Dependence of death and injury of people in fires on the duration of fires

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Introduction. The effectiveness of the actions of the fire protection units depends on their readiness for action, that is, on the state of the forces and means of the station and the ability to perform the main task within the existing tactical capabilities.

Problem Statement. When developing mathematical models of the operational activities of the fire department, its effectiveness and the assessment of the readiness of fire protection units to extinguish fires, it is important to study the dependence of the death of people in fires on the duration of the fire. This study is devoted to this task.

Theoretical Part. The distribution of fires in the Russian Federation for 2016-2020 by their duration and the dependence of deaths and injuries of people in fires, as well as their ratio to the duration of fires in the Russian Federation for 2016-2020, is studied. It is shown that the average duration of the fire during the studied period was 26 minutes, the median value of the distribution was 18 minutes. The dependences of deaths and injuries of people in fires on the duration of fires are approximated by a logarithmic function. When the duration of the fire is up to 26 minutes. the ratio of the number of people injured in fires to those killed decreases exponentially, but remains stable in the rest of the time range.

Conclusions. It is concluded that it is necessary to increase the readiness of the fire department for actions to extinguish fires and rescue people, which includes the development of an information and analytical model of the operational activities of the fire department.

Keywords: fire, duration, death, injury, efficiency.

Introduction. In accordance with the Field Manual of fire departments, "fire extinguishing is an action aimed at saving people, property and eliminating fires" [1]. The duration of a fire is considered to be the time from the moment of its occurrence until the complete elimination of fire [2]. In this work, the duration of a fire is considered to be the interval between the time of detection and the time of elimination of open fire. Many scientific studies have studied various stages of the development and extinguishing of fires, as well as the dependence of the death of people in fires on the actions of fire departments [3−8].

The effectiveness of the actions of fire departments depends on their combat readiness, that is, on the state of the forces and means of the garrison and the ability to perform the main task within the available tactical capabilities [1].

Problem Statement. When developing mathematical models of operational activities of fire protection, its effectiveness and assessment of the readiness of fire departments to extinguish fires, it is important to study the dependence of the death of people in fires on their duration. This study is devoted to this task.

Theoretical Part. The information is calculated from electronic databases of accounting for fires and their consequences [9]. Figure 1 shows the distribution of fires for 2016-2020 by their duration, which were extinguished by the territorial fire and rescue departments of the Federal Fire Service of the State Fire Service
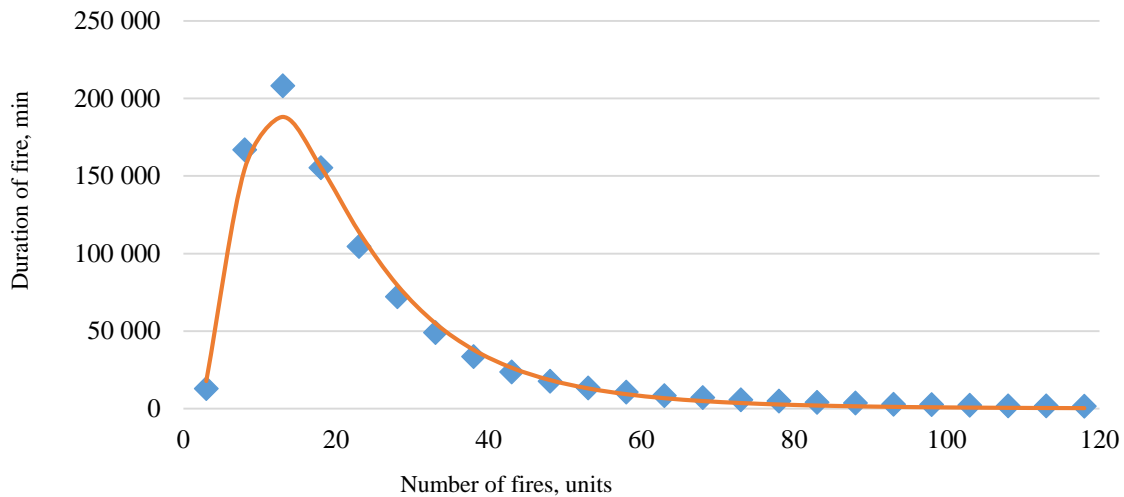
Fig. 1. Distribution of fires in the Russian Federation for 2016-2020 by their duration
The curve is lognormal distribution

The average duration of the fire during the studied period was 26 minutes. However, given the pronounced asymmetry of the distribution (the asymmetry coefficient is 2.5); it is advisable to use the median of the distribution, which is 18 minutes, to estimate the mathematical expectation. The duration of 69% of fires did not exceed 30 minutes. This distribution is well described by the lognormal function

$$f(t) = \frac{1}{t\sigma\sqrt{2\pi}} \exp\left(\frac{-(\ln t - \mu)^2}{2\sigma^2}\right), \tag{1}$$

where t — the duration of the fire, min; parameters $\mu = 2.9$ and $\sigma = 0.64$. The coefficient of determination is $R^2 = 0.99$.

Figure 2 shows the dependence of the death of people in fires on the duration of fires.
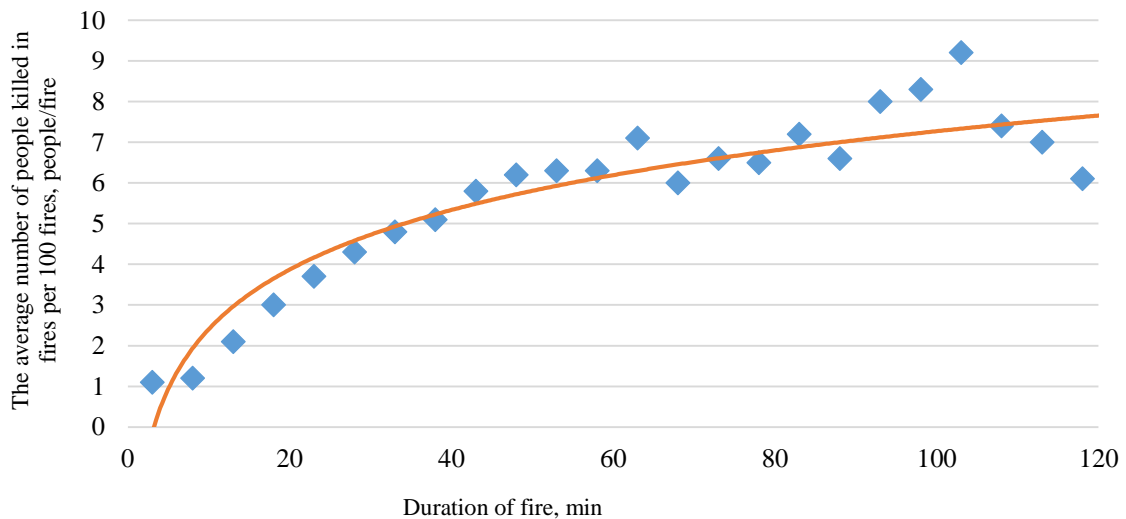

Fig. 2. Dependence of the death of people in fires on the duration of fires in the Russian Federation for 2016-2020

The curve is logarithmic function
The resulting dependence is well approximated by the logarithmic function

$$h(t) = a \ln t + b \tag{2}$$

with parameters $a = 2.113$ and $b = -2.461$. The coefficient of determination is $R^2 = 0.86$.

However, it is necessary to treat the presented data with caution, since it is unclear when the critical duration of the fire occurred and at what point people died [2, 4]. In the same way, it is necessary to treat the dependence of injury to people in fires on the duration of fires, shown in Fig. 3.
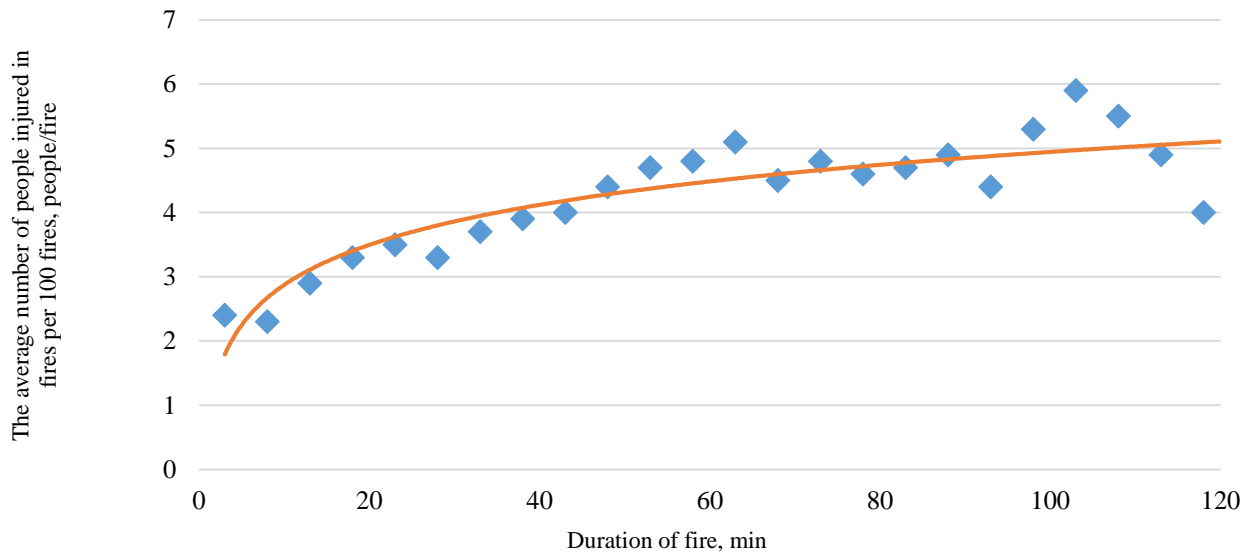

Fig. 3. Dependence of injury to people in fires on the duration of fires in the Russian Federation for 2016-2020. The curve is a logarithmic function

The obtained dependence is also well approximated by the logarithmic function (2) with parameters $a = 0.899$ and $b = 0.804$. The coefficient of determination is $R^2 = 0.81$.

In recent studies, an indicator of "the ratio of the number of people injured in fires to the dead" is singled out separately [10-13]. This indicator characterizes the level of development of fire protection measures (fire alarm systems, primary fire extinguishing means, etc.), as well as fire protection actions to extinguish fires and rescue people, neutralizing fire hazards, reducing the number of people killed in fires. Figure 4 shows the dependence of the ratio of the number of people injured in fires to those killed on the duration of fires. This dependence is described by the function:

$$g(t) = \begin{cases} A \exp(-bt), & t \le 25\ min \\ 0.71, & t > 25\ min \end{cases} \tag{3}$$

with parameters $A = 2.69$, $b = 0.048$. The coefficient of determination is $R^2 = 0.99$.
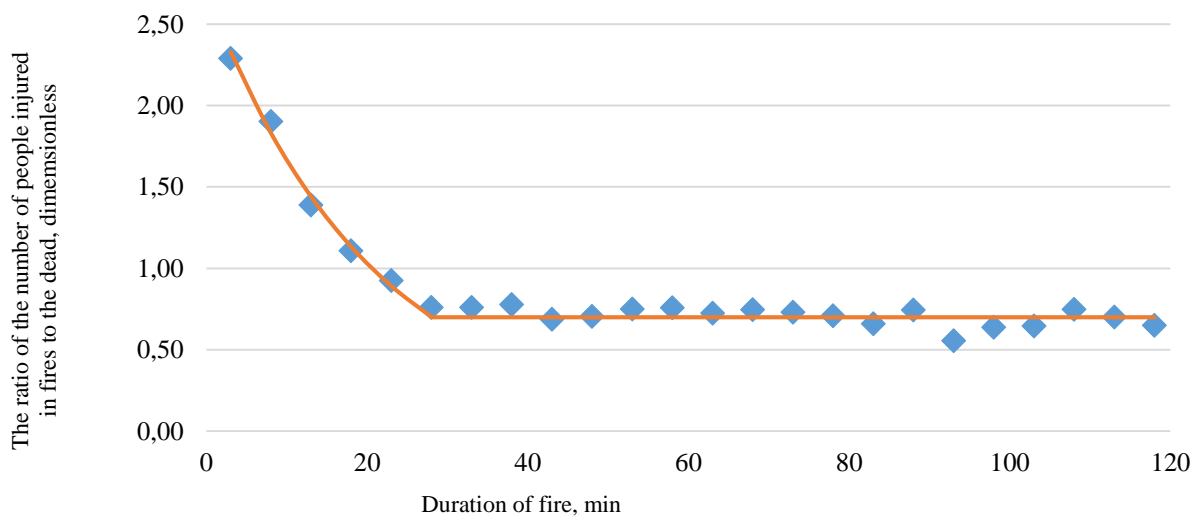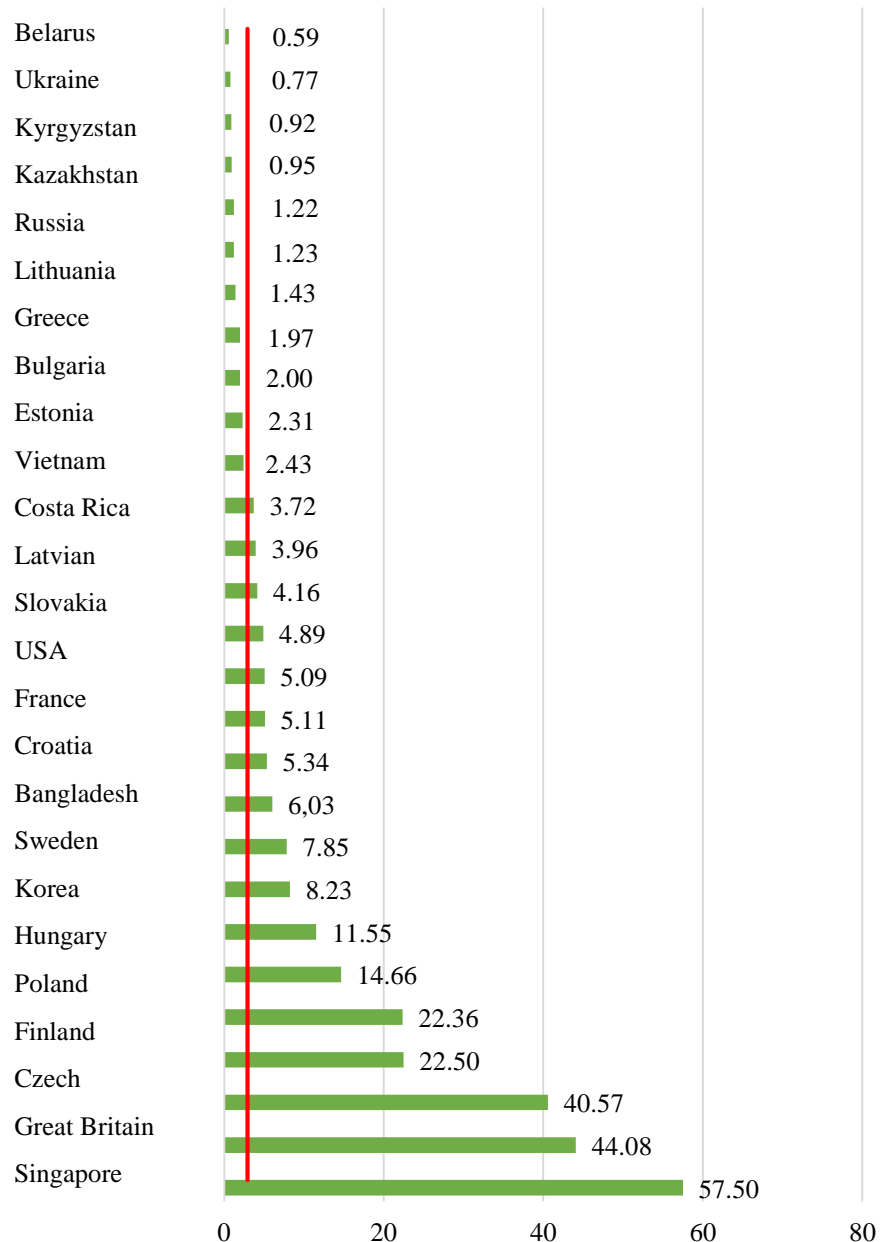

Fig. 4. Dependence of the ratio of the number of people injured in fires to those killed on the duration of fires in the Russian Federation for 2016-2020. The curve is the dependence described by formula (3)

It should be noted that a significant result is observed from the actions of the fire department to rescue people only if the duration of the fire does not exceed 25 minutes, and the effectiveness of the actions is described by a linear function with a negative slope coefficient. That is, the shorter the duration of the fire, the more effective the actions of the fire department to rescue people. With fire duration of 26 minutes or more, rescue actions reach a constant level (the slope coefficient of the approximating function is close to 0); the average ratio of the number of people injured in fires to those killed is 0.71.

For example, Figure 5 shows the values of the ratio of the number of people injured in fires to those killed in a number of foreign countries in 2018 [14].

Country	Value
Belarus	0.59
Ukraine	0.77
Kyrgyzstan	0.92
Kazakhstan	0.95
Russia	1.22
Lithuania	1.23
Greece	1.43
Bulgaria	1.97
Estonia	2.00
Vietnam	2.31
Costa Rica	2.43
Latvian	3.72
Slovakia	3.96
USA	4.16
France	4.89
Croatia	5.09
Bangladesh	5.11
Sweden	5.34
Korea	6,03
Hungary	7.85
Poland	8.23
Finland	11.55
Czech	14.66
Great Britain	22.36
Singapore	22.50
	40.57
	44.08
	57.50

The ratio of the number of people injured in fires to the dead, dimensionless

Fig. 5. The ratio of the number of people injured in fires to those killed in 2018 in some countries of the world

As it can be seen from Fig. 5, the Russian Federation, with an indicator of 1.22 people injured in fires per 1 person killed, occupies one of the last places in the list of countries. The situation on this indicator is worse only in Belarus, Ukraine, Kyrgyzstan and Kazakhstan. The red vertical line corresponds to the average value of the indicator under consideration for all the countries listed (2.93).

The data obtained can be explained by a number of factors: climatic, socio-economic conditions, the activities of fire departments, personnel qualifications, etc.

Conclusions. The presented data indicate a large reserve among fire departments of the Russian Federation in terms of increasing readiness for fire extinguishing and rescue operations, which include improving the tactical capabilities of fire departments, fire equipment, extinguishing agents, the creation of new fire departments taking into account the identified patterns.

References

1. Order of the Ministry of Emergency Situations of Russia No. 444 of October 16, 2017 "On Approval of the Field Manual of Fire Departments Defining the Procedure for Organizing Fire Extinguishing and Emergency Rescue operations". Available from: http://base.garant.ru/71846130/#ixzz6rnhIXUbf (accessed 12.04.2021). (In Russ.)

2. Puchkov V. A., Artamonov V. S., Dagirov Sh. Sh. et al. Pozharnaya bezopasnost': uchebnik: v 2 ch. Ch. 1. Moscow: Akademiya GPS MChS Rossii, 2016. 476 p. (In Russ.)

3. Shebeko Yu. N., Shebeko A. Yu., Gordienko D. M. Assessment of equivalent fire duration for building structures based on compartment fire modeling. Fire Safety. 2015;1:31–39. (In Russ.)

4. Lapshin S. S. Mathematical Model of Critical Fire Duration in Adjacent Room with Fire Source. Vestnik IGEU. 2010;4:83–86. (In Russ.)

5. Goryacheva M. N., Puzach S. V., Goryachev S. A., Doan V. M. K opredeleniyu kriticheskoy prodolzhitel'nosti pozhara po toksichnym produktam goreniya. Fire and Explosion Safety. 2012;21(1):47–50. (In Russ.)

6. Artemyev N. S., Bondarenko M. V. Fire and emergencies: prevention, elimination. Fire and emergencies: prevention, elimination. 2011;1:47–49. (In Russ.)

7. Bobrinev E. V., Kondashov A. A., E Udavtsova . Yu. The use of regression analysis of indicators of loss of life in fires from the time of arrival of the first fire division the fire. Vestnik of Saint-Petersburg university of State Fire Service of EMERCOM of Russia. 2019;3:95–102. (In Russ.)

8. Poroshin A. A., Kharin V. V., Kondashov A. A. et al. Investigation of the Risk of Death in Fires from the Time of Arrival of the First Fire Department. Life Safety. 2019;9:3–9. (In Russ.)

9. Fire statistics for 2007-2020. Available from: https://sites.google.com/site/pojstat/home/statistika (accessed 14.04.2021). (In Russ.)

10. Brushlinskiy N. N., Sokolov S. V., Evdokimov V. I., Ivanova O. V. Statistical analysis of deaths and injuries from fires worldwide and in Russia (2008–2012). Medico-Biological and Socio-Psychological Problems of Safety in Emergency Situations. 2015;2:30–37. (In Russ.)

11. Zimonin A. A., Firsov A. V., Butenko V. M. Traumatizing of people at fires. Tekhnologii tekhnosfernoy bezopasnosti. 2014;5(57):4. (In Russ.)

12. Kharin V. V., Bobrinev E. V., Kondashov A. A., Udavtsova E. Yu. Statistical approach of assessing the degree of fire hazard by the ratio of injuries and deaths in fires. Vestnik NTsBZhD. 2019;4(42):127–135. (In Russ.)

13. Kharin V. V., Poroshin A. A., Udavtsova E. Yu. et al. Sootnoshenie chisla travmirovannykh i pogibshikh kak pokazatel' opasnosti posledstviy pozhara. Aktual'nye problemy pozharnoy bezopasnosti: sb. materialov XXXI Mezhdunar. nauch.-prakt. konf. Moscow, 2019. p. 568–571. (In Russ.)

14. World Fire Statistics. Available from: https://www.ctif.org/sites/default/files/2020-06/CTIF_Report25.pdf (accessed: 14.04.2021).

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Contribution of the authors:

V. V. Kharin — review of publications on the topic of the article, participation in the collection and processing of the material, participation in the writing of the text of the manuscript, editing and revision of the text. V. I. Sibirko — participation in the collection and processing of the material, participation in the writing of the text of the manuscript, the design of the final version of the article. E. Y. Udavtsova — development of the design of the study, preparation of literature, participation in the collection and processing of the material, participation in the writing of the text of the manuscript. E. V. Bobrinev — formulation of the main idea and concept of the study, scientific supervision, analysis of the research results, participation in writing the text of the manuscript, correction of the conclusions. A. A. Kondashov — development of the purpose and objectives of the study, calculations, analysis and interpretation of data, formulation of conclusions, participation in writing the text of the manuscript.