Statistical Analysis of the Effectiveness of Fire Protection System Technologies – Extract from the Project Survey Phases I of the *vfdb Fire Loss Statistic*

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Abstract

The following paper presents the Fire loss statistics project. The objective of the project is to examine the effectiveness of (system technology) fire protection measures based on real fire service interventions using statistical methods. In Germany, there is a need for statistical findings about fire interventions across the fire services, about the fire phenomenon and about the effectiveness of (system technology) fire protection measures. A comparable situation is found in many countries. The project is based on fire service intervention data which are systematically collected and assessed by means of a survey sheet with uniform criteria for fire alarms in buildings. These data are used to record statistical findings on the fire phenomenon, fire service intervention and the effectiveness of fire protection measures. Such findings are useful for the risk assessment of many different situations, particularly for reaching specific and ascertained protection aims. The first survey phase of the project (2014/2015) yielded findings, extracts of which are presented in this paper.

Keywords: Fire protection system technologies, effectiveness, fire losses, statistic, analysis

Introduction

Department 14 of the German Fire Protection Association e. V. (vfdb) focuses its work on (system technology) fire protection measures. This department initiated the fire loss statistics project the objective of which is to examine the effectiveness of (system technology) fire protection measures based on fire service interventions using statistical methods. This project is required because, so far, there has been no evidence of the effectiveness of (system technology) fire protection measures in

Germany and there is a need for comprehensive statistical findings about fire interventions and the fire phenomenon. This is due to the fact that, in Germany, the responsibility for preparing fire intervention reports lies with the fire services who handle this matter in many different ways. As regards fires, the causes, the spread of fires and the losses incurred through fires as well as the effectiveness of the initiated protection measures, there are therefore no uniform criteria for the documentation and analyses. A comparable situation is found in many countries. The fire loss statistics project aims at bridging this gap or even closes it in parts.

Statistical findings are urgently and increasingly required to assess a great number of different actual situations, such as specifications and provisions in building legislation, in standards and in the terms and conditions of insurances (cf. [1] and [2]). Statistical evidence can help authorities to increase their acceptance of practical compensation options. As a result, it is, for example, easier to enforce deviations from building legislation and make construction projects more flexible, so that changes of building use or additional alleviations can be approved more rapidly and easily. It is, however, not allowed to fall below the present protection level. Flexible solutions to reach protection aims by specific and adequately ascertained compensation measures based on fire protection system technologies are, for example, even required when the cutback in qualified staff [3] and the consumption of areas available for construction projects [4] – this affecting the building structures when people's needs remain as they are – make further progress. The results of the project are useful for many different groups of persons involved in fire protection, e.g., fire services, fire protection engineers, insurances, manufacturers, and providers, as well as for science in general.

Project method

In the project, fire intervention data of several different fire services across Germany (voluntary, professional and private/industrial fire services) relating to building fire alarms (incl. false alarms) are collected in a survey sheet with uniform criteria [5]. The survey sheet contains 149 uniform criteria (plus summations) that are subdivided into 20 survey blocks in order to collect information about the fire service intervention conditions, the causes, the development and spread of building fires, (from the initiation of alarms to the losses incurred), as well as the initiated fire protection measures. The survey blocks are shown in the following table 1.

The commanding officer or another person being familiar with the intervention conditions has to fill in the survey sheets immediately during or after intervention. The survey sheets then have to be provided with the fire service's official stamp and sent to us. Preferably, all building fire interventions of the respective fire service should be completely registered over a freely defined time period. However, it is

not mandatory to completely register all interventions because, within the scope of the project, conclusions are drawn from a random sample of data on fire interventions across Germany using statistical methods. The project is not aimed at reaching full statistics on fires in Germany and is therefore basically different from previous approaches dealing with the subject of fire statistics in Germany (e.g., [6]).

The intervention data obtained from the received filled-in survey sheets are anonymized and saved to a central database of the Furtwangen University (Germany) where they are evaluated under the direction of Ernst-Peter Döbbeling and myself. The evaluation is classified in A) individual assessments, B) cluster assessments, and C) a total assessment.

Table 1. Survey blocks in the uniform survey sheet of the *Fire Loss Statistic* project.

1. general	11. assumed location of fire outbreak
2. fire service status	12. assumed object of fire outbreak
3. building type	13. fire size on arrival of the fire service
4. building use	14. fire limited to (spread)
5. emergency call / notification	15. smoke spread (arrival of the fire service)
6. real fire / false alarm	16. smoke layering
7. false alarm trigger	17. usability of the escape route
8. triggered fire protection system technologies	18. human lives saved / fatalities
9. assumed cause of fire causes	19. estimated material damage
10. floor where the fire broke out	20. use of fire-fighting water

In the individual assessments (A), the data of the individual fire services involved in the project are evaluated separately, on an average and as a whole based on the survey criteria, in order to identify fire-service-specific dependencies, key aspects and trends with respect to the fire phenomenon and the fire interventions (fire services with small case numbers are summarized to observe them as a group). The individual assessments are analyzed fire service by fire service, on the one hand using the simple frequency distribution in the survey blocks (e.g., distribution of the frequency of the *assumed cause of fire outbreak* or the *building use*) and, on the other hand, using linked survey criteria (e.g., *real fires / false alarms* in combination with the *floor where the fire broke out* or the *building use* in combination with the *assumed object of fire outbreak*). In a first step, 2 survey blocks are combined, wherein these combinations can be extended by other survey blocks

(e.g., *building use* in combination with *fire / false alarm* and *fire size on arrival of the fire service*).

In the cluster assessments (B), questions across all fire services are processed (e.g., common issues and differences between key aspects of the interventions in relation to the *type of fire service* or the *size of the fire service* or the *size of the intervention area*).

The total assessment (C) is the core of the project. In the total assessment, the survey sheets of all fire services involved are consolidated in an overall data set which is then used to examine the effectiveness of fire protection (system technology) measures. To achieve this, the intervention data are compared with respect to fires in buildings of the same type and use with or without various measures, using combined survey blocks and/or criteria. The damage difference allows to making a statement on the effectiveness of the fire protection (system technology) measures initiated.

After a pilot project phase (see [7] and [8]) in 2011 with fire intervention reports of 4 fire services and 580 filled-in survey sheets on building fires (incl. false alarms), the survey sheet was updated. Thereafter, the main project (cf. [1], [9] and [10]) was started. This main project is subdivided into several survey phases. The first survey phase which started on 01/01/2014 and ended on 12/31/2015 comprises intervention data from 18 fire services across Germany having been operated in about 3000 building fires, 681 of which were real fires. The data obtained in the first survey phase are presently evaluated based on the described procedure and have already been published in part (cf. [1], [9], [11]).

Results

The results from the first survey phase of the project I are structured according to the evaluation procedure in A) individual assessments, B) cluster assessments, and C) a total assessment (see above).

Individual assessments (A)

The individual assessments are analysed fire service by fire service (fire services that have only participated in the project with a few survey sheets are examined together in a collection group), using 1) the simple frequency distribution in the survey blocks (see table 1) and 2) linked survey criteria (in Phase I there are more than 72 tables in which 2 criteria can be linked). Table 2 shows an excerpt from the table of results concerning the simple frequency distribution in the survey blocks.

Table 2. Individual assessment (of fire services; FS); excerpt [N=2,775; n_{Fire}=681] [1].

criterion		FS 1	FS 2	FS 3	FS 4	FS 5	FS 6	FS 7	group	total	
		[no]	[no]	[no]	[no]	[no]	[no]	[no]	[no]	[no]	[%]
	sum	**223**	**274**	**139**	**619**	**1022**	**147**	**139**	**212**	**2775**	
	real fires	108	62	59	141	114	56	42	99	681	25
emergency call	telephone	58	49	81	81	19	35	27	47	397	14.4
	mobile phone	35	41	17	78	134	21	8	46	380	13.8
	fire detection and fire alarm system, automatic	84	145	36	413	804	90	78	99	1749	63.6
	fire detection and fire alarm system, manual call point	8	20	3	26	27	4	7	2	97	3.5
	fire extinguishing system	1	1		12	39		1	7	61	2.2
	other alarm	3	14	1	25			17	6	66	2.4
	sum	**189**	**270**	**138**	**635**	**1023**	**150**	**138**	**207**	**2750**	**100**
floor	basement/cellar	6	13	5	11	10	7	8	15	75	13.1
	ground floor	27	23	17	44	65	19	15	38	248	43.4
	1st - 2nd upper floor	17	11	3	42	23	21	12	33	162	28.4
	3rd - 7th upper floor	3	5	5	30	16	6	5	9	79	13.8
	from 8th upper floor				5		2			7	1.2
	sum	**53**	**52**	**30**	**132**	**114**	**55**	**40**	**95**	**571**	**100**

Table 3 supplies an example of one of many tables of results of linked survey criteria.

Table 3. Example of crossed criteria (floor where the fire broke out; emergency call).

criterion	Basement / cellar	ground floor	1st - 2nd upper floor	3rd - 7th upper floor	from 8th upper floor	sum
telephone	37	80	69	23	2	211
mobile phone	20	110	65	26	1	222
fire detection and fire alarm system, automatic	18	42	20	27	5	112
fire detection and fire alarm system, manual call point		1	1			2
fire extinguishing system	1	3	2		1	7
other alarm	2	7	6	1		16
sum	78	243	163	77	9	570

Cluster assessments (B) – sample

A cluster assessment of an intermediate result of 2,294 recorded fire service interventions with 482 real fires from phase I was summarised for the fire services involved at a) voluntary, b) professional and c) private/industrial fire services. Table 4 shows an excerpt of the results. The evaluation shows in example [1]:

- The 2,294 fire service interventions consist of 1,044 interventions of professional fire services (approx. 46 %), 1,022 interventions of works fire services (45 %) and 228 interventions of voluntary fire services (10 %) – which shows that the voluntary fire services are under-represented here in the results.
- The total proportion of real fires among the alarms is 21 %. This proportion is lowest for the private/industrial fire services, with 114 cases (11 %), followed by the professional, with 279 real fires (27 %), and 89 cases (39 %) for the voluntary fire services.
- The fire service is in most cases, 68 %, alerted by automatic fire detection and fire alarm systems, and in 13 % via mobile phone and in 13 % via telephone. Mobile phones account for a roughly equal proportion across the different fire service types (between 12 % and 13 %), while the proportion of alarms via telephone is

roughly equal for the professional (21 %) and voluntary fire services (24 %) and plays almost no role for private/industrial fire services at 2 %. In 81 cases the alarm comes from manual call points and in 53 cases via fire extinguishing systems.

- As regards the material damage, the insight that most fires cause minor material damage is confirmed. The losses are lowest with the private/industrial fire services (as can be recognised from the proportions in which the damage is less than € 1,000), followed by the professional and then the voluntary fire services.
- When examining building use, flats (25 %), hospitals, retirement and nursing homes (13 %) and administrative and office buildings (13 %) are predominant among the actual fires.
- Across all alarm paths, false alarms are above all triggered by unknown causes (19 %), water vapour (14 %), technical faults in systems (13%), aerosols, such as oils, grease vapours or spray (12 %), and blind alarms and/or in good faith (12 %). The proportion of unknown causes for the professional fire services is, at around 21 %, almost twice as high as for the voluntary fire services at 12 %.
- The “stove/oven” is the most frequently assumed object of fire outbreak at 28 % and the kitchen the most frequently assumed place of fire outbreak at around 30 %.

Total assessment – proof of effectiveness (C)

Using Phase I, with this database (N=2,775 fire intervention reports with a total of 681 real fires), proof of effectiveness can only be rendered for fire detection and fire alarm systems [1]. Such evidence is to follow for other systems technologies as soon as higher numbers of cases are available for them. The effectiveness of fire detection and fire alarm systems can be measured based upon various damage criteria, e.g. estimated material damage, spread and/or limiting of the fire, usability of escape routes and in extinguishing water consumption. These criteria are drawn upon as reference values taken together with the values of manual alerting via telephone and mobile phone. The values for the damage criteria are listed in table 5. Based on these data, it is clear that the fire damage turns out lower across all criteria due to the use of automatic installed fire detection and fire alarm systems and that also the escape routes were more frequently accessible than in cases where the fire service was manually alerted via telephone and mobile phone.

Table 4. Cluster assessment; excerpt – professional (FS_P), voluntary (FS_V) and private/industrial fire services (FS_I) [1].

criterion		**FS_P**		**FS_V**		**FS_I**		**cluster (total)**	
survey sheets / fire interventions		1044		228		1022		2294	
real fires **(RF)**		279		89		114		482	
false alarms **(FA)**		765		139		908		1812	
emergency call	landline telephone	214	21.4	52	24.0	19	1.9	285	12.7
	mobile telephone	134	13.4	25	11.5	134	13.1	293	13.1
	fire detection and fire alarm system, automatic	589	58.8	133	61.3	804	78.6	1526	68.1
	fire detection and fire alarm system, manual call point	49	4.9	5	2.3	27	2.6	81	3.6
	fire extinguishing system	14	1.4	0	0.0	39	3.8	53	2.4
	other/no data	1	0.1	2	0.9	0	0.0	3	0.1
	Sum	**1,001**	**100**	**217**	**100**	**1,023**	**100**	**2,241**	**100**
material damage	< 1,000 EUR	149	55.8	38	50.0	93	84.5	280	61.8
	< 10,000 EUR	40	15.0	24	31.6	4	3.6	68	15.0
	< 100,000 EUR	30	11.2	10	13.2	3	2.7	43	9.5
	< 500,000 EUR	5	1.9	1	1.3	0	0.0	6	1.3
	< 1,000,000 EUR	1	0.4	0	0.0	0	0.0	1	0.2
	no data	42	15.7	3	3.9	10	9.1	55	12.1
	Sum	**267**	**100**	**76**	**100**	**110**	**100,0**	**453**	**100**

Table 5. Fire damage criteria for the alerting of the fire services via fire detection and fire alarm systems in comparison to manual telephone calls [N=2,775; n_{Fire}=681] [1].

Criterion		alarm via		proportion	
		FDAS [no]	phone [no]	FDAS [%]	phone [%]
material damage	D < 1,000	84	276	0.84	0.63
	D < 10,000	13	97	0.13	0.22
	D < 100,000	3	52	0.03	0.12
	D < 500,000	0	7	0.00	0.02
	D < 1,000,000	0	2	0.00	0.00
	D > 1,000,000	0	2	0.00	0.00
	no data possible	10	49	---	---
	sum	**110**	**485**	**1.00**	**1.00**
fire spread	object	98	351	0.84	0.70
	room	13	91	0.11	0.18
	several rooms	4	16	0.03	0.03
	flat	0	8	0.00	0.02
	floor	0	8	0.00	0.02
	several floors	0	6	0.00	0.01
	fire compartment	0	4	0.00	0.01
	several fire compartments	0	2	0.00	0.00
	stairwell	1	3	0.01	0.01
	whole building	0	9	0.00	0.02
	other buildings	0	1	0.00	0.00
	sum	**116**	**499**	**1.00**	**1.00**
spread of smoke	not noteworthy	54	222	0.46	0.42
	room, shaft	36	85	0.31	0.16
	flat	12	102	0.10	0.19
	floor	4	33	0.03	0.06
	stairwell	5	37	0.04	0.07
	corridor	4	20	0.03	0.04
	several floors	3	27	0.03	0.05
	sum	**118**	**526**	**1.00**	**1.00**
	escape route usable? yes	92	291	0.78	0.57
	sum (of all fires)	**118**	**515**		
extinguishing water consumption	no extinguishing water used	81	158	0.74	0.32
	< 500 L	24	217	0.22	0.44
	< 2,500 L	4	85	0.04	0.17
	> 2,500 L	1	32	0.01	0.07
	Sum	**110**	**492**	**1.00**	**1.00**

Conclusion

The Project Phase I of the project *vfdb Fire Loss Statistics* has been completed and supplies interesting preliminary results. Findings have been acquired about the range of interventions and the phenomenon of fire from across different fire services. The data quality and quantity of the fire services often varies greatly. This shows that there is no one fire service that can be regarded as representative of all others in terms of its experiences [and statistics].

Using the database of Phase I proof of effectiveness can be rendered for fire detection and fire alarm systems. The fire damage turns out lower across all criteria due to the use of automatic installed fire detection and fire alarm systems. Also the escape routes were more frequently accessible than in cases where the fire service was manually alerted. These systems are effective.

Work on the project is proceeding. At present, the data pool is being supplemented with data from other fire services, a further approx. 2,000 survey sheets, which is then being assessed as in Phase I. This increases the case numbers, which increases the representativeness of the results. Moreover, additional evaluations can be performed, because in Phase I some questions could not be processed due to low case numbers.

References

[1] Festag, S. (09/2015). Ergebnisse zur Erhebung der Brandschadenstatistik [Results of the statistical survey on fire losses]. In: Jochen Zehfuß (ed.): *Braunschweiger Brandschutz-Tage 2015. 29th Fachtagung Brandschutz bei Sonderbauten*, No. 227, pp. 227-248.

[2] Hegger, T. (9/2014). Entwicklung einer nationalen Brandschadenstatistik [Development of national fire loss statistics]. In Jochen Zehfuß (ed.): *Braunschweiger Brandschutz-Tage 2014. 28th Fachtagung Brandschutz und Sonderbauten*, 16 to 17 September 2014, No. 224, pp. 261-272.

[3] Müller, J. (2009). *Zukunft der Feuerwehr – Feuerwehr der Zukunft im ländlichen Raum [Future of the Fire Services – Fire Services in Future in Rural Germany].* PhD thesis, University Wuppertal.

[4] Nationale Nachhaltigkeitsstrategie (10/2011). *Nationale Nachhaltigkeitsstrategie – Fortschrittsbericht 2012* [National sustainability strategy – Progress report 2012]. Presse- und Informationsamt der Bundesregierung (ed.) [Press and Information Office of the Federal Government], URL:www.bundesregierung.de, p. 194.

[5] vfdb Department 14 – Vereinigung zur Förderung des Deutschen Brandschutzes e. V. – Brandschadenstatistik [German Fire Protection Association e.V. – Fire loss statistics]. URL: www.ref14.vfdb.de.

[6] Brushlinsky, N.N., Hall, J.R., Sokolov, S.V. & Wagner, P. (2012). *World Fire Statistics*. CTIF – International Association of Fire and Rescue Services, Center of Fire Statistics, Report No. 17.

[7] Döbbeling, E.P., Festag, S. & Witzigmann, M. (8/2012). Brandschadenstatistik zur Wirksamkeit anlagentechnischer Brandschutzmaßnahmen [Fire loss statistics for the effectiveness of fire protection measures]. VFDB, 3rd edition, pp. 123-127.

[8] Festag, S., Ruhs, A. & Döbbeling, E.P. (6/2014). Projekt „Brandschadenstatistik“ [fire loss statistics project]. BRANDSchutz / Deutsche Feuerwehr-Zeitung, 6th edition, pp. 22-24.

[9] Festag, S. (03/2015). Brandschadenstatistik: Diskussion erster Projektergebnisse [Fire loss statistics: discussion of first project results]. Presentation, 4th Magdeburg Day of Fire and Explosion Safety. 26/03/2015 to 27/03/2015, Magdeburg.

[10] Festag, S. (05/2016). Brandschadenstatistik – Der Wert für die Wissenschaft [Fire loss statistics and their value for research]. In: vfdb-Jahresfachtagung 2016, Stuttgart, pp. 209-226.

[11] Döbbeling,E.P. (05/2016). Brandschadenstatistik – Der Wert für die Feuerwehrpraxis [Fire loss statistics and their value for fire safety practice]. In: vfdb-Jahresfachtagung 2016, Stuttgart, pp. 227-239.