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Risk Assessment and Governance Strategy of Production Safety Accidents in Jinwan District of Zhuhai City—Based on Integrated Application of Risk Matrix and Borda Count Methods

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Abstract

Based on the literature research and the actual situation of investigation in Jinwan district of Zhuhai city, the risk factors of production safety accidents in Jinwan district of Zhuhai city were constructed, and the risk factors of production safety accidents are divided into 6 secondary indicators and 20 tertiary indicators. According to the risk matrix formula, the risk levels of production safety accidents in Jinwan district of Zhuhai city are evaluated from the two aspects of occurrence probability and consequence severity, and further ranked by the Borda count method. The results show that road traffic accidents, construction accidents, fire accidents, network and information security incidents, maritime traffic accidents and heavy pollution weather are intolerable risks. Finally, this paper puts forward the risk governance strategy from the aspects of advancing the construction of rule of law, strengthening responsibility, enhancing the investigation and rectification of the risk, improving emergency rescue capabilities and consummating the support safeguard system.

Keywords

Production Safety Accidents, Risk Assessment, Risk Matrix Method, Borda Count Method, Governance Strategy

1. Introduction

With the opening of the Hong Kong-Zhuhai-Macao Bridge, the Guangdong-Hong

Kong-Marco Greater Bay Area will become the new economic growth pole of Zhuhai, which will promote the further development of Zhuhai's economy. As one of the important administrative regions of Zhuhai City, Jinwan District is playing an increasingly important role as a comprehensive transportation hub. In recent years, the economic development of Jinwan District has been rapid, especially the development of the secondary industry. Along with the growth of the economy, safety in production has also been attached more and more importance by the party and the country. With the continuous development of the theory and practice of emergency management, the concept of emergency management has gradually changed from "emergency after the event" to "prevention before the event". The government and scholars pay more attention to the risk assessment and hidden danger screening in advance, so timely and effective risk assessment can not only reasonably judge hidden dangers, but also take necessary measures to eliminate risks in advance.

In this paper, the risk matrix method and Borda count method are used to assess the risk of production safety accidents in Jinwan district of Zhuhai city, and the corresponding governance strategies are proposed. The risk assessment of production safety accidents in the region in advance is conducive to the targeted investigation of hidden dangers and the early elimination of hidden risks. Accelerating the management and control of production safety risks is conducive to curbing the outbreak and spread of major risk accidents. It is of great significance to establish and improve the hidden danger control system to ensure the safety of people's lives and property.

This paper analyzes the data of production safety accidents in Jinwan District of Zhuhai City in 2017. The method of risk matrix is used to divide the consequence criterion into four dimensions and the possibility criterion into five dimensions. In this paper, the principle of risk importance is determined according to the m-by-n risk matrix, and the risk level of production accidents is divided into three levels, including acceptable risk, tolerable risk and intolerable risk. Based on the actual situation of Jinwan District in Zhuhai, this paper adopts the influence scorecard to obtain the consequence value and possibility value, and determines the risk level of production safety accidents in Jinwan District according to the calculation results. Borda count method is adopted to rank the production safety accident risks in Jinwan District. Finally, combining with the actual situation of Jinwan District, this paper puts forward the corresponding risk management strategy.

2. Literature Review

From the perspective of public management, there are abundant articles on "production safety accidents". Some scholars have conducted researches on "emergency plan", "emergency material reserve", "public opinion communication", "accountability mechanism", "accident investigation mechanism" and other aspects. At present, the article about "risk assessment of production safety accidents" mainly focuses on the study of single disaster. Zeng Liang (2008) [1] took the civil aviation insecurity events as the analysis object, took the four subsystems of human, aircraft, environment and management as the analysis framework, and adopted the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) to carry out risk assessment. Sun Aijun (2010) [2] established the causation analysis model of major production safety accidents from the perspective of social technology system, and made a case analysis of the Especially serious gas explosion accident in Tunlan coal mine of Shanxi Province. Compared with "single disaster bell", the research results of "multi-disaster bell" are relatively few. Based on the accident cause theory, Li Weiquan (2016) [3] analyzes 150 production safety accidents from 2011 to 2015，and summarizes the 24 measures of risk factors， and six risk superposition factors.

ISO31000:2009 "risk management—principles and guidelines" defines "risk management" as "the coordinated activities of the command and control organization for risk". ISO31000:2009 defines "risk assessment" as "the whole process of risk identification, risk analysis and risk assessment". This definition indicates that the three sub-processes of risk assessment are indispensable and executed in sequence. The Electronic Systems Center (ESC) procurement engineering group first proposed the risk matrix method in April 1995. In the ISO guide73:2009 Risk management—terminology, Risk Matrix is defined by the international organization for standardization (ISO) as a tool for displaying and ranking risks by defining the range of consequences and possibilities. IEC 31010:2009 "risk management techniques" provides a total of 31 risk assessment methods and techniques, with serial number b.29, consequence/probability matrix, also known as "risk matrix". In the process of project management, risk matrix is a structural method to identify the importance of project risk. It is a method that is easy to operate and combines qualitative analysis with quantitative analysis [4]. However, in the qualitative and semi-quantitative risk matrix, the risk level is very limited, resulting in the same or similar risk level of some risks. For the same or similar level of risk, it is necessary to determine which risk is more important and which risk can be put aside in the case of limited resources. The Borda count method can open the "risk knot" generated by the risk matrix and relatively accurately rank the importance of each risk.

At present, the risk matrix methods been applied in many fields such as health care, enterprise economy and public management, and it is often used in combination with Borda count method in the process of case analysis. Zhu Qichao [5], Li Shuqing [6] and other scholars adopted Borda count method to improve the risk matrix method. Dong Yan (2010) [7] took social security incidents in some area of Beijing city for example, identified the risks of four types of disasters within the jurisdiction, determined the risk level based on the risk matrix method, and carried out risk ranking based on Borda count method. Zhang Hongxia (2013) [8] took 3300 food safety incidents in China as research samples, and adopted the risk matrix method to evaluate the risk factors in each link. In addition, some scholars combine the risk matrix method with Analytic Hierarchy Process (AHP). Xiong Jie (2010) [9] took the aerospace research project as the research object, used the Analytic Hierarchy Process (AHP) to construct the index system, obtained the relative weight of risk factors at all levels, and used the risk matrix method to carry out the single factor risk assessment. Liu Jin (2012) [10] used Borda count method and Analytic Hierarchy Process (AHP) to improve the risk matrix method in the risk assessment of hospital building fires.

In view of that above, the research achievement of "production safety accident" is abundant, but there is a relatively limited study of the risk assessment of the safety accident in a region. The overall assessment of the risks of various production safety accidents is conducive to the thorough investigation of hidden dangers in the jurisdiction, the timely detection of unsafe factors in the jurisdiction, and the targeted prevention measures for disasters with high risk levels. Based on the unique advantages of risk matrix method and Borda count method in risk assessment, this paper carries out risk assessment of production safety accidents in Jinwan district of Zhuhai city, and proposes corresponding risk management strategies.

3. Risk Assessment of Production Accidents in Jinwan District of Zhuhai City

Based on the classification of accidents and disasters in the National Emergency Plan for Public Emergencies, and in combination with the actual situation in Jinwan District of Zhuhai City, this paper constructed the risk factor index of production safety accidents in Jinwan District of Zhuhai City. Risk level is determined by analyzing consequence criterion (C criterion), possibility criterion (L criterion) and risk importance criterion. According to the risk matrix formula, the risk level of production safety accidents in Jinwan District of Zhuhai City is evaluated from the two aspects of occurrence probability and consequence degree. Borda sequence value method is used to rank the risk of production safety accidents in Jinwan District of Zhuhai City. The specific structure of the article is shown in **Figure 1**.

3.1. Production Accident Risk Factor Index Framework

This paper mainly evaluates the production safety accidents in Jinwan district of Zhuhai city, taking the production safety accidents as the first-level indexes. On the basis of the classification of accidents and disasters in the National Emergency Plan for Public Emergencies, combined with the actual situation learned from the investigation in Jinwan District of Zhuhai City, the Delphi method is adopted to adjust the individual indicators. In this paper, six kinds of indexes including industrial and mining accidents, fire accidents, transportation incident, public facilities and equipment accidents, radiation accidents, environmental pollution and ecological destruction events are taken as secondary indexes. On this basis, the relevant indicators are further divided into 20 three-level indexes. Industrial and mining accidents are divided into dangerous chemicals accidents,

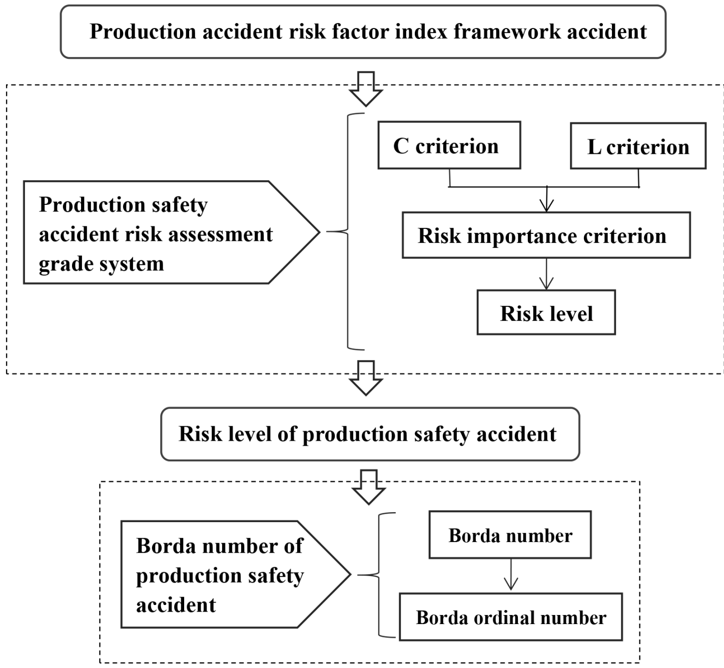

Figure 1. Schematic diagram of the research framework.

mining accidents, construction accidents, fireworks accidents and special equipment accidents. Transportation incidents are divided into road traffic accidents, water traffic accidents, bus operation emergencies, railway traffic accidents and civil aircraft flight accidents. Public facilities and equipment accidents are divided into water supply emergencies, power emergencies, gas emergencies, highway and bridge emergencies, network and information security incidents, and civil air defense engineering accidents. Environmental pollution and ecological destruction events are divided into heavy pollution weather events and environmental emergencies.

3.2. Production Safety Accident Risk Assessment Grade System

Risk criteria are mainly used for risk assessment. In the ISO guide73:2009 risk management—terminology, "risk criteria" is defined as "a reference to evaluate the importance of risks". The risk criterion involved in this paper includes consequence criterion (C criterion), possibility criterion (L criterion) and risk importance criterion.

3.2.1. Consequence Criterion (C Criterion)

Consequence criterion is mainly used to judge the severity of risk consequence. Pursuant to article 3 of Production Safety Accident Reporting and Investigation Regulations, according to the casualties or direct economic loss caused by the last year, the consequences of the accidents are divided into four grades, which are not serious, generally serious, respectively serious and very serious, and the corresponding scores are 1, 2, 3 and 4. The severity of risk consequences is shown in Table 1.

Table 1. Risk consequence severity judgment table.

Risk consequence severity score		1	2	3	4
Risk consequence severity		Not serious	Generally serious	Respectively serious	Very serious
Description of risk consequence severity	Casualties	In one year, the cumulative results are less than 3 people died, or less than 10 people seriously injured.	In one year, the cumulative results are more than 3 people and less than 10 people died, or more than 10 people and less than 50 people seriously injured.	In one year, the cumulative results are more than 10 people and less than 30 people died, or more than 50 people and less than 100 people seriously injured.	In one year, the cumulative results are more than 30 people died, or more than 100 people seriously injured.
	Direct economic losses	In one year, the cumulative results are direct economic losses of less than RMB 10 million.	In one year, the cumulative results are direct economic losses of less than RMB 10 million and more than RMB 50 million.	In one year, the cumulative results are direct economic losses of less than RMB 50 million and more than RMB 100 million.	In one year, the cumulative results are direct economic losses of more than RMB 100 million.

Note: Meet the death toll or direct economic losses.

3.2.2. Possibility Criterion (L Criterion)

Possibility criterion is mainly used to judge the probability of risk occurrence. According to the number of the accidents in a certain period of time, the probabilities of the accidents are divided into five grades, which are very low frequency, relatively low frequency, generally high frequency and very high frequency, and the corresponding scores are 1, 2, 3, 4 and 5. The probability of risk occurrence is shown in Table 2.

3.2.3. Risk Importance Criterion

The risk importance criterion, also known as the "risk acceptance criterion", refers to the standard to classify all risks according to their importance. This paper divides the risk importance criterion into three levels. The risk matrix is m by n matrix. "m" for the consequences, "n" for probabilities. As can be seen in Table 3 dark gray areas are called "high risk areas", light gray areas are called "medium risk areas", and white areas are called "low risk areas".

3.2.4. Risk Level

In the ISO guide73:2009 risk management—terminology, "risk level" is defined as "the size or magnitude of a risk or combination of risks expressed as a combination of consequences and possibilities". This paper divides the risk levels of production safety accidents into three levels, including acceptable risk, tolerable risk and intolerable risk. According to the calculation of the risk assessment matrix formula, the risk score within 1 - 3 is an acceptable risk, the risk score within 4 - 9 is a tolerable risk, and the risk score within 10 - 20 is an intolerable risk. The risk levels are shown in Table 4.

3.3. Risk Level of Production Safety Accident in Jinwan District of Zhuhai City

In the actual investigation of Jinwan District, the influence scorecard was used to obtain the consequence C value, and the possibility scorecard was used to obtain

Table 2. Risk occurrence possibility judgment table.

Risk occurrence possibility score	1	2	3	4	5
Risk occurrence possibility	Very low frequency	Relatively low frequency	General frequency	Relatively high frequency	Very high frequency
Description of risk occurrence possibility	An average of less than one cases per year	An average of one or more cases per year, but less than 4 cases per year	An average of one or more cases per season, but less than 3 cases per season	An average of one or more cases per month, but less than 4 cases per month	An average of one or more cases per week

Table 3. Schematic diagram of risk importance criteria.

Risk consequence severity	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		Risk occurrence possibility				

Table 4. Risk level judgment table.

Risk score	Risk level	Colored areas	Response measures
1 - 3	Acceptable risk	White areas	Maintain monitoring and review
4 - 9	Tolerable risk	Light gray areas	Maintain focus, monitor and review in a timely manner
10 - 20	Intolerable risk	Dark gray areas	Develop a response plan immediately

the possibility L value. The specific score results are shown in Table 5. Special equipment accidents, railway traffic accidents, highway and bridge emergencies, civil air defense engineering accidents and radiation accidents are acceptable risks. Dangerous chemicals accidents, mining accidents, fireworks accidents, bus operation emergencies, civil aircraft flight accidents, water supply emergencies, power emergencies, gas emergencies and environmental emergencies are tolerable risks. Construction accidents, fire accidents, road traffic accidents, water traffic accidents, network and information security incidents and heavy pollution weather events are intolerable risks.

3.4. Borda Number of Production Safety Accident in Jinwan District of Zhuhai City

For the same or similar level of risk, Borda count method can effectively determine which risk is more important [11]. According to the calculation formula, this paper calculates the Borda number and Borda ordinal number of 20 third-level indexes respectively. The specific calculation results are shown in Table 6.

The Borda ordinal number of safety production risk in Jinwan District of Zhuhai City is ranked from low to high. The smaller Borda ordinal number is, the greater

Table 5. Risk assessment list of production safety accidents in Jinwan District of Zhuhai City.

Serial number	Risk factors	Consequence criterion	Possibility criterion	Risk importance criterion
C1a	Dangerous chemicals accidents	4	2	8
C1b	Mining accidents	2	2	4
C1c	Construction accidents	4	4	16
C1d	Fireworks accidents	2	3	6
C1e	Special equipment accidents	1	1	1
C2a	Fire accidents	3	5	15
C3a	Road traffic accidents	4	5	20
C3b	Water traffic accidents	3	4	12
C3c	Bus operation emergencies	3	3	9
C3d	Railway traffic accidents	3	1	3
C3e	Civil aircraft flight accidents	4	1	4
C4a	Water supply emergencies	1	4	4
C4b	Power emergencies	2	4	8
C4c	Gas emergencies	3	2	6
C4d	Highway and bridge emergencies	1	3	3
C4e	Network and information security incidents	4	3	12
C4f	Civil air defense engineering accidents	1	2	2
C5a	Radiation accidents	2	1	2
C6a	Heavy pollution weather events	2	5	10
C6b	Environmental emergencies	1	5	5

Table 6. Borda number list of production safety accidents in Jinwan District of Zhuhai City.

Serial number	Risk factors	Borda number	Borda ordinal number
C1a	Dangerous chemicals accidents	28	6
C1b	Mining accidents	18	15
C1c	Construction accidents	36	1
C1d	Fireworks accidents	22	12
C1e	Special equipment accidents	9	19
C2a	Fire accidents	35	2
C3a	Road traffic accidents	40	0
C3b	Water traffic accidents	31	4
C3c	Bus operation emergencies	27	7
C3d	Railway traffic accidents	19	14

Continued

C3e	Civil aircraft flight accidents	24	10
C4a	Water supply emergencies	21	13
C4b	Power emergencies	26	8
C4c	Gas emergencies	23	11
C4d	Highway and bridge emergencies	17	16
C4e	Network and information security incidents	32	3
C4f	Civil air defense engineering accidents	13	18
C5a	Radiation accidents	14	17
C6a	Heavy pollution weather events	30	5
C6b	Environmental emergencies	25	9

the risk is. As can be seen in **Table 6**, the risk ranking results of production safety accident in Jinwan District of Zhuhai City are as follows: road traffic accidents, construction accidents, fire accidents, network and information security incidents, water traffic accidents, heavy pollution weather events, dangerous civil aircraft flight accidents, gas emergencies, fireworks accidents, water supply emergencies, railway traffic accidents, mining accidents, highway and bridge emergencies, radiation accidents, civil air defense engineering accidents and special equipment accidents.

4. Risk Governance Strategy of Production Safety Accidents in Jinwan Ddistrict of Zhuhai City

4.1. Promoting the Legal Construction of Safety Production

Under the guidance of the overall national security concept, the government shall focus on developing laws and regulations in various fields. First of all, the government shall further clarify the list of responsibilities of production safety supervision departments and comprehensively carry out administration by law. The relevant government departments shall establish the legal operating evaluation mechanism, assess the effectiveness of law enforcement, strengthen supervision and law enforcement, and prevent abuses of power. Secondly, the government shall improve the democratic and scientific decision-making mechanism for production safety, and establish the system of expert argumentation and public opinion solicitation. Next, suspected criminal acts discovered in the process of administrative law enforcement shall be transferred to judicial organs in a timely manner, and law enforcement officials shall assist judicial organs in investigation and evidence collection according to law. Then, the local standards of safety production shall be formulated in accordance with the national safety production standards system and the local reality, and the government shall supervise and guide enterprises strictly enforce the laws and regulations of safety production. Finally, the large enterprises shall be encouraged to take the lead in formulating technical safety standards for new products, new materials and new processes, and further develop and improve relevant operating procedures in accordance with the standards.

4.2. Improving Emergency Rescue Capabilities

First of all, the government shall strengthen the number of grass-roots staff, rationally arrange relevant tasks according to the actual situation, and increase relevant subsidies. Next, the government emergency departments shall strengthen the compilation and revision of emergency plans to ensure that emergency plans are complete and feasible, and that emergency response can be carried out timely and effectively in case of emergencies. Meanwhile, the government emergency departments shall formulate special emergency drill plan, organize enterprises, schools and other units to conduct safety drills, effectively improve the quality and effectiveness of emergency drills, and improve the ability of the masses to deal with emergencies. Then, the government shall further strengthen the training of leading cadres and staff in relevant departments of production safety at all levels, and effectively improve the leadership and decision-making abilities of managerial cadres through on-the-spot investigations, special lectures and other forms. In the end, government staff should do a good job in daily emergency duty, especially in special time periods, to ensure timely transmission of information [12]. Moreover, the government shall standardize information reporting, broaden access to information, enrich content and means of information reporting, further improve the quantity and quality of information submitted to relevant units at higher levels, and ensure information security for decision-making and handling of all kinds of emergencies.

4.3. Reinforcing the Production Safety Support System

In the first place, the government shall strengthen the construction of emergency rescue teams, give full play to the comprehensive emergency rescue functions, and improve the ability to deal with emergencies. Secondly, the relevant departments shall engage qualified professional technical institutions or experts to participate in the work of production safety by purchasing services. Meanwhile, the government shall establish safety production mechanism for experts to participate in consultation, evaluation, training and drill, and actively provide high-quality and efficient services for emergency management experts to devote themselves to the construction of emergency management. Next, the government shall build an enterprise information and data management platform for production safety, strengthen the statistical analysis of work safety data, and make all safety supervision information available. Then, by employing an external consulting agency, the company shall hold free training classes for the main responsible persons, safety management personnel and workshop leaders, and employ legal consultants to provide legal services on production safety. In the end, the government shall carry out safety production liability insurance, give full play to the economic compensation and social management functions of insurance in safety production, and improve the ability of enterprises to resist risks.

4.4. Strengthening the Investigation and Rectification of Production Safety Hazards

Firstly, in accordance with the unified arrangements of the state and the province, the relevant government departments shall conscientiously organize and carry out major inspections of production safety, eliminate major hidden dangers, and effectively prevent major accidents in production safety. Secondly, the government shall reasonably determine the spatial layout of residential living areas, infrastructure construction, and enterprise site selection, and implement the "one-vote-down system" for production safety hazards. Next, the government shall intensify the use of information technology to urge enterprises to carry out self-examination and self-reporting, and take the initiative to identify and rectify all kinds of potential accidents. At last, the government shall make solid progress in addressing major hazardous sources and focus on improving security in key areas and industries [13].

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Zeng, L. (2008) Application of Multi-Layer Fuzzy Evaluation Method to Risk Assessment in Civil Aviation. *China Safety Science Journal*, **18**, 131.

[2] Sun, A.J. and Liu, M. (2010) Cause Analysis Model for Major and Serious Accidents in a Social-Technical Perspective. *Journal of China Coal Society*, **35**, 876-880.

[3] Li, W.Q. and Nie, Y.W. (2016) A Research on the Risk Factors Evaluation Model of Superposition Type Risk Accident: Based on the AHP Method and 150 Cases. *Journal of Guangzhou University* (*Social Science Edition*), No. 12, 17-27.

[4] Dui, J.M. and Jan, N. (2015) Recommendations on the Use and Design of Risk Matrices. *Safety Science*, **76**, 21-31. https://doi.org/10.1016/j.ssci.2015.02.014

[5] Zhu, Q.C., Kuang, X.H. and Shen, Y.P. (2003) Risk Matrix Method and Its Application in the Field of Technical Project Risk Management. *Engineering Science*, **5**, 89-94.

[6] Li, S.Q., Yan, Z. and Duan, Y. (2010) Application of Risk Matrix in Classification of Dangerous and Hazardous Factors. *China Safety Science Journal*, **20**, 83-87.

[7] Dong, Y., Li, J.F. Wang, L.J. and Wang, T. (2010) Hazard Assessment of the Urban Area Emergencies Based on the Hazard Matrix and Borda Ranking Method. *Journal of Safety and Environment*, **10**, 213-216.

[8] Zhang, H.X., An, Y.F. and Zhang, W.S. (2013) Identification, Assessment and Management of Food Safety Risks in China: An Empirical Analysis Based on Food Safety Incidents. *Inquiry into Economic Issues*, No. 6, 135-141.

[9] Xiong, J. and Zhang, S.C. (2010) Risk Assessment of Aerospace Development Project Based on AHP and Risk Matrix. *Science & Technology Progress and Policy*, **27**, 124-126.

[10] Liu, J. and Gao, X.N. (2012) Fire Risk Assessment of Hospital Building Based on Improved Risk Matrix Method. *Mathematics in Practice and Theory*, **42**, 115-121.

[11] Tan, L.F., Hao, D.P., Sun, X.L., Yan, X.D., Duan, J.R., Guan, X.Y., *et al*. (2012) Integrated Application of Risk Matrix and Borda Count Methods to Assessment of the Risks of Public Health Emergency Events during Regional Large-Scale Activities. *Journal of Environmental & Occupational Medicine*, **29**, 556-560.

[12] Lu, W.G., Wang, Y.N. and Liu, P. (2016) Emergency Management of Safety Production: Dilemma, Situation and Strategic Choice—A Case Study of Guangdong Province. *Administration Reform*, No. 12, 42-47.

[13] Lu, W.G. and Shu, D.Y. (2017) Emergency Preventive Management of Safety Production: Innovative Exploration and Challenge Response—Based on the Investigation of Jinwan District of Zhuhai City. *Safety*, No. 11, 7-10.