Meta-analysis of UK, USA and New Zealand fire statistics databases with respect to damage and financial loss.

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ABSTRACT: The optimization of structures for fire is a growing area of research and practice, however much of the optimization is conducted with respect to life safety and not with property damage. Resilience optimization of structures for fire events represents an evolution from pure life safety objectives. Fire statistics provide information that can fill the knowledge gap related to the response and damage of real buildings to real fires. From damage, it is easy to correlate the direct financial loss, which estimates the consequences caused to structures by fires. Different countries have developed individual fire statistics databases and reporting structures, which can give detailed description of fire incidents divided by different property types, but also the structural damage exhibited by the buildings and the strict relation with the financial loss. The paper presents an analysis of three such fire statistic databases: IRS of the UK, NFIRS in USA and one produced by the New Zealand Fire Service looking specifically at the relationship between damage and financial losses.

1 INTRODUCTION

Performance-based design within the fire safety engineering community is an ever-growing research topic and is being used in practice (Meacham & Powell 1995). However, many of the performance criteria are related to life safety goals rather than other drivers such as property protection, or limiting direct and indirect losses. Resilience optimization of structures for fire identifies and mitigates fire-induced risks to enable swift recovery in the aftermath of an event. It is very difficult to give a unique definition so it will be described through the whole fields that are covered under its range. Life safety, property and business continuity are three big categories to consider, able to guarantee the fundamental principles at the base of fire safety.

Governments regulations aim to ensure life safety. Previsions of prescriptive codes (i.e. BS EN 1992-1-1 2004) assume that the intended life safety fire performance criteria is implicitly satisfied by meeting the minimum code requirements for design and detailing of structural and nonstructural components. This represents an expectation and not necessarily the reality since the complexity of actual fires and the interaction with structures is difficult to predict accurately.

Once life safety requirements have been met, property protection can be assessed and mainly focusses on the possible responses of a structure in the aftermath of an event. Performance-based design is used to explicitly demonstrate, using pre-identified performance objectives, that the same level of life safety can be provided with enhanced property protection. This is possible through advanced computer simulations using 3D models. However, these models are rarely validated or benchmarked due to a lack of relevant data and can also be limited in their ability to describe structural behavior close to the point of failure. To overcome this, much research has been in the field of probabilistic performance-based design (Borg et al. 2015). Again, lack of validation data for these models limit their application in practice.

The final factor to ensure resilience is continuity. Continuity is applied to both individuals and to businesses, and aims to guarantee the same quality of life or business after an event. For businesses, adequate business impact analysis and business continuity plans can help ensure this resilience (BSI 2012).

The prescriptive codes and much of the performance-based design knowledge is developed from single element tests exposed to standard fire conditions (Bisby et al. 2013). However structural frames show better performances compared to individual element when subjected to fire, due to a beneficial effect of the connection between beam and column (Cooke & Latham 1987; Rubert & Schaumann 1986). Therefore, for performance-based design, it is preferable to collect data from real structures exposed to real fires, instead of tests on single elements under standard fire conditions. However, due to the expense and the complexities of fire, it is impossible to create all the probabilistic data required through experimentations. Therefore, the use of fire statistics can be used to understand the real relationships between fire occurrence, fire size, damage caused by fire and interventions to extinguish the fire, and financial losses.

Different countries have developed individual fire statistics databases and reporting structures, which give detailed descriptions of fire incidents divided by different property types, but also the structural damage exhibited by the buildings and their strict relation with the financial loss. This paper presents an analysis of three such fire statistic databases: IRS of the UK, NFIRS in USA and one produced by the New Zealand Fire Service. The reporting structure of each country is similar and appears as a form filled by fire departments in the aftermath of an event, with common fields such as: fire department, causalities, fatalities, fire size and structural damage. This paper focusses on parts related to the horizontal and vertical spread of fire, the confinement of fire and the area damaged, and comparing possible trends in the statistics. Moreover, the USA and New Zealand databases provide methods or estimates of the financial losses due to fire. The correlations between damage and direct financial loss presented as part of this paper will be an essential part of future quantifications of financial loss consequences (direct and indirect) due to fire.

2 FIRE STATISTICS DATABASES

Nationally reported fire statistics are a collection of data due to real incidents and usually include false alarms, fire and non-fire incidents reported by the Fire and Rescue Services. Each country has its own database and at the end of the year, a report is published to show the trend of casualties, fatalities and fires and compare them with the other data available for the previous years. After an incident, Fire and Rescue Services fill an online form, which presents questions about the causes and frequency of fires, response time, description of the type of property, damage of structure, dollar losses as well as people involved. While each form is different for every nation, as not all the same information is required in the different forms or with the same categories, the databases are similar enough to be comparable even if it is unavoidable that some errors appear due to the lack of data, as the presence of empty boxes, and errors in the answers. These annual reports are a significant source of data of real incidents.

This paper analyses the UK, USA, and New Zealand databases from April 2014 to March 2015. The Incidents Reporting System (IRS) database in the UK has been divided in four main regions: England, Northern Ireland, Scotland and Wales. The IRS is composed of around 150 questions, which cover the whole description of the incident from the property to the people injured. This paper considers only the data published for England (Gaught et al. 2016) since it is the most complete with the relevant and comparable information to the other databases. It should also be noted that within the database, properties are divided in dwellings and other buildings (i.e. offices and call centers, retail premises, industrial premises, agricultural premises; hospital and medical care, educational premises, food and drink premises, entertainment, culture and sport, hotels, boarding houses, hostels, communal living, private non-residential buildings, other public buildings and services), and damage is expressed in average area damaged (m^2) while no financial losses are reported.

In the USA, the National Fire Incident Reporting System (NFIRS) has been established since 1976 with the aim to collect data on fires (USFA 2014). On a yearly basis, approximately 600,000 fire incidents and more than 5 million non-fire incidents are added in the database by the Fire and Rescue Service of all the 50 States and more than 40 major metropolitan areas. NFIRS is a voluntary system so not all States and fire departments decide to participate, however the majority do (USFA 2014). With respect to damage, the NFIRS define the damage as a percentage of number of stories damaged by flame, using four main categories; Minor Damage (from 1 to 24%); Significant Damage (25 to 49%); Heavy Damage (50 to 74%); Extreme Damage (75 to 100%.). Additionally, the NFRIS reports fire loss data, as reported by the U.S. Fire Administration (USFA), "Fire loss is an estimation of the total loss to the structure and contents in terms of replacement in like kind and quantity. This estimation of fire loss includes contents damaged by fire, smoke, water and overhaul. It does not include indirect loss, such as business interruption". The estimated dollar losses are divided into property and contents losses to asses a magnitude of the fire problem. This is fundamental to define fire prevention programs where high monetary losses are expected. The forms include spaces for fire departments to estimate the pre-incident value of the property and the dollar loss caused by the event. Fire departments fill the form using the International Code Council's Building Valuation Data (BVD) formula (International Code Council 2017). An average construction costs per square foot is given by the BVD and the evaluation is realized according to:

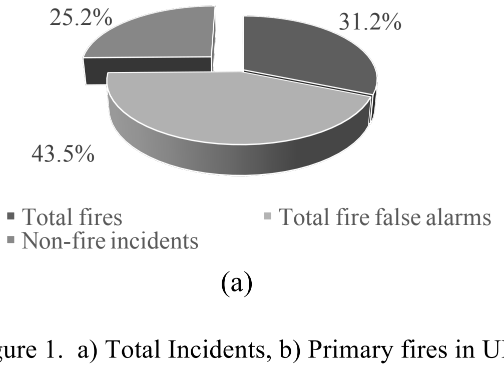
Total square foot x square foot construction cost

The New Zealand Fire Service fills the New Zealand Fire Service Incident database, as in the other cases, in the aftermath of an event. Only relevant information is reported and in general the Incident, General, Equipment and Response groups are always reported. In the reports, damage is considered as the inverse parameter of the percentage of property saved and the financial losses are expressed in term of value loss. How these are measured or quantified is not clear. The New Zealand Fire Service does not publish an annual report and data are presented for single incidents. The work of this paper has been first the collection of all the information for the period of interest and then the reclassification according to different categories for each major class. It is possible to observe that the classification for the spread of fire is comparable to the one of UK and USA where here there are also further details regarding not only the flame damage but also the smoke and water one. Small differences can be found in the nomenclature adopted, however, buildings are generally categorized in dwellings and other buildings, with similar subclasses as presented in the other countries.

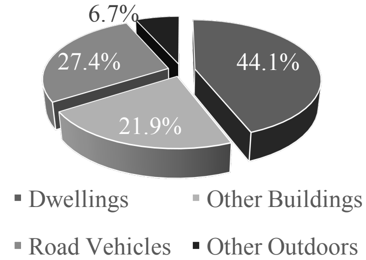
3 ANALYSIS OF INDIVIDUAL REPORTING AREAS

3.1 England Database - IRS

From April 2014 to March 2015, all the 496,051 incidents attended by the Fire and Rescue Service in England, are divided in three big categories with the following percentage: 31.2% of total fires, 43.5% of fire false alarms and 25.2% of non-fire incidents (Figure 1a). IRS subdivides the Total Fires into primary fires and secondary fires, which include just small outdoor fires not involving people or property, and chimney fires. Within the Primary Fires (71,089 fires), there are fires in dwellings (31,329 fires), other buildings (15,548 fires), road vehicle (19,464 fires) and other outdoor fires (4,748 fires) with the distribution for the year in consideration shown in Figure 1b.



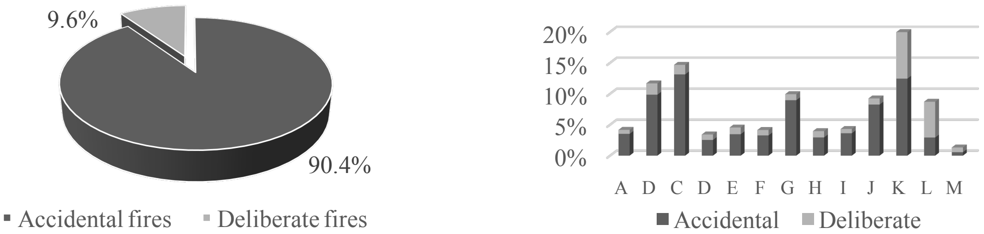
(a)



(b)

Figure 1. a) Total Incidents, b) Primary fires in UK 2014/2015

Figure 2 shows the comparison of deliberate and accidental fires in dwellings and other buildings and shows that in each of the two groups of buildings, accidental fires represent the significant majority of fires (approximately 90%), apart from for Private non-residential buildings and other public buildings and services where the fires are often more deliberate.



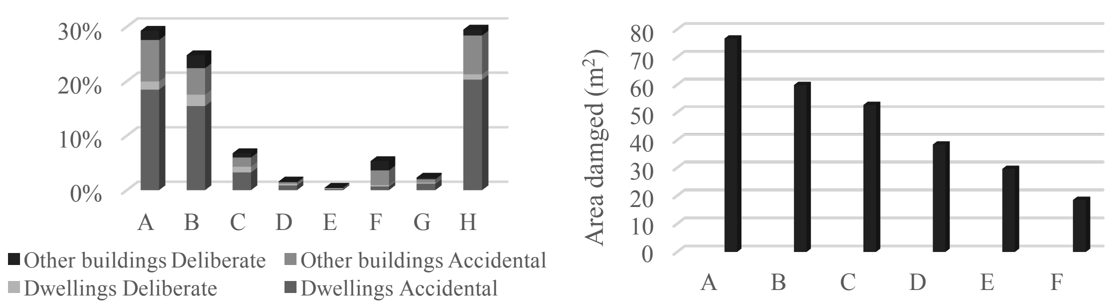
(a) (b)

A. Offices and call centers, **B.** Retail premises; **C**. Industrial premises; **D.** Agricultural premises; **E**. Hospitals and medical care; **F.** Education premises; **G**. Food and drink premises; **H**. Entertainment, culture and sport; **I.** Hotels, boarding houses, hostels etc.; **J.** Communal living; **K.** Private non-residential buildings; **L.** Other public buildings and services; **M.** Unspecified

Figure 2. a) Dwellings fires, b) Other Buildings fires in UK 2014/2015

The damage of fire con be evaluated through the spread of fire. As can be seen in Figure 3a, the compartmentation works well both in dwellings and other buildings. This is evidenced for the two categories referring to the spread of fire limited to the item 1st ignited (A) or to the room of origin (B) with values of 29.2% and 24.8%, respectively. However, it should be noted that a not-insignificant amount, 8.5%, of the fires spread beyond the compartment; 6.8% limited to the floor of origin, 1.6% limited to 2 floors, and 0.1% to more than two floors. The whole building was damaged in 5.3% of occasions, however it should be noted that some of these incidents include garden sheds and standalone garages.

The IRS in England also reports an average area damaged in square meters. When comparing the areas between dwellings and other buildings, the average area damaged is considerably larger in other buildings, at 76.7m^2 compared with 18.5m^2. Furthermore, for other buildings, there are subdivisions to exclude large floor area structures, i.e. those above 10,000 m^2, 5,000 m^2, 2,000 m^2, and 1,000 m^2, which reduces the area damaged to 59.9 m^2, 52.7 m^2, 38.4 m^2, and 29.6 m^2 respectively. This is still greater than the area damaged in dwellings of 18.5 m^2 (Figure 3b).



(a) (b)

A. Limited to item 1st ignited; **B.** Limited to room of origin; **C.** Limited to floor of origin; **D.** Limited to 2 floors; **E.** Affecting more than 2 floors; **F.** Whole building; **G.** Roofs and roof spaces; **H.** No fire damage

A. Other Buildings; **B.** Other Buildings excluding 10,000+ m^2 ; **C.** Other Buildings excluding 5,000+ m^2; **D.** Other Buildings excluding 2,000+ m^2; **E.** Other Buildings excluding 1,000+ m^2; **F.** Dwellings

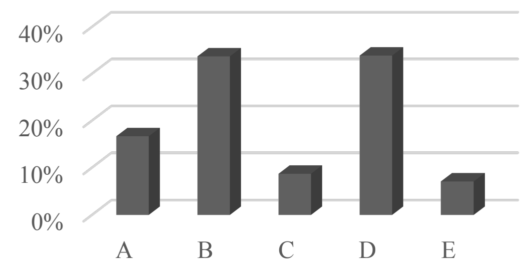
Figure 3. a) Spread of fire in dwellings and other buildings, b) Average area of fire damage (m^2) in UK 2014/2015

It is possible to conclude that the spread of fire is, in general, contained to the item or room of origin, limiting the area that the fire can damage. We can also conclude that the average area damaged in dwellings is less than 20 m^2 and in other buildings less than 80 m^2.

3.2 USA Database

The total number of fires in the USA from, April 2014 to March 2015, was 379,500; 79.2% were residential fires and 20.8 % non-residential fires. The proportion of residential to non-residential fires is reported higher in the USA than in England. The residential fires also occur mainly (64.3%) in 1 & 2 family occupancies, and over a quarter of residential fires occur (28.6%) in 3+ family occupancy buildings. The USA NFRIS also report the average dollar loss relating to the different family occupancy rate of the buildings damaged in fire and state that the average dollar losses are $21,317, $12,346, and $13,321, for 1&2 family, multifamily and other residential occupancy buildings, respectively.

Fire spread, according to Figure 4, is confined to object of origin (A) and to room of origin (B) respectively for the 16.67% and 33.70%, while for the 33.87% fire is confined to building of origin (D). Only the 7.0% of fires overpasses the structure of origin (E). By comparing Figure 4 with Figure 3a, it is possible to see that fires in the US are less well contained than in the UK database, where fires are generally confined to the item, or room of origin, and less frequently spread to more than a single floor. However more analysis of the data needs to identify the causes of this and whether there are specific building classes that are skewing the data (i.e. garage fires being defined as buildings or rooms).



A. Confined to object of origin; **B.** Confined to room of origin; **C.** Confined to floor or origin; **D.** Confined to building of origin; **E.** Beyond building of origin

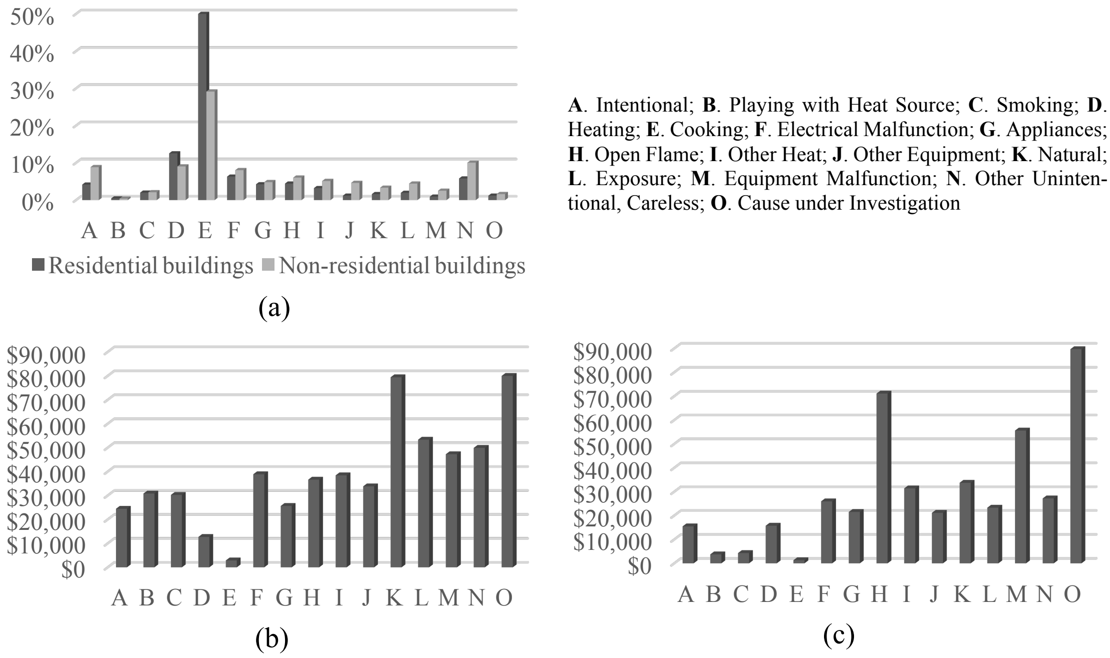
Figure 4. Fire spread in USA 2014/2015

Figure 5a shows the non-residential buildings fires, separated with respect to different occupancy types, occurring mainly in stores & offices (E – 18%), storage (H – 16.4%) and outside or special property buildings (J – 20.9%). Figure 5b shows the direct dollar loss of these fires with the most expensive places to have a fire being an educational facility (average dollar loss per fire – $117,000), followed by manufacturing ($73,500) and basic industry ($52,000). Figure 5 shows that the type of occupancy plays a major role in the frequency of the fires and the cost of damage caused by a fire and that these are not directly correlated.

A. Assembly; **B**. Eating & Drinking Establishments; **C**. Educational; **D**. Institutional; **E**. Stores and Offices; **F**. Basic Industry; **G**. Manufacturing; **H**. Storage; **I**. Detached Garages; **J**. Outside or Special Property Buildings; **K**. Other

Figure 5. Non-residential buildings in USA 2014/2015 - a) fires; b) Dollar loss ($) per fire

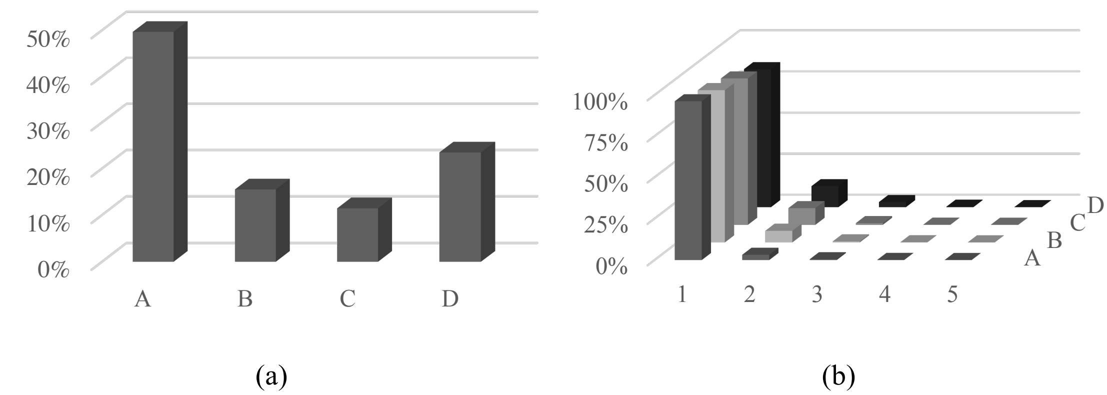
Figure 6 separates the fires and dollar losses with respect to causes of the fire. Figure 6a shows that for both residential and non-residential buildings the main reason for fire is due to cooking with a peak that reaches the 50% for residential and almost the 29.1% for non-residential buildings. The second cause, which implies high dollar losses, is heating with 12.5% in residential and 9% in non-residential buildings. All the other classes appear to be lower than 10% except for other unintentional cause in non-residential buildings that is equal to 10.1%.



A. Intentional; **B**. Playing with Heat Source; **C**. Smoking; **D**. Heating; **E**. Cooking; **F**. Electrical Malfunction; **G**. Appliances; **H**. Open Flame; **I**. Other Heat; **J**. Other Equipment; **K**. Natural; **L**. Exposure; **M**. Equipment Malfunction; **N**. Other Unintentional, Careless; **O**. Cause under Investigation

Figure 6. a) Fire causes in residential and non-residential buildings, b) Dollars ($) per fire per cause in residential and c) Dollars ($) per fire per cause in non-residential buildings in USA 2014/2015

Dollars per fire per cause for each class of causes in residential buildings, is on average between $30,000 - $50,000 with some exceptions as natural and cause under investigations, which reach almost $80,000 (Figure 6b). The lowest average dollar loss per fire is found for the highest frequency of fires, cooking (E) and heating (D) with dollar losses of $2,900, and $12,700, respectively. Surprisingly, for non-residential buildings, Figure 6c, the dollar loss per fire per cause is on average between $20,000 - $30,000, lower than the losses for residential buildings, with two notable exceptions of fires due to open flames ($71,000), and equipment malfunction ($55,500). Playing with heat source (B), smoking (C) and cooking (E) are all below $5,000 average cost per fire (Figure 6c). Figure 6 shows again that the most frequent fire cause does not necessarily lead to the costliest fire.



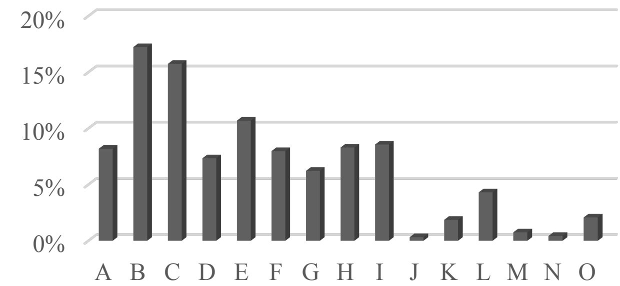
A. Minor damage; **B**. Significantly damage; **C**. Heavy damage; **D**. Extreme damage

Figure 7. a) Percentage of fires per area damaged and b) Floors involved per class of area damaged in USA 2014/2015

The USA data for area damaged is divided into 4 categories: minor, significant, heavy and extreme damaged. For each class, the fire departments must specify the number of floors subjected to fire. Figure 7a presents the percentage of fires within these four categories, and shows that 49.6% of all the fires cause only minor damage, with significant, heavy, and extreme damage being realized 15.5%, 11.4% and 23.5%, respectively. Figure 7b shows the same data expressed with respect to the number of floors subjected to fire, and shows that 84% (D – heavy damage) to 96% (A – minor damage) of these fires are limited to a single floor. Predictably, the more damage that you see, the more likely that the fire has spread to more than 1 floor, with heavy damage being experienced on 2 and 3 floors, 12.7% and 3.1% of the time respectively.

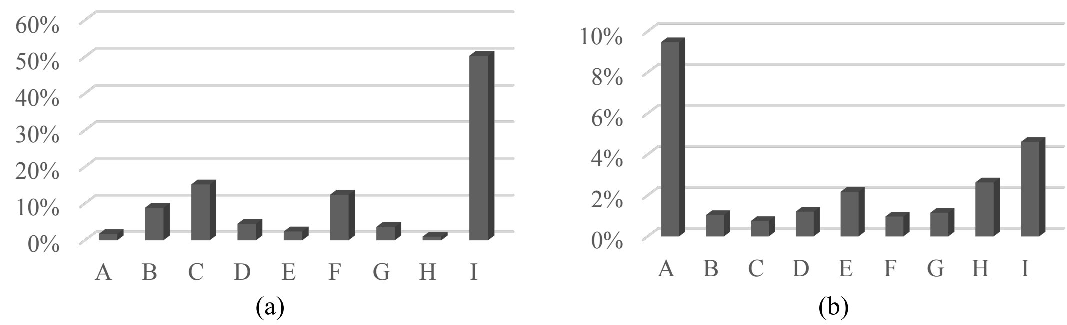
3.3 New Zealand database

All the New Zealand (NZ) data come from the New Zealand Incident Reporting System. As with the other database, the analysis start with the evolution of the total incidents in the different buildings. For 2014/2015, 65% (3,500/5,380) of fires were in dwellings compared with 35% (1,880/5,380) in other buildings; this is similar to the proportion found in the England Database. Figure 8 shows the distribution of fires in other buildings, excluding dwellings, by occupancy types similar to those in the England Database (Figure 2). Similar peaks are seen in both databases for Retail (B) and Industrial (C) premises, however in the NZ database, the frequency of fires in food and drink (G), communal living (J), private non-residential (K) and other public buildings and services (K) do not show the similar peaks in frequency.



A. Offices and call centre; **B**. Retail premises; **C**. Industrial premises; **D**. Agricultural premises; **E**. Educational premises; **F.** Hospital and medical care; **G**. Food and drink premises; **H**. Entertainment, culture and sport; **I**. Hotels, Boarding houses, Hostels, etc.; **J**. Communal living; **K**. Private non-residential building; **L**. Other public buildings and services; **M**. Road Vehicles; **N**. Other Outdoors; **O.** Others

Figure 8. Fire incidents in other buildings in New Zealand 2014/2015



A. Confined to fire cell of origin; **B**. Confined to object of origin; **C**. Confined to part of room or area of origin; **D**. Confined to room of origin; **E**. Confined to floor of origin; **F**. Confined to structure of origin; **G**. Extended beyond structure of origin; **H**. No damage of this type; **I**. Not Recorded

A. 0 - 10%; **B**. 11 - 20%; **C**. 21 - 30%; **D**. 31 - 40%; **E**. 41 - 50%; **F**. 51 - 60%; **G**. 61 - 70%; **H**. 71 - 80%; **I**. 81 - 90%

Figure 9 a) Structure damaged by fire, b) Property saved in New Zealand 2014/2015

The damage of fire con be evaluated also through the spread of fire. As can be seen in Figure 9a, the compartmentation works well for both in dwellings and other buildings. However, it should be noted that a significant amount, 18.4%, of the fires spread beyond the compartment;

2.4% confined to the floor of origin, 12.4% confined to the structure of origin, and 3.6% extended beyond the structure of origin. It should also be noted that there is a high percentage, 50.3%, of fire spread data not reported.

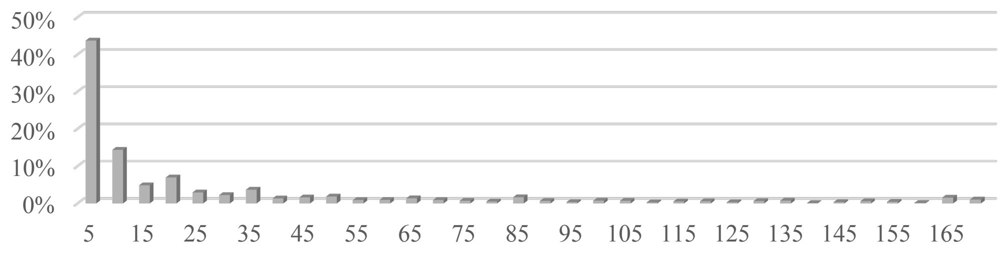


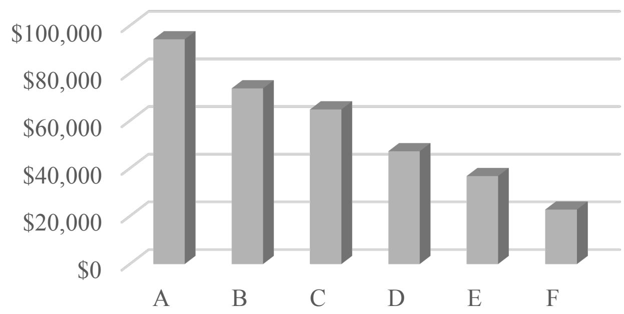
Figure 10. Value Lost in thousands of dollars in New Zealand 2014/2015

For the percentage of property saved, according to Figure 9b, structures saved for a percentage between 91 and 100% are equal to the 74.6% of the total structures subjected to fires. Redefining the property saved for classes below 90%, there is a decreasing trend from 90% to 10% and then a high peak in the class of property saved between 0 and 10%, which identifies the number of structures in which the incident has afflicted the whole property.
For the value lost related to structures, in Figure 10 a decrement from 0 to 5,000, to the last interval that reaches 170,000, New Zealand dollars can be evaluated. This implies that very dangerous fire incidents in term of dollars loss are not frequent and fire protections and fire systems work adequately.

4 META-ANALYSIS

Using the area of damage presented in the UK database, it is possible to estimate the average dollar losses using the BVD formula. The BVD (International Code Council 2017) is classified into 9 construction types (from rated fire-resistive construction to non-rated timber frame) and 24 occupancy types (from assembly areas with and without stages, to storage and utility facilities), thus creating a matrix of 216 building valuations per square foot. The UK database does not provide data on the construction type for the damaged structures, therefore an assumption has been made to average the 9 construction types in a single occupancy classification. The 24 occupancy types match relatively well with the UK database and with some averaging of similar occupancies (i.e. storage with moderate hazard and storage with low hazard), 13 $/sq.ft values can be created that match the occupancy types shown in Figure 2b. The percentage values presented in Figure 2b) are then used to weight each of 13 $/sq.ft values to create a single value to be used with the average area damaged in Figure 3b. A weighted average dollar per square foot ($/sq.ft) of $114.18/sq.ft for the other buildings was obtained evaluating an average for all the costs per property types present in the BVD. For dwellings, the BVD provides data for 1 & 2 family dwellings between $112.7 and $143.9 per sq.ft with an average across the types of $129.9/sq.ft. The average areas damaged in Figure 3b estimated by the UK database have then been converted first in square foot and multiplied by the average $/sq.ft values to determine the average dollar loss of the fires. For other buildings in the UK database these are further divided into 4 classes based on four maximum areas (10,000; 5,000; 2,000 and 1,000 m^2) and for each of them the analysis is repeated. The results clearly show that dollar losses increase with the increasing areas of the buildings as shown in Figure 11 as would be expected as the area damaged also increases with area of the building.
Comparing the results shown in Figure 11 to the USA NFIRS database, dividing the total dollar loss for all fire by the total number of fires reported, the average cost per dollar per fire in the USA is equal to $26,412. The average dollar loss in UK, according to a general classification presented in Figure 11, is $94,266, and it is only when the data excludes buildings of 1000+ m^2 from the data set, that a more comparable loos figure of $36,748 is found. These values are higher than that found in the USA, particularly for the general classification, which is most likely an

effect of the assumptions used in the analysis. A greater interrogation of the damage per property type for the UK database is required to remove some of these assumptions. If the same analysis is repeated for one and two family buildings, it is possible to obtain an average of $21,316 in USA and $26,028 in UK. The results appear certainty comparable if seen in the light of the general assumptions considered in the evaluation of the financial loss in UK.



A. Other Buildings (76.7 m^2); **B.** Other Buildings excluding 10,000+ m^2 (59.9 m^2) ; **C.** Other Buildings excluding 5,000+ m^2 (52.7 m^2); **D.** Other Buildings excluding 2,000+ m^2 (38.4 m^2); **E.** Other Buildings excluding 1,000+ m^2 (29.6 m^2); **F.** Dwellings (18.5m^2)

Figure 11. Estimate of dollar losses ($) considering the area damaged presented in the UK database

Another analysis is evaluated obtaining the percentage damaged from the one saved in New Zealand. According to Figure 9b, the 74.6% show an area damaged between 0 and 10% (90-100% of property saved) with an average percentage of property damaged being 18% (based on midpoint values for the different bands in Figure 9b. This is similar to the percentage of area damaged present in the USA database which shows the highest value of 49.6% in the class related to minor damage (0-24%). The limits in the New Zealand as in the USA database is that the percentage of property saved or damaged is not classified according to different buildings types and use, and are banded with wide ranges of damage.

4.1 Gaps in the data

Considering the reporting system for the different countries, the major difference is that while in New Zealand and USA an estimate of financial losses is given, this is absent in the UK database. Another aspect that associate New Zealand and USA is the fact that the area damaged is express in term of percentage compared to the total property while in UK is an average area per square meters. The classification of fire spread is almost the same for the three countries instead and shows that the confinement is limited to the item of origin or maximum to the area of origin for the major part of times. Several differences are presented in the way of collecting data and in the classification of the information for each category in the different countries. As shown in the meta-analysis explained before, it is still possible to compare the common data and, even if some of them are not in the database, thanks to elaborations and inverse proportions, guarantee a comparison based on generalizations and assumptions. Anyway, some improvements should be applied in each of the fire statistics of the different countries. In UK, the database should be implemented with an estimate of financial losses. An annual report, which summarizes the data of England, Northern Ireland, Wales and Scotland, would help to give a national estimate of fire statistics. In USA, as explained before, damage is classified in four major class: Minor damage (from 0 to 24%); Significant Damage (25 to 49%); Heavy Damage (50 to 74%); Extreme Damage (75 to 100%.). A redefinition of this aspect according to the different property types and uses would help in giving a more detailed classification of fire damage. Finally, in New Zealand, an annual report where data are grouped for the different information and classes, would show the trend of fire incidents and fire protections in different years and help defining the investments and applications of further researches in this field. Generalizing, these databases represent an important source of fire statistics and help the international fire engineering community to understand the actual trend of fire and non-fire incidents and, overall, show the actual response of real structures subjected to real fire.

5 DISCUSSION & CONCLUSIONS

This paper presents statistical data from three databases (IRS of the UK, NFIRS in USA and one produced by the New Zealand Fire Service) and shows important statistics on the spread of fire (and associated confinement), damage of structures, and their immediate correlations with dollar losses. From these statistics, we can conclude:

- Although the classifications of structures or categories of structures are defined in different ways, results seem to be comparable between the three reporting areas and similar within the different countries.
- Fire spread is usually concentrated within the item first ignited or maximum within the area of the room of origin. However, in all databases, there are significant percentages of fires that spread beyond the room of origin, and beyond the floor of origin to more than a single floor. This could have implications on how we design structures for fire.
- The occurrence of fire and the associated cost of fire damage (as demonstrated with the USA data) is dependent on the occupancy type of the structure, with educational and manufacturing occupancies realizing the highest dollar losses per fire, but less than 5% of the fires each.
- The New Zealand database shows that there are a high proportion of low value fires. However, the data also shows that there are some low probability, but high consequence events occurring
- When the USA method for calculating dollar losses are combined with property types and damaged areas in the UK, the analysis show values sufficiently comparable with the ones of the other country.

The analysis presented will allow further developments of performance-based design approaches and the estimate of direct dollar losses. Further work is required to understand in more detail the distributions of the damage and dollar losses of fire able to be used in probabilistic analyses for resilience, understanding the probabilities of the low frequency high consequence (monetary loss) events, and the influence of building occupancy type on the probabilities and associated damages and direct loss. Further work is also required to better understand the indirect monetary loss due to fire, and how these can be minimized.

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