Innovative: International Multi-disciplinary Journal of Applied Technology
(ISSN 2995-486X) VOLUME 04 ISSUE 02, 2026

Analysis of Dispatch Flows of City (District) Fire and Rescue Service Units

Doniyorov Azizbek Narzulla o'g'li
Center for Advanced Training of Employees of the Ministry of Poverty Reduction and Employment

Javliyev Asomiddin Elmirzaevich
Center for Advanced Training of Employees of the Ministry of Poverty Reduction and Employment

Abstract:

Urban fire and rescue service operates for unpredictable incidents, such as fires, explosions, road traffic accidents, and life support systems failure. Estimating incoming dispatch call flows is majorly critical for demand predictions and for establishing operational readiness. While the call streams from a given area may be assumed to be driven by a stationary Poisson process, dispatch activity at the city level will often present monthly and seasonal variation—an effect that can lead to less robust statistical verification if an entire year is treated as a single uniform flow. The analysis is made based on dispatch call data of the Termez city fire and rescue service units in 2022. Theoretical Poisson distributions were computed to match empirical daily call distributions. The agreement between empirical and theoretical results was tested with the Pearson chi square goodness of fit criterion (with the additional interpretation with the Romanov criterion). Seasonal variability was examined by dividing the year into three periods (January–March, April–August, and September–December). They found an average call intensity of about 1.7 calls/day, with monthly variability between 1.2 and 2.1 calls/day. When the seasonal grouping was recalculated the Pearson criterion test showed that stationarity can be accepted for the dispatch call flow and this flow can be described by the Poisson distribution. This data supports the continuous adoption of Poisson based mathematical models as a tool for forecasting dispatch demand as well as optimizing staffing and resource allocation for the overall efficiency of the fire and rescue service process.

Keywords: emergency situations, fire and rescue service, call flow, Poisson distribution, Pearson criterion, empirical and theoretical distribution, statistical modeling, seasonal fluctuations

Introduction

Random in time, emergency incidents in cities, in the districts and at the objects of the cities, classified as fires, explosions, the road traffic accidents (RTA), the failures of life support systems et cetera, needs immediate response of the fire and rescue service units. While equipment, personnel and tech play a role in dispatch and operational readiness, having some foresight on call demand and a sound statistical understanding of how emergency flows behave helps quite a lot [1]. In such cases, dispatch calls are discrete random variable taking non negative integer values in fixed time intervals (eg., hours or days) so probabilistic model can play an important role in service planning.

The stationary Poisson process is one of the most frequently used concepts in emergency flow analysis, where the {number} of calls remains an increasing function of the average intensity of the flow. On the theoretical side, dispatches are largely independent and if they are sufficiently stable in terms of frequency, the number of calls averaged over the day should follow the Poisson distribution. But previous studies also mention that real emergency flows might reflect the seasonal or monthly variations that break strict stationarity [2]. As a result, if annual-level data seem Poisson-distributed, the month-specific variance may lessen any good of fit results and weaken the predictability and optimization power of these models.

In response, this study uses statistical modelling to analyze fire brigade response call data from the city of Termez, the small eastern capital of Uzbekistan in 2022. The empirical daily call distributions are then compared to theoretical poission distributions, with the agreement evaluated using the pearson chi square criterion. Also for the year are three seasonal periods, to check if grouping helps assessing stationarity. We anticipate the flow will mostly be Poisson-like, though vary in strength by month [3]. The results confirm that the dispatch flow can be assumed to be stationary and governed by the Poisson distribution, thus endorsing the practicality of mathematical models in demand forecasting, staff scheduling and the efficiency of fire and rescue service delivery processes.

Methodology.

This study describes a methodology to examine dispatch calls by conducting statistical analysis and probabilistic modelling of real-life dispatch calls received in Termez city, fire and rescue service units through 2022. It is a 1 year (365 days) daily count of emergency calls received (one day being 24 hours). We first modeled the daily number of calls as a non negative integer valued discrete random variable. An empirical frequency distribution was defined based on a discrete variational series whereby for each value of the daily call count, the number of days in which that value occurred was listed [4]. This distribution was then used to calculate the mean daily call flow (calls section) which was considered the primary parameter of flow. The next step consisted of modeling the theoretical distribution of the dispatch calls following the Poisson probability law, where the estimated intensity parameter was considered as the mean expected value of significant number of calls per day. For each category of call counts these were calculated theoretically, and statistical testing requirements were satisfied by grouping categories yielding low frequencies. The closeness between empirical and theoretical distributions were evaluated by applying the Pearson chi square goodness of fit criterion by comparing observed and expected frequencies of all categories and the decision on model acceptance was based on the critical values at the chosen significance level. Based on the results of preliminary analysis showing monthly variation in call intensity, the year was further divided into three seasonal intervals (January–March, April–August, and September–December). The same process was followed for each period: intensity estimation, construction of the joint empirical and theoretical distributions for all the periods, and Pearson criterion testing [5]. It enabled the evaluation of annual stationarity and seasonality of the dispatch call flow and it gave a statistically-benched basis for forecasting and operational planning.

Result and Discussion

In any city and districts, various types of emergency incidents may occur at random times (fires, explosions, road traffic accidents, emergencies, accidents in life support systems, and others) [6].

The number of various emergency incidents occurring within a certain time period (minutes, hours, days, and so forth) is a constantly changing quantity and may take any non negative integer values 0, 1, 2, … . At present, there exists a large number of reliable facts formed on the basis of statistical study of emergency incident flows, which in many cases makes it possible to form a statistical assumption that various incident flows can be described by a stationary Poisson distribution [7]:

$$\mathrm{P}_k(\tau) = \frac{(\lambda_{ei} \cdot \tau)^k}{k!} \cdot e^{-\lambda_{ei}\tau} \; (k = 0, 1, 2, \dots), \qquad (1.1)$$

Here**,** $\mathrm{P}_k(\tau)$ is the probability that kkk emergency incidents will occur in the studied area within the time interval (τ);

λ_{ei} – is the intensity (density) of the flow of the average number of calls (emergency incidents) per unit time, calls/day..

The average daily number of calls received by fire and rescue units is calculated on the basis of a discrete variational series.

$$\lambda = \frac{\sum_{k=0}^{n} x_k m_k}{\sum_{k=0}^{n} m_k} \qquad (1.2)$$

Here, x_k is the number of calls per day;

m_k is the number of days with the specified number of calls.

Using formulas (1.1) and (1.2), we will carry out calculations of the empirical and theoretical distributions for the calls of the fire and rescue units of Termez city for 2022.

$$\lambda = \frac{0 \cdot 70 + 1 \cdot 127 + 2 \cdot 83 + 3 \cdot 42 + 4 \cdot 26 + 5 \cdot 12 + 6 \cdot 5}{70 + 127 + 83 + 42 + 26 + 12 + 5} = 1{,}7\ call/day =$$
$$= 0{,}071\ call/day.$$

In order to test the assumption regarding the nature (character) of the Poisson hypothesis for the flow of calls received by fire and rescue units, it is necessary to assess the degree of closeness of the obtained empirical distributions to the assumed theoretical distribution (the Poisson distribution) by comparing distribution graphs using the relevant goodness of fit criteria [8][9]. It was determined that the theoretical distribution of the number of days with a certain (random) number of calls received by fire and rescue units during the analyzed period can be found using the following formula.

$$f_k = \left(\sum_{k=0}^{n} m_k\right) \cdot P_k(\tau) \qquad (1.3)$$

Here, $P_k(\tau)$ is theoretical probability of $k = 0, 1, 2, \dots, n$ calls occuring withing the time interval τ = 1 day. The empirical and theoretical (Poisson) distribution of the number of calls received by the fire and rescue service units of Termez city.

Number of calls k for τ=1 day	Distribution of the number of calls			
	Empirical		Theoretical	
	Frequency m_k	Probability $w_k(\tau)$	Frequency f_k	Probability $P_k(\tau)$
0	70	0,1918	68,1	0,1865
1	127	0,3479	114,3	0,3132
2	83	0,2274	96,0	0,2630
3	42	0,1151	53,7	0,1472
4	26	0,0712	22,6	0,0618
5	12	0,0329	7,6	0,0208
> 6	5	0,0137	2,1	0,0058
Overall	365	1,000	365,0	1,000

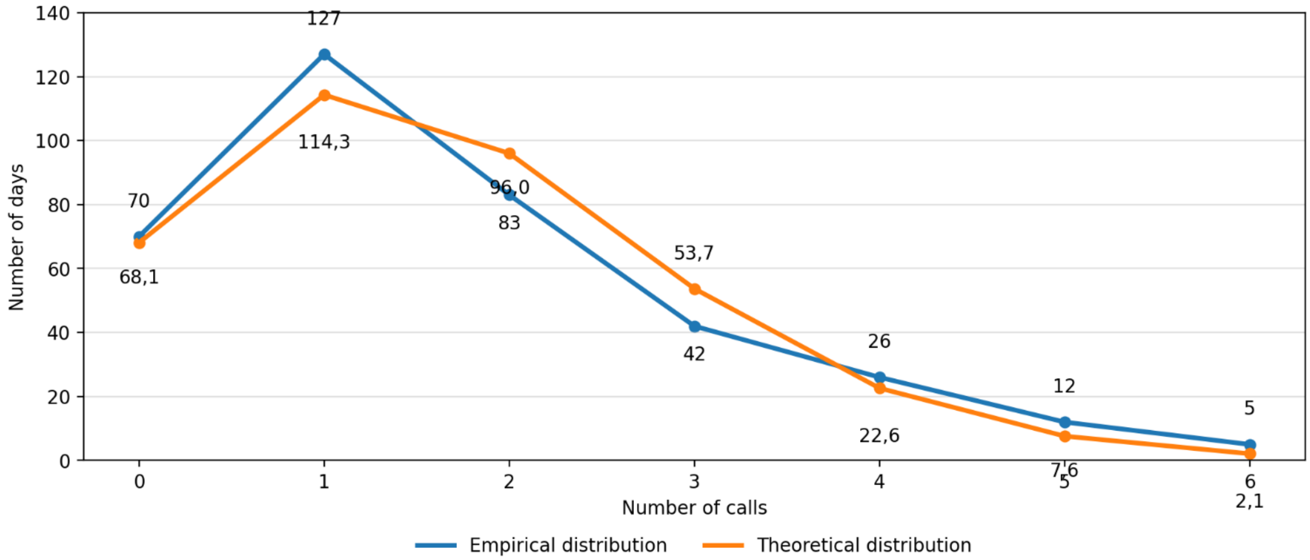

Figure 1.1. Empirical and theoretical (Poisson) distribution of the number of calls received by the fire and rescue units of Termez city in 2022.

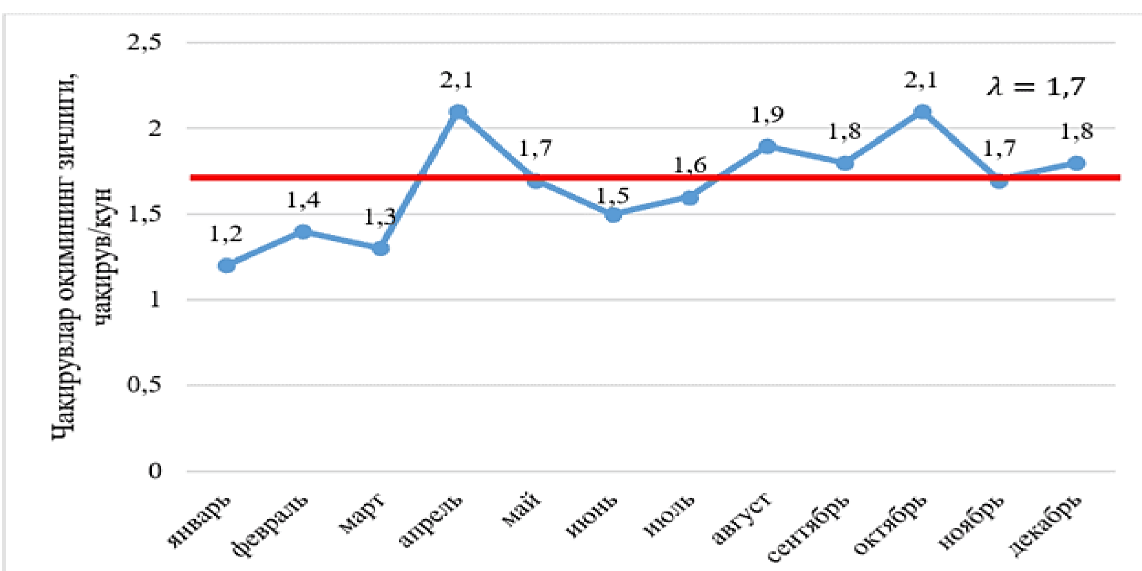

Figure 1.2. Dynamics of the density of the flow of calls received by the fire and rescue units of Termez city by months in 2022.

The analysis of Figures 1.1 and 1.2 shows the following:

1. In 2022, the empirical and theoretical distributions of the number of calls received by the fire and rescue units of Termez city are generally sufficiently close to each other, but this must be verified using a goodness of fit criterion (see Figure 1.1);
2. The call flows received by the fire and rescue units of Termez city by months in 2022 were variable; therefore, in this case, testing the call flow distribution using a goodness of fit criterion may yield unsatisfactory results (see Figure 1.2) [10].

This hypothesis (assumption) must be tested.

To verify the appropriateness of the statistical hypothesis, it is necessary to perform calculations using a goodness of fit criterion, namely the Romanov criterion (98–106):

$$R = \frac{|x^2 - k|}{\sqrt{2k}}, \qquad (1.4)$$

Here, R – is the Romanov criterion;

$k = n - 2$ is the number of degrees of freedom.

The Romanov criterion is interrelated with the Pearson criterion:

$$X^2 = \sum_{i=1}^{k} \frac{(m_i - np_i)^2}{np_i}, \qquad (1.5)$$

Here, X^2 – The Pearson criterion (or chi square criterion);

m_i- is the empirical frequency;

np_i- is the theoretical frequency.

The empirical and theoretical distributions of the number of dispatches of the fire and rescue units in Termez city are presented in the following table (see Table 1.1).

Table 1.2

Distribution of the number of calls received by the fire and rescue service units of Termez city by months in 2025.

Months		Number of calls per day						
		0	**1**	**2**	**3**	**4**	**5**	**≥6**
January	Emperical	7	14	7	2	1	0	0
	Theoretical	9,1	11,2	6,8	2,8	0,9	0,2	0,0
February	Emperical	4	15	5	3	1	0	0
	Theoretical	7,2	9,8	6,6	3,0	1,0	0,3	0,1
March	Emperical	5	16	6	3	1	0	0
	Theoretical	8,3	10,9	7,2	3,2	1,1	0,3	0,1
April	Emperical	4	8	8	4	3	2	1
	Theoretical	3,6	7,6	8,1	5,7	3,1	1,3	0,5
May	Emperical	8	9	6	4	2	1	1
	Theoretical	5,8	9,7	8,1	4,6	1,9	0,6	0,2
June	Emperical	7	10	8	3	1	1	0
	Theoretical	6,9	10,2	7,4	3,6	1,3	0,4	0,1

July	Emperical	7	10	6	4	3	1	0
	Theoretical	6,0	9,8	8,1	4,4	1,8	0,6	0,2
August	Emperical	8	6	7	4	3	2	1
	Theoretical	4,5	8,7	8,4	5,4	2,6	1,0	0,3
September	Emperical	5	8	9	5	2	1	0
	Theoretical	5,0	8,9	8,0	4,8	2,2	0,8	0,2
October	Emperical	6	7	6	5	4	2	1
	Theoretical	3,7	7,9	8,4	5,9	3,2	1,3	0,5
November	Emperical	4	12	8	3	2	1	0
	Theoretical	5,7	9,4	7,9	4,4	1,8	0,6	0,2
December	Emperical	5	12	7	2	3	1	1
	Theoretical	5,3	9,3	8,3	4,9	2,2	0,8	0,2
Year	Emperical	**70**	**127**	**83**	**42**	**26**	**12**	**5**
	Theoretical	**68,1**	**114,3**	**96**	**53,7**	**22,6**	**7,6**	**2,1**

Months		Number of days	λ	X^2	k	R
January	Emperical	31	1,2	1,63	5	1,07
	Theoretical					
February	Emperical	28	1,4	4,97	5	0,01
	Theoretical					
March	Emperical	31	1,3	4,32	5	0,22
	Theoretical					
April	Emperical	30	2,1	1,45	5	1,12
	Theoretical					
May	Emperical	31	1,7	4,98	5	0,01
	Theoretical					
June	Emperical	30	1,5	1,71	5	1,04
	Theoretical					
July	Emperical	31	1,6	2,02	5	0,94
	Theoretical					
August	Emperical	31	1,9	6,85	5	0,59
	Theoretical					
September	Emperical	30	1,8	0,49	5	1,43
	Theoretical					
October	Emperical	31	2,1	3,43	5	0,5
	Theoretical					
November	Emperical	30	1,7	2,16	5	0,9
	Theoretical					
December	Emperical	31	1,8	6,26	5	0,4
	Theoretical					

Year	Emperical	**365**	**1,7**	**12,8**	**5**	**2,5**
	Theoretical					

Table 1.2 (Continue).

It is clear that the smaller the value of the X^2 statistic, the more grounds there are to conclude that the distribution of empirical frequencies is satisfactorily described by the theoretical distribution (98–106).

$$x^2 = \frac{(70-68{,}1)^2}{68{,}1} + \frac{(127-114{,}3)^2}{114{,}3} + \frac{(83-96)^2}{96} + \frac{(42-53{,}7)^2}{53{,}7} + \frac{(26-22{,}6)^2}{22{,}6} + \frac{(12-7{,}6)^2}{7{,}6} + \frac{(5-2{,}1)^2}{2{,}1} = 12{,}8$$

$$R = \frac{|12{,}8-5|}{\sqrt{2\cdot 5}} = 2{,}5.$$

When testing the appropriateness of the statistical hypothesis, a test is carried out to verify whether the distribution law of a certain (random) number of calls received by fire and rescue units corresponds or does not correspond to the Poisson distribution, based on the table of critical points of the $X^2(xi - square)$ distribution, at the significance level α with an accuracy level of $\alpha = 0{,}05$ [11]. The accuracy level of the criterion is $\alpha = 0{,}05$ – nd the number of degrees of freedom is $k = 7 - 2 = 5$. $\alpha = X^2(0{,}05;\ 5) = 11{,}07$.

Thus since, $2{,}5 < 11{,}07$ the inequality $R < \alpha$ holds. Therefore, from the inequality, $R = 2{,}5 < 11{,}07$ it follows that the hypothesis that the flow of calls received by the fire and rescue service is a Poisson flow can be accepted at the accuracy level $\alpha = 0{,}05$ nd this means that the agreement between the empirical and theoretical distributions of calls by days should be recognized as satisfactory.

This occurs due to the fact that the flow of calls is variable.

Table 1.1 shows that in 2022 the calls received by the fire and rescue service of Termez city were distributed unevenly [12][13]. The highest value was observed in April and October λ=2,1 (calls/day), and the lowest value was observed in January λ=1,2 (calls/day) that is, 1.8 times higher than the minimum value, and 1.2 times higher than the annual average value λ=1,7 (calls/day). Therefore, the flow should be divided into 3 parts (see Table 1.3).

Table 1.3. Distribution of the number of calls received by the fire and rescue units of Termez city, taking into account seasonal dispatches.

Months		Number of calls per day							Number of days	λ	X^2	k	R
		0	1	2	3	4	5	≥6					
January-March	Emperical	16	45	18	8	3	0	0	90	1,3	9,8	5	1,5
	Theoretical	24,5	31,9	20,7	9,0	2,9	0,8	0,2					
April-August	Emperical	34	43	35	19	12	7	3	153	1,8	10,7	5	1,8
	Theoretical	26,0	46,1	40,8	24,1	10,7	3,8	1,1					
September-December	Emperical	20	39	30	15	11	5	2	122	1,8	3,7	5	0,4
	Theoretical	19,3	35,6	32,8	20,2	9,3	3,4	1,1					

Across the three periods, the density of the call flow ranged from 1.3 to 1.8 calls per day (see Figure 1.3).

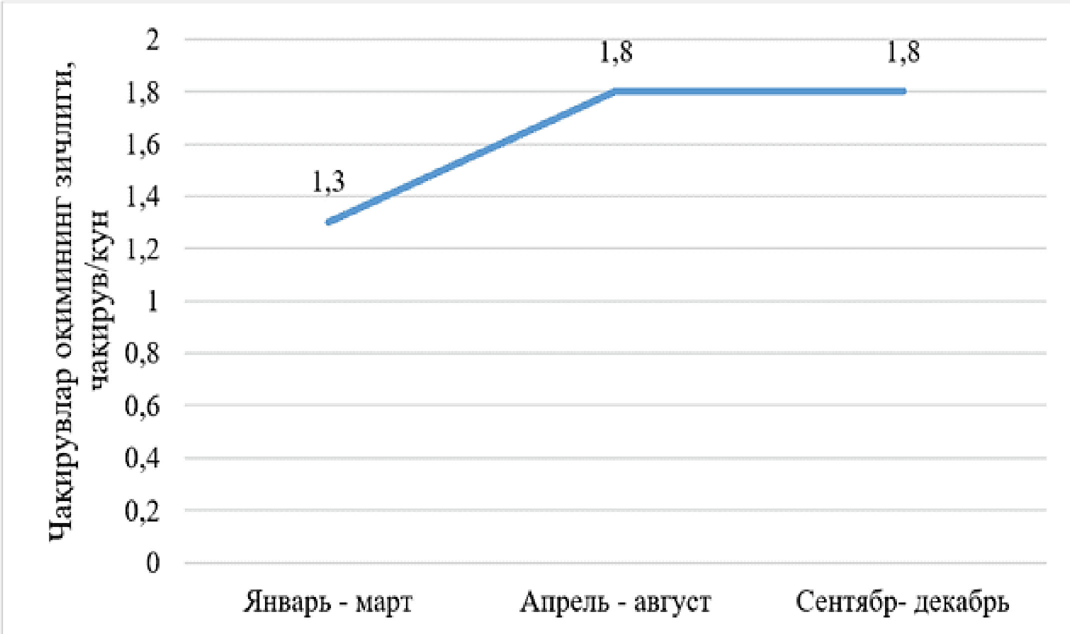

Figure 1.3. Dynamics of the density of the flow of calls received by the fire and rescue services of Termez city across the three periods of 2022.

As a result of the recalculations carried out based on the distributions of calls received by the fire and rescue service units of Termez city when dividing 2022 into three periods, the call flow was evaluated using the Pearson criterion (or the chi square criterion), and the following results were obtained: in January–March $R = 1{,}5 < 11{,}07$; in April–August $R = 1{,}8 < 11{,}07$; in September–December $R = 0{,}4 < 11{,}07$ [14][15].

Conclusion.

Based on the Pearson criterion, it was determined that the flow of calls received by the fire and rescue service units is stationary throughout all months of the year.

Thus, according to the results of modeling the probability distribution and statistical study of the number of calls received by the fire and rescue service units of Termez city in 2022, it was determined that the call flow is stationary. In addition, the flow of calls received by the fire and rescue service units of Termez city has a stationary form and is described by the Poisson distribution law, which makes it possible to use certain mathematical models in studying the service processes of fire and rescue services.

Methods for analyzing and statistically modeling the flow of calls received by the fire and rescue service units in Termez city were considered. As a result of calculations and analyses, it was determined that the flow of emergency incidents is described by the Poisson distribution, while the agreement between the empirical and theoretical distributions was assessed using the Pearson criterion. In addition, the seasonal variability of the call flow and its distribution across the three periods of the year were analyzed, which makes it possible to use them effectively in mathematical models. As a result of testing the statistical hypothesis, the consistency of the call flow in Termez city in 2022 with the stationary flow hypothesis was confirmed. In general, the presented analyses and modeling methods showed that they are of significant importance for forecasting the service processes of fire and rescue services and improving their efficiency.

References

[1]. N. N. Brushlinskii, S. V. Sokolov, and P. Vagner, *Chelovechestvo i pozhary*. Moscow, Russia: Maska, 2007.

[2]. N. N. Brushlinskii et al., *Osnovy teorii pozharnykh riskov i ee prilozheniya*. Moscow, Russia: Akademiya GPS MChS Rossii, 2012.

[3]. I. A. Zakharov, *Informatsionno-analiticheskaya podderzhka upravleniya pozharno-spasatel'nymi podrazdeleniyami pri reagirovanii na krupnye pozhary*, Ph.D. dissertation, Moscow, Russia, 2018.

[4]. K. Pearson, "Mathematical contributions to the theory of evolution," *Philosophical Transactions of the Royal Society of London*, vol. 195, pp. 1–66, 1900.

[5]. Official statistics of Termez city fire and rescue service units, 2022.

[6]. *Russkie nauchnye trudy po pozharnoy bezopasnosti i upravleniyu riskami*. Moscow, Russia, 2005–2010, pp. 8–22.

[7]. D. J. Daley and D. Vere-Jones, *An Introduction to the Theory of Point Processes: Volume I: Elementary Theory and Methods*, 2nd ed. New York, NY, USA: Springer, 2003.

[8]. A. Papoulis and S. U. Pillai, *Probability, Random Variables, and Stochastic Processes*, 4th ed. New York, NY, USA: McGraw-Hill, 2002.

[9]. W. Feller, *An Introduction to Probability Theory and Its Applications*, vol. 1, 3rd ed. New York, NY, USA: Wiley, 1968.

[10]. D. R. Cox and V. Isham, *Point Processes*. London, U.K.: Chapman and Hall, 1980.

[11]. J. R. Taylor, *An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements*, 2nd ed. Sausalito, CA, USA: University Science Books, 1997.

[12]. P. J. Diggle, *Statistical Analysis of Spatial and Spatio-Temporal Point Patterns*, 3rd ed. Boca Raton, FL, USA: CRC Press, 2013.

[13]. A. J. Baddeley, E. Rubak, and R. Turner, *Spatial Point Patterns: Methodology and Applications with R*. Boca Raton, FL, USA: CRC Press, 2015.

[14]. S. M. Ross, *Introduction to Probability Models*, 12th ed. Boston, MA, USA: Academic Press, 2019.

[15]. N. H. Chan, *Time Series: Applications to Finance*. Hoboken, NJ, USA: Wiley, 2011.