FORECASTING OF THE PROBABILITY OF UNNATURAL DESTRUCTIVE EVENTS OCCURRENCE AT REFINERY COMPLEXES

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Abstract

The paper proposes some approaches to building a model for predicting the probability of emergency situations at the enterprises of the oil refining complex in modern conditions. The approach is based on modeling using the binomial distribution. The initial data of the model are open data on the occurrence of emergencies on the territory of the Russian Federation for the period 2022–2023.

Keywords: forecasting, destructive events, emergency, oil refinery

I. Introduction

About 80 thousand hazardous production facilities (HPF) of the oil and gas complex are registered on the territory of the Russian Federation, of which the petrochemical and oil and gas processing industries and oil product supply facilities account for approximately 5% (4096 facilities according to [1] for 2021). The main types of accidents are explosion (with the destruction of technical devices and structures), fire, and release of hazardous substances. Distribution of the total number of accidents at HPFs by the considered industries for the period 2011-2021 shown in Fig. 1.

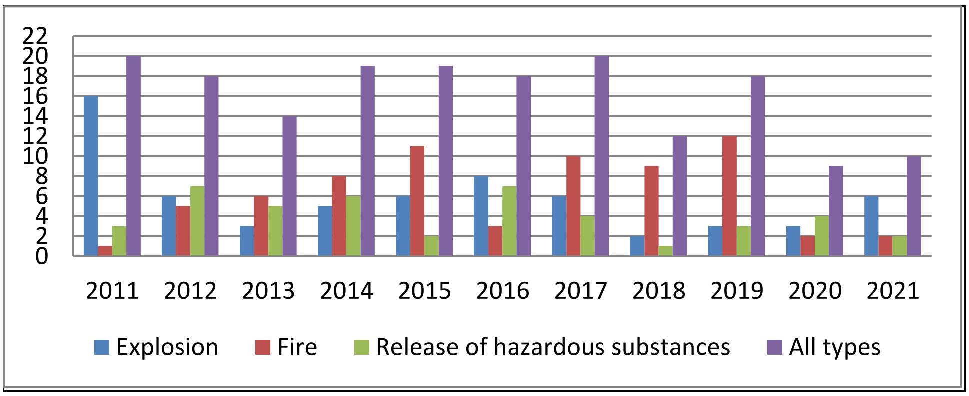

Fig. 1: *Distribution of the total number of accidents of HPFs in the petrochemical and oil and gas processing industries and oil products supply facilities by types of accidents for the period 2011-2021*

In recent years, the following trends have been observed in the industry:

• Reduction in the number of HPFs in the petrochemical and oil and gas processing industries and oil product supply facilities (Fig.2)

• Reduction of the total number of accidents

• Increase in the number of accidents associated with explosions

• The main contribution to the total number of accidents was made by accidents at HPFs of the oil and gas processing industry (Fig.3) [2]

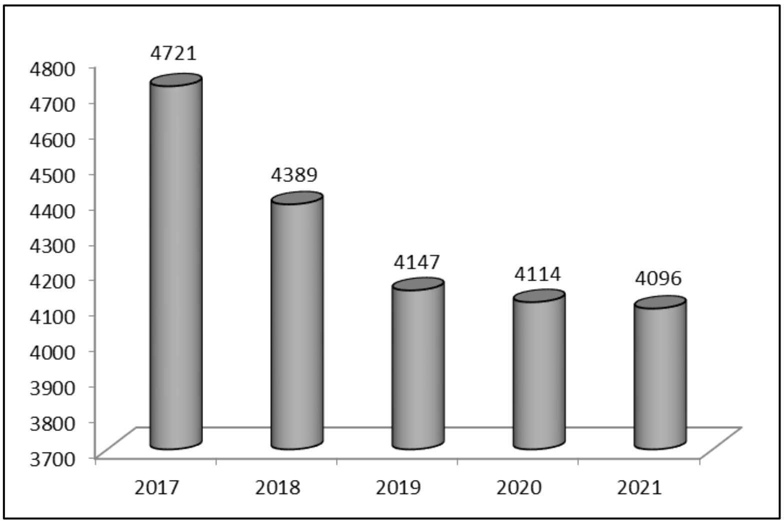

Fig. 2: *The number of HPFs in the petrochemical and oil and gas processing industries and oil product supply facilities for the period 2017-2021*

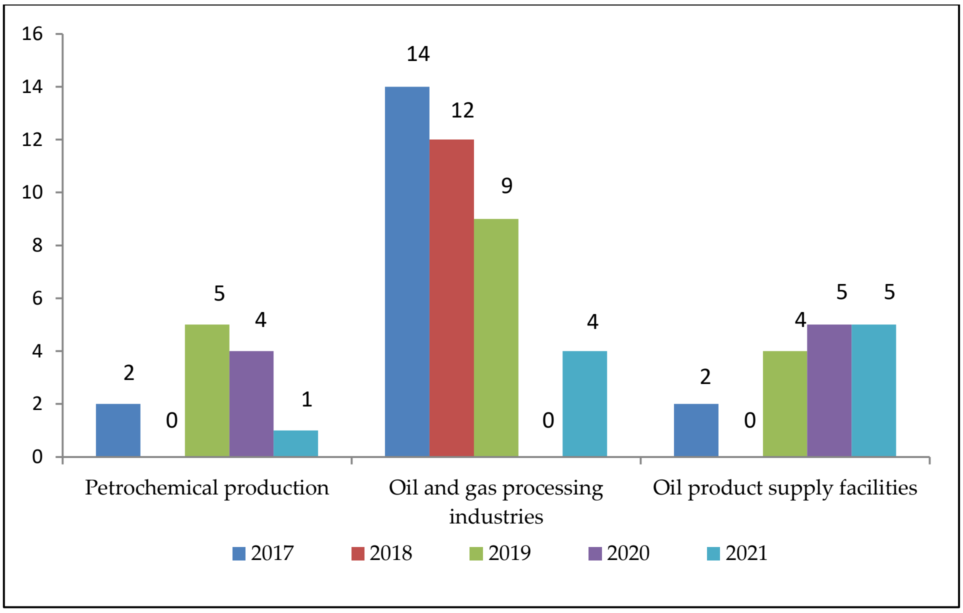

Fig. 3: *Distribution of accidents at HPFs by industry sectors for the period 2017-2021*

During the period from February 2022 to March 2023, 26 negative events (accidents, emergencies, terrorist attacks) occurred at HPFs of the petrochemical and oil and gas processing industries and oil product supply facilities. Examples of such events include the following:

• Belgorod region: April 1, 2022 – fire at eight tanks of "Belgorodnefteprodukt" JSC in Belgorod, two people from the tank farm personnel were injured [4]

• Bryansk region: April 25, 2022 – fire at the RVS-10000 with diesel fuel at the oil depot "Transneft Bryansk Druzhba" [5]

• Republic of Crimea: June 20, 2022 – fire on the drilling platform of "Chernomorneftegaz" in the Black Sea. Three people were injured, seven were missing. 94 people were evacuated [6]

• Rostov region: June 22, 2022 - explosion and fire at the oil refinery at the Novoshakhtinsk refinery [7]

73% of events occurred for external reasons, 27% for other reasons.

II. Methods

In domestic and foreign practice, to predict the occurrence of accidents and emergencies at the enterprises of the oil refining complex, approaches are used based on the use of technologies for identifying and understanding the consequences, probability and risk [3]. The initial data for the developed forecasting methods is statistical information.

This article discusses a model for predicting the likelihood of emergencies at the enterprises of the oil refining complex in modern circumstances.

To build a mathematical model, consider data on 73% of the events. The initial data for building the model are data from open sources for the period 2022–2023 in the format: subject of the Russian Federation, object, and type of event (fire / explosion / release of hazardous substances), causes, and brief description of the event.

Consider the number of negative events per month as a binomial variable B (Fig. 4). Let's call a "successful" event the occurrence of a negative event at the facilities of the petrochemical and oil and gas processing industries and oil products supply facilities. In a month of such successful events, k occur, and $0 \le k \le n$, where n is the total number of attempts to create artificial negative events per month (n is an unknown value). Of course, such a model greatly simplifies reality, since a number of assumptions are made, namely:

1) all events are independent of each other
2) the probability of "success" is fixed
3) n remains constant from month to month

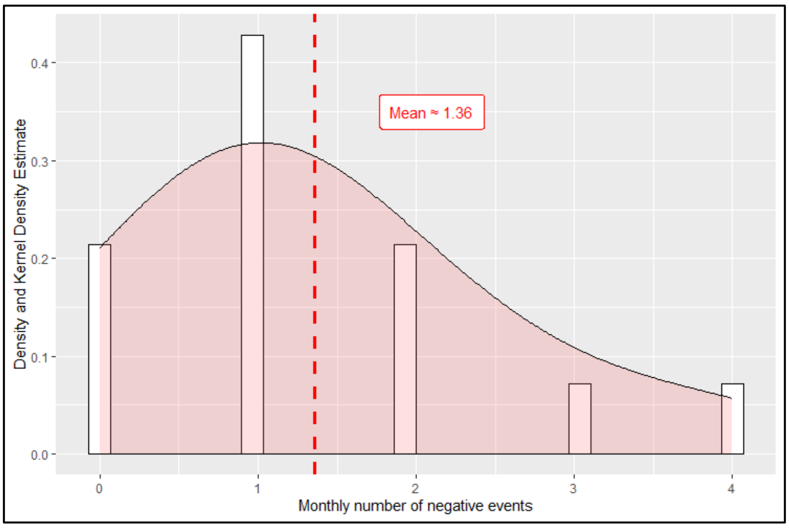

Fig. 4: *Negative events (incidents) as a random binomial variable*

It should be noted that neither the total number of trials per month n nor the probability of "success" p is known. A small sample of successful outcomes is used to build the model. However, the shape of the histogram suggests that B can be modeled as variable with Poisson distribution which is an extreme case of the binomial distribution for large n and small p. Restoration of the distribution of a random variable over the sample $\{x_i\}$, where i=1,..m, can be performed through a point estimate of the unknown parameter λ (that is, $\hat{\lambda}$) of the Poisson distribution by the maximum likelihood method:

$$\hat{\lambda} = \frac{1}{m}\sum_{i=1}^{m} x_i \quad (1)$$

In our case: $\hat{\lambda} = 1.357143$.

A sample from Poisson distribution with such a parameter $\lambda = \hat{\lambda}$ can give different results in general, similar in form. Examples of samples obtained from the Poisson distribution with the parameter λ=1.357143 are shown in Fig.5 and Fig.6.

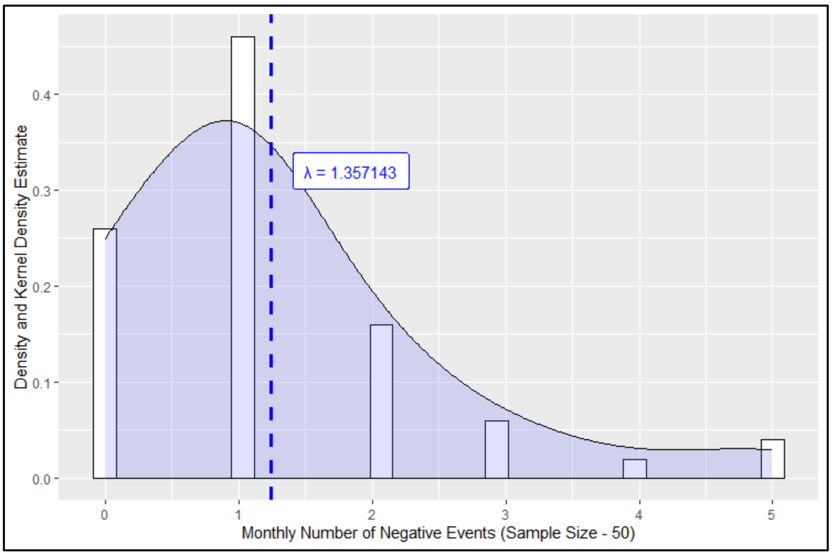

Fig. 5: *An example of a histogram of a sample of 50 values from a Poisson distribution with a parameter λ=1.357143*

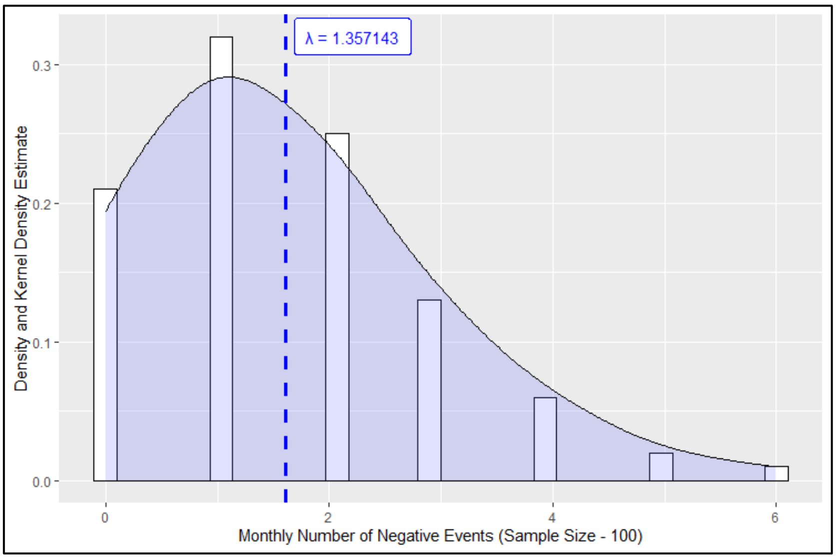

Fig. 6: *An example of a histogram of a sample of 100 values from a Poisson distribution with a parameter λ=1.357143*

Using the general case of the binomial distribution, it would be possible to model the number of negative events for a known number of external influence attempts n. The estimate of the probability of success p by the maximum likelihood method depends on n and the number of "successes". However, the desired value is unknown, so the transition to the extreme case of the binomial distribution, the Poisson distribution, has been made.

As a result of calculations based on the theoretical Poisson distribution with the selected parameter λ, it is possible to estimate the probability of a specific number of negative events during the month. So you can see that the absence of negative events corresponds to a probability estimate of approximately 0.26 (Fig. 7), and the probability of more than one negative event is approximately 0.39 (Fig. 8) (the histograms in Fig. 7 and Fig. 8 are built according to actual data, while the probabilities are calculated for the theoretical Poisson distribution with the parameter λ=1.357143).

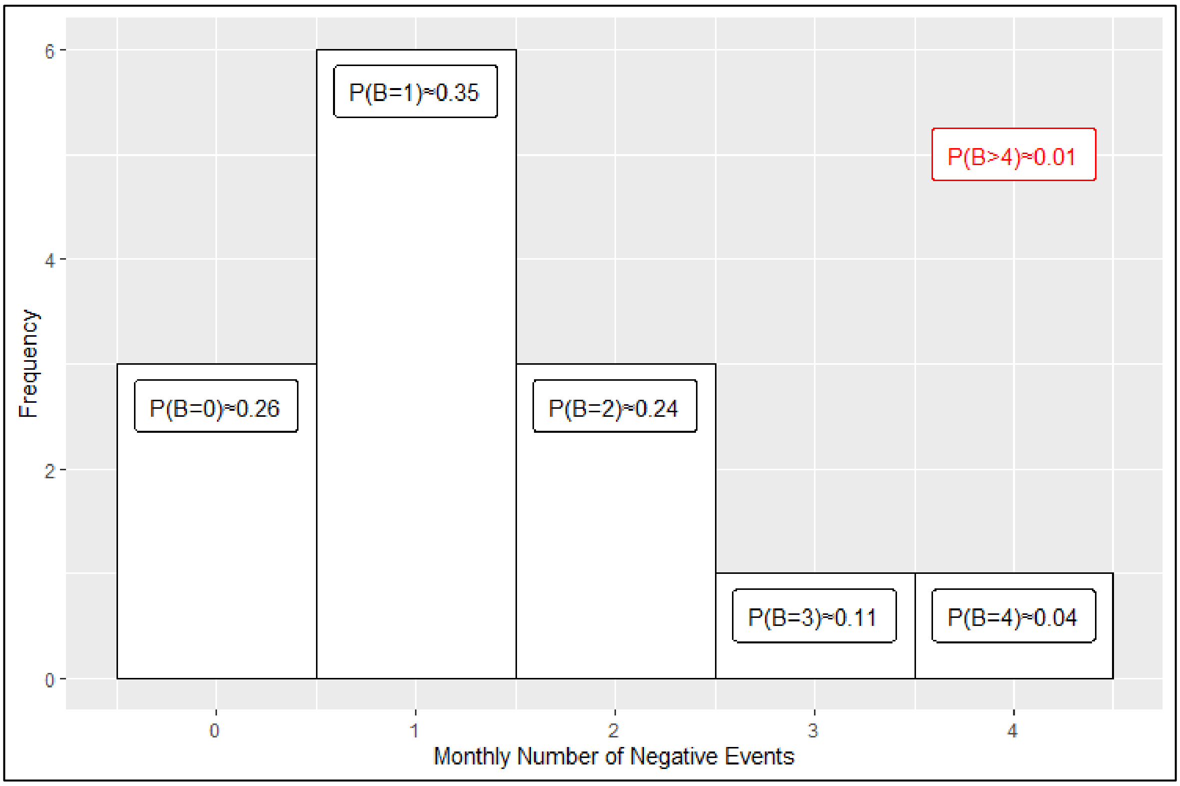

Fig. 7: *Estimates of the probability of specific values of "success" for the Poisson distribution with a chosen parameter*

III. Results

The results obtained indicate that the proposed model can be used as a valid tool for predicting the likelihood of emergencies at the enterprises of the oil refining complex in modern circumstances. Improving the quality of forecasting can be further carried out taking into account the following strategies: enriching the initial data with additional parameters, increasing the analyzed number of negative events, as well as changing the type of mathematical model. The practical significance of the introduction of the proposed model lies in the possibility of early adjustment of measures to improve the stability of the operation of oil refinery facilities located on the territory of the Russian Federation in order to reduce the scale of the consequences of man-made emergencies.

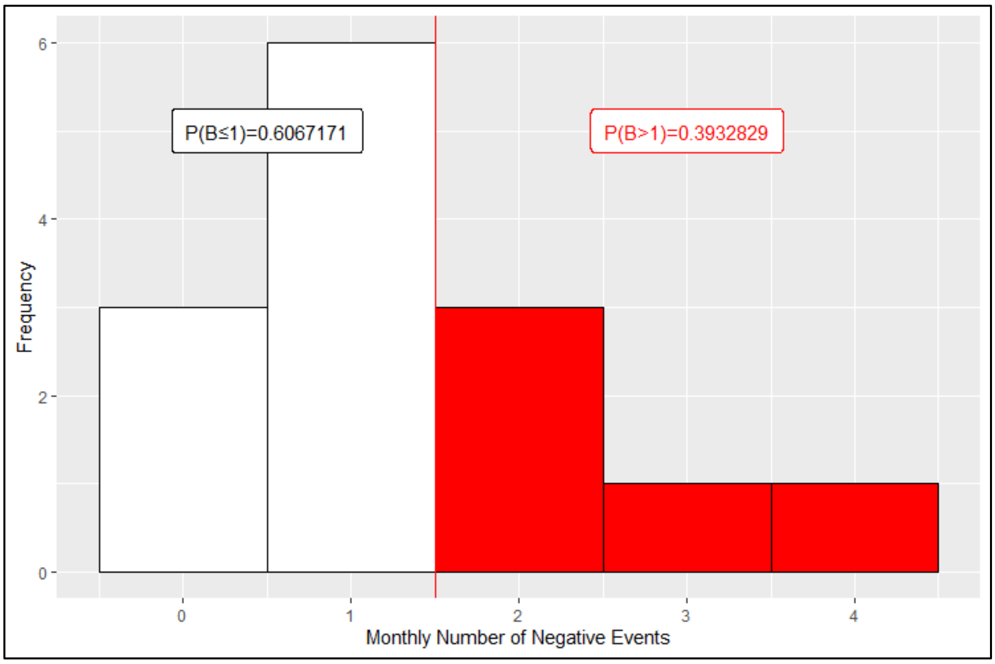

Fig. 8: *Estimation of the probability of occurrence of negative events: less than two and more than one for the Poisson distribution with the selected parameter*

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