Analysis and Forecast of Production Safety Accidents of Housing Municipal Engineering in China

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Abstract—The problem of production safety accidents in housing municipal engineering has always been a big trouble in China, which has clearly rebounded in recent years. This shows that China's management performance in this regard still needs to be improved, and there is still a lot of work to be done to prevent and reduce the occurrence of accidents. This article collected data on 11,948 cases of production safety accidents in housing municipal engineering in 31 provinces, municipalities, and autonomous regions in China from 2003 to 2018. It performs data preprocessing and makes preliminary analysis; uses SPSS software to perform factor analysis, variance analysis, and cluster analysis based on the time and space dimensions of the data. Results show the total number of such production safety accidents is still very large, but there are certain regularities in the time and space dimensions. Relevant government departments and enterprises should focus on controlling the time and region where accidents occur frequently. Besides, this paper establishes the ARIMA model to predict the number of security accidents from 2020 to 2022, and the number of security accidents will continue to increase, so we should be vigilant and prevent it in advance.

1. INTRODUCTION
In recent years, China’s production safety accidents in housing municipal engineering still occur frequently. Workers’ personal safety is not effectively protected during the production operations, and the construction industry has not made timely predictions and prevention of various accidents. Scholars have done some research towards it. Sun Lei et al. [1] used analysis theory to study the spatial and temporal distribution characteristics of safety accidents in China's construction industry, and put forward effective suggestions based on the analysis results. Li Chengyu [2] and Gao Yong [3] made reasonable analysis and early warning on the cause of safety accidents. Li Xinxin [4] used the corresponding analysis model to discuss the relationship between construction safety accidents and time between 2012 and 2018, and Li Wei [5] conducted relevant research and analysis on the characteristics of accidents during this period. According to ARIMA model, Cui Weijie [6] predicted the number of fatalities in various production safety accidents nationwide in 2020 with high accuracy. In summary, scholars mostly consider a single dimension in the analysis of construction production safety accidents. Although the analysis is more detailed, the occurrence of accidents is often the result of the interaction of different factors in multiple dimensions; and in the aspect of accident prediction, most scholars are studying various types of safety accidents, and the results are not targeted. Therefore, it is necessary to analyze the safety accidents of housing municipal engineering production with a systematic and structured thinking and effectively prediction.

In view of this problem, this article will combine the data of construction safety accident in recent years, use factor analysis, cluster analysis, variance analysis and other methods, starting from regional
and seasonal aspects, to analyze the construction safety accident from multiple perspectives. And then it will carry out reasonable accident prediction, put forward corresponding countermeasures and suggestions, in order to provide a new way for exploring the causes of frequent construction safety accidents, provide new tools and methods for analyzing and predicting construction safety accidents, provides reference for improving the safety status of construction and reducing accidents rate [7].

1.1 Research on trends in construction safety accidents

1.1.1 Analysis of the overall trend of safety incidents

With the advancement of technology and technology, China has won the title of "infrastructure maniac" in the field of construction. The number of housing municipal engineering projects has increased steadily every year, but at the same time, construction safety accidents have also occurred frequently. By consulting the express report system on housing municipal engineering production safety accidents from the official website of the Ministry of Housing and Urban-Rural Development, it was learned that there were 11,948 production safety accidents in China from 2003 to 2018, and the number of deaths reached 14,603, of which 503 were major and above. After analyzing and sorting the data, the trend charts of the three indicators are obtained (Figures 1-1 and 1-2).

It can be seen from the combination of Figures 1-1 and 1-2 that in the 10 years from 2003 to 2012, the three indicators of the number of safety accidents, the number of deaths, and the number of major and above safety accidents all showed a downward trend, among which the number of security accidents has been steadily decreasing, and the other two have fluctuated. From 2012 to 2015, these three indicators were in a state of up and down. In the following years, the number of security accidents and the number of deaths have been rising (Figures 1, 2), the number of major and above security accidents has fluctuated within 20-30 since 2009, and the magnitude is relatively small (Figure 1).

![Fig. 1. The number of national security accidents and the trend of major and above accidents from 2003 to 2018](image1)

![Fig. 2. National security accident fatalities trend chart from 2003 to 2018](image2)

It can be seen from the monthly statistical chart (Figure 3) that the number of construction safety accidents in China has a certain regularity in the distribution of month dimension, of which July and
August are the peak months of accidents, and it is relatively safe in February. The number of security incidents in June was slightly lower than in May and July.

The reason why June has become a "sinking month" for the number of annual accidents, is that June is a production safety month in China, and construction production is guaranteed by the government; while January and February are around the Spring Festival, most of the projects are basically at a standstill. In addition, under cold weather, the soil layer, some materials and machinery in most parts of the north will be affected by cold air, and as a result, there will be adjustments or even work stoppages, so there is fewer accidents; the biggest problem of construction in July and August is that the weather is too hot. Workers work at high temperatures, and efficiency will inevitably be discounted. The most important thing is that in this case, operators are prone to burnout and accidents due to operational errors. In addition, the soil, materials, and construction machinery at high temperatures will also be affected. Such factors will inevitably cause problems.

![Fig. 3. Distribution of the number of security accidents in each month of 2003-2018](image)

### 1.1.2 Trend analysis of types of security accident

The types of production safety accidents in China's housing municipal engineering are relatively concentrated, mainly including "six major injuries" falling from high places, striking objects, collapsing, electric shock, mechanical injuries, and lifting accidents, so strictly controlling these six hazards is a strong measure to decrease the occurrence of safety accidents.

On the official website of the Ministry of Housing and Urban-Rural Development of China, in addition to the "six major injuries", data on vehicle injuries, fires and explosions, poisoning and suffocation, and other injuries are recorded. Although they do not fall into the six categories, their impact should not be ignored. From 2003 to 2018, there were 117 vehicle accidents, accounting for 0.98%, 32 fire and explosion accidents, accounting for 0.27%, 153 poisoning and suffocation accidents, accounting for 1.28%, and 302 other accidents, accounting for 2.53%. From an overall perspective, the "six injuries" are still in an overwhelming position, accounting for more than 90% of all accidents each year.

By analyzing the trend of the number of various accidents each year (Figure 4), it can be learned that the incidence of falling accidents from high places is much higher than other accidents. A total of 6113 accidents occurred in 2003-2018, accounting for 51.12%. The accidents occurred in 16 years. The accident showed a trend of decreasing first and then increasing within 16 years, which is extremely pessimistic, so the government should strengthen management; the same situation also includes object strikes, vehicle injuries and other injuries. These three types of accidents have a clear growth trend in recent years, especially the number of the last two types of accidents in 2018 has surpassed that of 2003, and this type of problem needs to be focused on. Among them, although the number of machine injury, poisoning and suffocation accidents has increased, the rising and falling fluctuations are slightly smoother; the number of accidents and fire and explosion accidents is relatively stable, and the proportion has not increased or decreased significantly. In addition, at present, China has strict control over two types of accidents, collapse and electric shock. So the number of their occurrences is basically in a downward trend year by year, which is closely related to the development of modern technology and the level of construction management.
2. DIFFERENCE ANALYSIS OF CONSTRUCTION SAFETY ACCIDENTS

2.1 Spatial differences in security incidents

2.1.1 Spatial difference evaluation based on factor analysis

- Statistical inspection

In SPSS software analysis, factor analysis has a basic premise, which requires that the analyzed factors themselves have a certain correlation. Usually, this correlation analysis is usually completed by "KMO and Bartlett test". If KMO $> 0.5$ and the significance level of chi-square statistic value $<0.05$, it is considered to pass the test [8]. Among them, the closer the KMO value is to 1, the more suitable for factor analysis. This article uses SPSS software to perform KMO and Bartlett tests on the sample data.

| KMO sampling suitability measure | 0.556 |
|---------------------------------|-------|
| Bartlett sphericity test        |       |
| Approximate chi-square          | 155.282 |
| Degrees of freedom              | 15    |
| Distinctiveness                 | 0.000 |

Table 1 shows the test results of KMO and Bartlett, where the value of KMO is 0.556, indicating that it is suitable for factor analysis. The significance value is 0.000 $<0.05$. Because the test assumes that the two are unrelated, the original hypothesis is rejected, which means that the variables are related and can be analyzed.

| initial | extract |
|---------|---------|
| Number of accidents | 1.000 | 0.935 |
| Number of major accidents | 1.000 | 0.670 |
| Death toll | 1.000 | 0.901 |
| Mortality rate | 1.000 | 0.632 |
| Death rate of 100,000 employees | 1.000 | 0.882 |
| Million square meters of housing construction mortality | 1.000 | 0.676 |

The common factor variance in Table 2 shows the results of the commonness of each variable. From the table, the commonness of the variables in the factor analysis is very high, indicating that most of the information in the variables can be extracted by the factor, showing the results of factor analysis are valid.

- Extract common factors
Through the above factor analysis method, the principal components are obtained.

**Table 3 Interpretation of Total Variance**

| Component | Initial eigenvalue | Extract the sum of squared loads | Rotational load sum of squares |
|-----------|-------------------|---------------------------------|-------------------------------|
|           | Total             | Variance percentage | Accumulation % | Total             | Variance percentage | Accumulation % | Total             | Variance percentage | Accumulation % |
| 1         | 3.141             | 52.354              | 52.354          | 3.141             | 52.354              | 52.354          | 2.621             | 43.684              | 43.684           |
| 2         | 1.554             | 25.908              | 78.262          | 1.554             | 25.908              | 78.262          | 2.075             | 34.578              | 78.262           |
| 3         | 0.734             | 12.233              | 90.495          |                    |                    |                |                    |                    |                |
| 4         | 0.383             | 6.388               | 96.883          |                    |                    |                |                    |                    |                |
| 5         | 0.173             | 2.886               | 99.769          |                    |                    |                |                    |                    |                |
| 6         | 0.014             | 0.231               | 100.000         |                    |                    |                |                    |                    |                |

Extraction method principal component analysis.

Table 3 shows the newly obtained factors, weights of factors and cumulative weights. The sum of the eigenvalues of the first two factors has accounted for 78.262% of the total eigenvalues. Therefore, extract component 1 and component 2 as the main factors, which are denoted by F1 and F2, respectively.

- **Factor score**

Through the above methods, the analyzed principal components and corresponding weights are obtained, and the safety management level evaluation function is established

\[
F = \frac{0.43684F_1 + 0.34578F_2}{0.78262}
\]  

(1)

Comprehensive analysis of safety management performance in 31 provinces, municipalities and autonomous regions (Table 4)

**Table 4 Safety Management Performance Scores and Rankings by Region**

| Region            | F1   | F2   | F   | Ranking | Region            | F1   | F2   | F   | Ranking |
|-------------------|------|------|-----|---------|-------------------|------|------|-----|---------|
| Jiangsu Province  | 2.86 | -0.71| 1.28| 1       | Ningxia Hui Autonomous Region | -0.90 | 1.17 | 0.01| 17      |
| Jiangsu Province  | -0.46| 3.38 | 1.24| 2       | Hubei Province    | 0.29 | -0.55| -0.08| 18      |
| Shanghai          | 1.26 | 0.80 | 1.06| 3       | Inner Mongolia Autonomous Region | -0.45 | 0.22 | -0.15| 19      |
| Zhejiang Province | 1.72 | -0.36| 0.80| 4       | Liaoning Province | 0.10 | -0.59| -0.21| 20      |
| Guangdong Province| 1.73 | -0.46| 0.76| 5       | Fujian Province  | -0.13| -0.33| -0.22| 21      |
| Hainan Province   | -0.71| 2.06 | 0.51| 6       | Tianjin          | -0.56| 0.06 | -0.29| 22      |
| Heilongjiang Province | 0.26 | 0.76 | 0.49| 7       | Hebei Province   | -0.16| -0.56| -0.34| 23      |
| Yunnan Province   | 0.50 | 0.46 | 0.48| 8       | Hunan Province   | -0.15| -0.57| -0.34| 24      |
| Beijing           | 0.53 | 0.41 | 0.48| 9       | Jiangxi Province | 0.36 | -0.35| -0.36| 25      |

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According to the safety management level evaluation function, the larger the calculated function value, the better the safety management in the region and the higher the ranking. Jiangsu Province, Qinghai Province, Shanghai City, Zhejiang Province and Guangdong Province have larger values, respectively 1.28, 1.24, 1.06, 0.80 and 0.76, ranking first, second, third, fourth and fifth in the country, respectively. Therefore, the overall status of engineering safety in these five regions is better. The Tibet Autonomous Region, Shanxi Province, and Henan Province have relatively small values, and their overall scores are all around -1, indicating that the safety management of these provinces is lagging behind, and the relevant departments should pay sufficient attention. In comparison, Anhui Province has a large population and good economic development, and its value is still relatively large, ranking high in the middle, indicating that this region has unique insights and methods for safety management.

2.1.2 Spatial difference evaluation based on cluster analysis
Taking the number of accidents, the number of major and above accidents, the number of deaths, the mortality rate, the death rate of 100,000 employees and the death rate of a million square meters of housing construction as variables, this paper uses the "system clustering analysis" in the SPSS software, 31 provinces, municipalities and autonomous regions are classified according to their characteristics, forming different groups and represented on the pedigree chart (Fig. 5.).

| Region                  | Value 1 | Value 2 | Value 3 | Value 4 | Value 5 | Rank |
|-------------------------|---------|---------|---------|---------|---------|------|
| Guizhou Province        | 0.16    | 0.47    | 0.30    | 10      | Chongqing | -0.07 | -0.75 | -0.37 | 26     |
| Anhui Province          | 0.50    | -0.11   | 0.23    | 11      | Shandong Province | -0.17   | -1.31  | -0.67 | 27     |
| Xinjiang Uygur Autonomous Region | -0.25 | 0.74    | 0.19    | 12      | Shaanxi Province    | -0.79   | -0.65  | -0.73 | 28     |
| Guangxi Zhuang Autonomous Region | 0.02 | 0.19    | 0.09    | 13      | Henan Province     | -0.46   | -1.45  | -0.90 | 29     |
| Jilin Province          | -0.30   | 0.52    | 0.06    | 14      | Shanxi Province    | -1.44   | -1.12  | -1.30 | 30     |
| Jilin Province          | -0.20   | 0.32    | 0.03    | 15      | Tibet Autonomous Region | -2.79   | -1.21  | -2.09 | 31     |
| Sichuan Province        | 0.41    | -0.49   | 0.02    | 16      |              |       |       |       |       |

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![Pedigree chart using average connection in 31 regions](image-url)
The cluster analysis pedigree chart shows the clustering situation of each cluster analysis. Combined with the pedigree chart obtained by analysis, the 31 provinces, cities, and autonomous regions are divided into four categories with the distance of 5, as shown in Table 5.

**TABLE 5 CLUSTERING OF SAFETY ACCIDENT MANAGEMENT PERFORMANCE BY REGION**

| Area category | provinces, cities, and autonomous regions |
|---------------|------------------------------------------|
| **Type 1 area** | Jilin Province, Xinjiang Uygur Autonomous Region, Jiangxi Province, Hebei Province, Gansu Province, Inner Mongolia Autonomous Region, Henan Province, Liaoning Province, Guizhou Province, Heilongjiang Province, Guangxi Zhuang Autonomous Region, Fujian Province, Hunan Province, Shandong Province, Yunnan Province, Beijing, Anhui Province, Sichuan Province, Hubei Province |
| **Type 2 area** | Hainan Province, Ningxia Hui Autonomous Region, Shanxi Province, Shaanxi Province, Tianjin City, Qinghai Province, Tibet Autonomous Region |
| **Type 3 area** | Guangdong, Zhejiang, Shanghai, Chongqing |
| **Type 4 area** | Jiangsu Province |

The first type is the most widely distributed, including 19 provinces and autonomous regions. In these areas, the number of accidents, the number of major and above accidents, and the number of deaths are small, while the mortality rate, the death rate of 100,000 employees and the death rate of a million square meters of housing construction are relatively high, and the level of safety management is generally reasonable.

The second category includes seven provinces the six variables in these areas are relatively high, and comprehensive safety management is relatively unreasonable.

The third category includes 4 provinces and autonomous regions the number of accidents, the number of deaths, the mortality rate, and the death rate of 100,000 employees in these areas are low, and the safety management is reasonable.

The fourth category includes only one province the death rate of 100,000 employees and the death rate of a million square meters of housing construction in this province are very low, and the number of accidents, the number of deaths and the number of major and above accidents are very high, and the safety management is more reasonable.

### 2.2 Time difference of security accidents

SPSS software is used to analyze the variance of the accident time.

**TABLE 6 VARIANCE HOMOGENEITY TEST (NUMBER OF ACCIDENTS)**

| Levene Statistic | df1 | df 2 | Sig. |
|------------------|-----|------|------|
| 16.430           | 23  | 360  | 0.000|

As can be seen from the results in Table 6, the significance is 0.000, less than 0.05, the variance homogeneity test fails, so the analysis of variance cannot be done. But at the same time we also got the ANOVA table of analysis of variance, which can be seen in Table 7.

**TABLE 7 ANOVA (NUMBER OF ACCIDENTS)**

| Sum of Squares | df | Mean Square | F | Sig. |
It can be seen from the ANOVA analysis in Table 7 that the sig value is 0.000 <0.05, so the null hypothesis should be rejected, that is, there is a significant difference in the number of accidents at 24 time points, and the significance is very high. Therefore, the difference in time can still be analyzed by analysis of variance, and this analysis of variance can be considered meaningful.

As can be seen from the average graphs at various time points, fewer accidents occurred at 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, 2100 hours, 2200 hours and 2300 hours. At 0 hours and 9 hours, 10 o'clock, 15 o'clock and 16 o'clock, accidents occurred more.

Because at 0 o'clock, the human body is in a fatigue period, due to the workers' numbness and slackness, there will be naps, sleepy situations, coupled with night work, loose management, leading to the occurrence of accidents. 9 o'clock and 10 o'clock are generally the most energetic periods of the human body. Building construction operations often seize this opportunity to arrange some key and intensive work at this time. Workers need to be highly focused and sustained operation, the consequence of this "good opportunity" is that operators are prone to fatigue, which eventually leads to disaster. 15 o'clock and 16 o'clock are the phases of leaving work or finishing work. When workers are about to leave work, they will have the urge to take a break as soon as possible, and they will gradually slack off the details and relevant safety regulations of their work, which lead to accidents.

3. FORECAST OF DEATHS FROM CONSTRUCTION SAFETY ACCIDENTS

This paper uses SPSS software to draw a sequence diagram of the number of security accidents in China from 2003 to 2018, as shown in Figure 3-1. It can be seen from the figure that the number of security accidents from 2003 to 2018 did not show a significant seasonal component, so there is no need to do seasonal decomposition, but the number of accidents shows an obvious trend of change, so autocorrelation and partial autocorrelation graphs are required to analyze the stationarity of the sequence, and both ACF and PACF are trailing. It can be preliminarily judged that the sequence is a non-stationary sequence, which needs to be further stabilized[9].
Fig. 7. The 2003-2018 national security accident number sequence diagram

This paper uses first-order difference processing on the data to obtain new sequence diagrams, autocorrelation diagrams, and partial autocorrelation diagrams (Figure 8, Figure 9). It can be seen from Figure 3-2 that the sequence diagram after differential processing is basically uniformly distributed on the upper and lower sides of the 0 scale, which is a wide and stable process, which meets the zero mean [10], and both the ACF diagram and the PACF diagram are in a trailing state, so it can be considered that the difference sequence is stationary. After repeated simulation analysis, the model was finally determined to be ARIMA (0,2,0).

Fig. 8. Difference sequence diagram in the number of national security accidents from 2003 to 2018

Fig. 9. National auto accident number differential autocorrelation graph and partial autocorrelation graph from 2003 to 2018
This paper simulates the number of production safety accidents of national housing municipal engineering from 2003 to 2022, obtains the autocorrelation graph and partial autocorrelation graph of the residuals, and fits the true values from 2003 to 2018 with the simulated values to obtain 2019 Forecast analysis charts from year 2022 (Figure 10, Figure 11).

![Residual autocorrelation graph and partial autocorrelation graph](image)

**Fig. 10.** Residual autocorrelation graph and partial autocorrelation graph

![Number of fittings and predictions of the number of security accidents in 2003-2022](image)

**Fig. 11.** The number of fittings and predictions of the number of security accidents in 2003-2022

### 4. Conclusion

For China, the safety accident of housing municipal engineering production has always been a thorny problem. In order to study the internal law of accidents, this article uses SPSS software to sort and analyze the relevant data from 2003 to 2018, and finds that this problem has obvious trend characteristics in certain dimensions.

From 2003 to 2018, the number of security incidents, the number of larger and above security incidents, and the number of deaths all showed a trend of decreasing first and then increasing. In previous years, under the vigorous control of relevant government departments and enterprises, this problem has been improved to a certain extent, but in recent years, the number of these three indicators has increased significantly.

In the time dimension, it is not difficult to find that July and August of the year are the months where construction safety accidents occur frequently in China, and February is relatively safe; by using the analysis of variance, we can get that during the day, there are fewer accidents at 1 o'clock, 2 o'clock, 3 o'clock, 4 o'clock, 5 o'clock, 21 o'clock, 2 o'clock and 23 o'clock. There are many accidents occurring at 000, 900, 1000, 1500 and 1600. Therefore, in the future construction safety management, we can focus on those high-frequency occurrences.

Under the spatial dimension, 31 provinces, cities and autonomous regions are divided into four categories by factor analysis. The first category contains 19 regions, the second category contains 7 regions, and the third category covers 2 provinces and 2 cities. The fourth category only includes Jiangsu Province, and the management level of this province is also the highest compared with other regions;
using cluster analysis to analyze, the conclusions are almost the same. The safety management level function value $F$ of Jiangsu Province is 1. 28, indicating that the overall condition of engineering safety is better.

By using the ARIMA (0,2,0) model to fit the forecast of the number of security accidents from 2003 to 2018, the results show that the fitting effect is very good, and the number of security accidents in 2020, 2021 and 2022 are predicted for reference.

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