1. Introduction

This paper deals with the topic of fire loss classification and quantification. An analysis was carried out, using the available data which represent direct fire losses in the Slovak Republic. Direct loss was also supplemented by a quantitative expression of indirect loss. The aim of the paper is, based on statistical analysis, to offer managerial information on the probability of total loss in €, as well as the associated probabilities of loss occurrence. The outcomes of the analysis are then transformed into a set of recommendations for the Fire & Rescue Service management.

Loss may be analysed from the following points of view:

• trend,
• occurrence probability,
• interdependencies with other statistical descriptors and benchmark comparison (including international comparison).

The results of these analyses should have a positive impact on the realisation of the management process in the Fire & Rescue Service, as well as on the structure and process of statistical analysis (internal and external communication of processes and results).

2. Analysis

There is a number of approaches to incident loss classification; by an incident we understand, for the purposes of this paper, an event, the consequences of which lead to loss and potential system dysfunction (for more also see [1]).
Another view of costs results from their categorisation into direct - losses caused on the building and equipment due to a fire, and indirect - e.g. loss of production impacting profit, loss of customers, markets etc.

The direct loss on the building is expressed through an estimation of the expected replacement cost of the property damaged (for more also see [2]).

There is a number of approaches for fire loss quantification and they are organisation-specific. The insurance industry uses the following indicators (for more also see [3]):

**Estimated maximum loss (EML):** Usually expressed as percentage of value of unit under consideration. The fraction is likely to be charged in a serious conflagration.

**Maximum possible loss:** Financial loss that would occur under catastrophic or extremely unfavourable conditions (Failure of two or more protective systems - active and passive).

**Maximum probable loss:** Maximum financial loss under normal conditions, for example one protective system failing.

**Normal loss expectancy:** Financial loss under average operating conditions - all protective systems functional.

Figure 2 illustrates the relationship between fire losses and the cost of fire protection measures. It is obvious, that for a given curve of costs and losses the (FLS – optimum C/L) point represent an optimum level - i.e. for the given level of costs, the losses are at their minimum value.

The extent of economic consequences of an accident is determined by the following elements:

- Economic consequences are divided into direct and indirect,
- Life loss and injuries represent specific forms of loss which are, although difficult, quantifiable,
- Economic consequences of an accident are driven by system’s resilience,
- The ratio of direct and indirect loss is inconsistent among the sources (for more also see [1]), states that the indirect loss represent 25 – 40 % of direct loss,
- There is only a limited theoretic methodology basis and statistical data required for incident consequence quantification.

The current methodology of Slovak Fire & Rescue Service (FRS) recognizes only direct losses. They are recorded in accordance with internal guidelines of FRS (for more also see [4], [5] and [6]).

### 3. Results

The analysis included the following steps:

- Total direct loss calculated from statistic report data was adjusted for inflation; direct loss was also used as the basis for the calculation of indirect loss for the analysed statistical set (see Table 1).
- Based on the above total adjusted direct and indirect loss, direct and indirect loss per fire was calculated (see Table 2).

### Direct and indirect loss in SR in 2003 – 2012

| Year | Inflation (%) | Direct losses DL (€) | Direct losses with inflation (€) | Indirect losses IDL (€) | Total losses TL (€) | TL - (€) | Growth coef. TL |
|------|---------------|----------------------|---------------------------------|------------------------|---------------------|---------|-----------------|
| 2003 | 8.5           | 18734874.0           | 20327338.3                      | 6726573.0              | 27053911.3          | 8319037.3 | -               |
| 2004 | 7.5           | 19539670.0           | 21005145.3                      | 7006951.3              | 28012096.6          | 8472426.6 | 1.0             |
| 2005 | 2.7           | 27003084.0           | 27732167.3                      | 9902582.3              | 37634749.6          | 10631656.6 | 1.3             |
| 2006 | 4.5           | 27121208.0           | 28341662.4                      | 10174267.2             | 38515929.6          | 11394721.6 | 1.0             |
| 2007 | 2.8           | 46921954.0           | 48235768.7                      | 19725511.6             | 67961280.3          | 21039326.3 | 1.8             |
| 2008 | 4.6           | 43493564.0           | 45494267.9                      | 18339592.7             | 63833860.6          | 20340296.6 | 0.9             |
| 2009 | 1.6           | 38761305.0           | 39381485.9                      | 15324004.8             | 54705490.7          | 15944185.7 | 0.9             |
| 2010 | 1.0           | 69148435.0           | 69839919.4                      | 31271071.3             | 31962555.7          | 31962555.7 | 1.8             |
| 2011 | 3.9           | 33561130.0           | 34870014.1                      | 13170022.3             | 48040364.3          | 14479064.4 | 0.5             |
| 2012 | 3.6           | 41394490.0           | 42884691.6                      | 17039230.2             | 59923921.9          | 18529431.9 | 1.2             |

Where:

\[ TL = DL_{inf} + IDL \quad and \quad ID = c \times (DL_{inf})^{b} \]

where \( c = 0.015 ; b = 1.245 \) (due to missing data, calculation method form [2] was adopted).
subsequently, the total adjusted direct and indirect loss was recalculated as a percentage ratio of GDP (see Table 3), and the results were compared with selected European countries (see Table 4 and Table 5).

finally, the adjusted direct and indirect loss was fitted to an appropriate statistical distribution (see Table 7 and Table 8); these values were then analysed for a relationship between probability and total loss value (variably for each given probability of total loss occurrence and the given amount of total loss) (see Table 9 and Table 10).

Having calculated the direct and indirect losses, their values were divided by the number of fires which had occurred in SR during the monitored period. The outcomes are as follows:

- the average value of direct loss per fire adjusted for inflation is 3 200 € and the average indirect loss per fire is 1 263 €,
- the total loss per fire adjusted for inflation in the monitored period in the range of 1781 – 10 264 €; statistically, year 2010 is interesting due to the significant decrease of the number of fires, compared to preceding period, however, fire loss was extremely high; only a more detailed analysis of individual fires would provide explanation,
- by analysing the total loss per fire, it is possible to state that the development of its value has a significant variability; particularly the period of 2008 – 2012 would require further attention.

The further area of analysis was a comparison of direct and indirect loss in relation to GDP in the monitored period. The obtained results were compared with selected European countries (see Table 3).

| Year | GDP (mil. €) | Direct losses with inflation- (€) | Indirect losses -IDL (€) | /fire (%) | IDL/GDP (%) | IDL/ |  
|------|--------------|----------------------------------|-------------------------|-----------|-------------|------|
| 2003 | 40 612.00    | 20 327 338.29                    | 6 726 572.98            | 0.050%    | 0.017%      | 0.331|
| 2004 | 45 161.40    | 21 005 145.25                    | 7 006 951.32            | 0.047%    | 0.016%      | 0.334|
| 2005 | 49 314.20    | 27 732 167.27                    | 9 902 582.34            | 0.056%    | 0.020%      | 0.357|
| 2006 | 55 001.60    | 28 341 662.36                    | 10 174 267.2            | 0.052%    | 0.018%      | 0.359|
| 2007 | 61 449.70    | 48 235 768.71                    | 19 725 511.6            | 0.076%    | 0.032%      | 0.409|
| 2008 | 66 932.30    | 45 494 267.94                    | 18 339 592.6            | 0.068%    | 0.027%      | 0.403|
| 2009 | 62 895.50    | 39 381 485.88                    | 15 324 004.8            | 0.063%    | 0.024%      | 0.389|
| 2010 | 65 887.40    | 69 839 919.35                    | 31 271 071.3            | 0.106%    | 0.047%      | 0.448|
| 2011 | 69 058.20    | 34 870 014.07                    | 13 170 022.3            | 0.050%    | 0.019%      | 0.378|
| 2012 | 71 463.00    | 42 884 691.64                    | 17 039 230.2            | 0.060%    | 0.024%      | 0.397|

Table 2 Direct and indirect loss per fire in SR during the period of 2003 – 2012

| Year | GDP (mil. €) | Indirect losses -IDL (€) | /fire (%) | IDL/GDP (%) | IDL/ |
|------|--------------|-------------------------|-----------|-------------|------|
| 2003 | 40 612.00    | 6 726 572.98            | 0.050%    | 0.017%      | 0.331|
| 2004 | 45 161.40    | 7 006 951.32            | 0.047%    | 0.016%      | 0.334|
| 2005 | 49 314.20    | 9 902 582.34            | 0.056%    | 0.020%      | 0.357|
| 2006 | 55 001.60    | 10 174 267.2            | 0.052%    | 0.018%      | 0.359|
| 2007 | 61 449.70    | 19 725 511.6            | 0.076%    | 0.032%      | 0.409|
| 2008 | 66 932.30    | 18 339 592.6            | 0.068%    | 0.027%      | 0.403|
| 2009 | 62 895.50    | 15 324 004.8            | 0.063%    | 0.024%      | 0.389|
| 2010 | 65 887.40    | 31 271 071.3            | 0.106%    | 0.047%      | 0.448|
| 2011 | 69 058.20    | 13 170 022.3            | 0.050%    | 0.019%      | 0.378|
| 2012 | 71 463.00    | 17 039 230.2            | 0.060%    | 0.024%      | 0.397|

Table 3 Relation of direct and indirect loss to GDP in monitored loss
the ratio of indirect loss to GDP in selected EU countries is in agreement with values (see Table 4 and Table 5).

The results of the above are determined by the following factors:

- from the available data, we presume that direct loss is not adjusted for inflation,
- the value of direct and indirect loss is determined by limited data; the presumed fact of different indirect loss for various building groups is simplified (see Table 5).

The following is evident from Table 4 and Table 5 (for more also see [7] and [8]):

- the ratio of direct loss to GDP is significantly lower than in other EU countries.
The tests were carried out on the 5% significance levels. With 95% level of confidence, the data fit the Lognormal distribution, since the p-value of Kolmogorov-Smirnov test is the highest for this distribution.

Having found that the total fire loss in SR for the period of 2003 – 2012 fits best to the Lognormal distribution, future extreme values for selected probabilities can be predicted.

### Total fire loss prediction for selected probabilities

| Probability of Total fire loss (%) | Total fire loss (€) |
|-----------------------------------|---------------------|
| 20                                | 69 116 700          |
| 10                                | 82 948 900          |
| 5                                 | 96 435 700          |
| 2                                 | 114 255 000         |
| 1                                 | 127 929 000         |

### Probabilities for selected total fire loss

| Total fire loss (€) | Probability of Total fire loss (%) |
|---------------------|------------------------------------|
| 30 000 000          | 12.07                              |
| 50 000 000          | 52.43                              |
| 70 000 000          | 80.85                              |
| 90 000 000          | 93.03                              |
| 110 000 000         | 97.51                              |

The results from Table 9 and Table 10 can be interpreted as follows:

- with 10% probability, the expected loss in SR for the next year is 82 948 900 €,
- the probability that the total loss will not exceed 70 000 000 € is 80.81%,
- analogically same interpretation applies to other values in Table 9 and Table 10.

Similar logic may be applied to other probabilities of total fire loss.

The analysis of the results yields the following outcomes:

- the average value of total direct loss in the monitored period is 36 568 000 €; the average value of adjusted total direct loss is 37 811 000 €; on average, inflation caused a 4% increase of direct loss,
- the increase of total loss, when compared to the direct loss for the given year, is approximately 44%,
- the average difference of the total and adjusted direct loss is 16 mil. € and the median of this item is 14.5 mil. €,
- the standard deviation value of the difference of total and direct loss is 7.2 mil. €, which suggests a significant variability of the analysed items,
- the average value of indirect loss is 14 868 000 €; the median of this item 13170 000 €,
- the growth coefficient of total lost has a significant variance; the periods of growth and decrease alternate, with extremes in 2003 – 2004 (4% increase) and years 2010 – 2011 (137% growth).

### Conclusion

The analysis of fire risk is carried out with the aim of risk reduction in decision making which deals with fire source identification, determination of the probability of a fire starting and consequence quantification. The process of loss analysis is also part of the risk management process. Knowing the probable consequences and their quantification allows to take appropriate measures as part of risk management, which help the organisation (FRS) decrease the risk to an acceptable level. In other words, the realised measures decrease the level of risk from unacceptable to acceptable.

From the presented results it is possible draw the following application conclusions for FRS:

- formulate a methodology for direct fire loss calculation and decide on the way of inflation integration,
- extend the current methodology for indirect fire loss,
- compare direct and indirect loss as part of analyses and quantify loss per fire,
- categorise fires by sectors/industries, and based on these extend the analysis of direct and indirect fire loss for the individual categories,
- carry out a trend analysis for each sector/industry - development of direct and indirect loss in time,
- carry out an international comparison of the direct loss/GDP, indirect loss/GDP, and indirect and direct loss ratios,
- extend loss quantification for life loss and injury factors,
- analyse the methods currently used by the insurance industry for quantification (for more also see [3]).

The above proposed measures have an ambition to include the results of statistical analyses into the FRS management more effectively.

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