



Updating the national average figures for likelihood and severity of harms for fire and explosions in English dwellings

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ABSTRACT

The Housing Health and Safety Rating System (HHSRS) allows English housing inspectors to evaluate the risk posed by 29 different hazards affecting the health and safety of occupiers in a given dwelling. HHSRS assessors use national average likelihood and spread of harm outcomes scores alongside hazard specific guidance to produce an overall dwelling hazard score, the magnitude of which indicates the risk to health and safety posed to the dwelling occupiers. This article describes how the average scores for likelihood and the spread of harm outcomes for the hazard of fire and explosions were updated as part of a wider review of the HHSRS. National data from ACORN, the English Housing Survey and Fire and Rescue Services were used to provide trend data and new annual figures for use in housing assessments. Results showed a steady decline in the likelihood of harm from fire in English dwellings since 2010/11. Class III harms were found to be lower than in the original HHSRS guidance while the percentage of class IV harms was greater. The overall reduction in risk from fire and explosions indicates that persistent regulatory attention and societal reductions in behaviours contributing to the risk of fire are having a positive impact on public health. The new averages will be used in an update of the HHSRS and subsequent regulatory work by local authorities across England, Wales and potentially the USA (who also use the HHSRS). Our methods may be adapted for use elsewhere.

Introduction

Morbidity and mortality from dwelling fires remains a significant public health concern in the UK. However, the total number of fires (of all types) attended by the English Fire and Rescue Services is decreasing. Reaching a peak of around 474,000 in 2003/4, the total number of fires has reduced to 241,462 in 2009/10 and then 154,000 in 2019/20. More recently, the number of dwelling fires attended have also shown a similar downward trend from 33,032 in 2009/12 to 26,484 in 2019/20 [8].

The fatalities and injury statistics from all fires, and accidental dwelling fires, have shown a similar downward trend. Thompson, Hulse and Galea [23] combined data from Fire and Rescue Services in England, Scotland and Wales to show all fire fatalities and accidental dwelling fire fatalities had reduced from 554 and 363 in 2000/01 to 367 and 237 in 2015/16. Thompson et al. also found that all categories of fire related injuries and accidental dwelling fire injuries had reduced from 16,542

and 11,263 in 2000/01 to 9493 and 6490 in 2015/16.

The overall public health risk from fires has reduced as the number of reported fires has decreased over time, but once a fire has occurred the rates of fatalities and injuries have remained at similar levels since 1999. The fatality rate once a dwelling fire has started remains between 0.63 and 0.72 per 100 fires. The situation is similar for non-fatal casualties, with injury rates remaining between 17.6 and 20.6 per 100 fires [23].

The most common recorded cause of English fire-related fatalities in 2019/20 was 'overcome by gas or smoke' (responsible for 32 % of fatalities) followed by 'burns alone' (30 % of fatalities) and the combination of both (21 % of fatalities), 17 % other/unspecified [8].

Behaviour related factors are a common cause of accidental dwelling fires in England. Cooking appliances were the largest ignition source (48 % of fires in 2019/20, responsible for 14 % of fatalities) and misuse of electrical equipment accounted for 34 % of fires. Food was the material mainly responsible for the development of fire in 20 % of dwelling fires (but these were only linked to 3 % of fire-related fatalities). Smoker's

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materials caused 7 % of fires in 2019/20 but these were linked to the greatest proportion of the fire-related fatalities (23 %) [8].

Those over-represented in English fire related mortalities include:

- under 5 s and those over 65 years of age,
- those with a cognitive or physical impairment,
- those whose behaviour makes them less likely to recognise and respond to fire (including drink and drug use),
- those who live with social isolation,
- smokers, and
- those living in areas of deprivation.

[23].

The link to deprivation can be explained by a range of factors associated with disadvantaged areas and those who live within them, including smoking prevalence, housing quality and maintenance. The greater representation of elderly residents in fire related morbidity and mortality figures can also be accounted for by multiple factors including living alone, reduced access to fire safety advice, and diminished ability to recover from fire-related injuries [23].

For professionals visiting dwellings and assessing the risk to health from fire, the current trends are a testament to their work to reduce fire related harms. In England Environmental Health Private Housing Officers, Fire and Rescue Services, Building Control Officers, and a national building regulator for tall buildings all share responsibility for ensuring continued public awareness of the risk posed by fire and continued improvements to buildings including fire separation and detection in new and existing dwellings.

The process of assessing the level of risk posed by fire is complex, involving a range of interacting elements. Since the 2017 Grenfell Tower disaster, levels of awareness and knowledge of fire safety and risk reduction measures amongst UK construction professionals have improved, assisting the public health response to this hazard. The disaster has raised the profile for fire safety in England, sensitising the population to the risk posed by fire. Grenfell has also resulted in significant negative media coverage highlighting both construction technology issues and classism in the causes of the fire. The disaster appears to have its underlying causes in a wide range of factors relating to the fire safety testing and use of construction materials, oversight of building refurbishment, designation of responsible persons, and the response to fires in flats by the Fire and Rescue Service. The incident and ensuing investigation have highlighted inadequacies in the regulatory regime used to manage the risk from fire in new and existing dwellings [17].

One of the key regulatory tools used to assess the risk from fire in existing dwellings is the Housing Health and Safety Rating System (HHSRS) [20]. The system has been in use for 19 years and concerns were raised over the age of some of the data underpinning the system [3]. The political fallout resulting from the Grenfell Tower disaster accelerated a programme of work intended to update the HHSRS. This article describes one part of that update. It sets out the process used to update the national average scoring values for the hazard of Fire and Explosions in dwellings, as part of the wider update of the HHSRS and its associated Operating Guidance.

1.1. The housing health and safety rating system

The HHSRS allows housing assessors to evaluate the risk posed by 29 different hazards affecting the health of occupiers in residential accommodation. Assessors using the system identify elements of a dwelling which are less than the ideal for safety and health due to their design, maintenance, or condition. The system refers to these as 'deficiencies' [20].

The cumulative impact of deficiencies is used to judge the risk to health from a given hazard, by deciding how they will alter the likelihood of a harmful occurrence due to that hazard over the 12 months following the inspection. The assessor also determines the severity of

potential harm outcomes for someone living in the dwelling. Harm outcomes are broken down into classes I to IV, where class I is the most severe and class IV is the least severe outcome still requiring some form of medical attention. The likelihood and harm outcome scores are put into a formula to produce an overall risk score for the hazard, the magnitude of the score indicates the level of risk posed by the hazard (ibid).

For each hazard being assessed, the HHSRS Operating Guidance provides national average scores and general information about the hazard including health effects, causes, preventative measures and dwelling related factors aggravating or mitigating the threat from that hazard. This is used to support the assessor in judging the likelihood of a harmful occurrence and spread of potential harm outcomes for the dwelling for the hazard being assessed. The national average values are broken down by dwelling type and age and have been determined using statistical analysis of national datasets. The supporting information provided in the hazard profiles is based on a review of the literature for each of the 29 hazards (e.g. falls, damp, fire, food safety, indoor air pollution, etc.) (ibid).

The HHSRS has been enshrined in law in England and Wales by the Housing Act 2004 and has been adopted by the US Department of Housing and Urban Development under the alternative title, the Healthy Home Rating System [13].

In 2017 the Chartered Institute of Environmental Health published the findings of a survey of their membership on HHSRS in which 97 % of respondents supported an update of the system. Sixty-two percent of respondents considered HHSRS to be an improvement on the checklist of fixed criteria it replaced (known as the Housing Fitness Standard), however only 55 % wanted to retain the existing risk based HHSRS approach. Respondents opposed to the risk assessment approach argued that the HHSRS was overly complicated and difficult to understand for those without training in the system. The most recent sources in the HHSRS Operating Guidance were from 2003, which led to criticism about the age of the data underpinning the system [3].

In 2018 the Office of the Deputy Prime Minister launched a scoping exercise to consider whether the HHSRS should be updated and to what extent. Using the results of this process a two-year review was initiated in 2020. This review took its direction from extensive public consultation, informing the activities of a consortium of universities, legal practices and consultants drawn together under a private contractor to execute the review for the government's Department of Levelling Up, Housing and Communities. Their activities resulted in the updating of the evidence base, hazard scoring methods, guidance documents, training for assessors, and the worked examples used to support the system. A list of standards was also produced which, once met, would mean a property would be very likely to be free of Category 1 hazards (those with high scores indicating substantial levels of risk).

The Operating Guidance for HHSRS assessors is designated as statutory guidance. This means that assessors are required to have regard to the guidance in their use of the system. The HHSRS review made large changes to this document including an update of the national average likelihood of harm estimates. These scores are provided for every hazard and give an indication of the likelihood of the hazard causing a harmful occurrence at an average property, providing an initial reference point for scoring decisions [4].

The HHSRS was being used to support remedial action to improve fire safety in buildings. The legal powers to require these works rested with local authority Environmental Health Officers. Individual local authorities and a national Joint Inspection Team were carrying out risk assessments which resulted in large scale works being required to high rise residential buildings.

To support these inspectors, an addendum providing further guidance on fire risk assessment in tall buildings was created for the original Operating Guidance [15] but the national average scores and hazard profile for the hazard of Fire (based on pre-2003 sources) were retained. This increased the pressure to update the English housing stock's

national average HHSRS scores for Fire. As part of the HHSRS update the hazards of Fire and Explosions were amalgamated to simplify risk assessments and both the national average likelihood scores for a harmful occurrence and the spread of potential harm outcomes were updated.

1.2. Statement of purpose

This research was done as part of the project to update the estimates of likelihood of harm from hazards included in the HHSRS for England. The purpose of the research specifically described in the current paper was to update the likelihood estimate for harm from fire and explosions. The scope of the research was for dwellings including one or more dwellers aged 60 years or over in England. The main objectives of the research were to:

- Determine the trend for the likelihood of harm from fire in flats and houses from 2011 to 2020.
- Predict the likelihood of harm from fire in flats and houses in 2022.
- Determine the likelihood of harm from fire and explosions for flats and houses in 2022.
- Determine the trend for the spread of harm outcomes from fire in flats and houses from 2011 to 2020.
- Predict the spread of harm outcomes from fire in flats and houses in 2022.
- Determine the spread of harm outcomes from fire and explosions for flats and houses in 2022.

The HHSRS uses likelihood and spread of harm estimates for the age group considered to be most at risk for each of the different hazards. The age group of interest to fire and explosions is those aged 60 years and above. This is the age group deemed to be at greatest risk from fire. Estimation of likelihood of harm from a hazard requires us to determine two values. The first of these is the number of dwellings that contain occupants of the relevant age group in England. The second value is the number of harms from suffered by dwellers in the relevant age group in a 12-month period in England. Dividing these two numbers gives us an estimation for the likelihood of harm in the form 1 in N. The HHSRS classifies harm into class I, II, III and IV harms which are defined as follows:

- Class I harms – these include fatalities, permanent paralysis below the neck, malignant lung cancer, permanent loss of consciousness, and 80 % burns.
- Class II harms – these include stroke, loss of hand or foot, serious fractures, serious burns, and loss of consciousness for days.
- Class III harms – these include loss of a finger, malignant but treatable skin cancer, fractured skull, severe concussion, serious puncture wounds, and severe burns to the hands.
- Class IV harms – these include occasional severe discomfort, chronic skin irritation, some benign tumours, moderate cuts to the face or body, severe bruising to the body, and 10 % burns.

The expected harms from harmful event are split into percentages of harms at each class of severity (e.g. 90 % class 1 and 10 % class 2 for a fall from a fourth storey window) to give the spread of harms. Harms that are less serious than class IV harms are not included in the HHSRS statistics as data on lower levels of harms is not usually captured through national data sets (for instance such harms would be unlikely to result in a visit to a doctor's surgery). The spread of harm for a hazard is expressed as the percentages of included harms that are class I, II, III and IV harms. The 2003 HHSRS determined the likelihood of harm and spread of harm for fire and explosions shown in [Table 1](#).

Table 1

Likelihood and spread of harm for those over 60 years of age for fire and explosions taken from the Operating Guidance for the 2003 HHSRS [20].

Dwelling type	Dwelling age	Annual average likelihood (1 in)	Spread of harm			
			Class I (%)	Class II (%)	Class III (%)	Class IV (%)
<u>Fire</u>						
Houses	Pre 1920	4496	8.7	3.2	35.4	52.7
	1920–45	6248	10.2	5.1	15.6	69.1
	1945–79	6341	5.4	4.3	31.8	58.5
	Post 1979	5701	5.7	0.0	32.8	61.5
Flats	Pre 1920	1681	5.6	0.0	27.7	66.7
	1920–45	3372	5.6	0.0	27.7	66.7
	1945–79	2729	6.0	0.0	26.5	67.5
	Post 1979	2157	3.1	0.0	17.2	79.7
All		4760	7.0	2.6	29.1	61.3
<u>Explosions</u>						
All		156,528	11.2	0.0	5.4	83.4

2. Methods

2.1. Research design

Data were gathered and analysed to estimate the number of harms suffered by persons aged 60 years and over in dwellings in England as well as the number of dwellings in England where at least one person aged 60 years or over lived. Dividing the number of harms into the number of dwellings determined a likelihood estimate for harm from fire. Harms were also classified into the four levels of harm used by the Housing Health and Safety Rating System (HHSRS) in England. This estimation of likelihood of harm and spread of harm was done for a ten-year period from 2011 to 2020. This allowed a trend to be analysed using linear regression so that estimates for 2022 could be made. The harm from fire was then amalgamated with harm from explosions and separate likelihood estimates were determined for flats and houses. The process of estimating likelihood of harm was validated using an alternative data set.

2.2. Data sources

The current research required two main types of data. Firstly, data about the national housing stock and dwellers was required. Permission was granted to use the ACORN lifestyle database [2] for this part of the analysis. This is a large commercial marketing data set that classifies households into 61 different “ACORN types” characterised within pen portraits which include the age range of the primary dweller, the number of adults in the household, the number of children in the household, and the type of dwelling (e.g. detached house, flat, etc.). The ACORN data include the following details for each postcode in the UK:

- the ACORN type of the typical dwelling,
- the total number of dwellings, and
- the total population.

The ACORN lifestyle database does not specify total numbers of dwellers of different age groups. It was, therefore, necessary to use population estimates from the UK Office of National Statistics [21]. The ONS population estimates include the number of people of different ages in each of the 374 local authority districts in the UK, including 309 English local authority districts. The data set contains the number of people of each age to the nearest year (0 to 90+) for each calendar year from 2001 to 2020 for each local authority district.

The second main type of data required in the current research was about harm from fires and explosions. Permission was applied for and

granted to use fire and rescue data for the ten-year period from 2010 to 2020. Contact was gained through the email address fire-statistics@homeoffice.gov.uk. The researchers were required to explain the intended use of the data and how it would be managed then confirm its deletion at the end of the project. There were separate data sets for non-fatal casualties [9] and fatalities [10]. There were 60,553 records for non-fatal casualties (24,388 of these being multiple casualty incidents) and 2215 records for fatalities during the ten-year period. The non-fatal casualty records included the type and severity of injury suffered. Both of these data sets classified victim age as under 1, 1 to 5, 6 to 10, 11 to 16, 17 to 24, 25, to 39, 40 to 54, 55 to 64, 65 to 79, 80 or over, or unspecified.

Further data were used to validate the likelihood estimates for fire. These were secure access data for fire incidents for which special permission had to be applied for and granted [11] and [12]. Like the original fire and rescue data set used in this project [9] and [10], the secure access data were for fire incidents from 2010 to 2020. The data set consisted of two files. Firstly, there was a file of fire incident records [11] which included details such as financial year, incident number, property type and post code among other fields. These details had been recorded for 319,223 fire incidents over the ten-year period. Property type used eight values which are listed below:

- Bungalow – single occupancy.
- Converted flat / maisonette – single occupancy.
- Dwelling - multiple occupancy.
- House – single occupancy.
- Other swelling.
- Purpose built high rise (10+) flats.
- Purpose built low rise (1 to 3) flats.
- Purpose built medium rise (4 to 9) flats.

The second file contained details for 74,160 incidents over the ten-year period where there were victims [12]. The details for victims included incident number, whether harm was fatal or not, the victim's age, injury type and injury severity.

The likelihood of harm from explosions used the value reported in the 2003 HHSRS. However, further data about harm from explosions were used to validate this. This data came from hospital episodes in 2019–20 [19]. The hospital episode records included fields for age of patient and cause of hospitalisation. These causes included explosion and rupture of a boiler, rupture and explosion of a gas cylinder, and explosions involving of other materials.

3. Data analysis

3.1. Estimating the number of dwellings

The ACORN lifestyle database for 2020 and ONS population estimates for 2011 to 2020 were used to estimate the number of dwellings in England containing occupants aged 60 years or over. The total number of dwellings and total number of dwellers in England was summed for each of the 59 domestic ACORN types. There are two additional ACORN types that do not represent residential dwellings and were not included in the current analysis.

It was necessary to estimate the number of dwellings that contain dwellers of the different age groups of interest to the HHSRS. This paper is concerned with a single age group which is those aged 60 years or above. However, determining the number of dwellings containing dwellers aged 60 years or above was done within the same analysis of the ACORN data set that determined the number of dwellings containing dwellers of each of the other age groups used in the HHSRS. Thus, it is necessary to describe the process of determining the number of dwellings containing dwellers of each age group of interest in order to explain where the specific value used in the current paper came from.

Having already summed the number of dwellers and dwellings in

each of the 59 domestic ACORN types in England, the mean number of dwellers per dwelling for each of these ACORN types was determined. This was done by simply dividing the number of dwellers by the number of dwellings. The next step was to determine the number of dwellings of each ACORN type of different household sizes. Two discrete probability distributions that are relevant here are Binomial and Poisson distributions. Binomial distributions are appropriate where there is a stated maximum household size in a dwelling type. Where a fixed upper limit cannot be assumed, household size can be represented by Poisson distributions. There were 7 ACORN types where the pen portrait descriptions indicated a maximum of 2 dwellers per household, 13 ACORN types where the maximum household size could be assumed to be 3 persons and 1 ACORN type where the maximum household size could be assumed to be 4. For each of these ACORN types, the number of dwellings of each household size was assumed to follow a binomial distribution. For example, if the mean number of dwellers per dwelling for a given ACORN type was 2.17 and the maximum household size for the ACORN type was 3, then the probability of a randomly selected dwelling having 1, 2 or 3 dwellers was assumed to be probability 0, 1 or 2 successful trials out of 2 when the binomial distribution had a mean number of successful trials of 1.17. This ensured that there would be at least one dweller per dwelling. The remaining ACORN types allowed for the possibility of larger household sizes. Therefore, the number of dwellings with different numbers of dwellers was assumed to follow Poisson distributions. However, the probability of a randomly chosen dwelling having a household size of 8 or more was negligible (<0.025 for each ACORN type). Therefore, a maximum of 8 dwellers per dwelling was assumed. Consider an ACORN type where the mean number of dwellers per dwelling is 2.63. The minimum number of dwellers per dwelling was assumed to be 1. Therefore, the probabilities of a randomly chosen dwelling containing 1, 2, 3, 4, 5, 6, 7 or 8+ dwellers were 0.196, 0.319, 0.260, 0.141, 0.058, 0.019, 0.005, and 0.001 respectively. These values came from the probabilities of 0 to 7+ successful trials from a Poisson distribution with a mean of 1.63. These probability distributions combined with the total number of dwellings of each ACORN type in England allowed the total number of dwellings with different numbers of dwellers to be determined for each ACORN type.

Having estimated the number of households of different sizes for each ACORN type, it was necessary to determine the breakdown of these household sizes into different age groups. There were 7 different age groups which could be used in isolation or combined to form the age groups of interest to the HHSRS. These were under 3 years, 3 to 4 years, 5 to 14 years, 15 to 17 years, 18 to 59 years, 60 to 64 years and 65 years or older. The pen portrait descriptions of the ACORN types indicated the numbers of adults and children that households could be made up of. However, this was not in sufficient detail to calculate the number of dwellers in each age group that would make up a household of a given size for a given ACORN type. Therefore, the expected number of dwellers within households that were of different age groups had to be estimated. Consider an ACORN type where household sizes could be between 1 and 8, where the primary dweller is aged between 45 and 64 years, and where there may be children aged between 5 and 17. Where the household size is 1, we could estimate that the expected number of 18 to 59 year olds and 60 to 64 year olds is 0.3 and 0.7 respectively. This means that the occupiers living in 70 % of such dwellings are aged between 60 and 64 years. Where the household size is 5, we could estimate the expected numbers of dwellers aged 5 to 14 years, 15 to 17 years, 18 to 59 years, and 60 to 64 years is 2.9, 0.6, 0.6 and 0.9 respectively. This allows for one, two, or more adults within the household with differing numbers of children in two broad age groups. The omission of age groups under 5 years and the 65 years and older age group is based on the pen portrait description of the ACORN type. These expected values were entered into a spreadsheet for each household size for each of the 59 domestic ACORN types. The total number of dwellers and dwellings for each ACORN type, as well as the Poisson or binomial distributions for household sizes were also entered into this spreadsheet. The spreadsheet

was then programmed to determine the total number of dwellers of each of the 7 age groups for each of the 59 domestic ACORN types. This required 59 separate grids of 7 rows (one for each age group) and 8 columns (one for each household size). The total number of dwellers of each age group was summed from the 59 ACORN types.

The grand total for the number of dwellers and dwellings in England matched the corresponding totals of 55,292,359 and 23,459,023 respectively that was determined from the ACORN data set. It was necessary to check that the total numbers of dwellers in each age group were consistent the total number of people in these age groups living in England. This was done by comparing the totals derived from the processing of the ACORN data with population estimates from the UK Office of National Statistics for 2020 [21]. The total population of England in 2020 according to the ONS data was 56,550,138. Therefore, the values for each age group needed to be scaled down by $55,292,359 / 56,550,138$ to allow a comparison with the totals estimated during the processing of the ACORN data set. There were some minor differences between the totals for each age group according to the ONS and the processing of the ACORN data set. Therefore, the estimates of expected numbers of dwellers in some combinations of age group, household size and ACORN type were adjusted until the national percentage for each age group that was derived from the expected values differed by no $>0.5\%$ to the corresponding scaled value from the ONS population estimates.

This process estimated that there were 13,510,870 dwellers aged 60 years or over when the population of England was assumed to be the total from the ACORN data of 55,929,359. It also estimated that 8321,143 of the 23,459,023 dwellings in England contained at least one dweller aged 60 years or over. It was necessary to determine the number of dwellings containing dwellers aged 60 years and above in each year from 2011 to 2020. The ACORN data set did not provide totals for the number of people of different ages. Therefore, the number of dwellings containing at least one person aged 60 years or above was estimated by scaling it based on the population in the given year. For example, in 2020, the number of dwellings occupied by residents aged 60 or above was estimated by scaling up the 8321,143 derived from the ACORN data set by a factor of $56,550,138 / 55,929,359$ giving 8413,502. Fig. 1 shows the estimates for the number of dwellers of different ages living in different household sizes in 2020. Table 3 shows the values for the

remaining years.

3.2. Estimating the number of harms from fire

The number of harms from fire was estimated using fire and rescue data [9] and [10]. Records for victims of fires in dwellings who were aged 60 years or over were used to estimate the likelihood of harm in each of the 10 years from 2010–11 to 2019–20. There were 24,388 of the 60,553 non-fatal fire incidents that were multiple casualty incidents with 36,165 being single casualty incidents. The classification of harm in the fire and rescue data was different to the class I to IV classification used in the HHSRS. Therefore, the classification of cases into class I to IV harms was based on the type and severity of injury as shown in Table 2. This classification scheme was created during a review process by the authors. There were 47,579 of the non-fatal 60,553 fires in dwellings over the ten-year period considered to involve class I to IV harm. Where an injury type and severity were classed as representing class I/II harm, 50 % of such cases were assumed to be class I harms with the remaining 50 % assumed to be class II harms. The excluded cases were for some injury types that did not involve hospitalisation.

The age groups from the Home Office fire and rescue data were combined into 4 broader age groups, under 55, 55 to 64, 65 or over, and unspecified. The cases of unspecified age of victim were redistributed assuming they had the same distribution within the given year as those of specified age. The cases of unspecified ages were redistributed for the fatalities and non-fatal injuries assuming the same distribution as cases of known age category. The fatalities were then added to the class I non-fatal harms. The number of class I to IV harms to victims aged 60 or over required an estimation of how many of those aged between 55 and 64 years were aged 60 years or over. This used knowledge of the wider population in England [21]. The proportion of 55- to 64-year-olds in the wider population that were aged 60 years or older was applied to the number of harms from fire suffered by those aged 55 to 64 years. This gave an estimate for the number of harms from fire suffered by those aged 60 to 64 years in each of the 10 years. The resulting estimates for harms to 60- to 64-year-olds were added to the harms for those aged 65 years or older to give the values for those aged 60 years.

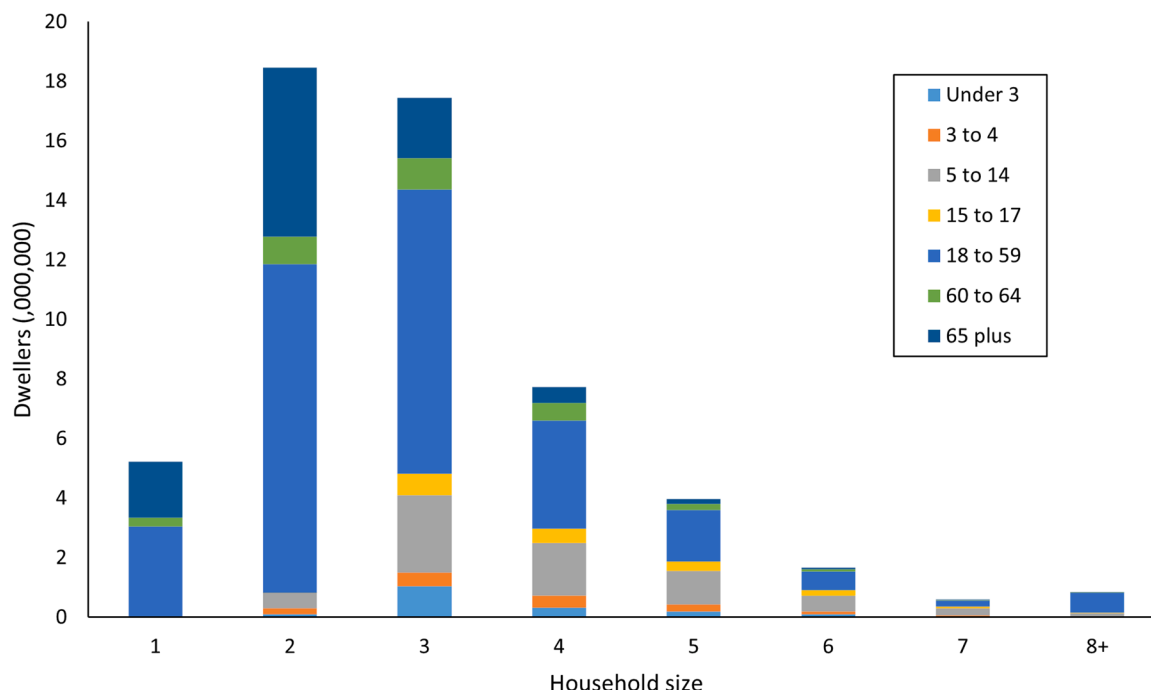


Fig. 1. Estimated numbers of dwellers of different age groups in different household sizes in 2020.

Table 2

Classification of fire injuries as class I to IV harms using injury type and severity.

Injury type	First aid	Hospital severe	Hospital slight	Precautionary checks
Back/Neck injury (spinal)		I	II	
Bruising		III	IV	
Burns – severe	III	I	II	III
Burns – slight	IV	IV	IV	IV
Chest pain/Heart condition/Cardiac arrest	IV	I/II	III	IV
Chest/Abdominal injury	IV	II	III	IV
Collapse		III	IV	
Combination of burns and overcome by gas/smoke		II	III	
Cuts/Lacerations		III	IV	
Fracture	IV	II	III	IV
Head injury		I/II	IV	
Not known		III	IV	
Other		III	IV	
Other Breathing difficulties		III	IV	
Other medical condition		III	IV	
Other physical injury		III	IV	
Overcome by gas, smoke or toxic fumes; asphyxiation	IV	III	IV	IV
Shock/Anaphylactic shock	IV	II	III	IV
Unconscious, fitting or unresponsive (no other evident significant injury)	IV	II	III	IV

3.3. Estimating the likelihood of harm from fire

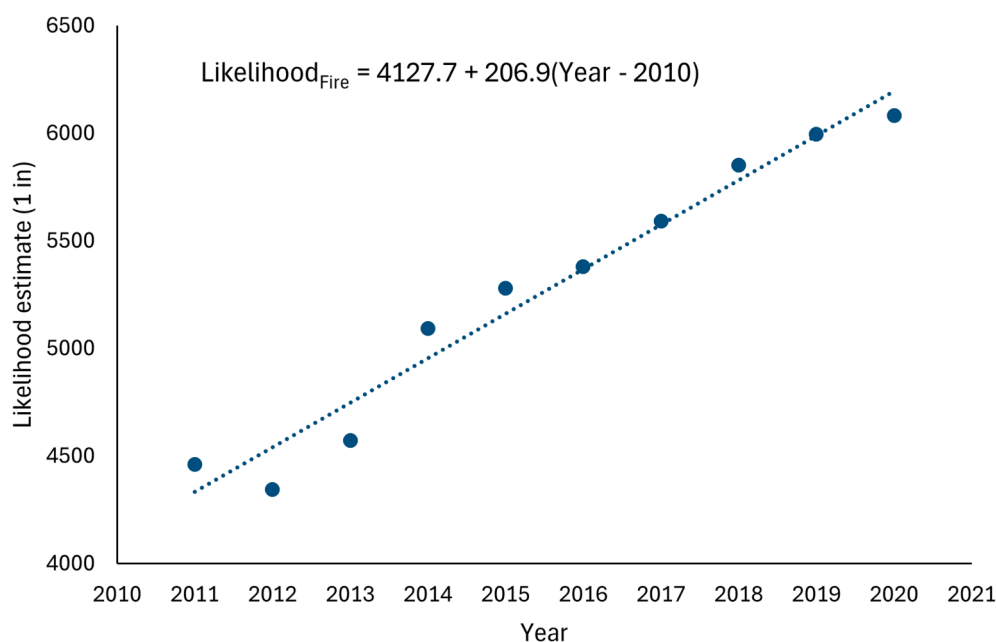
The likelihood of harm from fire to dwellers aged 60 years or older was determined by dividing the harms from fire to those aged 60 years and over into the number of dwellings in England with at least one dweller aged 60 years or older. This was done for each of the 10 years.

The trend in harms from fires was explored using curve estimation in

SPSS version 28.0.1.1 (IBM, New York). This showed that a linear trend fitted the likelihood estimates more significantly than quadratic, cubic, logarithmic and inverse models. Therefore, linear regression was used to predict likelihood of harm from fire for 2022. The regression equation for likelihood of harm from fire ($\text{Likelihood}_{\text{Fire}}$) is shown in Fig. 2.

3.4. Validation of the likelihood estimates

The likelihood estimates were validated using a more detailed fire and rescue data source that represented age of victim to the nearest year rather than in broad categories [11] and [12]. The file of victim details was processed in a similar manner to the original analysis of likelihood of harm. The same classification of harms based on injury type and severity (Table 2) was applied to the validation data set as to the original data set. Counting victims as aged 60 or over was more straightforward during the validation process because age was expressed to the nearest year. Cases where the age of the victim was not specified were redistributed for each of the 10 years. For each year, it was assumed that the proportion of cases with unspecified age that were 60 years or older was the same as the proportion of cases where ages were known. The estimated number of harms was divided into the estimated number of dwellings containing one or more dweller aged 60 years or over as before. Fig. 3 shows the regression model produced from fire and rescue data. Percentage error between corresponding likelihood estimates was calculated by expressing the absolute difference between these values as a percentage of the mean of the two values. The percentage error between the number of harms determined by each approach ranged from 0.88 % to 3.21 % over the ten-year period. The mean of the 10 percentage error values is 1.51 % which represents an acceptable level of absolute reliability between the two methods. The relative reliability was very good with the two sets of harm values having a correlation coefficient of +0.998. The differences in harm frequencies between the two methods can be explained by two reasons. Firstly, the data used to determine the likelihood estimates classified age into broad age groups whereas the number of 55- to 64-year-olds who were over 60 had to be estimated assuming a similar distribution to the population of England. Age was specified to the nearest year in the secure access data used in the validation study. Secondly, there were differing numbers of cases where the victims were of unspecified age between the two data sets.

**Fig. 2.** Trend for the likelihood of harm from fires.

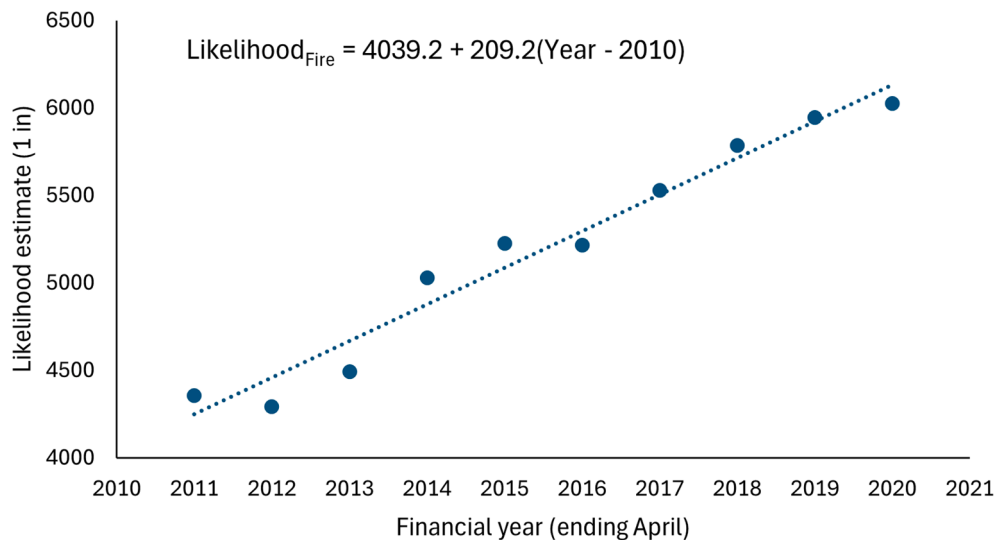


Fig. 3. Trend for likelihood of harms from fire using Fire Service data.

3.5. Likelihood of harm in different types of dwelling

The incident number of the secure access fire data permitted the dwelling type to be augmented to the victim details file. Bungalows and houses were counted as houses while converted flats, maisonettes, and purpose-built flats were counted as flats. Other dwellings and dwellings of multiple occupancy could be either houses or flats. These were redistributed using the proportions of cases where dwelling had already been classified as flat or house. The ACORN data gave an estimate of 8321,143 dwellings in England containing at least one person aged 60 years or over. There were 7168,896 of these dwellings deemed to be houses with the remaining 1152,247 deemed to be flats. These values were based on the ACORN estimate of the population of England which was 55,929,359. Therefore, estimates of the likelihood of harm from fire needed to scale the numbers of houses and flats where at least one person aged 60 or over lived by the population of England in the given year divided by 55,929,359. The estimated number of harms was divided into the estimated number of dwellings containing residents aged 60 years or over to obtain a likelihood estimate for each class of

dwelling in each of the 10 years. Curve fitting was done to explore the trend in likelihood of harm from fire for houses and flats. The linear model shown in Fig. 4 was the most significant ($p < 0.001$) for houses ahead of logarithmic, quadratic, cubic and inverse models. However, for flats the logarithmic model shown in Fig. 4 was more significant ($p = 0.000544$) than the linear model ($p = 0.000558$). These models were used to predict the likelihood of harm from fire to those aged 60 years and over in houses and flats respectively.

3.6. Amalgamation of the likelihood of harm from fire and explosion

There was no equivalent data set to the Home Accident Surveillance System (HASS) data that was used to determine the likelihood of harm from explosions in the 2003 HHSRS. Therefore, a similar likelihood of harm from explosions was assumed in 2022. The Operating Guidance for the 2003 HHSRS did not distinguish between dwelling type when showing the likelihood and spread of harm from explosions. Therefore, the same likelihood of harm from explosions was assumed for houses, flats and dwellings overall. This likelihood estimate was validated

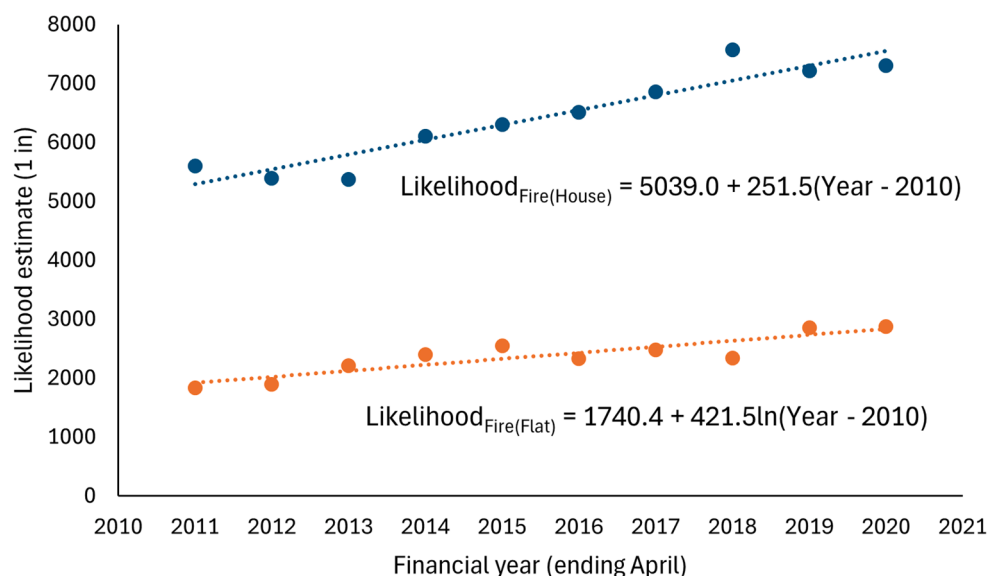


Fig. 4. Trend in likelihood of harm from fire in houses and flats.

against an alternative source for hospital episodes in 2019–20 [19]. Hospital episodes with unspecified age of victim were redistributed proportionately leading to harm estimates not being whole numbers. There were 53.2 hospital episodes where the patient was 60 years or over and the cause of hospitalisation involved an explosion. These were 1.0 case due to an explosion and rupture of a boiler, 16.2 cases due to rupture and explosion of a gas cylinder and 36.0 cases due to explosion of other materials. The number of hospital episodes caused by explosions was divided into the number of dwellings containing at least one person aged 60 years or over in 2020 to determine the resulting likelihood of harms from explosions. The percentage error between this and the likelihood estimate from the 2003 HHSRS was 0.2 %. This was low enough to justify combining the likelihood of harm from explosions from the 2003 HHSRS with the updated likelihood of harm from fire. Assuming fires and explosions are independent, the probability of harm from either fire or an explosion is given by Eq. (1), where $Likelihood_{Hazard}$ represents the likelihood of harm for the given Hazard. The likelihood of the combined fire and explosion hazard leading to harm in a dwelling to persons aged 60 or over is the reciprocal of this probability. The same equation was applied to determine the amalgamated harm from fire and explosions for flats and houses.

Probability(harm from fire or explosion to dweller aged 60 or over =

injury. The type of dwelling had already been reclassified broadly into flat or house when estimating the likelihood of harm for different types of dwelling. Some fractional values for non-fatal class I and class II harms resulted from splitting odd numbers of harms deemed “I / II” level harm. As when determining the likelihood estimates, the estimation of the spread of harm distributed cases of “other” dwellings proportionately between flats and houses for each year. The cases of unspecified age were also redistributed proportionately as 60 years or over or under 60 years for each year. The numbers of class I to IV harms for each type of dwelling in each of the 10 years were converted into percentages for the given years. Curve estimation was used to explore trends in the percentage of class I, II, III and IV harms in terms of year. The most significant trend models of class I and class IV harms were linear models for flats (class I harm: $p = 0.040$, class IV harm: $p = 0.027$), houses (class I harm: $p = 0.042$, class IV harm: $p = 0.002$), and dwellings as a whole (class I harm: $p = 0.004$, class IV harm: $p = 0.002$). None of the trend models for class II or class IV harms were statistically significant ($p \geq 0.160$) with three of the six best fitting models for class II to III harms being linear, two being quadratic and one being logarithmic. Given the predominantly linear trends and to ensure any predicted spread of harm for 2022 added up to 100 %, linear regression was applied to the percentage of each class of harm for flats, houses and dwellings as a whole. The regression models for the percentage of harms of each class in dwellings overall are shown in Fig. 5. Corresponding models for flats and

$$(1 / Likelihood_{Fire}) + (1 / Likelihood_{Explosion}) - (1 / (Likelihood_{Fire} \times Likelihood_{Explosion})) \quad (1)$$

3.7. Estimating spread of harm

The number of class I to IV harms from fire were determined from the secure access fire and rescue data. This involved applying the classification scheme for harms shown in Table 1 to the type and severity of

houses are shown in equations Figs. 6 and 7 respectively.

The updated HHSRS amalgamated the fire and explosion hazards. The spread of harm for fire and explosions was determined using Eq. (2) which weighted the harm of each of these hazards by the likelihood of occurrence. This was done for all 4 classes of harm for flats, houses and

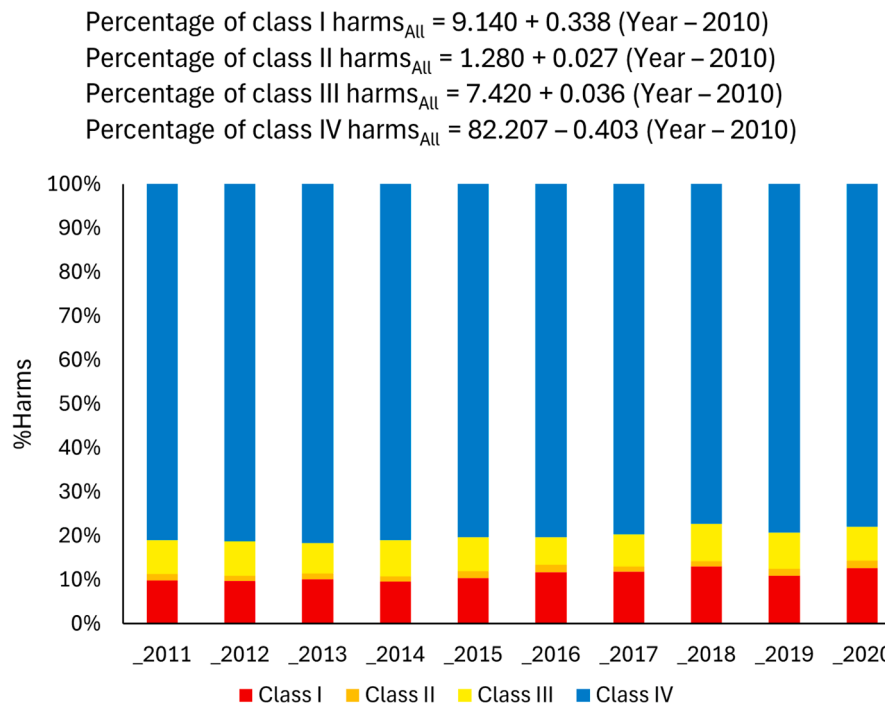


Fig. 5. Trend for the spread of harm in all dwellings.

Percentage of class I harms_{Flat} = $6.367 + 0.444 (\text{Year} - 2010)$
 Percentage of class II harms_{Flat} = $1.260 + 0.012 (\text{Year} - 2010)$
 Percentage of class III harms_{Flat} = $6.020 + 0.189 (\text{Year} - 2010)$
 Percentage of class IV harms_{Flat} = $86.353 - 0.646 (\text{Year} - 2010)$

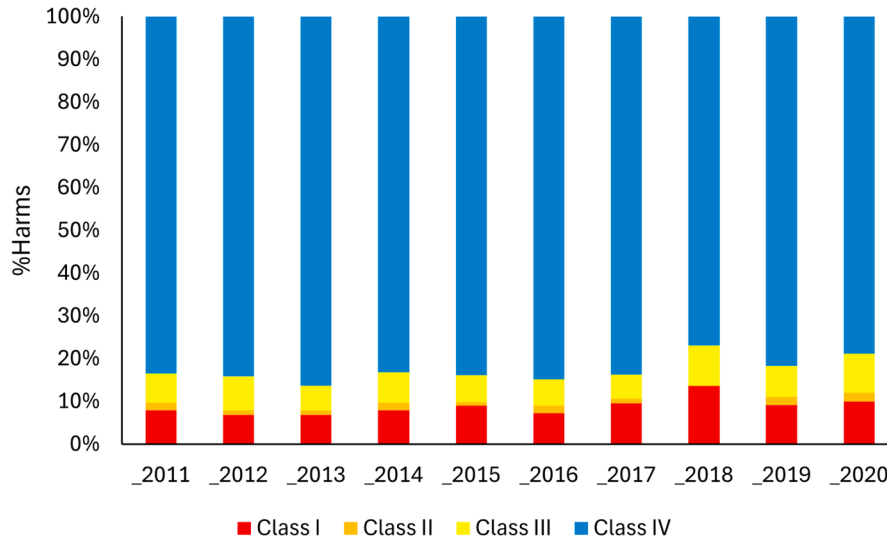


Fig. 6. Trend for the spread of harm in flats.

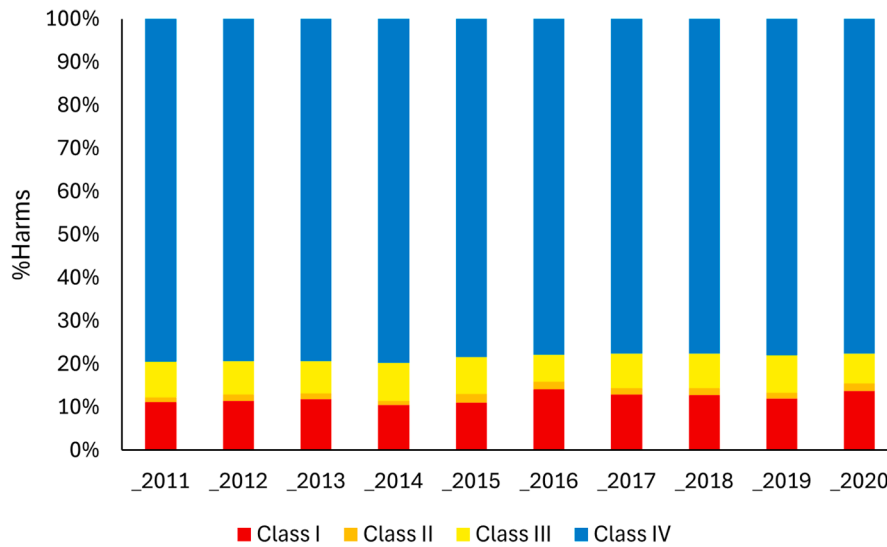


Fig. 7. Trend for the spread of harm in houses.

dwellings as a whole.

likelihood estimates to gives an estimated likelihood of harm of 1 in 6610 in 2022. Table 4 shows the likelihood of harm in different types of

$$Spread_{Fire+Explosion} = (Spread_{Fire} / Likelihood_{Fire} + Spread_{Explosion} / Likelihood_{Explosion}) / (1 / Likelihood_{Fire} + 1 / Likelihood_{Explosion}) \quad (2)$$

4. Results

Table 3 also shows that the likelihood of harm from fire in dwellings has reduced over the ten-year period. Applying Eq. (1) to these

dwelling from 2011 to 2020. Applying linear and logarithmic regression to these estimates predicted likelihood estimates of 1 in 8057 and 1 in 3039 for houses and flats respectively.

The likelihood of harm from explosions reported in the 2003 HHSRS was 1 in 156,528 while the value derived from hospital episode data during the validation study was 1 in 158,149. Eq. (2) determined the

Table 3

Estimation of harm from fires in dwellings and likelihood of harm from fires in dwellings for those aged 60 years or over.

Year	Total harms to those aged 60 years or over	Number of dwellings containing people aged 60 years or over	Likelihood of harm for those aged 60 years or over
2011	1770.7	7901,259	1 in 4462.2
2012	1832.3	7958,771	1 in 4343.6
2013	1752.6	8014,130	1 in 4572.6
2014	1586.5	8081,200	1 in 5093.8
2015	1543.8	8151,083	1 in 5280.0
2016	1528.3	8222,756	1 in 5380.5
2017	1479.9	8275,032	1 in 5591.8
2018	1423.5	8328,258	1 in 5850.6
2019	1396.5	8374,347	1 in 5996.7
2020	1383.4	8413,502	1 in 6081.7

Table 4

Likelihood of harm from fire to dwellers aged 60 years and older in different types of dwelling (1 in).

Year	House	Flat
2011	5599.0	1830.6
2012	5390.8	1895.9
2013	5373.1	2210.9
2014	6108.0	2399.0
2015	6301.9	2549.2
2016	6507.1	2326.5
2017	6857.7	2482.8
2018	7573.9	2341.4
2019	7209.5	2855.4
2020	7299.3	2878.0

likelihood of harm from fire or explosions to be 1 in 6342 for dwellings in general, 1 in 7663 for houses and 1 in 2981 for flats.

Table 5 shows the spread of harm from fires and the predicted spread of harms for 2022 determined by equations (5) to (16). Table 6 also shows the predicted spread of harms when 2017 (the year of the Grenfell Tower fire, resulting in 72 deaths [6]) is not included in the regression analysis. Table 6 shows the predicted spread of harm for 2022 for fires as well as for the amalgamated fires and explosions hazard.

5. Discussion and conclusions

The hazards of fire and explosions have particularly thorough and

well-organised data collection and retention due to the requirement for Fire and Rescue Services to complete a Fire Damage Report (FDR1) up to 2009, then a report in the electronic Incident Recording System after 2009. Reports from this system can be requested at postcode level, allowing them to be matched against the ACORN dataset. They are a rich source of data and provide details of harm outcomes from incidents of fire and explosions in residential dwellings. Governance around the system means that data collection has been consistent over time, which has allowed trend analysis for particular sections of the population and dwelling types.

The likelihood of harm from fires to dwellers (aged 60 years or over, in 2022) of 1 in 6610 is lower than the likelihood of 1 in 4760 reported in the original Operating Guidance [20]. The national average likelihoods for houses and flats are also lower than those reported in the 2006 guidance. This is in keeping with the overall reductions in the numbers of house fires and subsequent morbidity and mortality described above.

Reviewing the spread of harm outcomes the percentage of class III harms is lower than in 2003 while the percentage of class IV harms is greater than in 2003. This may be methodological due to the use of Table 2 to classify harms.

The reduction in fire occurrence and fire morbidity and mortality may be explained by a number of factors. Fire safety has received significant regulatory attention over this period, focussing on the materials and layouts used in the original construction and refurbishment of dwellings and fire safety remediation measures. Fire and Rescue Services and local authority Environmental Health departments have been proactively inspecting and improving fire safety in existing dwellings. This has been supported by a range of legislation including:

- Housing Act 2004.
- The Regulatory Reform (Fire Safety) Order 2005 (SI 2005/1541).
- The Management of Houses in Multiple Occupation (England) Regulations 2006 (SI 2006/372).
- The Licensing and Management of Houses in Multiple Occupation (Additional Provisions) (England) Regulations 2007 (SI2007/1903).
- The Building Regulations 2010 (SI 2010/2214).
- The Smoke and Carbon Monoxide Alarm (England) Regulations 2015 (SI 2015/1693).
- The Electrical Safety Standards in the Private Rented Sector (England) Regulations 2020 (SI 2020/312).
- The Fire Safety (England) Regulations 2022 (SI 2022/547).
- The Building Safety Act 2022.

Table 5

Spread of harm from fire to those aged 60 years or older.

Year	Flats				Houses				All dwellings			
	Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV
2010/11	7.9	1.8	6.7	83.6	11.2	1.1	8.2	79.5	9.9	1.4	7.6	81.1
2011/12	6.8	0.9	7.9	84.4	11.4	1.5	7.8	79.3	9.7	1.3	7.8	81.2
2012/13	6.8	1.2	5.6	86.4	11.9	1.3	7.5	79.3	10.2	1.3	6.9	81.6
2013/14	7.8	1.8	7.0	83.4	10.5	0.9	8.8	79.8	9.6	1.2	8.2	81.0
2014/15	9.1	0.8	6.1	84.0	11.1	2.0	8.6	78.3	10.4	1.6	7.7	80.3
2015/16	7.3	1.7	6.1	84.9	14.1	1.8	6.2	77.9	11.7	1.8	6.2	80.3
2016/17	9.6	1.1	5.5	83.8	13.0	1.4	8.0	77.6	11.8	1.3	7.1	79.8
2017/18	13.6	0.1	9.4	76.9	12.8	1.7	8.0	77.5	13.1	1.1	8.5	77.3
2018/19	9.2	1.9	7.2	81.7	12.0	1.3	8.7	78	11.0	1.5	8.2	79.3
2019/20	10.0	2.0	9.1	78.9	13.8	1.7	6.9	77.6	12.6	1.8	7.6	78.0

Table 6

Spread of harm from fire and fire and explosions in 2022.

Year	Flats				Houses				All dwellings			
	Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV
Fire	11.7	1.4	8.3	78.6	13.9	1.8	7.6	76.8	13.2	1.6	7.8	77.4
Fire+Expl	11.7	1.4	8.2	78.7	13.8	1.7	7.5	77.1	13.1	1.5	7.7	77.6

Bryant and Preston [1] have also noted other reasons for the decline including:

- A reduction in the use of chip pans.
- An increase in the number of people with smoke alarms (89 % in 2015/16).
- A reduction in the proportion of the population who smoke (in 2001 27 % of over-16 s smoked, in 2016 this had reduced to 16 %).
- Drug and alcohol consumption has reduced.
- A reduction in the levels of arson.
- Improved fire safety standards including mains wired smoke alarms, escape windows, electrical safety standards and general product standards.
- Fire and Rescue Services initiatives such as home fire safety checks.

To a small extent these have been offset by increased levels of overcrowding and the ageing population, but the prevailing factors have reduced levels of morbidity and mortality.

Our findings show that the percentage of class I harms suffered in houses is slightly higher than in flats, however the likelihood of a harmful event caused by fire and/or explosion is much lower. Overall, the national average HHSRS risk scores for flats are slightly higher than for houses. This supports the findings of Turner et al's [24] review of the literature on risk factors associated with accidental dwelling fire injuries and deaths, and Xiong, Bruck and Ball's [25] study of factors affecting the risk of mortality in accidental dwelling fires in Victoria, Australia which both found an elevated risk in flatted accommodation.

The Home Office's [7] ad hoc statistical release on flatted accommodation in England presented data on the numbers of dwelling fires attended by the Fire and Rescue Services. Between 2009/10 and 2016/17 there was a mean of 25,000 incidents per year for houses, bungalows, converted flat and 'other.' The mean for purpose-built flats was 8444. However, over this period purpose-built flats only made up 16.1 % of dwellings [16] indicating that fires in purpose-built flats were over-represented in Fire and Rescue Service callouts.

Home Office [8] data indicates that 7 % of fires in 4+ storey buildings spread beyond the room of origin and 14 % of fires do so in houses, bungalows, converted flats and other dwellings (combined). The average area of damage to dwellings in 2019/20 was 16.2m² (decreased from 19.7m² in 2009/10). The Incident Reporting System data does not make it possible to identify whether the fire has spread outside of the flat or origin in flatted building fires, but this data suggests that fires are unlikely to spread very far and are likely to remain within the dwelling or room in which they started.

Drawing on Thompson et al's (2018) discussion of occupier responses in a fire situation, within a dwelling occupiers will have a greater attachment to the dwelling and what it contains. Houses will be unlikely to have staff or fire wardens and formalised procedures in the case of a fire and residents will be more likely to attempt to tackle the fire and attempt re-entry, something which Runefors, Johansson and van Hees [22] note as a risk factor in dwelling fire fatalities (class 1 outcomes). Occupiers will be more likely to encounter feelings of guilt or responsibility for causing a fire and therefore experience the resultant desire to deal with the fire before calling the emergency services. Thompson et al. also cite four studies showing that between 60 % and 80 % of dwelling fires are not reported to the Fire and Rescue Services.

Lower socioeconomic status is also associated with higher risk of mortality in dwelling fires [14,18,23]. English Housing Survey data shows that approximately 42 % of social rented accommodation is made up of purpose-built self-contained flats [16]. The range of factors associated with the elevated risk to health from fire for more disadvantaged occupiers may also be a contributory factor to the elevated likelihood scores in flatted accommodation.

The prevailing risk of harm from uncontrolled combustion in dwellings is relatively low and has reduced over time in part due to lifestyle changes, consistent and successful regulatory intervention, and

maintenance of the public's awareness of the risk posed by this hazard. Fire continues to attract considerable public attention and subsequently receives substantial public investment to control the risk it presents to the population. When compared to other housing related hazards the perceived risk seems to be greater than the actual risk posed by this hazard.

A range of publications have been produced by the Building Research Establishment which use modelling of the frequency of 'Category One' HHSRS hazards (those scoring over 999, indicating a substantial risk to dwelling occupiers). Their 2021 attempt to rank HHSRS hazards affecting vulnerable age groups nationally, places the hazard of Fire (based on the 2003 HHSRS national average data) as the fifth most frequently occurring Category One hazard in the English housing stock. The hazards of Falls on Stairs and Steps, Excess Cold, Falls on Level Surfaces and Falls Between Levels occur more frequently. To provide an indication of the relative impact of different hazards, their report gives a total potential savings to society for reducing the risk from Excess Cold Category One hazards across the whole English housing stock of £15.26 billion. When compared to the combined savings from resolving the other four hazards in their 'top five' (£2.56 billion) and their reported savings from resolving Category One hazards for Fire (£282 million) [5] the attention this hazard receives from the public and regulatory bodies does seem disproportionate.

Fire will always capture the public's imagination, and it is likely to remain a high priority for more interventionist approaches in the regulation and management of the English housing stock. This study has contributed towards those efforts through the updating of the benchmark figures used by HHSRS assessors when judging the Fire and Explosion risk in English dwellings. These figures are also likely to be used in Wales and in the US, where the HHSRS has also been adopted for assessing public health risk from housing related hazards.

This study has only considered houses and flatted accommodation. It did not look at the differences in levels of risk between rental and owner-occupied accommodation. It has not attempted to assess levels of morbidity and mortality with regard to levels of deprivation on a geographical basis or to summarise characteristics (such as sex and living alone) which would contribute towards the risk of harm from dwelling fires. There is significant coverage of these areas in the existing literature.

CRediT authorship contribution statement

Henry Dawson: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Peter O'Donoghue:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Fahmida Khandokar:** Writing – review & editing. **Sophie Grinnell:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Henry Dawson reports financial support was provided by Department for Levelling Up Housing and Communities. This work was completed under contract for RH Global Limited as part of a larger project funded by the UK Government's Department of Levelling Up, Housing and Communities. Neither party had any influence on the study design, data collection, analysis and interpretation, and the writing of the report. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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