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Fire Statistics as a Tool for Emergency Prevention

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Introduction. It is known that fires are one of the most large-scale emergencies. It is possible to systematize and formalize their causes only if you take into account the effective analysis of statistical data. The scientific problem lies in the lack of effective mathematical tools and techniques that allow the use of fire statistics as an emergency prevention tool. The solution of this problem is relevant for science and technology. Based on the identified problem, the purpose of this study is formulated, which consists in the analysis of fire statistics and its formalization in predicting emergencies.

Problem Statement. The objective of this study is to analyze the state and causes of fires, as well as to find a tool for their prediction.

Theoretical Part. The methodological tools for solving this problem are the use of multiple regression and correlation analysis methods that allow criticizing and formalizing the available fire statistics. It is established that an acceptable parameter characterizing the reliability and closeness of the connection of empirical data with their mathematical function in relation to the task is the correlation coefficient.

Conclusions. It is proved that an effective tool for predicting fires is the use of linear regression analysis methods. The practical significance of the results obtained for science and technology lies in the possibility of creating digital tools for predicting and preventing emergencies, which will significantly reduce resource costs for eliminating their consequences.

***Keywords*:** emergencies, forecasting, forecasting models.

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Introduction. It is known that the occurrence of emergency situations is a multifactorial process that depends on a large number of components. One of the most frequently occurring categories of emergencies is fire. Fires, regardless of the object, lead to significant, and in some cases catastrophic, socio-economic and technological consequences. The work of the State Fire Service of the Ministry of Emergency Situations of Russia is aimed at preventing and minimizing such situations.

Information about fires at industrial and civil facilities is published annually in open sources [1–4]. This statistic is of a precautionary nature, since it allows us to assess the relationship between some of the factors leading to the occurrence of an emergency. Based on the analysis of sources [1–4], it was possible to identify the following factors leading to fires: violation of the rules of operation of electrical equipment and household electrical appliances, malfunction of production equipment, violation of the technological process of production, careless handling of fire, cases when children play with fire, violation of fire safety rules during electric and gas welding works, explosions, spontaneous combustion of substances and materials, malfunction and violation of the rules of operation of furnace heating, arson and other unidentified causes. However, despite the consistency of the information provided, there are no tools to formalize it and build a probabilistic forecast of the development of emergencies in the current conditions. These forecasts are necessary to indicate the significance of preventive measures with the presentation of indicative socio-cultural losses. Based on the above, we believe that the analysis of fire statistics and its formalization is a practically significant, urgent task for both industry and the civilian population.

The aim of the study is the analysis of fire statistics and its formalization in predicting emergencies.

Problem Statement. Representative statistical data on the number of fires are the values published in [1–4]. These materials are reliable and have convergence with the results published in [5–7].

It is established that a promising tool for the formalization of statistical data is the use of multiple regression analysis methods, the essence of which can be summarized using mathematical coefficients that estimate the value of the reliability of the functional approximation of a certain data array. Based on the analysis of [8–10], it has been found that, in relation to the task, the most rational is the use of linear regression models of the form:

$$y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ij} x_i x_j, \qquad (1)$$

where b_0, b_i, b_{ii}, b_j — coefficients characterizing the strength of the influence of free, linear, quadratic and paired interaction effects of the mathematical model; x_i x_j — factors the influence of which on the response under consideration is demonstrated by the mathematical model.

We take the correlation coefficient as the parameter that most representatively characterizes the reliability and closeness of the connection of empirical data with their mathematical function. The practical experience of assessing the reliability of statistical models using the correlation coefficient is presented in [11, 12]. Let us consider the general regularities of the algorithm for using the correlation coefficient. Let us suppose there is a sample n of the values (x_1, y_1), (x_2, y_2),…, (x_n, y_n) with their joint distribution, then the correlation coefficient is determined as:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\{\sum_{i=1}^{n}(x_i - \bar{x})^2\}^{1/2}\{\sum_{i=1}^{n}(y_i - \bar{y})^2\}^{1/2}}. \qquad (2)$$

The correlation coefficient between x and y evaluates an empirical measure of the linear relationship between them. Moreover, $n\bar{x} = \sum x_i$, $n\bar{y} = \sum y_i$. If we put multipliers *1/(n-1)* before all sums, then r_{xy} will allow us to take into account variances and covariance with their sample estimates replaced. However, in relation to the task, we will limit ourselves to the representation of the numerical values of the correlation coefficient relative to –1 and +1, where the value –1 indicates the absence of a connection, and +1 indicates its presence.

After choosing a mathematical tool for formalizing statistics, we will proceed to the analysis of empirical data necessary for the construction of probabilistic forecasts. Table 1 presents data on fires in the Russian Federation for 2015-2020, published in [1].

Table 1

Statistics of fires in the Russian Federation for 2015-2020

Year / Emergency factor	1	2	3	4	5	6	7	8	9	10	11
2015	10228	25456	338	29243	1414	618	54	305	13502	1184	9376
2016	9034	25118	300	25828	1279	552	50	287	13683	1369	8761
2017	8296	24995	318	24255	1100	549	40	273	12912	1450	8056
2018	7698	25868	351	22668	1080	531	47	298	14087	1378	8009
2019	8814	25360	327	25498	1218	563	47	291	13546	1345	8551
2020	8296	24995	318	24255	1100	549	40	273	12912	1450	8056

Note to the table: the emergency occurrence factor: 1 — violation of the rules of operation of electrical equipment and household electrical appliances; 2 — arson; 3 — malfunction of production equipment, violation of the technological process of production; 4 — careless handling of fire; 5 —children play with fire; 6 — violation of fire safety rules during electric and gas welding works; 7 — explosions; 8 — spontaneous combustion of substances and materials; 9 — malfunction and violation of the rules of operation of furnace heating; 10 — unidentified; 11 — other causes.

Theoretical Part. Figure 1 shows the distribution of the number of fires depending on the year.

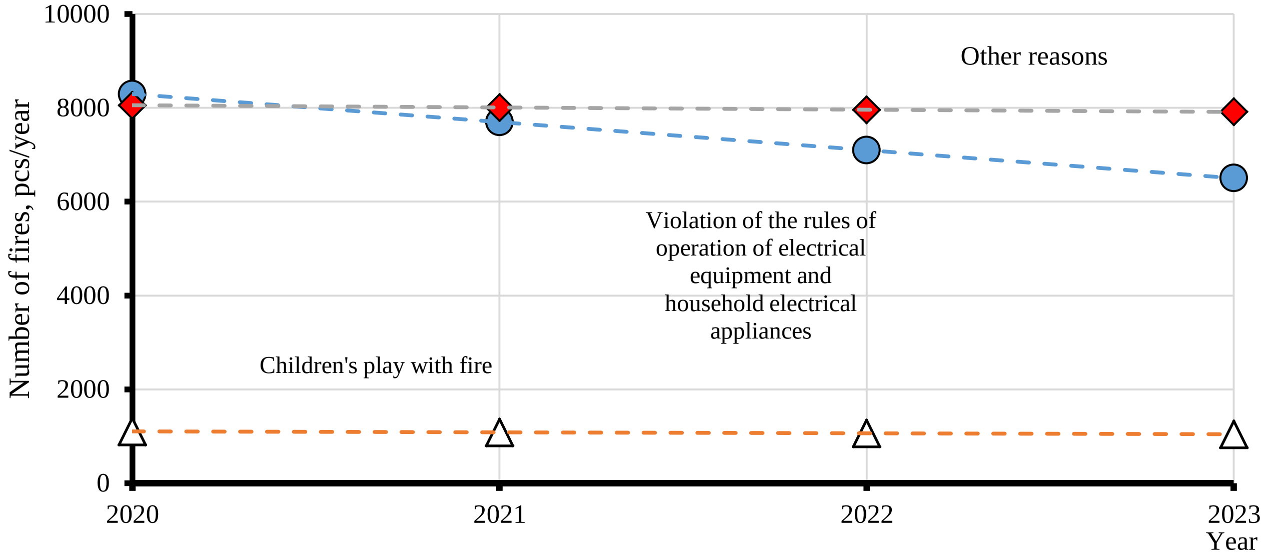

Fig. 1. Distribution of the number of fires depending on the year

The analysis of the presented statistics allowed us to establish that:

– linear model (3) characterizes with a sufficient degree of reliability the annual distribution of the number of fires from violations of the rules of operation of electrical equipment and household electrical appliances at the level of statistical significance α = 0.05:

$$y = -598.00x + 1\,216\,256.00, \quad (3)$$

while the correlation coefficient is r = 1.0;

– linear model (4) characterizes with a sufficient degree of reliability the annual distribution of the number of fires from other causes at the level of statistical significance α = 0.05:

$$y = -47x + 102\,996, \quad (4)$$

while the correlation coefficient is r = 1.0;

– linear model (5) characterizes with a sufficient degree of reliability the annual distribution of the number of fires caused by children's play with fire at the level of statistical significance α = 0.05:

$$y = -20x + 41\,500, \quad (5)$$

while the correlation coefficient is r = 1.0;

– linear model (6) characterizes with a sufficient degree of reliability the annual distribution of the number of fires from malfunction of production equipment, violation of the technological process of production at the level of statistical significance α = 0.05:

$$y = 33x - 66\,342, \quad (6)$$

while the correlation coefficient is r = 1.0;

– linear model (7) characterizes with a sufficient degree of reliability the annual distribution of the number of fires from careless handling of fire at the level of statistical significance α = 0.05:

$$y = -1\,587.00x + 3\,229\,995{,}00, \quad (7)$$

while the correlation coefficient is r = 1.0;

– linear model (8) characterizes with a sufficient degree of reliability the annual distribution of the number of fires from violations of fire safety rules during electric and gas welding operations at the level of statistical significance α = 0.05:

$$y = -18x + 36\,909, \quad (8)$$

while the correlation coefficient is r = 1.0;

– linear model (9) characterizes with a sufficient degree of reliability the annual distribution of the number of fires during explosions at the level of statistical significance α = 0.05:

$$y = 7x - 14\,100, \quad (9)$$

while the correlation coefficient is r = 1.0;

– linear model (10) characterizes with a sufficient degree of reliability the annual distribution of the number of spontaneous combustion of substances and materials at the significance level α = 0.05:

$$y = 25x - 50\,227, \quad (10)$$

while the correlation coefficient is r = 1.0.

– linear model (11) characterizes with a sufficient degree of reliability the annual distribution of the number of fires from malfunction and violation of the rules of operation of furnace heating at the level of statistical significance $\alpha = 0.05$:

$$y = 1\,175.00x - 2\,360\,588.00, \tag{11}$$

while the correlation coefficient is $r = 1.0$.

– linear model (12) characterizes with a sufficient degree of reliability the annual distribution of the number of unidentified fires at the level of statistical significance $\alpha = 0.05$:

$$y = -72x + 146\,890, \tag{12}$$

while the correlation coefficient is $r = 1.0$.

– linear model (13) characterizes with a sufficient degree of reliability the annual distribution of the number of fires due to arson at the significance level $\alpha = 0.05$:

$$y = 873.00x - 1\,738\,465.00, \tag{13}$$

while the correlation coefficient is $r = 1.0$.

Conclusions. From the above we can conclude:

– based on the statistics from 2015 to 2020, it was found that the largest share of fires falls on arson and careless handling of fire;

– it is proved that an effective tool for predicting fires is the use of linear regression analysis methods;

– formalization of fire statistics using linear regression models makes it possible to structure and digitalize the available data arrays in terms of the criteria presented;

– mathematical structuring of statistics from the point of view of the presented criteria allows the use of data arrays in an automated mode.

References

1. Unified Interdepartmental Statistical Information System Register. Federal State Statistics Service. Available from: https://rosstat.gov.ru/emiss (accessed 23.03.2022). (In Russ.)

2. Shabanov N. S., Malov V. V. Analysis of fire statistics at healthcare facilities, home for the elderly in the period 2016-2020. Technosphere safety in XXI century, 2021. P. 228–231. (In Russ.)

3. Darmanyan A. P., Veselova N. M., Nekhoroshev D. D., Moroz V. P. Analysis of Fires Using Mathematical and Statistical Methods. Life safety. 2019;2(218):53–58. (In Russ.)

4. Kozlova A. S., Chuikov D. A., Smetankina G. I. Unified state system for account of fires and their consequences as a tool of fire statistics. Sovremennye tekhnologii obespecheniya grazhdanskoi oborony i likvidatsii posledstvii chrezvychainykh situatsii. 2019;1(10):153–155. (In Russ.)

5. Mordvinenko S. E., Ershov A. V., Pikush D. S. Express method of assessment of compliance of the object of supervision with fire safety requirements. Safety of Technogenic and Natural Systems. 2021;4:29–35. https://doi.org/10.23947/2541-9129-2021-4-29-35 (In Russ.)

6. Egelskaya E. V., Romanenko M. Yu. Aspects of application of a risk-based approach to hazardous production facilities. Safety of Technogenic and Natural Systems. 2020;4:45–49. https://doi.org/10.23947/2541-9129-2020-4-45-49 (In Russ.)

7. Panfilov A. V., Bakhteev O. A., Deryushev V. V., Korotkiy A. A. Adaptive remote monitoring and control system for the operation of hazardous facilities based on a risk-based approach. Safety of Technogenic and Natural Systems. 2020;2:19–29. https://doi.org/10.23947/2541-9129-2020-2-19-29 (In Russ.)

8. Ventsel E. S. Issledovanie operatsii [Operations research]. Moscow: Sovetskoe radio, 1976. 552 p. (In Russ.)

9. Voznesenskii V. A. Statisticheskie metody planirovaniya eksperimenta v tekhniko-ekonomicheskikh issledovaniyakh [Statistical methods of experiment planning in technical and economic research]. Moscow: Statistika, 1974. 192 p. (In Russ.)

10. Gmurman V. E. Teoriya veroyatnostei i matematicheskaya statistika: uch. posobie lya VUZov [Probability theory and mathematical statistics: textbook for universities]. Moscow: Vysshaya shkola. 2003. 479 p. (In Russ.)

11. Sankovets A. A., Rezuvaeva I. S. Mathematical analysis of the use of production capacities of the enterprise with the application of correlation-regression analysis (on the example of LLC "Ugolny Razrez"). Vektor ekonomiki. 2021;3(57). (In Russ.)

12. Azimova N. N., Ladosha E. N., Kholodova S. N. et al. Statistical analysis of sizing features of dust generated under the mechanical metal-working. Vestnik of DSTU. 2020;1(20):68–78. https://doi.org/10.23947/1992-5980-2020-20-1-68-78 (In Russ.)

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