fatalities, as shown in Table 8:

Table 8: Vehicle Fire Rescues/Fatalities within Response Time Bands (1994 - 1997): All Vehicle fires Involving Casualties

Response Times (mins)	Fatalities (all vehicle fires)	Rescues (all vehicle fires)	Rescues as a percentage of Fatalities (all vehicle fires)
	No.	No.	%
0 - 5	77	31	40
6-10	162	52	32
11 -15	69	12	17
16-20	20	1	5
> 20	8	0	0
Total	336	96	-

Rescues as a percentage of fatalities are illustrated in Figure 2, where we can see a significant steady reduction in the rate of rescues as the response time increases. Within the 0 to 5 minute response time, there was one rescue for every 2.5 fatalities (i.e. 40%). This rate decreases eightfold when the response time is between 16 to 20 minutes, with 1 rescue for every 20 fatalities (i.e. 5%). Therefore, the results shown in Figures 1 and 2 may suggest that a prompt fire brigade attendance to an accident has a significant contribution in saving lives.

Figure 2: Rate of Rescues as a percentage of Fatalities According to Response Times



4. HOW MIGHT A CHANGE IN FIRE BRIGADE RESPONSE TIME AFFECT THE RATE OF FATALITY IN VEHICLE FIRES?

We can see that the vast majority of vehicle fires (i.e. 83%) involving casualties were attended within 10 minutes from the time the brigade was called, as illustrated in Table 9:

Table 9: Fire Brigade Response Times - Vehicle Fires (1994 - 1997)

Response Times (mins)	Fire Attendance
0-5	40%
6-10	43%
11-15	12%
16-20	3%
20	1%
Total	100%

The impact that a change in fire brigade response times would have on the rate of fatality may be evaluated by applying the fatality rates for the different response intervals.

Thus, for example, a 5 minute increase in the response time can be estimated by applying the fatality rate for accidental vehicle fires attended in 6 to 10 minutes, to those currently attended in 1 to 5 minutes and so forth. The same principle is valid for estimating a 5 minute reduction in the response time, with the fatality rate for fires attended in 1 to 5 minutes being applied to those currently attended in 6 to 10 minutes, and so forth, as demonstrated in the Table 10 below:

Table 10: Impact of Change in Response Times on Number of Fatal Casualties from Accidental Vehicle fires (1994-1997)

Response Time (mins)	Number of fatalities with current response times	Number of fatalities if response times increase by 5 minutes		Number of fatalities if response times decrease by 5 minutes	
		Fatalities (new total)	Increase	Fatalities (new total)	Decrease
0-5	47	73	55 %	47 (*)	0(*)
6-10	112	129	15 %	73	35 %
11-15	43	48	12%	37	14%
16-20	10	14	40%	9	10%
> 20	3	3 (*)	0 (*)	2	33%
Total	215	264	23%	168	22%

(*)assumed to remain unaltered

The results show that, for accidental vehicle fires:

- there would be a 23% increase in the number of vehicle fire related fatalities per annum (i.e. 49 additional fatalities for a 4-year period, or approximately

12 per year), with a 5 minute increase in the fire brigade response time nation-wide,

- there would be a 22% decrease in the number of vehicle fire related fatalities per annum (i.e. 47 lives saved for a 4-year period, or approximately 12 per year), with a 5 minute reduction in the fire brigade response time nation-wide.

Accordingly, the UK individual risk of fatality for accidental vehicle fires will be subject to the same variations when considering reduced and increased fire brigade response times, as shown in Table 11:

Table 11: Individual Risk of Fatality for Increased and Reduced Response Times (1994 - 1997): Accidental Vehicle fires

Response Times	Fatalities per Year (accidental vehicle fires)	Individual Risk of Fatality (per year)	
		Popul. Estimate: 25.9 million	Popul. Estimate: 56 million
Current Response Times	215/4	2.1×10^{-6}	1.0×10^{-6}
5 minute Increase in Response Time	264 / 4 (all vehicle fires)	2.5×10^{-6}	1.2×10^{-6}
5 minute Reduction in Response Time	168 / 4 (all vehicle fires)	1.6×10^{-6}	0.8×10^{-6}

Therefore, a 5-minute increase in the fire response time for accidental vehicle fires would result in a 23% increase in the individual risk of fatality for accidental vehicle fires involving casualties (i.e. from 2.1×10^{-6} to 2.5×10^{-6} per year for a population estimate of 25.9 million, and from 1.0×10^{-6} to 1.2×10^{-6} per year for a population estimate of 56 million), with both risk levels still within the UK tolerable individual risk level (i.e. 1.0×10^{-5} per year).

5. DOES THE FREQUENCY OF ABNORMAL FIRE DEVELOPMENT THWART RESCUE?

In order to investigate the impact that abnormal fire development could have on rescues from vehicle fires involving casualties, the proportion of vehicle fires reported to have an abnormal rate of fire development and/or explosion have been analysed.

The data show that out of the 2,337 vehicle fires involving casualties reported, 10.4 % (i.e. 243) involved abnormal rate of fire development and/or explosions, whilst 28% (i.e. 94) of the fatalities (i.e. 336) involved abnormal fire development/explosion.

Thus, it would appear that a rescue is less likely to be reported where abnormal fire development / explosions occur. However, abnormal fire development / explosions occur only in a small minority of cases, thereby not thwarting rescues in most cases.

The casualties involved in these reported vehicle fires are summarised in Table 12:

Table 12: Vehicle Fire Casualties from Abnormal Fire Development and/or Explosions(1994 - 1997)

Cause of Vehicle fires	Fatalities		Non-Fatal		Rescues		Total Casualties	
	No.	%	No.	%	No.	%	No.	%
Abnormal Fire Development and/or Explosions	94	28	257	9	6	6	357	11
Others	242	72	2,576	91	90	94	2,908	89
Total	336	100	2,833	100	96	100	3,265	100

The variations on the rates of fatalities in comparison with rescues, casualties and vehicle fires are calculated in Table 13:

Table 13: Relationship Between Fatalities and Rescues/Casualties/Vehicle fires: Abnormal Fire Development and/or Explosions (1994 - 1997)

Cause of Fire	Ratios		
	Ratio of Rescue to Fatality	Ratio of Fatality to Casualty	Ratio of Fatality to Vehicle fires
Abnormal Fire Development and/or Explosions	1 to 15.6 (6 to 94)	1 to 3.8 (94 to 357)	1 to 2.6 (94 to 243)
Others	1 to 2.7 (90 to 242)	1 to 12 (242 to 2,908)	1 to 8.7 (242 to 2,094)
Variation	6	3	3

This shows that vehicle fire casualties are 6 times less likely to be rescued, and are 3 times more likely to become fatalities, in vehicle fires involving abnormal fire development and/or explosions, than from fires not involving abnormal fire development and/or explosions.

In order to further investigate the impact that abnormal fire development and/or explosions have on vehicle fire rescues, the rate of fatalities has been estimated in Table 14 and Table 15 for the different response time bands:

Table 14: Vehicle fires Involving Rescues / Fatalities within Response Time Bands (1994 - 1997): Abnormal Fire Development and/or Explosions

Response Times (mins)	Fatalities (abnormal fire development and/or explosions)	Casualties (abnormal fire development and/or explosions)	Fatalities as a percentage of Casualties (abnormal fire development and/or explosions)
	No.	No.	%
0-5	25	116	21.6
6-10	46	179	25.7
11-15	17	52	32.7
16-20	4	7	57.1
> 20	2	3	66.7
Total	94	357	-

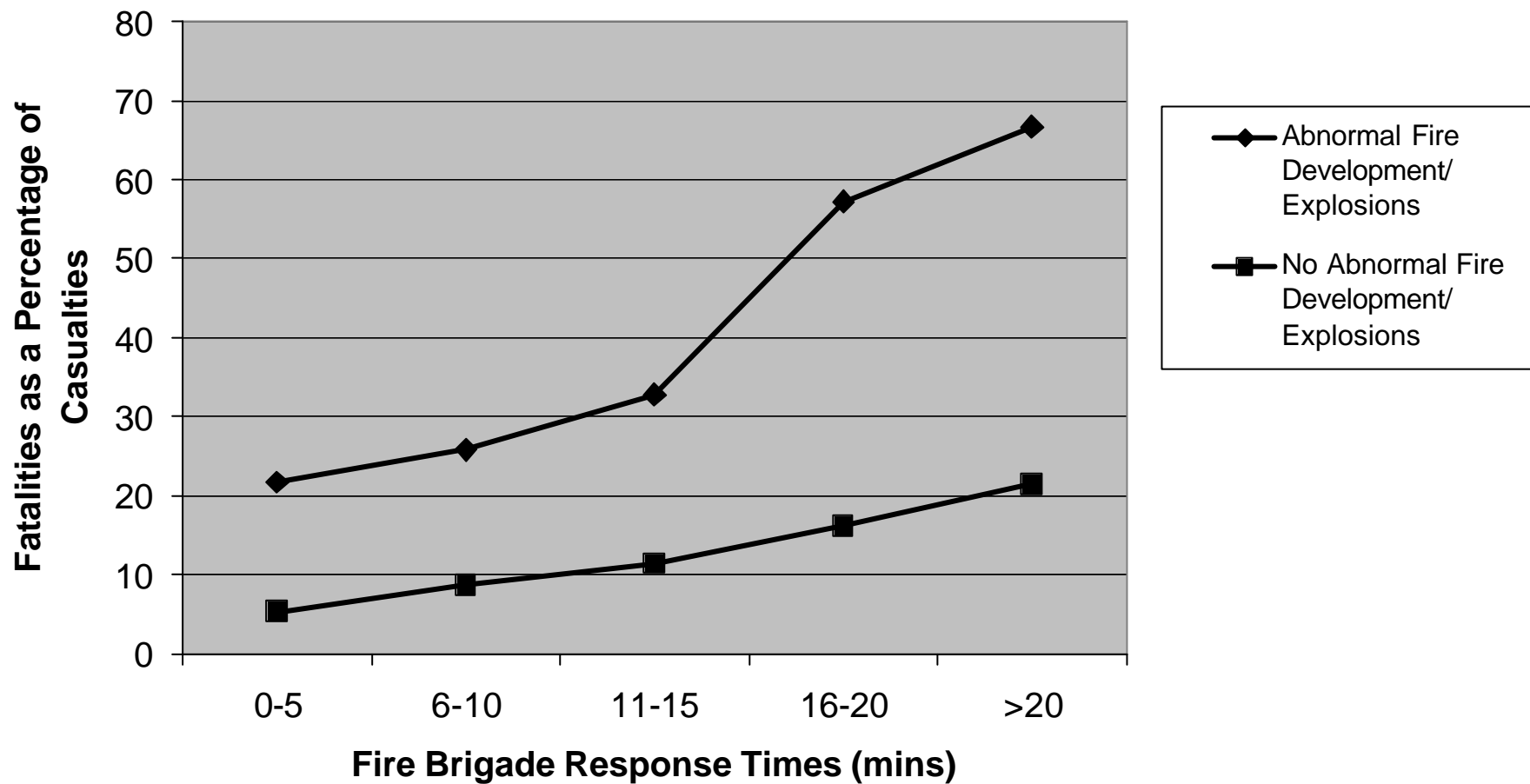
Table 15: Vehicle fires Fatalities/Casualties within Response Time Bands (1994 - 1997): Not Involving Abnormal Fire Development and/or Explosions

Response Times(mins)	Fatalities (other than abn. fire develop. and/or explosions)	Casualties (other than abn. fire develop. and/or explosions)	Fatalities as a percentage of Casualties (other than abn. fire develop. and/or explosions)
	No.	No.	%
0-5	52	956	5.4
6-10	116	1,371	8.5
11-15	52	453	11.5
16-20	16	100	16.0
>20	6	28	21.4
Total	242	2,908	-

The tables show the rate of fatalities for vehicle fires with abnormal fire development and/or explosions to be about 3 times greater than for vehicle fires not involving abnormal fire development and/or explosions, as illustrated in Figure 3.

However, there is still an apparent relationship between response times and fatality rates in vehicle fires involving abnormal fire development/explosions, with a 21.6% fatality rate for 0-5 minutes response time and a 57.1% fatality rate for 16-20 minutes response time.

**Figure 3: Fatality Rate According to Response Times:
Abnormal Fire Development / Explosions**



6. DOES THE STATISTICAL RELATIONSHIP HOLD FOR ALL AREAS IN THE UK?

6.1 Introduction

It may be speculated that the apparent affect of fire brigade response times is confounded by another variable, namely the location where the vehicle fire took place. In particular, it is possible that longer response times coincide with longer time taken to discover a fire and call the fire brigade in isolated areas, for instance.

6.2 Does Fire Discovery / Reporting Times Affect the Rate of Fatalities?

To investigate this, the relationship between fire brigade response times was examined with the time taken to discover the fire and call the fire brigade (namely reporting time), as shown in Table 16:

Table 16: Relationship Between Reporting and Response Times (1994 - 1997)

Response Times (mins)	Total No. of fires	Fires Discovered and Reported within 10 minutes		Fires Discovered and Reported after 10 minutes	
		No.	%	No.	%
0-5	825	681	36.3	144	31.3
6-10	1,081	897	47.8	184	40.0
11-15	331	235	12.5	96	20.9
16-20	79	51	2.7	28	6.1
> 20	21	13	0.7	8	1.7
Total	2,337	1,877	100	460	100

The table shows that 84.1% (i.e. 1,578) of all fires reported within 10 minutes were attended within 10 minutes by the fire brigade, compared to 71.3% of fires reported after 10 minutes.

This suggests that there is a coincidence of longer response times with longer discovery reporting times. However, the majority of fires were attended in 10 minutes in the case of shorter and longer reporting times, suggesting that this is not a very significant relationship.

This is illustrated in Figure 4, where we can see that the rate of fires attended after 10 minutes decreases accordingly to an increase in the reporting time.

Next, the rate of fatalities per casualties per response times was estimated for different reporting times for all vehicle fires, as summarised in Table 17 below:

Figure 4: Relationship Between reporting Times and Response Times

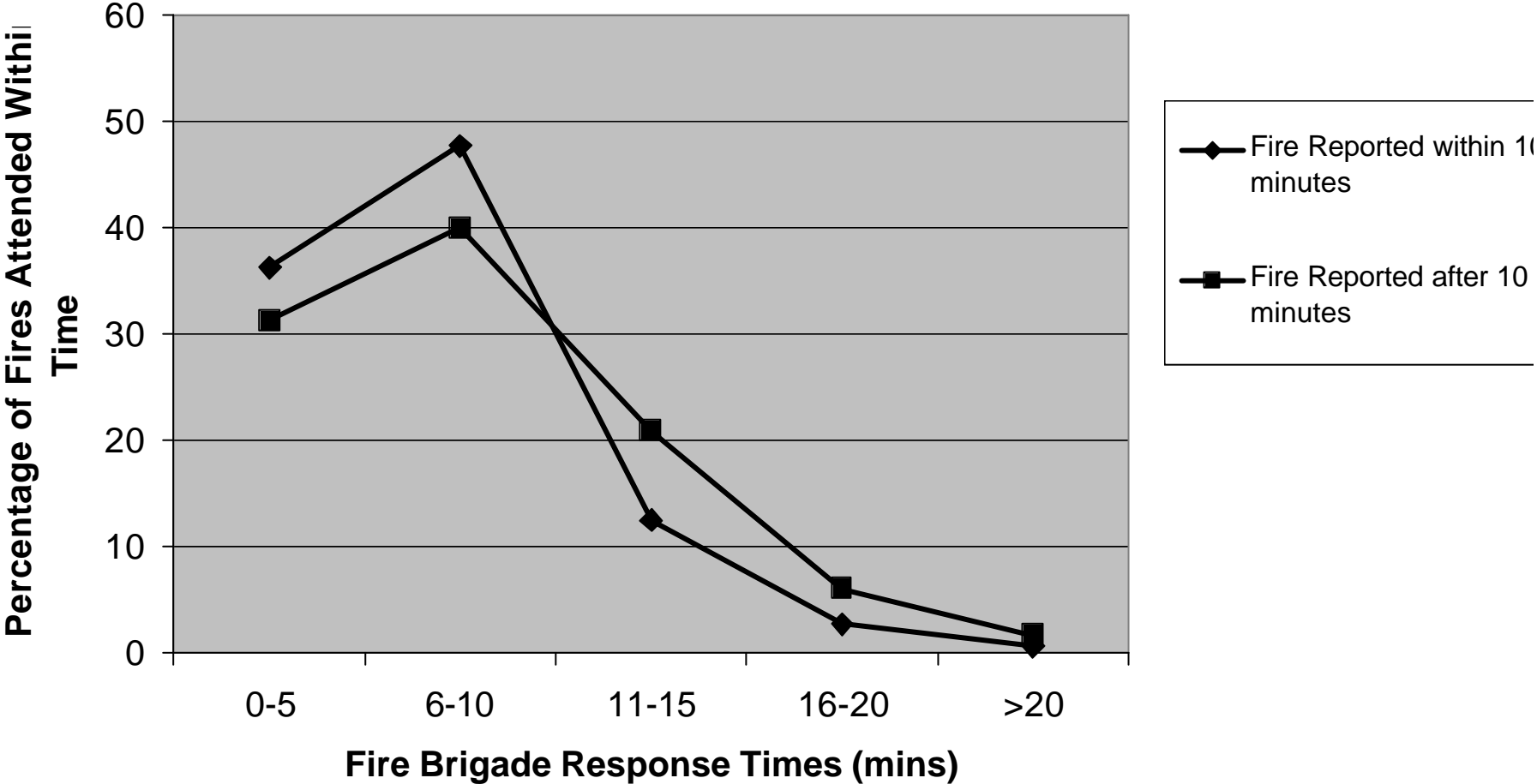


Table 17: Variation in Fatality Rates for Different Response/Reporting Times (1994 - 1997): All Vehicle Fires

Response Times (mins)	Fires Discovered and Reported within 10 minutes (All Vehicle fires)			Fires Discovered and Report after 10 minutes (All Vehicle fires)		
	No. of Casualties	No. of Fatalities	Casualties Fatally Injured (%)	No. of Casualties	No. of Fatalities	Casualties Fatally Injured (%)
0-5	909	64	7.0	163	13	8.0
6-10	1,315	129	9.8	235	34	14.0
11-15	373	37	9.9	132	31	22.7
16-20	73	8	11.0	34	12	35.3
> 20	23	3	13.0	8	5	62.5
Total	2,393	241	-	572	95	-

The results show a rate of 1 fatality for every 14.2 casualties (i.e. 7.0%) for fires reported within 10 minutes and attended within 5 minutes by the fire brigade. This rate increases to 1 fatality for every 7.6 casualties (i.e. 13.0%), an 85% increase, for response times greater than 20 minutes

When the reporting times were greater than 10 minutes, there was 1 fatality for every 12.5 casualties (i.e. 8.0%) for fires attended within 5 minutes by the fire brigade, increasing to 1 fatality to every 1.6 casualties (i.e. 62.5%), an eight fold increase, for response times greater than 20 minutes.

This is illustrated in Figure 5, and implies that the higher probability of fatality for longer response times is partly due to longer reporting times. It also shows that there is a much stronger relationship between fire brigade response times and fatality rates when the fire reporting time exceeds 10 minutes, than when it is reported within 10 minutes.

Similarly, in order to investigate this relationship for accidental vehicle fires, the rate of fatalities per casualties per response times was estimated for different reporting times for only accidental vehicle fires, as summarised in Table 18 below:

Figure 5: Relationship Between Fatalities and Fire Reporting Times for Different Response Time Bands: All Vehicle Fires

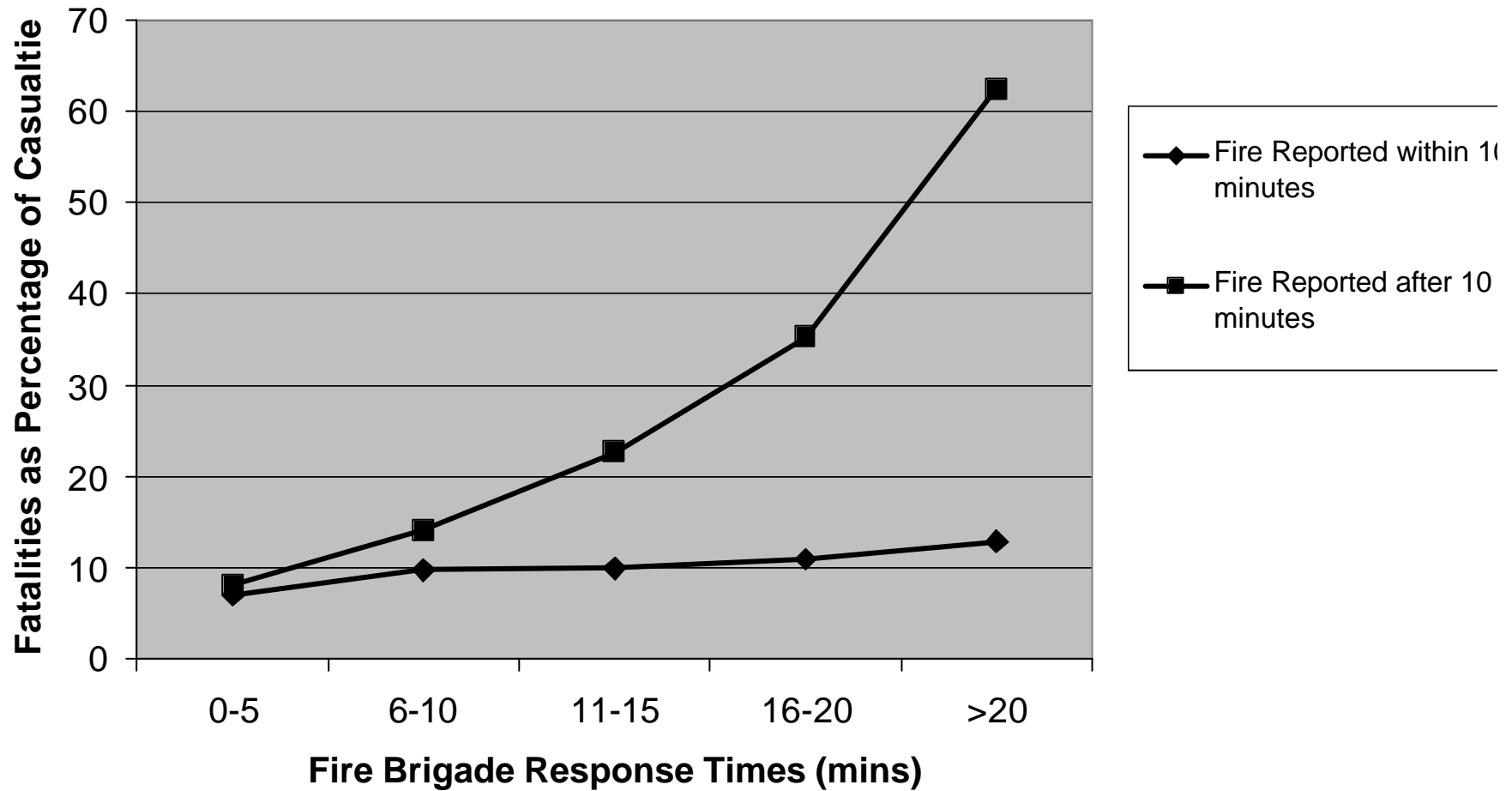


Table 18: Variation in Fatality Rates for Different Response/Reporting Times (1994 - 1997): Accidental Vehicle fires

Response Times (mins)	Fires Discovered and Reported within 10 minutes (Accidental Vehicle fires)			Fires Discovered and Reported after 10 minutes (Accidental Vehicle fires)		
	No. of Casualties	No. of Fatalities	Casualties Fatally Injured (%)	No. of Casualties	No. of Fatalities	Casualties Fatally Injured (%)
0-5	774	42	5.4	82	5	6.1
6-10	1,187	98	8.3	132	14	10.6
11-15	351	31	8.8	89	12	13.5
16-20	69	5	7.2	24	5	20.8
>20	19	3	15.8	1	0	0.0
Total	2,400	179	-	328	36	-

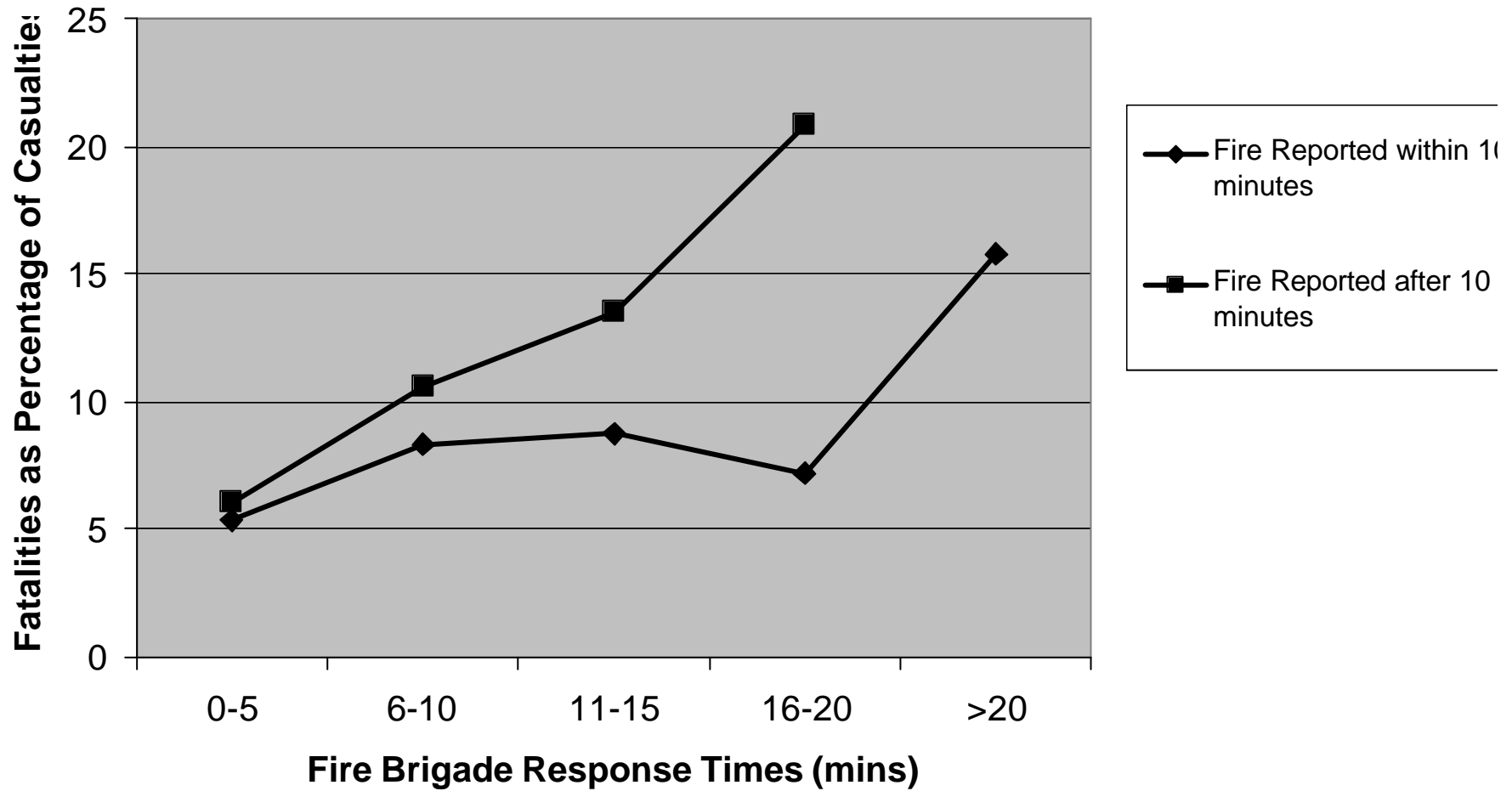
The results show, for accidental vehicle fires, a rate of 1 fatality for every 18.4 casualties (i.e. 5.4%) for fires reported within 10 minutes and attended within 5 minutes by the fire brigade. This rate increases to 1 fatality for every 13.8 casualties (i.e. 7.2%), a 33% increase, for response times between 16 and 20 minutes.

When the reporting times were greater than 10 minutes, there was 1 fatality for every 16.4, casualties (i.e. 6.1%) for fires attended within 5 minutes by the fire brigade, increasing to 1 fatality to every 4.8 casualties (i.e. 20.8%), a three fold increase, for response times between 16 and 20 minutes.

This is illustrated in Figure 6, and, as in the case for all vehicle fires, shows a higher probability of fatality for longer response times where there are longer reporting times. It also shows that there is a much stronger relationship between fire brigade response times and fatality rates when the fire reporting time exceeds 10 minutes, than when it is reported within 10 minutes.

This somewhat suggests that the opportunity to rescue vehicle fire casualties is affected by the fire reporting time.

Figure 6: Relationship Between Fatalities and Fire Reporting Times for Different Response Time Bands: Accidental Vehicle Fires



6.3 Does Location of Vehicle fires Affect Fire Discovery / Reporting Times and the Rate of Fatalities?

The apparent moderating influence of the reporting times (i.e. time to discover a fire and alert the fire brigade) is only of significance for fire cover planning, if longer reporting times are consistently reported in particular geographic areas. To investigate this, vehicle fires have been re-analysed for areas assigned A, B, C, D and R risk categories, which coincide broadly with inner cities, suburban, rural towns/villages, sparsely populated countryside and largely unpopulated rural areas, respectively.

This has been investigated separately for all vehicle fires and accidental vehicle fires involving casualties.

6.3.1 All Vehicle Fires Involving Casualties

Firstly, the percentage of vehicle fires involving casualties reported within/after 10 minutes has been calculated for the 5 risk areas. Secondly, the number of fatal fires have been calculated for each area. These are shown in Table 19 and Table 20, respectively:

Table 19: Percentage of Fires in Each Risk Area Reported within/after 10 minutes (1994 - 1997): All Vehicle Fires

Risk Areas	Total Fires	Fires Discovered and Reported within 10 minutes		Fires Discovered and Reported after 10 minutes	
	No.	No.	%	No.	%
A	49	41	84	8	16
B	237	193	81	44	19
C	1,227	1,003	82	224	18
D	782	611	78	171	22
R	42	29	69	13	31
Total	2,337	1,877		460	-

Table 20: Fatalities per Response Times for the Various Risk Areas (1994 - 1997): All Vehicle fires

Response Times	No. of Fatalities per Risk Areas				
	A	B	C	D	R
0-5	1	14	51	9	2
6-10	4	3	67	84	5
11-15	0	0	11	53	4
16-20	0	0	5	13	2
20	0	0	0	6	2
Total (336)	5	17	134	165	15

In Table 19, we can see that as the vehicle fires move from a more densely populated area (i.e. A/B) to a less densely populated one (i.e. DIR), there is an increase in the rate of fires reported after 10 minutes. A vehicle fire is twice as likely to be reported after 10 minutes in an isolated rural area (i.e. R) as in a densely populated area (i.e. A).

However, there is a minimal difference in reporting times between A, B and C risk areas, and between B, C and D risk areas. Thus, it appears that vehicle fires reporting times are only significantly affected once fires occur outside of towns and villages.

In Table 20 we see that risk areas C and D were responsible for 89% (i.e. 299) of the overall fire vehicle fatalities. Risk areas A/B accounted for 22 fatalities (i.e. 6.51/o), with rural areas accounting for 15 (i.e. 4.5%).

These low figures for A/B and remote rural risk areas mean that less confidence can be placed on the statistical relationship between response times and fatality rates in these risk areas.

Nonetheless, the effect that reporting / fire brigade response times have on the rate of fatalities was considered for the different risk areas, as summarised in Table 21 (A and B risk areas have been merged):

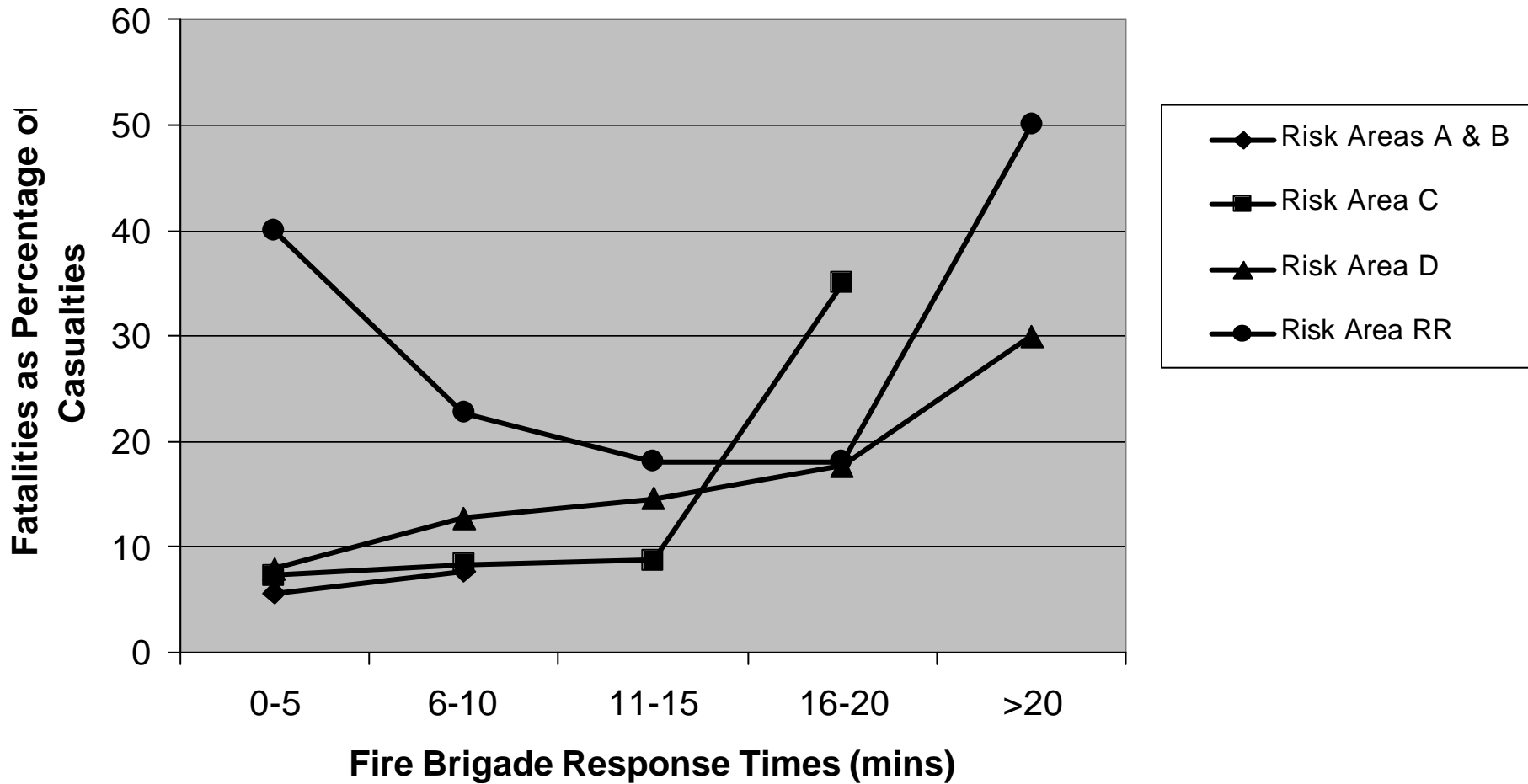
Table 21: Fatality Rates for Different Risk Areas According to Response Times (1994 - 1997): All Vehicle fires

Response Times	Fatalities as a Percentage of Casualties (%)			
	Risk Areas A&B (n=22)	Risk Area C (n=134)	Risk Area D (n=165)	Risk Area R (n= 15)
0-5	5.7	7.3	8.0	40.0
6-10	7.8	8.4	12.7	22.7
11-15	0.0	8.8	14.6	18.2
16-20	0.0	25.0	17,8	18.2
> 20	0.0	0.0	30.0	50.0

The table shows a consistent relationship between response times and fatality rates in C and D risk areas, i.e. fatality rates increase with response times in both cases. However, this pattern is not observed for vehicle fire casualties taking place in remote rural areas (i.e. R.).

This is better illustrated in Figure 7, where we can notice that longer response times had a major impact on the rate of fatalities in risk areas C and D.

Figure 7: Relationship Between Fatalities and Fire Reporting Times for Different Response Time Bands (Risk Areas A, B, C, D, RR): All Vehicle Fires



6.3.2 Accidental Vehicle fires Involving Casualties

The percentage of accidental vehicle fires involving casualties reported within/after 10 minutes has been calculated for the 5 risk areas. Secondly, the number of fatalities per response time bands have been calculated for each area. These are shown in Table 22 and Table 23, respectively:

Table 22: Percentage of fires in Each Risk Area Reported within/after 10 minutes (1994 - 1997): Accidental Vehicle fires

Risk Areas	Total Fires	Fires Discovered and Reported within 10 minutes		Fires Discovered and Reported after 10 minutes	
		No.	No.	%	No.
A	36	32	89	4	11
B	172	154	90	18	10
C	970	867	90	103	10
D	678	575	85	103	15
R	35	27	77	8	23
Total	1,891	1,655	-	236	-

Table 23: Fatalities per Response Times for the Various Risk Areas (1994 - 1997): Accidental Vehicle fires

Response Times	No. of Fatalities per Risk Areas				
	A	B	C	D	R
0-5	1	4	37	5	0
6-10	2	1	46	59	4
11-15	0	0	4	36	3
16-20	0	0	2	6	2
> 20	0	0	0	2	1
Total (336)	3	5	89	108	10

In Table 22, we can see that as the accidental vehicle fires move from a more densely populated area (i.e. A/B) to a less densely populated one (i.e. D/R), there is an increase in the rate of fires reported after 10 minutes.

A vehicle fire is twice as likely to be reported after 10 minutes in an remote rural area (i.e. R) as in a more densely populated area (i.e. A, B or C), although the vast majority is still discovered and reported in under 10 minutes in remote rural areas.

It should also be noted that there are few accidental fatal fires attended in 11 to 20 minutes in C risk areas, and after 16 minutes in D risk areas, thus reducing confidence in these data.

In Table 23 we see that risk areas C and D were responsible for 92% (i.e. 197) of the accidental fire vehicle fatalities (i.e. 215). Risk areas A/B accounted for 8 fatalities (Le. 3.5%), with rural areas accounting for 10 (i.e. 4.5%).

These low figures for A/B and rural risk areas mean that less confidence can be placed on the statistical relationship between response times and fatality rates in these risk areas. Nonetheless, the effect that reporting / fire brigade response times have on the rate of fatalities was considered for the different risk areas, as summarised in Table 24:

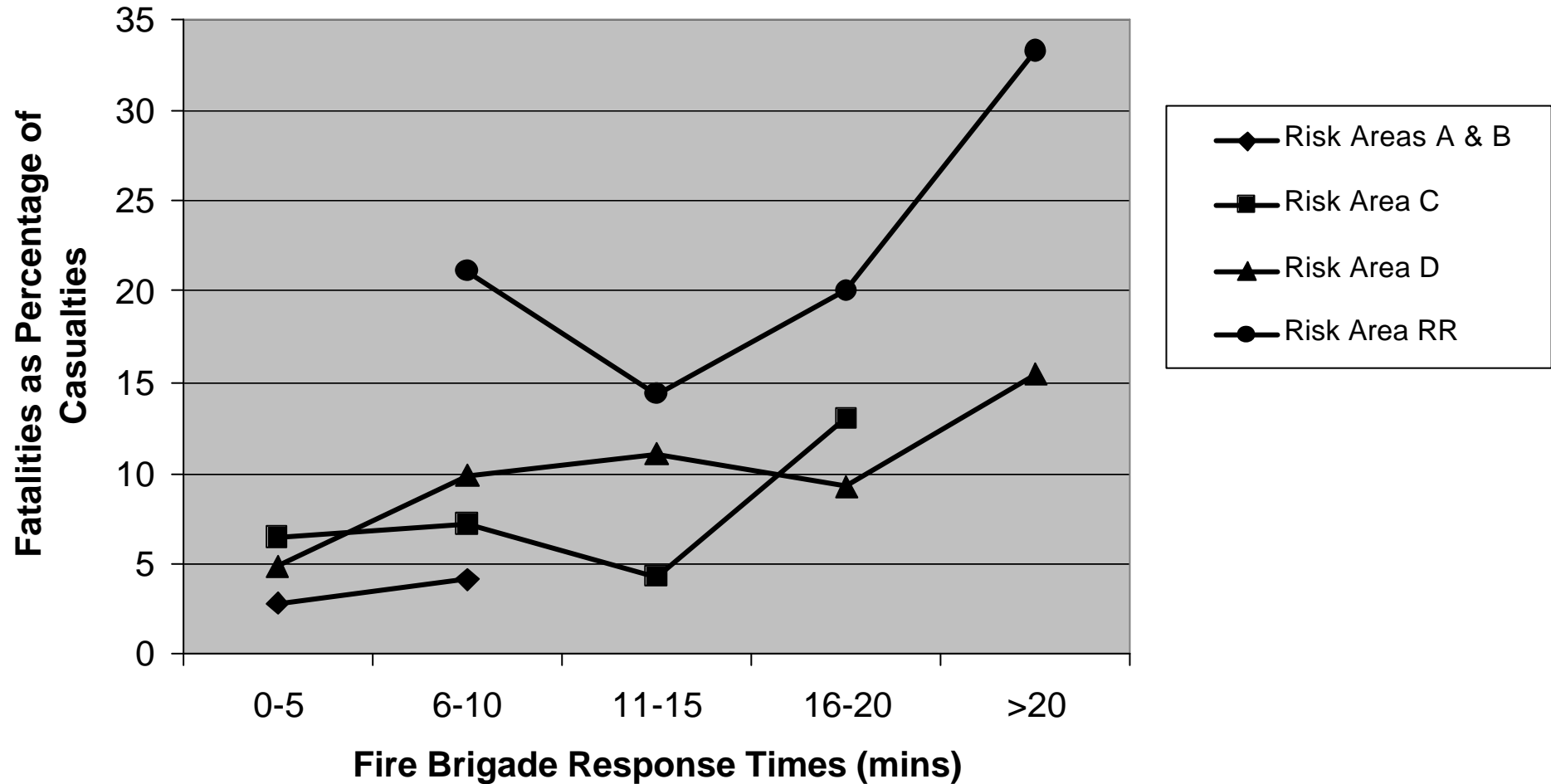
Table 24: Fatality Rates for Different Risk Areas According to Response Times (1994 - 1997): Accidental Vehicle Fires

Response Times	Fatality Rates as a Percentage of Casualties (%)			
	Risk Areas A&B (n=8)	Risk Area C (n=89)	Risk Area D (n=108)	Risk Area R (n=10)
0-5	2.8	6.4	4.9	0.0
6-10	4.1	7.2	9.9	21.1
11-15	0.0	4.2	11.1	14.3
16-20	0.0	13.0	9.2	20.0
> 20	0.0	0	15.4	33.3

We can see that the relationship between response times and fatality rates for accidental vehicle fires is not as consistent as for all vehicle fires, although there is a general trend for fatality rates to increase with longer response times. However, we can observe that there is a significant increase in the fatality rates for risk areas D and R as the response time exceeds 20 minutes (as illustrated in Figure 8), and for C risk areas where response time exceeds 15 minutes.

The lower level of consistency could be due to the small number of fires attended in R risk areas and in C/D risk areas with longer response times.

Figure 8: Relationship Between Fatalities and Fire Reporting Times for Different Response Time Bands (Risk Areas A, B, C, D. RR): Accidental Vehicle Fires



7. FIRE RESEARCH INTO VEHICLE FIRES AND CASE STUDIES

7.1 Introduction

This section summarises three case studies, shown in Table 25, and the findings of a research study into car fires by LMangs and O. Keski-Ralikonen (February, 1994).

The case studies have been selected to illustrate 3 vehicle fire scenarios, namely:

1. a collision with less rapid fire development in which a trapped driver was rescued from a burning lorry about 20 minutes after the crash.
2. a suicide when victims are intimate with the fire, dying instantly on ignition.
3. a collision involving rapid fire development, without time for a rescue attempt.

The research study is not wholly representative of “real” vehicle fires, as a strong ignition source was used in all experiments. Nonetheless, it found that conditions in the car cabin were tenable for up to approximately 8 minutes for fires starting in the engine.

7.2 Car Fire Research

In the research study, three cars (i.e. inexpensive models representing ordinary medium-size passenger cars manufactured in the late 1970s) were ignited in different positions with heptane placed in an open tray.

The fire positions took account of a 1973 USA study concerning the origin of fires in passenger cars involved in non-collision incidents, which found that 59% of the fires started from the engine and 35% from the passenger cabin. The figures do not include fires of unidentified origin, which comprised 17% of the passenger cars surveyed.

The aim of the experiments was to obtain a maximum rate of heat release curve for a car fire. Therefore, a rather high ignition source energy was used to ensure that the fires would grow to a fully developed stage. The role of possible smouldering phases in a car fire was not investigated in this study.

In the three experiments, doors and/or windows were left open to let the fire increase freely in accordance with the purpose of the experiments, which again may have exaggerated the heat release curve.

They found that:

1. The fires spread from the passenger cabin to the engine compartment within 12 minutes, and from the engine compartment to the cabin within 4-5 minutes. The simultaneous burning of the engine and the passenger cabin gave rise to a more intense rate of heat release.

2. Conditions within the cars deteriorated rapidly after approximately 8 minutes from ignition for fires started in the engine, but almost immediately for fires started in the cabin.
3. The fire tests showed that after approximately 10 minutes from ignition, about one-third of the windscreen collapsed, increasing fire in the passenger cabin. Twenty minutes later, fuel burned from the filler pipe mouth
4. The petrol in the fuel tanks burned in different modes in the experiments, but it was ignited between 20 to 29 minutes for the three different car models.
5. The fires developed rapidly with a fast spread from one part of the car to another after ignition in all experiments, and much smoke was produced throughout the burning.
6. Fire spread to other cars due to radiation was proved to be possible, at least if the window of the adjacent car was open.

The research and case studies lend support to the view that the rate of fire growth in vehicles varies considerably, permitting rescue in some cases and not in other cases.

7.3 Table 25: Vehicle Fires Case Studies

Cause	Location	Response Time	Casualties	Description
Accidental Collision	M4 motorway, rural area	16 mins.	10 dead 25 injured at least 1 rescue	<p>Just before seven o'clock in conditions of dense fog, early morning commuter traffic was streaming eastwards along the M4 motorway when a car suffered a tyre failure causing the vehicle to collide with, and scrape along the central crash barrier. The car came to a safe stop, but the sudden braking of in-coming traffic resulted in a succession of collisions involving 4 heavy goods vehicles and 46 light vehicles. The collisions caused fuel tanks to rupture, with the petrol finally being ignited to involve 33 cars, two 38-tonne articulated lorries and one 16-tonne rigid lorry in a severe fire.</p> <p>The local fire brigade received the first of a series of calls at 0655 hr, reaching the area of the accident at 0711 hr. The delay in fire attendance was a result of the difficulty in obtaining the exact location of the accident from members of the public reporting the incident.</p> <p>A brief evaluation of the conditions on the site indicated a large number of vehicles piled up with a fast-spreading fire situation. Three more pumps arrived at 0712 hr. The first crew concentrated on the rescue of a lorry driver (trapped in the cab with the vehicle alight), using one hosereel to check top spread, with a second hosereel holding back the flowing petrol fire.</p> <p>A second appliance arrived at 0715 hr to supplement the water supply (being a rural area, the nearest hydrants were located two miles away).</p> <p>Finally, the lorry driver was cut free just as the water supply failed. In total, 25 people were injured and 10 lost their lives. <i>(Fire Magazine, May 1991)</i></p>
Suicide	Suburban area, Nottingham	8 mins.	4 fatalities	<p>Fire brigade was called at 18: 10 hr to attend a vehicle fire outside a sports centre. On arrival at 18:18 hr, the car was completely engulfed in flames, with the front and rear windscreens lying on the floor intact. The fire was promptly discovered and the cause found to be deliberate ignition of petrol inside the car.</p> <p>This was supported by the pattern of the burning, which showed that the fire had originated within the passenger compartment. The undamaged condition of the windscreens pointed to a forceful explosion inside the car prior to the fire taking hold. The fatalities comprised a man and his three children.</p> <p><i>(Fire Prevention Magazine, June 1995)</i></p>
Collision	Suburban area (risk area D, Aberchaldar)	12 mins.	1 fatality	<p>An accidental head on collision between two motor vehicles on a roadway on the Aberchaldar Bridge resulted in a fire which started in the engine compartment. An abnormal rapid fire development ensued.</p> <p>The fire was reported within 5 minutes from the time the accident occurred and the fire brigade attended the site 12 minutes after receiving the call.</p> <p>One person died in the accident. <i>(Fire Investigation Report, 28th July, 1995, brigade incident no. 5358)</i></p>

8. CONCLUSIONS

It is concluded that:

1. The individual risk of fatality in vehicle fires is close to the level classed as negligible.
2. There is a relationship between fire brigade response times and fatality rates in car fires. A 5-minute nation-wide increase in fire brigade response times would give 12 more accidental fire fatalities per annum.
3. The time taken to discover and report a vehicle fire significantly affects the fatality rates.
4. The vast majority of accidental vehicle fires is discovered and reported in under 10 minutes in all areas, but the percentage discovered/reported after 10 minutes doubles in remote rural areas, from about 10% to 20%.
5. The rate of rescues falls greatly when abnormal fire development/explosions occur, but the majority of vehicle fires involving fire casualties do not involve abnormal fire development/explosions.
6. The relationship between fire brigade response times and fatality rates is not apparent in remote rural areas, although the small numbers of fires involved reduce the confidence that can be placed in this assertion. The relationship holds true for A, B, C and D risk areas.
7. The findings from the case studies, research and statistics are consistent.