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Temporal Characterization of Fire Accidents in China

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Abstract: Based on the fire accident statistics, this study uses the seasonal index method to comprehensively analyze the temporal pattern of fire occurrence in China from 2010 to 2015. The study scientifically reflects that the number of fire occurrences has an extremely close relationship with time, and summarizes the temporal pattern and characteristics of fire occurrences. This study concludes that the high incidence of large fire accidents in China occurs in the time period of 3:00 a.m. to 5:00 a.m. The probability distribution model of the average total number of accidents in each time period was established and the Kolmogorov test was carried out, which shows that the time characteristics of fire accidents in China can be understood with the probability distribution model as a whole. The results of the analysis of the time characteristics of the fire accidents can provide decision-making information for combating fire accidents.

Keywords: Fire accidents; Seasonal index; Probability distribution model; Prediction

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1. Introduction

With the rapid development of the social economy and urbanization in recent years, the occurrence of fire accidents in China generally shows a decreasing trend from year to year, but the casualties and property losses caused by fire are still not negligible. Therefore, it is of great significance to use scientific methods to count and analyze fire accidents, to explore the development pattern of fire, to take precautionary measures, and to minimize fire losses. Foreign scholars began the study of fire modeling as early as the 1960s [1–3]. Harvard University professor Howard Emens developed the famous Harvard fire model [1]. In China, many scholars have established mathematical-statistical models to study the occurrence of fire accidents, and the main methods include fuzzy theory, multivariate statistical analysis, and the gray correlation degree method [4–11]. The research on fire accidents in the above literature has become more common and has achieved good results, but it has not yet analyzed the fire occurrence pattern in China in depth from the perspective of time. Liu Zhuojun, a scholar in China, uses the seasonal index method to give a temporal characterization of the current situation of safety production accidents in recent years and determines the high incidence of safety production accidents in the period. Additionally, the probability distribution model of the average total number of accidents in each time period of production safety accidents per year is given [12].

In this paper, 288 data from January 2010 to December 2015 from the website of the State Administration of Work Safety were organized, analyzed, and compared, focusing on the temporal characteristics of fire accidents, using the seasonal index method and the probability distribution model to comprehensively analyze and study the fire data. This study scientifically reflects that the number of fire starts has an extremely close relationship with time, and summarizes the characteristics of the high incidence time period and time pattern of fire. Accordingly, different resource allocation and response measures are taken for different seasons and time periods, so that safety precautionary measures can be formulated more scientifically and the early warning and emergency response system can be improved and perfected.

2. Seasonal index of fire accidents

Fire accidents always occur more in a particular quarter, month, or time period, with obvious time characteristics. The seasonal index method is to study the time pattern of events by analyzing the frequency of events at different times. The collected fire accident data is quantitatively analyzed to derive the high occurrence time of accidents. Through the data and information obtained from the database on the website of the State Administration of Work Safety, the number and time of occurrence of fire accidents of a larger scale with more than three deaths in China's provinces and cities from 2010 to 2015 were summarized. The number of occurrences was 54, 55, 45, 70, 34 and 30, respectively.

To analyze the temporal characteristics of fire accidents, a day was evenly divided into 12 time periods, and then the frequency of fire accidents was analyzed according to the seasonal index method to find out the time periods with a high frequency of fire accidents. The number of larger and above fire accidents in China between 2010 and 2015 was analyzed by the seasonal index method according to the time period, and its specific data is shown in **Table 1**. It can be seen that the high incidence of larger and above fire accidents in China is the 03–05 time period. Taking the 03–05 time period as the center, the bar chart of the relationship between the seasonal index and time period is drawn, as shown in **Figure 1**.

Table 1. Calculation table of the seasonal index for time period of fire accidents

Year	Number of fire accidents in specific time period												Total sum	Time period average
	17–19	19–21	21–23	23–01	01–03	03–05	05–07	07–09	09–11	11–13	13–15	15–17		
2010	3	2	6	4	5	9	6	4	2	0	7	6	43	4.78
2011	0	2	2	10	5	15	7	2	4	2	5	1	51	5.67
2012	3	1	0	1	12	15	5	2	0	2	0	4	41	4.56
2013	4	4	4	6	14	11	6	4	6	3	5	3	58	6.44
2014	4	5	4	3	3	5	0	1	1	1	6	1	21	2.33
2015	1	5	1	3	2	4	3	2	3	4	0	2	23	2.56
Total for each time period	15	19	17	27	41	59	27	15	16	12	23	17		
Average for the same time period	2.50	3.17	2.83	4.50	6.83	9.83	4.50	2.50	2.67	2.00	3.83	2.83		4.39
Seasonal index	0.57	0.72	0.64	1.03	1.56	2.24	1.03	0.57	0.61	0.46	0.87	0.64	11	
Adjustment of seasonal indices	0.62	0.78	0.70	1.12	1.70	2.44	1.12	0.62	0.66	0.50	0.95	0.70	12	

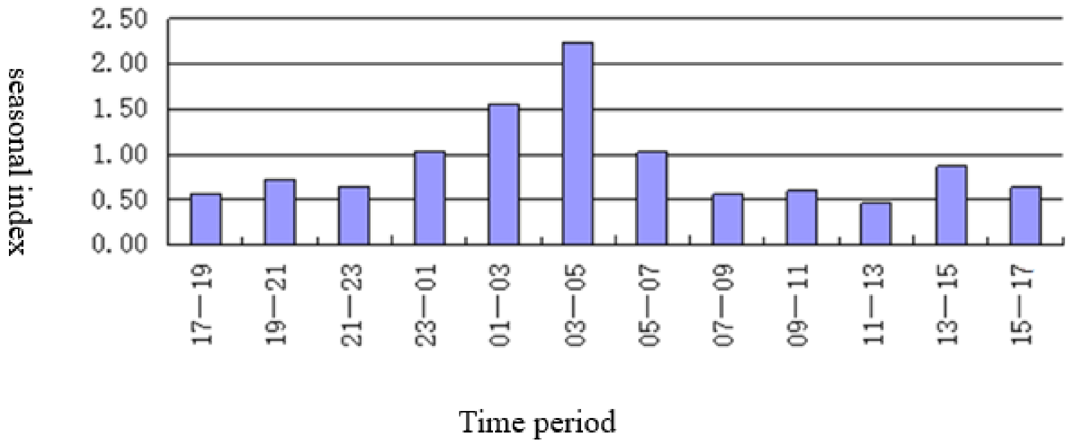

Figure 1. Graph of seasonal indices for the time period

2. Probability distribution model of fire incidents

2.1. Probability distribution model and hypothesis testing

Figure 1 shows that the highest incidence of fire accidents is in the morning at 3:00 a.m. to 5:00 a.m., in general, roughly in line with the normal distribution and follows the parameter characteristics of its specific distribution.

2.1.1. Normal distribution

From a probability point of view, the graph obeys the normal distribution of the random variable. The value probability gradually decreases from the middle to both sides. When approaching the upper and lower limits of the value range, the value probability becomes smaller and smaller, and the value probability on both sides is symmetrical. In layman's terms, the normal distribution is a probability distribution with a large number of quantities in the middle and a small number of quantities at both ends. It is also called a Gaussian distribution. Its equation is shown in **Equation 1** below.

$$Y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(X-\mu)^2}{2\sigma^2}} \tag{1}$$

Where y is the probability density, σ is the standard deviation of the distribution, x is the value of the variable, μ is the mean of the distribution, and e and π are constants.

2.1.2. Kolmogorov test

The Kolmogorov test is a hypothesis testing method to determine whether the assumption of normal distribution can be accepted. Grivenko proved in the early 20th century that DN=sup| FN(x) - F(x) | converges to 0 with probability 1, as shown in **Equation 2**.

$$P\left(\lim_{N\to\infty} D_N = 0\right) = 1 \tag{2}$$

Where let the distribution function of the aggregate x be F(x), and F(x) be a continuous function of x. x_1,

x_2, x_3, ... x_n are samples from x. The distribution function of the aggregate x is F(x). Thus, with F(x) known, for the distributional goodness-of-fit test, the original hypothesis H0: F(x) = F0(x); the opposing hypothesis H1: F(x) = F0(x);

It can be tested by D_N, Kolmogorov gives the distribution of D_N, so this method is called the Kolmogorov test. The basic steps of the test are shown below.

Step 1: Test the hypothesis: Set the original hypothesis H0: F(x)=F0(x); the opposing hypothesis H1: F(x)≠F0(x)

Step 2: Find the empirical distribution function; let {x_I, i = 1, 2, ...N} be the observation sample, and arrange it in non-decreasing order, denoted as $x_1 \le x_2 \le ... \le x_n \le x_n + 1 \le ... \le x_N$

Then for any -∞ < x < +∞, define FN(x) as in **Formula 3**.

$$F_N(X)=\begin{cases}0, & X \le X_1 \\ k/N, & X_k < X \le X_{k+1}, \quad k=1,...,N-1 \\ 1,, & X > X_N\end{cases} \quad (3)$$

Step 3: Find the maximum absolute error between FN(x) and F0(x), that is the value of D_N

Step 4: For a given significance level α, choose the negation domain Rα = {DN, α < D_N};

Step 5: Make a judgment that if the calculated value D_N ∈ Rα, then reject H_0, and F(x)=F0(x) cannot be accepted, otherwise accept H_0.

2.2. Construction of probability distribution model of fire accident time period

By establishing the probability distribution model of the average total number of accidents of fire accidents in each time period, the overall grasp of the changing characteristics of fire accidents and the size of the possibility of occurring in different time periods can be understood. Finally, the probability distribution model of fire accidents is established and hypothesis testing is carried out.

The overall change of fire accidents of larger or above in China in each time period is shown in **Figure 2**.

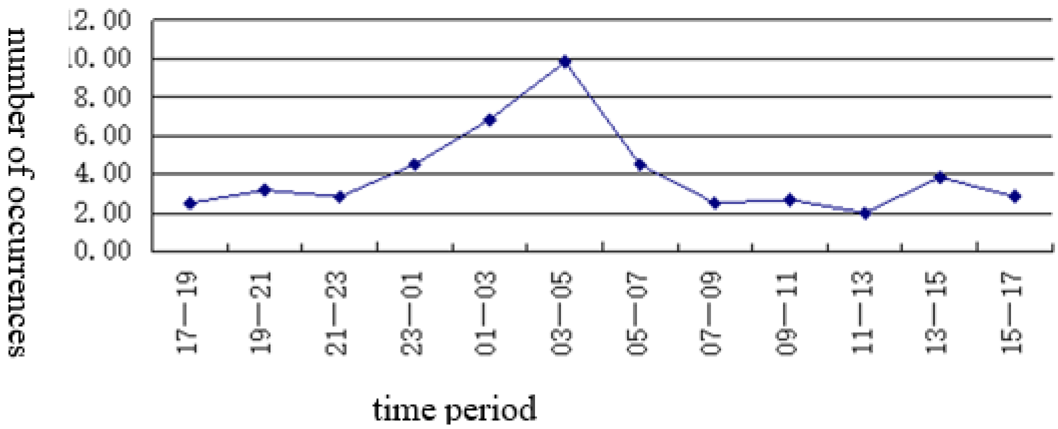

Figure 2. The number of larger and above fire accidents in each time period from 2010 to 2015

Figure 2 shows the time periods in which the number of larger and above fire accidents in China is increasing are 17–21 hours, 23–05 hours, 09–11 hours, and 13–15 hours, while the time periods in which it is decreasing are 21–23 hours, 05–09 hours, 11–13 hours and 15–17 hours. The average total number of accidents in each time period of the year is x. The Kolmogorov test is used to test whether x obeys a normal distribution.

The specific process is as follows.

Step 1: The hypothesis is tested. The hypothesis H_0 can be tested if the overall x obeys the normal N (μ, σ^2) distribution. Since μ, σ^2 is unknown, the sample mean and variance are used as estimates of μ, σ^2 respectively, as shown below.

$$\mu = (2.00\times1 + 2.50\times2 + ... + 6.83\times1 + 9.83\times1)/12 = 4.39$$

$$\sigma^2 = [(2.00\text{-}4.39)2 + (2.50\text{-}4.39)2 + ...(9.83\text{-}4.39)2]/12 = 4.842$$

To test the hypothesis H_0, the aggregate x obeys a normal N (4.39, 4.842) distribution. The standard transformation is as follows, with U-N (0, 1).

$$U = \frac{X - 4.39}{4.84}$$

To compute the value of Φ_i, simply use the standard normal distribution table directly to obtain it as shown below.

$$x_1 = 2.00\text{: } \Phi_1 = P(x \le 2.00) = P(\frac{X - 4.39}{4.84} \le \frac{2.00 - 4.39}{4.84})$$

$$= \Phi(-0.4938)$$

$$= 0.3121$$

Step 2: The empirical distribution function is calculated with the 3-3 equation below.

$$\text{For } x_1 = 2.00\text{: } x \le x_1,\ F_N(2.00) = 0$$

Step 3: The maximum absolute error between FN(x) and F0(x), which is the value of DN is calculated below.

$$d_1=\max\{|\Phi1\text{-}FN(x_1)|,\ |FN(x_2)\text{-}\Phi_1|\}=0.3121$$

The results of the above calculations are summarized in **Table 2**, and the maximum value in the eighth column d_i of that table is the value of the statistic calculated below.

$$D_N=\sup|F_N(x)\text{-}F(x)|,\ \text{where } D_{12}=0.3253$$

Table 2. Test statistics for x

x_i	n_i	μ=x-4.39/4.84	Φ_i	$F_N(X_i)$	$F_N(x_{i+1})$	$\lvert\varphi_i\text{-} F_N(x_i)\rvert$	$\lvert F_N(x_{i+1})\text{-} \Phi_i\rvert$	d_i
2.00	1	-0.4938	0.3121	0.0000	0.0833	0.3121	0.2288	0.3121
2.50	2	-0.3905	0.3483	0.0833	0.2500	0.2650	0.0983	0.2650
2.67	1	-0.3554	0.3596	0.2500	0.3333	0.1096	0.0263	0.1096
2.83	2	-0.3223	0.3745	0.3333	0.5000	0.0412	0.1255	0.1255
3.17	1	-0.2521	0.4013	0.5000	0.5833	0.0987	0.1820	0.182
3.83	1	-0.1157	0.4522	0.5833	0.6667	0.1311	0.2145	0.2145
4.50	2	0.0227	0.5080	0.6667	0.8333	0.1587	0.3253	0.3253
6.83	1	0.5041	0.6915	0.8333	0.9167	0.1418	0.2252	0.2252
9.83	1	1.1240	0.8686	0.9167	1.0000	0.0481	0.1314	0.1314

Step 4: For a given significance level α, the negation domain $R_\alpha=\{D_N,\alpha<D_N\}$. $D_{12,0.01}=0.708$ for the given significance level is α=0.01; $D_{12,0.05}=0.576$ for the given significance level is α=0.01.

Step 5: A judgment is made. Because 0.3253 <0.576 <0.708, so at the level of significance α = 0.01 or α = 0.05, the hypothesis H0 can be accepted, with the overall x obeying the normal N (4.39, 4.842) distribution. Hence, the overall average number of China's larger and above fire accidents each year in each time period obeys the normal distribution N (4.39, 4.842).

3. Conclusion

This paper analyzes the high incidence of fire accidents in the time period from the perspective of time characteristics by using the seasonal index method and applies the Kolmogorov test to establish the probability distribution model of the average total number of accidents in each time period. The results of the study show that fire accidents do exist in high-incidence time periods, and their patterns can be recognized. The temporal characteristics of fire accidents in China can be grasped as a whole through the probability distribution model. The temporal characterization of fire accidents in China and its results can provide decision-making information for combating fire accidents.

Disclosure statement

The authors declare no conflict of interest.

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