Fire ReSPONSE TIME: EFFECTS ON LIFE SAFETY AND PROPERTY.

Response time and consequences on life safety, spread and damage based on UK fire statistics.

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Abstract

Fire brigade response time has substantial consequences not only on life safety but also on property protection. UK fire statistics datasets released by the Home Office from 2010 to 2017 is used to investigate real fire incidents. The analysis examines Dwellings and Other buildings. The response time is classified as presented in the UK fire statistics but also in one-minute classes to have a detailed understanding of the results. The fatality/casualty rate according to the response time in Other buildings is almost 1/4 than in Dwellings. Fire spread usually presents a peak of frequency around 6% in the class of spread limited to item first ignited for an average response time of approximately six minutes. Fire damage and total damage frequencies quantify the structural building response and are related to the fire brigade time of attendance. Fire response time and its implications on occupants and buildings increase the awareness on direct consequences, mitigations and preparedness strategies.

# Keywords: fire statistics, response time, fatality/casualty rate, fire spread, fire and total damage.

# 1 Introduction and methodology

In a fire event, the risk of trapped people being exposed to untenable fire and smoke conditions increases with the response time of fire departments. In the same way, the risk of property loss depends on how widely the fire and smoke may have spread in the building before fire brigades are able to extinguish them (Yung, 2008). There are several different steps between ignition and a successful fire fighter intervention: notification of the incident, fire-fighter dispatch, preparation, travel time, setup after the arrival at the fire scene, occupant rescue and fire extinguishment. Response time is defined as the time between the call being made (notification of incident) and the first fire vehicle attending the scene (Home Office, 2017) and it is a sum of dispatch preparation and travel time. In the UK, there are four categories of fire risk areas that fire services have to respond to roughly equating to: commercial and industrial city complex, centres of large towns, built-up areas of towns, and rural areas. For each risk area, there is a specified minimum level of brigade attendance and recommended response time in minutes (Dessent and Harwood, 1986). The quicker the intervention, the more effective the rescue and fire extinguishment efforts are (Yung, 2008).

Occupant fatalities mainly occur due to their exposure to toxic gases, while fire spread beyond the room of origin is potentially due to either a structural member experiencing collapse or a compartmentation failure. Fatalities and fire spread are both influenced by the presence of sprinklers, the materials that are involved in the fire, time of occurrence and fire brigade attendance time (Ramachandran and Charters, 2011). Structural members are, in general, designed to withstand a code-specified amount of time to a standard time-temperature, which is based on an idealised full burnout of the fuel scenario, and on life safety and property protection criteria.

Fire brigade attendance time is directly influenced by the travel distance and the travel conditions experienced during the journey. If an optimum number of fire stations is selected and their position situated, they will reduce the overall time between the notification of incident and arrival on site and minimize the total loss of fire in terms of life safety and monetary loss from fire spread (Hogg, 1968). This specific relationship is difficult to obtain because several other factors can have large influence on the life or property loss metrics, such as a delay in discovering and reporting fires, number of openings or the specific materials involved (Ignall, Rider and Urbach, 1979). Most of the management in the fire protection field uses response time in measuring performances and it is fundamental to know the effect of reduced response time on fire losses. Reducing response time is not only a way to improve fire protection but also saving money that could be spent on prevention, regular inspections or improved fire detection and suppression (Halpern, Isherwood and Wand, 1979).

Data on structural fire incidents are essential to investigate the relationship between response time, life safety and property loss according to different occupancy types and understand the building response subjected to fires. Previous studies have updated and compared BSI PD 7974-7 (BSI Standards Publication, 2003) about fire frequency, fire spread and area damage based on the presence or absence of automatic extinguish systems to USA fire statistics (Manes and Rush, 2018). In UK, the Incident Recording System (IRS) by the Home Office collects detailed information on every incident attended by fire and rescue services. Information is entered by fire and rescue services, using data collected by automatic systems and those present at the time of the incident. The Home Office publishes on a yearly based the *Fire and rescue incidents statistics* (Home Office, 2018a) and the *Fire incidents response time* (Home Office, 2018b). In the latter, it affirms that the overall response times to fires have increased gradually over the past 20 years from less than 6 to almost 8 minutes for Dwellings and to 9 minutes in Other buildings respectively in 1994/95 and 2016/17. Possible factors that contribute are changing traffic levels, health and safety policies and control staff typically asking more questions of the caller to better assess the risk. In Dwellings, from 2015/16 to 2016/17 there has been a decrease of 6% in fire-related fatalities and 5% in non-fatal casualties. The average area damage increased by 1% in Dwellings and decreased by 1% in Other buildings (Home Office, 2018b).

In this paper, UK Home Office datasets for Dwellings and Other buildings from 2010/11 to 2016/17 considering primary fires, have been used to evaluate the average response time and its relationship with life safety and damage. Response times have been analysed based on UK fire statistics classification and redefined according to 1-minute bands response time. Fatalities and casualties are recorded as a unique value, while, when fire spread is evaluated, a room or floor as recorded in the fire statistics, does not necessarily relate to a fire compartment. Dwellings have been considered according to *Single occupancy*, *Multiple occupancy* and *Others* while the classes for Other buildings classified with six general property types: *Commercial*, *Educational*, *Utilities*, *Industrial*, *Leisure* and *Miscellaneous*. The aim of this research is to evaluate how an increase in response time affects the growth and spread of fire in different buildings and how it influences the fatality/casualty rates according to UK fire statistics. [NB: overall classes underlined and sub-properties in Italics].

Table 1: UK fire statistics fields analysed

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| **Response time** | **Fire spread** | **Occupancy types** | **Fire - Total Damage [m2]** |
| 1-2 mins | No fire damage | Dwellings | 0 |
| 2-3 mins | Limited to item 1st ignited | *Single occupancy* | Up to 5 |
| 3-4 mins | Limited to room of origin | *Multiple occupancy* | 6 to 10 |
| 4-5 mins | Limited to floor of origin (not whole building) | *Others* | 11 to 20 |
| 5-6 mins | Limited to 2 floors | Other buildings | 21 to 50 |
| 6-7 mins | Whole Building/Affecting more than 2 floors | *Commercial* | 51 to 100 |
| 7-8 mins | Roofs/Roof space | *Educational* | 101 to 200 |
| 8-9 mins | Not known | *Utilities* | 201 to 500 |
| 9-10 mins | **Fatality and casualty** | *Industrial* | 501 to 1000 |
| 10-15 mins | Fatality/Casualty | *Leisure* | Over 1000 |
| 15-20 mins | None | *Miscellaneous* | Not known |
| 20-60 mins |  |  |  |

# 2 Analysis

## 2.1 Response time

Response time reported in UK fire statistics have been investigated to understand the average time spent from the fire brigade to reach the fire incident, considering the period from 2010/11 to 2016/17 in Dwellingsand Other buildings. The attendance times have been reclassified to 1 min bands instead of 5 minutes band after 10 minutes and 40 minutes band between 20 and 60 minutes (Table 1), and the number of fires grouped by the related time interval. Consequently, fire frequencies evaluated according to the number of fires for a specified response time divided by the total number of fires. In Dwellings, the different property types have been grouped according to three main classes: *Single occupancy* (sum of House – single occupancy, Bungalow – single occupancy and Converted Flat/Maisonette – single occupancy), *Multiple occupancy* (Dwelling – multiple occupancy, Purpose built low rise (1-3) Flats/Maisonette) and Purpose built high-rise (10+) Flat) and *Others* (Caravan/mobile home, Castle, Houseboat, Other dwelling, Self-contained sheltered housing, Stately home and Tenement building). The response time for the three classes of Dwellings appears to have the highest percentages (over 15%) in 5-6 and 6-7 minutes followed by 4-5 and 7-8 minutes with values bigger than 10% (Fig. 1). The average response time for *Single, Multiple*, and *Other* occupancies are 8.27, 7.10 and 7.94 mins, respectively.

In Other buildings, *Commercial, Educational* and *Miscellaneous* present similar percentages with the highest value in 5-6 minutes response time (16.33%, 16.42% and 14.72% respectively) followed by 6-7 minutes (16.17%, 16.12% and 14.39%) and 7-8 minutes (13.65%, 14.81% and 11.96%) as shown in Fig. 2. In *Utilities, Industrial* and *Leisure* the highest peak is reached in 6-7 minutes attendance time (13.73%, 14.41% and 16.52%) but while in *Utilities* and *Leisure* the second highest value is in the class of 5-6 minutes (12.24% and 16.11%), in *Industrial* this shifts towards 7-8 minutes (14.20%). The average response time for *Commercial, Educational* and *Miscellaneous* occupancies are 8.02, 8.19 and 9.14 mins, respectively, while for *Utilities, Industrial* and *Leisure* average response times are 9.24, 9.07 and 7.98 mins, respectively.

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Fig. 1 Fire frequency and response time - Dwellings

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Fig. 2 Fire frequency and response time - Other buildings

In both Dwellings and Other buildings, the fire frequencies that assume highest percentages are concentrated between 4-5 and 7-8 minutes response time. The differences are mainly represented by the class of 9-10 minutes attendance time which in Dwellings does not exceed 2% while in Other buildings is approximately greater than 7% with peaks of 9.17% in *Utilities* and 9.47% in *Industrial*.

## 2.2 Response time and fatality/casualty rate

In UK fire statistics, fatalities and casualties are not separated but reported as a unique record (Table 1). This analysis has collected the number of fatalities and casualties and divided them by the total number of fires per each response time class to obtain the fatality/casualty rate per fire as evaluated in the BSI PD 7974-4 for the discovery time in Dwellings (BSI Standards Publication, 2003).

In this research, the fatality/casualty rate in Dwellings presents similar trends for *Single occupancy* and *Multiple occupancy* where they begin from a value of 0.10 while *Others* start from a higher point of 0.23. Even considering this difference, the three occupancy types reach a plateau approximately around 0.16 from 3-4 to 7-8 minutes with small variations, followed by a slow decrease. In this view, the response time does not affect much the fatality/casualty rate for the different dwelling types in the plateau area while it has bigger influences in the first minutes attendance time and after 9-10 minutes usually fire brigades should have arrived at the fire scene and started the occupant rescue operations (Fig. 3).

In Other buildings, Fig. 4, in general, fatalities are less frequent, as would be expected approximately between 1/4 and 1/3 of the fatality/casualty rate of Dwellings. The *Commercial* and *Industrial* classifications assume similar linear type trends from 5-6 minutes response at around a 0.04 fatality/casualty rate. In *Educational* and *Leisure*, some response times present zeros in the number of fatalities and casualties and this is the reason why *Leisure* starts from 2-3 minutes and *Educational* from 3-4 minutes until ending at 15-20 minutes. Even if they present similar values from 5 to 7 minutes attendance time, the other fatality/casualty rates have wide scatter. Moreover, *Educational* shows a slight increase up to 7-8 minutes followed by a plateau with values approximately between 0.025 and 0.03. Finally, *Miscellaneous* and *Utilities* are the ones with respectively the highest and lower tendency where Miscellaneous greatly exceeds the other occupancy types while *Utilities* have few similar rates with *Leisure* (from 4 to 6 and from 10 to 20 minutes) as shown by Fig. 4.

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Fig. 3 Fatality/casualty rate and response time - Dwellings

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Fig. 4 Fatality/casualty rate and response time – Other buildings

Fatality/casualty rates investigated in Dwellings and Other buildings appear influenced by the response time especially in the first minutes while this factor affects less the tendency once reached 4-5 minutes attendance times. These considerations are well associated with different Dwellings while in Other buildings, similar comments are not applicable to all the different property types. Further investigations are necessary to highlight if differences are due to properties or to the nature of data.

## 2.3 Response time, fire spread and fire and total area damage

Response time (in 1-minute bands) is investigated according to fire spread, and fire and total damage (in m2) to understand its impact on structural response. Fire damage is defined as the total horizontal area damaged by the flame and/or heat while the total damage also includes smoke and water (in m2) at the stop of the fire (Home Office, 2017). Both in Dwellings and Other buildings, the response increases until 7 minutes and then decreases tending to zero for time greater than 20 minutes.

In Dwellings, the highest percentages of fire are found for no fire damage and limited to first ignited (5.36%-5.34%) in 6-7 minutes and for limited to room of origin (4.94%) for 5-6 minutes response time. The other classes of spread are lower than 2% and according to the percentages shown in Fig. 5, fire spread seems to be well confined within the floor of origin. When fire and total damage are investigated, for both the highest values are reached for the classes of 5-6 and 6-7 minutes response time and damage seems to be well confined to *Up to 5* m2. The classes of *0* and *6 to 10 m2* represent the second and third highest trends in fire damage (Fig. 6a). In total damage, the gap between them and the one of *Up to 5 m2* appear bigger with the consequence that greatest classes of damage assume bigger impact and influence on the response with values that increase from up to 1.5% in fire damage to up to 2% in total damage (Fig. 6b).

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Fig. 5 Fire spread and response time - Dwellings

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| (a) | (b) |
| **A**. 0 m2; **B**. Up to 5 m2; **C**. 6 to 10 m2; **D**. 11 to 20 m2; **E**. 21 to 50 m2; **F**. 51 to 100 m2; **G**. 101 to 200 m2; **H**. 201 to 500 m2; **I**. 501 to 1000 m2; **J**. Over 1000 m2 | |

Fig. 6 Response time and (a) fire damage and (b) total damage in m2 - Dwellings

In Other buildings, the highest percentages of spread are the ones related to limited to item 1st ignited, no fire damage and limited to room of origin generally in this order, where similar considerations as for Dwellings can be applied. Values for the highest peaks are reached around 5 and 7 minutes and never exceed 6%. In *Commercial*, the spread for fire affecting the whole building or more than two floors represent the fourth highest trend and it is not negligible for *Miscellaneous* properties (Fig. 7).

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| (a) | (b) |
| **A**. No fire damage; **B**. Limited to 1st ignited; **C**. Limited to room of origin; **D**. Limited to floor of origin (not whole building); **E**. Limited to 2 floors; **F**. Whole building/Affecting more than 2 floors; **G**. Roofs/Roof spaces | |

Fig. 7 Response time and fire spread for (a) *Commercial* and (b) *Miscellaneous*

For fire and total damage in Other buildings, the highest percentages are usually in the class of *Up to 5* followed by the one of *0 m2*. In total damage, the other classes of spread tend to increase and reach the second highest curve represented by *0 m2* of damage. The distributions appear right skewed and percentages never exceed 10% for fire damage and 9% for total damage. The form of the curves for the following elaborations are similar to those shown in Fig. 6 but are not presented in this paper.

*Commercial* and *Leisure* have similar trends with two close highest peaks for the class of damage *Up to 5* m2 in 5-6 and 6-7 minutes response time respectively of approximately average value 8.42% and 9.43% in fire damage and 7.18% and 7.89% in total damage. Furthermore, in total damage, the two peaks assume smaller values but higher classes of damage are greater than zero with values tending or exceeding 2% for percentages related to 6-7 minutes response time.

In *Educational*, the highest values are the ones for 5 to 8 minutes response time approximately of 9.29% in fire damage and 8.20% in total damage in the class of *Up to 5* m2. Again, higher classes of damage increase and are no more negligible when total damage is considered.

In fire and total damage, the values for the interval between 10 and 15 minutes response time assume respectively 2.63% and 2.74% in *Utilities* and 2.08% and 1.87% in *Industrial* in *Up to 5* m2, showing greater damage for response time bigger than 10 minutes probably due to larger fires.

Finally, in *Miscellaneous* two peaks of almost equal heights (around 8.73% and 7.70% between 5 and 7 minutes for fire and total damage) are reached again for the class of *Up to 5* m2. In total damage, the other classes of spread tend to reach the second highest trend represented by *0 m2*. Response time in fire and total damage mostly affects few m2 of damage due to a high number of small fires and low number of large ones. In total damage, more severe classes of damage become more and more significant with higher consequences on structures.

# 3 conclusions

The analysis presented within this paper shows that the response time frequency is at its highest between 5 and 7 minutes for both Dwellings and Other buildings but is well distributed between 4 and 9 minutes. In Other buildings, attendance time in 9-10 minutes is not negligible at over 5%.

For Dwellings*,* it was found that the fatality/casualty rates show similar trends with the response time influencing mostly the increase in tendencies up to 4 minutes followed by a plateau. In Other buildings, general considerations for all the property types are not applicable due to a more scattered distribution of rates but analogies could be found in different occupancies.

The trend for fire spread and response time increases up to a maximum around 6 minutes and tends to zero for response time bigger than 10 minutes. The highest values for the class related to no fire damage, limited to item 1st ignited and room of origin are from 5 to 7 minutes. In general, for both Dwellings and *Other buildings*, percentages of total damage are lower than the ones of fire damage but with greater classes of damage that increase in values and are no more negligible. In conclusion, response time seems to influence the factors studied in this research, especially in the first minutes after the notification of a fire where the effectiveness of fire brigade has its biggest impact.

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