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Use of Statistical Data in Fire Engineering Design – an International Comparison

Wykorzystanie danych statystycznych w projektowaniu z zakresu bezpieczeństwa pożarowego budynków – porównanie międzynarodowe

Abstract

Probabilistic risk assessment (PRA) is increasingly being used as a technique to measure risk within fire safety engineering analyses of building designs. PRAs are reliant on good quality, up-to-date, statistical data. Data is published in various formats in different jurisdictions around the world and a British Standard was published in 2003 that collated statistics relevant to fire incidents, injury and deaths, specifically for use in PRAs.

This paper makes an international comparison by, firstly, looking at fire safety engineering within the United Kingdom and within the Slovak Republic. It outlines the fire safety regimes in the two jurisdictions describing how they have evolved over recent decades, and discusses how trends are changing from sole use of prescriptive codes towards more prevalent use of performance-based methods-environments where PRAs are most useful. After discussing how the British Standard shows statistical data, and questioning whether the data remains current, the paper then presents updated statistics based on the most recently available data in both the UK and the Slovak Republic. Comparisons between the data are drawn and discussed, along with limitations of the study.

The paper concludes that data relating to fire frequency, fire injury and fire death alter over time, and that data are quite specific to the country of origin. For fire safety engineering PRA studies to be meaningful, the most up-to-date data, and data relevant to the jurisdiction under consideration must be sought.

Keywords: Fire safety engineering, Buildings, structures & design, Risk & probability analysis

Streszczenie

Ocena probabilistyczna ryzyka (ang. probabilistic risk assessment – PRA) jest coraz częściej wykorzystywana jako technika szacowania ryzyka w ramach inżynierii bezpieczeństwa pożarowego w analizach projektów budowlanych. Analizy PRA są uzależnione od aktualnych danych statystycznych dobrej jakości. Dane takie są publikowane w różnych formatach w różnych krajach na całym świecie. Jeden z takich dokumentów to British Standard, opublikowany w 2003 roku, w którym zebrano statystyki dotyczące wypadków oraz ofiar i obrażeń związanych z pożarem, specjalnie do stosowania w analizach PRA.

Artykuł zawiera porównanie międzynarodowe w pod względem inżynierii bezpieczeństwa pożarowego w Wielkiej Brytanii oraz w Republice Słowackiej. Określa ona stan i ramy ochrony przeciwpożarowej wraz krótkim opisem procesu jej ewolucji w ostatnich dekadach oraz zawiera dyskusję na temat zmiany trendów od stosowania wyłącznie przepisów nakazowych w kierunku coraz częstszego stosowania przepisów funkcjonalnych (ang. performance based), w których analizy PRA mają szersze zastosowanie. Po przedstawieniu sposobu, w jaki British Standard przedstawia dane statystyczne i przeprowadzeniu analizy tego, czy dane pozostają aktualne, artykuł następnie przedstawia zaktualizowane statystyki oparte na najnowszych dostępnych danych, zarówno z Wielkiej Brytanii jak i Republiki Słowackiej. Następnie omówiono wykonane porównania pomiędzy danymi wraz z ograniczeniami badania.

Artykuł kończy się konkluzją, że dane dotyczące częstotliwości występowania pożarów oraz ofiar i obrażeń związanych z pożarami zmieniają się w czasie, a dane są dość specyficzne dla kraju pochodzenia. Aby analiza PRA z zakresu inżynierii bezpieczeństwa pożarowego miała sens, należy korzystać z najbardziej aktualnych danych oraz danych dotyczących rozpatrywanego kraju.

Słowa kluczowe: Inżynieria Bezpieczeństwa Pożarowego, budownictwo, projektowanie, analiza probabilistyczna ryzyka

1. Fire Safety System in the UK

Fire engineering is increasingly being used as an alternative to the traditional prescriptive means of meeting the functional requirements of Part B of the Building Regulations in England and Wales. Whilst fire engineering may be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings (Fire Protection Association, 2008) it is just one element of the UK fire safety system.

Statutory fire safety provision within the UK has evolved slowly over many centuries, largely driven in reaction to major disasters. In London, argues Law (1991), the most significant fire disaster was the Great Fire of 1666, when the major part of the city was destroyed. There was little loss of life, and the rules for rebuilding the city concentrated on reducing the spread of fire between buildings. Controls were placed on materials of construction, on the thickness of walls and on the width of streets, describes Law (1991) and Read (1993). These rules were rigidly prescribed.

In the 19th century, after disastrous industrial fires killed fire fighters and gave major financial losses, further regulations were developed. In the 20th century, experiences of fires during the Second World War were incorporated into the Post-war Building Studies on Fire Grading of Buildings. Malhotra, et al. (1987) suggests that these were seen as landmark documents of their day influencing the technical content of the subsequent Building Regulations. By the time further amendments were made by 1976, the regulations comprised 307 pages, were highly prescriptive, and, in Law's opinion, understood only by lawyers.

Despite criticism, prescriptive building regulations have been an important component in the evolution of fire safety in buildings. It is acknowledged that (Hasofer, Beck et al. 2007) prescriptive design has resulted in the achievement of safety levels which the community appears to accept.

As a result of the large and rapid increase in innovative and diversified building design, including the expansion of air travel in the early 1970s, prescriptive regulations became demonstrably restrictive and inflexible (Wilkinson, et.al., 2010). Designs based on the prescriptive standards of the time simply couldn't cope with this new design requirement. Some engineers and scientists saw the possibility of applying scientific research directly to the design of individual buildings (Charters, 2006). Others, including Ramachandran (2000), argued that prescriptive rules are highly empirical and could lead to costly over-designs, particularly for large buildings, thereby strengthening the case for an alternative approach.

The commitment of UK Government to deregulation and to reduce the burden on industry led, in 1985, to the introduction of new functional building regulations, i.e. the Building Regulations 1985 (Sanayei, 1995). The requirements for fire safety of buildings given in the 1985 regulations were set out in four functional requirements and the functional nature of the regulations provided greater opportunities for the adoption of fire engineered approaches to fire safety design. Since then, fire engineering, as a means of satisfying the requirements of building regulation, is an approach which has freed up building design, whilst at the same time provided suitable levels of safety. Many of the exciting buildings currently being enjoyed in the UK have been designed with engineered fire safety and could not have been built under the previous prescriptive methods.

2. Fire Safety System in the Slovak Republic

The fire safety system in the Slovak Republic recognizes only one approach to the design of buildings which is defined in Regulation 94/2004 (as amended) (Regulation, 2004) and the STN 92 0201 standard suite (SUTN, 2000). There is no legislative framework for the use of alternative design approaches such as fire safety engineering. All fire safety design submissions must be prepared by design professionals with a certificate issued by the Ministry of interior. Although utilizing a range of calculations, the standards are prescriptive in principle, as the acceptance criteria (maximum fire loads, evacuation times, etc.) are fixed and cannot be altered for a specific building.

In the first half of the 1900's, fire safety requirements were included in certain specific design standards, e.g. for theatres, cinemas etc. A standardised fire safety system in the Slovak republic based on a core fire safety standard was first introduced in 1954. The core standard – CSN 73 0760 Fire regulations for construction of industrial factories and housing estates (CSN, 1954). This standard set the requirements on fire safety based on the category or use of a building (similarly to purpose groups). This standard was solely prescriptive, with a minimum of calculations.

A significant change in the approach to fire safety design happened when a new suite of fire safety standards was introduced in 1977. The suite comprised a core standard CSN 73 0802 Fire protection of buildings – Common regulations, and other standards generally referred to as CSN 73 08xx. These included three categories of standards: design, values and test standards. The design standards provided design specification for buildings; certain building categories had dedicated standards, e.g. CSN 73 0833 Buildings for dwelling and lodging, CSN 73 0831 Places of assembly. In 1992, CSN 73 0804 Fire protection of buildings – Industrial buildings, was introduced.

Although a major revision of the fire safety standards, which led to the introduction of the STN 92 0201 suite, was carried out in 2000, the basic philosophy and design principles remained unchanged. Essentially, the revision meant a restructuration of the CSN 73 08xx suite; certain standards were amalgamated and obsolete standards were withdrawn.

The current STN 92 0201 suite is divided into four parts, each of which forming a separate part of the suite. They are as follows:

STN 92 0201 – 1 Fire risk and maximum fire compartment area

STN 92 0201 – 2 Building constructions

STN 92 0201 – 3 Escape routes and evacuation of occupants

STN 92 0201 – 4 Space separation (External fire spread).

The primary principle of structural design is the calculation of fire risk which is expressed as a calculated fire load for non-industrial buildings and an equivalent time of fire duration for industrial buildings. Fire risk is taken as the expected intensity of a fire in a given building. The calculation method is quite detailed, very similar to fire engineering calculations, involving fire load densities, ventilation areas, room heights etc. Based on the results of the above calculations, fire resistance requirements are established for building construction.

The design of evacuation routes also involves detailed calculations. Apart from the number of occupants, the lengths, widths and of escape paths, occupant category and other factors are accounted for. In this case the maximum allowable evacuation time is used as the acceptance criterion.

As mentioned previously, although a high degree of calculation is employed, the final acceptance criteria are set in the standards and regulation and cannot be adjusted in any way. This is a major drawback of the standards; detailed design calculations are evaluated against a general set of acceptance criteria. In addition, the acceptance criteria have not been reviewed for over 30 years in some cases, having therefore lost connection with the current state of fire safety engineering and science.

3. Use of Fire Statistics

BS7974 Code of Practice on the Application of Fire engineering Principles to the design of Buildings is a document that defines a process for undertaking fire engineering analysis. This code is supported by eight Published Documents, which contain detailed technical guidance on different aspects of fire engineering from background information to quantitative risk assessment (Charters, 2006).

Part 7 of this suite of documents is concerned with probabilistic risk assessment (PRA). (British Standards Institution, 2003). Although not commonly used, PRA is a useful in order to generate a measure of risk. Mozer and Klucka (2014) describe the technique as; statistical data gathered from similar scenarios is used to predict future fire extent and consequences.

The average levels of risks for a range of building types, in terms of both deaths per building per year and deaths per occupant per year, are expressed in Table 2 of BS7974 Part 7 (BSI, 2003). It is statistical data such as these that are used by fire safety engineers when conducting PRAs.

However, for PRA to be viably used, there is a total reliance on the availability of good quality statistical data. As discussed by Bird, et al. (2012), there are a variety of sources that report the financial and societal cost of fire within the UK. The Association of British Insurers (ABI) in its paper Tackling Fire: A Call for Action (ABI, 2009) estimates the insured cost of fire is Ƚ1.3bn. It also reports that 443 deaths and 13,200 casualties were caused by fire in 2007. The UK Government in its report The Economic Cost of Fire: Estimates for 2004 (Office of the Deputy Prime Minister, 2006) reports a projected figure of Ƚ7.03bn for the cost of fire for the year 2004. Therefore it is clear that the consequence and cost of fire remains significant. However, are the frequencies, and hence probabilities of fires remaining constant?

The latest data from the UK (Department of Communities and Local Government, 2014) suggests that the incidence of fires is falling, and significantly so. Local authority fire and rescue services attended 170,000 fires in England in 2013-14. This is the second lowest number of fire incidents recorded. The record low number of fires in 2012-13 was the result of fewer outdoor fires, due to above average rainfall that year. There were 275 fire fatalities in England in 2013-14. These were 14 (5%) fewer than in 2012-13 and 39% lower than in 2003-04. Two thirds of all fire fatalities were in accidental dwelling fires (181 in

2013-14). While these were six higher than in 2012-13, this is the second lowest number recorded and more than a third lower than in 2003-04. In 2012-13, there were 3600 hospital non-fatal fire casualties. These were 5% and 55% fewer than one year and ten years earlier respectively.

Table 1. Table 2, reproduced from BS7974-7 (BSI, 2003)

Occupancy	No. of buildings	No. of occupants	Average/year [95/97/98/99]				
			No. of deaths	No. of injuries	No. of fires	Death / building/year	Death/ occupant/year
Further education	1 051	845 617[a]	0.0	17	535	$< 2.4 \times 10^{-4}$	$< 3.0 \times 10^{-7}$
Schools	34 731	10 503 100[a]	0.0	51	1 669	$< 7.2 \times 10^{-6}$	$< 2.4 \times 10^{-8}$
Licensed premises	101 081	–	2.8	262	3 317	2.7×10^{-5}	–
Public recreation buildings	45 049	–	1.3	48	2 581	2.8×10^{-5}	–
Shops	354 475	–	3.3	284	5 671	9.2×10^{-6}	–
Hotels	28 371	389 174[a]	2.5	116	1 021	8.8×10^{-5}	6.4×10^{-6}
Hostels	9 829	–	0.5	60	1 338	5.1×10^{-5}	–
Hospitals	3 486	–	3.3	113	3 063	9.3×10^{-4}	–
Care homes	29 080	–	4.5	130	1 616	1.5×10^{-4}	–
Offices	209 627	4 107 000[b]	0.3	219	1 988	1.2×10^{-6}	7.3×10^{-8}
Factories	170 972	–	4.3	286	5 299	2.5×10^{-5}	–
All above occupancies	987 752	15 844 891	22.5	1 584	28 096	2.3×10^{-5}	6.5×10^{-6}

NOTE:
It might be more appropriate to uses the number of deaths per occupant for large or complex buildings.
[a]Number of occupants equals to the sum of the number of employees and other occupants.
[b]Number of occupants equals to the sum of the number of employees only.

The statistics that are published in BS7974 Part 7 (BSI, 2003) are taken from data collected in the early 1990s. They reference data sources such as the UK's Annual Abstract of Statistics of 1995, the Fire Statistics of 1993 and Health and Personnel Social Services Statistics for England of 1994. Therefore, it is reasonable to assume that the statistics are now out of date and in need of revision, in order to enable reliable PRA to be undertaken.

In the Slovak Republic, the probability of a fire starting is used in the standardized fire design calculations as input for the maximum allowable evacuation time and maximum allowable size of compartment. Part 2 of the STN 92 0201 standard (SUTN, 2001) contains an annex listing the probabilities of a fire starting for a range of occupancies. The data from which the probabilities were calculated had been collected during the period from 1974 to 1984 (Zoufal, 1982). Given the development in technologies and equipment, the validity of the probabilities of a fire starting is questionable. As stated previously, no alternative approach is available, hence, PRAs are not carried out in the Slovak republic.

4. Fire statistic data from United Kingdom and Slovak Republic – Revision of Table 2

To provide the same structure of results, the building categorisation from Table 2 of PD 7974-7 was used as a basis, with an addition of the following new categories: transport buildings, agricultural buildings, warehouses (significant fire loss) and blocks of flats (large number of fires). The hotel and hostel categories were amalgamated due to the similarities in their use. The updated structure of statistical data covers the standard building uses/occupancies in a greater extent.

In the UK, the data was gathered by analysing published statistical data from various sources such as:

- The UK Fire Statistics, (Department of Communities and Local Government, 2012);
- The economic cost of fire: Fire research reports (Department of Communities and Local Government); and
- The Annual Abstract of Statistics (Office for National Statistics)

Through analysis of this data, it is possible to derive updated figures for elements of the data presented in Table 2 of BS7974-7.

This research has found that there has been a significant change in the numbers of fire report in the UK since BS7974-7 was first published.

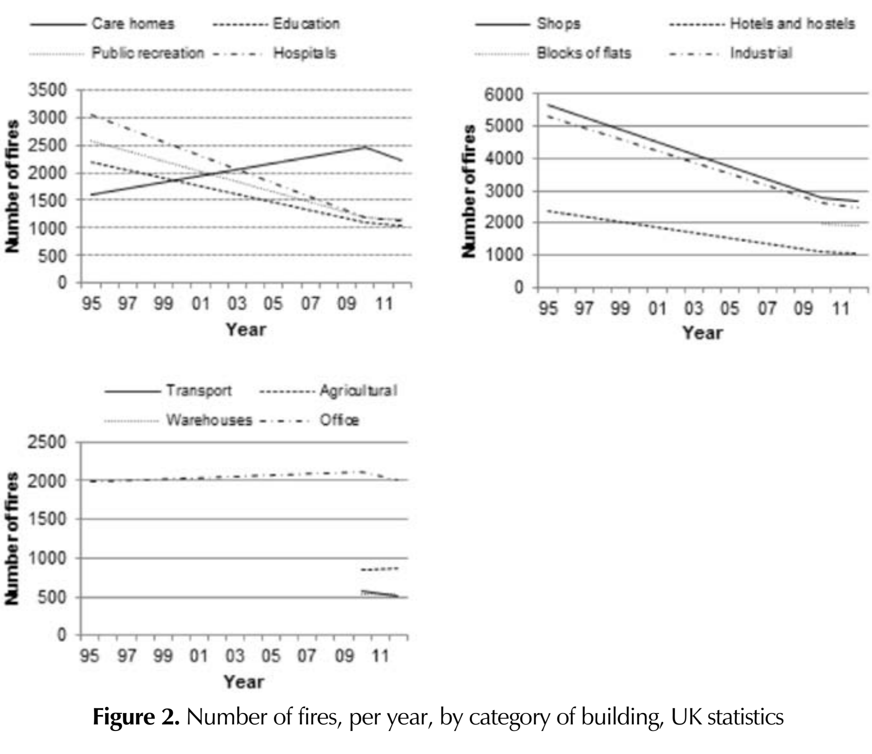

Figure 2. Number of fires, per year, by category of building, UK statistics

Figure 2 shows that the majority of building categories have seen a significant drop in the frequency of fires, especially retail and industrial categories. Interestingly, this drop hasn't been replicated in offices and care homes.

The Slovak statistical data were gathered from a 5-year period from 2008 to 2012 from statistical yearbooks published by the Fire & Rescue Service Headquarters. The graphical presentation of the number of fires for the individual building categories is shown in Figure 3. The data reveal that certain categories have seen a significant change in the number of fires, when comparing the 2008 baseline with the figures for 2012. It may also be seen that there is a relatively high degree of fluctuation and few categories show a consistent decrease.

Fire occurrence should be, however, analysed in connection to the number of buildings in each occupancy group. For this reason a survey conducted by the Slovak institute of building surveyors is included in Table 2, covering the period of 2008-2012.

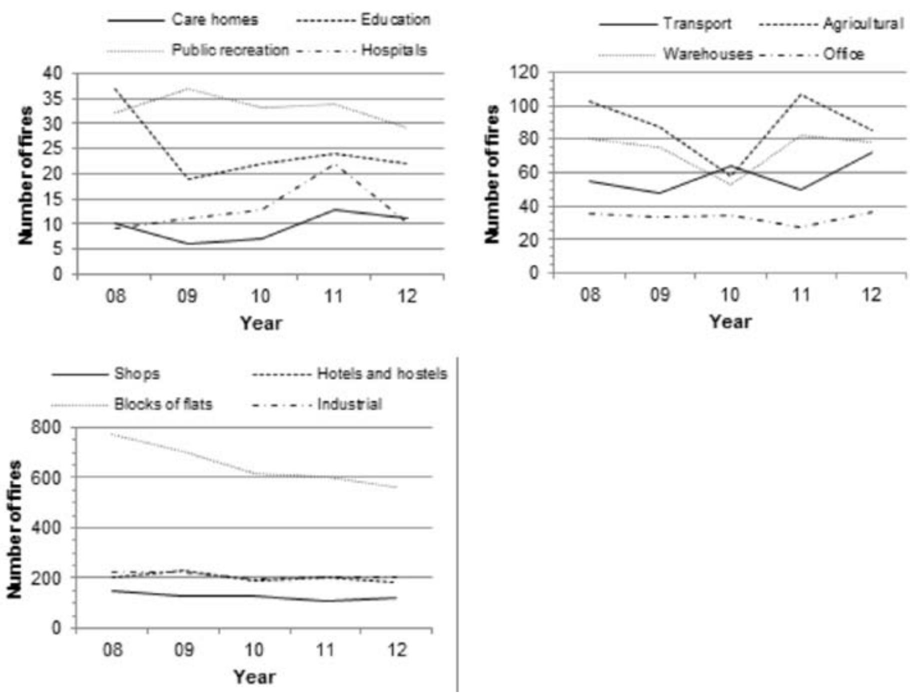

Figure 3. Number of fires, per year, by category of building, SK statistics

Although Table 3 suggests that the number of fires decreased in the majority of the building categories despite the increase in the number of buildings, the aforementioned fluctuation should be taken into consideration. Therefore, for each year, the probabilities of a fire starting, fire fatality and fire injury are calculated using the number of buildings, fires, fatalities and injuries recorded in that particular year. Subsequently, the yearly values of fire, death and injury probabilities are averaged over the monitored period, in order to avoid overly optimistic or pessimistic results. In addition to the 2008-2012 data, Table 3 presents probabilities calculated using fire occurrence, injury and fatality data from 1993-2012 against the number of buildings from 2012. This is due to the fact that in several cases a zero probability was calculated from the 2008-2012 data, which is not realistic.

Table 2. Number of buildings by category 1998-2012, SK statistics

Building category	Number of buildings					Change
	2008	2009	2010	2011	2012	2008-2012
Agricultural	49 435	52 233	53 696	59 626	60 605	22.6%
Blocks of flats	45 949	49 328	51 313	53160	53 673	16.8%
Care homes	–	–	–	–	–	–
Education	16 127	16 504	16 456	16 684	16 635	3.1%
Hospitals	3979	4173	4279	4601	4678	17.6%
Hotels and hostels	10 845	10 859	10 672	10 546	10 500	-3.2%
Industrial	23 613	24 913	25 688	27 813	281 11	19.0%
Office	6854	7819	8239	9385	9691	41.4%
Public recreation	53 771	58 524	61 497	68 481	70 992	32.0%
Shops	12 386	14 281	15122	16 920	17 591	42.0%
Transport	5186	5935	6652	7641	7843	51.2%
Warehouses	–	–	–	–	–	–

Table 3. Probabilities of fire starting, fire injury and fire fatality, SK statistics

Building category	Probability (2008-2012 fire and building data)			Probability (1993-2012 fire data and 2012 building data)		
	Fire starting	Fire injury	Fire fatality	Fire starting	Fire injury	Fire fatality
Agricultural	1.61×10^{-03}	4.45×10^{-05}	$0.00 \times 10^{+00}$	1.76×10^{-03}	9.59×10^{-05}	7.86×10^{-06}
Blocks of flats	1.29×10^{-02}	1.41×10^{-03}	1.21×10^{-04}	1.40×10^{-02}	1.72×10^{-03}	2.80×10^{-04}
Care homes	–	1.08×10^{-01}	$0.00 \times 10^{+00}$	–	1.29×10^{-01}	3.23×10^{-02}
Education	1.51×10^{-03}	4.84×10^{-05}	1.22×10^{-05}	1.95×10^{-03}	5.15×10^{-05}	5.73×10^{-06}
Hospitals	2.97×10^{-03}	9.70×10^{-05}	$0.00 \times 10^{+00}$	3.22×10^{-03}	1.71×10^{-04}	2.14×10^{-05}
Hotels and hostels	1.89×10^{-02}	1.16×10^{-03}	3.17×10^{-04}	1.47×10^{-02}	7.24×10^{-04}	2.52×10^{-04}
Industrial	8.13×10^{-03}	4.79×10^{-04}	7.11×10^{-06}	8.12×10^{-03}	7.89×10^{-04}	2.71×10^{-05}
Office	4.06×10^{-03}	3.02×10^{-04}	2.56×10^{-05}	4.39×10^{-03}	2.46×10^{-04}	5.90×10^{-05}
Public recreation	5.34×10^{-04}	3.55×10^{-05}	1.19×10^{-05}	4.74×10^{-04}	1.48×10^{-05}	4.93×10^{-06}
Shops	8.47×10^{-03}	5.56×10^{-04}	$0.00 \times 10^{+00}$	6.89×10^{-03}	2.61×10^{-04}	5.68×10^{-06}
Transport	8.81×10^{-03}	8.60×10^{-04}	3.37×10^{-05}	7.55×10^{-03}	4.91×10^{-04}	1.28×10^{-05}
Warehouses	–	6.90×10^{-02}	9.82×10^{-03}	–	6.16×10^{-02}	3.00×10^{-03}

Italicized values represent relative probabilities of a fire resulting in an injury or a fatality because the number of buildings is unknown.

Since the numbers of buildings were not available for all categories of building use, relative probabilities of fire injury and fatality were used. They express what proportion of all fires recorded for a given category of use resulted in an injury or death.

The UK statistical review found difficulties in determining the number of buildings in each occupancy group. This work involved analysis of the Annual Abstract of Statistics (Office for National Statistics, 2012) which proved interesting but inconclusive. By way of example, the number of schools has remained relatively constant between the mid 1990s to 2010, but data relating to further education has reportedly dropped from over 1000 to around 150. It is not likely that this means there are fewer buildings, but more an indication that vocational colleges and universities have amalgamated and consolidated into fewer, larger organisations. Another category of building analysis revealed that the number of shops has decreased from over 350000 to around 200000. This is likely to be an accurate reflection, but, as a general trend cannot be drawn from this analysis, the number of buildings has not been updated as part of this research. Hence, the following Table 4 determines probabilities based on the numbers of buildings determined in the mid 1990s.

Table 4. Probabilities of fire starting, fire injury and fire fatality, UK statistics

Building category	Probability (2012 fire data and 1999 building data)			Probability (1995-1999 fire and building data)		
	Fire starting	Fire injury	Fire fatality	Fire starting	Fire injury	Fire fatality
Agricultural	–	3.60×10^{-02}	$0.00 \times 10^{+00}$	–	–	–
Blocks of flats	–	2.49×10^{-01}	5.78×10^{-03}	–	–	–
Care homes	7.63×10^{-02}	7.70×10^{-03}	6.88×10^{-05}	$5.56 x 10^{-02}$	4.47×10^{-03}	1.55×10^{-04}
Further education	4.24×10^{-01}	5.71×10^{-03}	$0.00 \times 10^{+00}$	5.09×10^{-01}	1.62×10^{-02}	$0.00 \times 10^{+00}$
Hospitals	3.25×10^{-01}	1.38×10^{-02}	$0.00 \times 10^{+00}$	8.79×10^{-01}	3.24×10^{-02}	9.47×10^{-04}
Hotels and hostels	2.67×10^{-02}	2.64×10^{-03}	7.85×10^{-05}	6.18×10^{-02}	4.61×10^{-03}	7.85×10^{-05}
Industrial	1.45×10^{-02}	1.02×10^{-03}	3.51×10^{-05}	3.10×10^{-02}	1.67×10^{-03}	2.52×10^{-05}
Office	9.63×10^{-03}	5.01×10^{-04}	4.77×10^{-06}	9.48×10^{-03}	1.04×10^{-03}	1.43×10^{-06}
Public recreation	2.54×10^{-02}	3.55×10^{-04}	$0.00 \times 10^{+00}$	5.73×10^{-02}	1.07×10^{-03}	2.89×10^{-05}
Schools	1.68×10^{-02}	6.62×10^{-04}	$0.00 \times 10^{+00}$	4.81×10^{-02}	1.47×10^{-03}	$0.00 \times 10^{+00}$
Shops	7.54×10^{-03}	2.85×10^{-04}	2.82×10^{-06}	1.60×10^{-02}	8.01×10^{-04}	9.31×10^{-06}
Transport	–	7.12×10^{-02}	$0.00 \times 10^{+00}$	–	–	–
Warehouses	–	2.84×10^{-02}	9.47×10^{-03}	–	–	–

Italicized values represent relative probabilities of a fire resulting in an injury or a fatality because the number of buildings is unknown.

5. Comparision of UK and SK Statistics Review

To review the performance of the UK's and SK's fire safety systems the available statistical data was compared for the individual building categories. Since there is lack of information on the number of buildings in the monitored categories, the comparison is divided in two parts. Where the number of buildings was available, the respective probabilities of a fire starting were compared. In addition, to cover a broader range of buildings, the relative probabilities of fire injury and fatality occurrence were compared. The latter may be taken as a life-safety performance measure of the fire safety systems implemented in the United Kingdom and Slovak republic.

The comparison of the probabilities of a fire starting reveals a higher probability of a fire starting in the United Kingdom, apart from the “shops” category. The majority of building categories in the Slovak republic have the probabilities from the 10^{-3} range, the United Kingdom falls mostly into the 10^{-2} range. Very high and similar probabilities of a fire starting was found for the „hotels and hostels“ category – 1.89×10^{-2} (SK) and 2.67×10^{-2} (UK). The UK data revealed two occupancy categories with abnormally high probabilities of a fire starting – further education and hospitals – with their respective values of 4.24×10^{-1} and 3.25×10^{-1}; it is possible that the building number data included in PD 7974-7 (replicated in Table 1) had been derived incorrectly.

The comparison of the relative probabilities (no of injuries (deaths) / no of fires) revealed that there is no clear trend regarding fire injuries. Out of the 12 categories compared, higher education was excluded, each country had five categories with “better” performance and five categories with “worse” performance when compared to each other. Two categories – schools/education and care homes – had approximately the same relative probabilies of a fire injury, for detailed results refer to Table 5. The order of probability for most of the occupancy categories is 10^{-2}. The only exceptions are blocks of flats and care homes where the order is 10^{-1}.

Table 5. Relative probabilities of fire injury and fire fatality

Building category	**Relative probability of fire injury**		**Relative probability of fire fatality**	
	SK	**UK**	**SK**	**UK**
Agricultural	2.76×10^{-02}	3.60×10^{-02}	4.47×10^{-03}	–
Blocks of flats	1.09×10^{-01}	2.49×10^{-01}	9.35×10^{-03}	5.78×10^{-03}
Care homes	1.08×10^{-01}	1.01×10^{-01}	3.23×10^{-02}	9.02×10^{-04}
Hospitals	3.27×10^{-02}	4.25×10^{-02}	6.65×10^{-03}	1.08×10^{-03}
Hotels and hostels	6.14×10^{-02}	9.89×10^{-02}	1.68×10^{-02}	2.94×10^{-03}
Industrial	5.89×10^{-02}	7.03×10^{-02}	8.75×10^{-04}	2.42×10^{-03}
Office	7.44×10^{-02}	5.20×10^{-02}	6.31×10^{-03}	4.95×10^{-04}
Public recreation	6.55×10^{-02}	1.40×10^{-02}	2.23×10^{-02}	5.04×10^{-04}
Schools/education	3.21×10^{-02}	3.94×10^{-02}	8.08×10^{-03}	–
Shops	6.56×10^{-02}	3.78×10^{-02}	8.24×10^{-04}	3.74×10^{-04}
Transport	9.76×10^{-02}	7.12×10^{-02}	3.83×10^{-03}	–
Warehouses	6.90×10^{-02}	2.84×10^{-02}	9.82×10^{-03}	9.47×10^{-03}

Italicized values represent relative probabilities derived from older data since the new data yielded $0.00 \times 10^{+00}$.

On the contrary, the results in Table 5 indicate that for most types of occupancy, providing data is available, the probabilities of a fire fatality are lower in the United Kingdom. The only exception is the "industrial" category; warehousing is equal in both countries. This may be interpreted as a higher level of life safety in the United Kingdom, when compared to the Slovak republic. The order of probability of fire fatality is from 10^{-3} to 10^{-4} in the United Kingdom and 10^{-2} to 10^{-4} in the Slovak republic, meaning a higher variability in the fatality rates.

6. Limitations and Further Work

This study and its results highlight difficulties with statistical data and probabilities derived there from. On one hand, fire-related data are usually accurate and relatively easy to obtain; almost every country records the number of fire incidents, fire injuries and deaths as a minimum. Problems may, however, arise when fire data for a specific group/subgroup of occupancy is required. To obtain a probability of a fire starting, the size of the basic reference group, for which the number of fires has been recorded, is required. This is where the major difficulty lies; it is usually rather difficult to obtain data for the basic reference group – the number of buildings in a given occupancy category.

Firstly, if the numbers of buildings are recorded, the categorisation of buildings is usually not primarily related to fire safety. Therefore, if it is to be applied to fire safety, amalgamation of fire categories and/or their generalisation has often to be applied. And secondly, very few buildings are of a single use. This introduces a level of uncertainty for the majority of mixed-use buildings. If a building contains three types of occupancy, e.g. office, retail and car-park, should it be considered as three separated buildings or as fractions of one building based on the floor area of the respective occupancies? It could be argued that the probability of a fire starting relates to the prevailing use (occupancy type) of a building, as it seems to be the only practicable solution. Hence, when working with mixed-use buildings, the proportion of the various occupancies should be carefully considered when selecting an adequate value of the probability of a fire starting.

An example of the above problem may be observed in Table 4 based on the UK statistical data. The further education and hospital occupancies have extremely high probabilities of a fire starting – 8.80×10^{-01} being the worst. Looking in Table 1, there is only about 3000 buildings in the hospital category. In comparison, in the Slovak republic, a much smaller country, the number of hospital buildings is over 4500 in 2012. So there may be a discrepancy in how the number of buildings in this particular category is recorded in the UK and SK. Alternatively, the data may have been misinterpreted, hence, the abnormally high probabilities. These challenges are similar to those described in Cote, et. al,

(2008) and Rabash, et.al., (2004), with the addition of incompatibility of data between different countries or fire safety systems.

Based on the above observations, adjustments should be made, so that the fire statistics are not just a general representation of the fire occurrence trend, but a useful source of data for the fire safety engineer. This should include a finer categorisation of occupancies, based primarily on the commonly used purpose groups, e.g. within Approved Document B (DCLG, 2010) and SUTN (2001). Furthermore, the numbers of buildings in these categories are required in order to be able to determine fire occurrence, fire injury and fatality probabilities. It is therefore necessary to start a dialogue with the organisations responsible for the collection of statistical data relating to fires and built environment. An initiative has been started in the Slovak republic, but even if successful, it will take a number of years until a reliable source of fire safety probabilistic data is available.

7. Conclusions and Recommendations

This paper compares the fire safety regimes in two different countries, namely the United Kingdom and the Slovak Republic. It identifies how statistical fire data is used in fire engineering analysis, an increasingly important tool used in building design. The paper compares statistics across the two countries, and updates historically derived data to compile contemporary equivalents.

Two important conclusions can be drawn from this work;

1. Data relating to fire frequency, fire injury and fire death alters over time. This is due to evolving built environments, changes in design methods employed, use of materials and provision of fire precautions; as well as the changing human element, reduction in smoking within buildings, increased electrical safety practices, etc. Therefore, for fire safety engineering PRA studies to be meaningful, the most up-to-date data must be sought, not placing reliance on data published in Codes that are actually decades old.
2. Data relating to fire frequency, fire injury and fire death are specific to the country of origin. This is due to differences in practices in the built environments as well as human factors, but the implications are clear. If a designer cannot find a required value, or derive it from data available for a particular country, then applying a value from a different country is unreliable. Essentially, country specific data is not interchangeable and the resulting probabilities may vary in orders of magnitude, as the results confirm.

Use of statistics has always required great care, and this is no different in fire safety engineering PRA studies.

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