

Research on the Application Status and Trend of Fault Tree Analysis based on CiteSpace

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Abstract

In order to analyze the research status of accident tree analysis in China's domestic safety science, the data of 2,081 articles of accident tree analysis applied to safety research in CNKI were used as data samples, and data analysis was carried out by using CiteSpace and other information visualization software. The results showed that the institutions that frequently use fault tree analysis in the field of safety science in China are Central South University, Kunming University of Science and Technology, and Beijing University of Science and Technology. The more active authors are Cui Tiejun, Wang Wencai and Yuan Run. The research hot spots of the accident tree analysis in the security field are Safety evaluation, Risk assessment, Fire explosion and Bayesian network.

Keywords

Accident tree; Security; Citespace; Information visualization; Scientific measurement.

1. INTRODUCTION

Fault Tree Analysis (FTA), also known as accident tree analysis, is to start from a possible accident (top event), from top to bottom, layer by layer to find the direct and indirect causes of the accident Event, until the most basic cause of the accident (Elementary event) is found, and then the logical relationship between the events is expressed in a logical diagram. Due to the practicability and effectiveness of this method in safety assessment, its application has been widely promoted to industries such as military, machinery, electronics, mining, chemical, construction, and metallurgy. Practice shows that the fault tree analysis method is fully applicable to the safety management of various industries and units, and it is a system safety analysis method with a wide range of applications and development prospects.

As a qualitative and quantitative analysis method, the fault tree analysis method is widely used in safety scientific research such as system safety evaluation and risk early warning. In China's fault tree safety analysis research, in 2005, Wu Aiyu et al. established an accident tree model of building fires that caused casualties on the basis of analyzing building fires and causing casualties, and found out the cause The main factors of building fire causing casualties and the key ways of accident prevention. Finally, an example is used to prove that the fault tree analysis method can make a comprehensive elaboration on the factors that lead to accidents and provide a reference for accident prevention (Wu Aiyu et al., 2005). In 2007, Yu Ting'an et al. used the fault tree analysis method to systematically analyze the factors that caused the fire and explosion of LNG storage tanks, determined the main factors affecting the storage tank accidents, and proposed corresponding improvement measures (Yu Ting'an et al., 2007). In 2011, Zhang Cunfeng et al. used a combination of fault tree analysis and analytic hierarchy process to conduct risk analysis on college dormitories. Before the analytic hierarchy process,

the fault tree was introduced, and various important factors in the index layer were sought through the fault tree, thereby improving the accuracy and effectiveness of the analytic hierarchy process (Zhang Cunfeng et al., 2011). This article will analyze its application in the domestic security field by digging a large number of papers on fault tree security. On the one hand, the number of review documents in the security field of fault trees is small, and there are certain shortcomings. It is necessary to update and analyze the progress of related research; on the other hand, the scientific knowledge map can be used as a way to use computers, databases, and The research method of visualizing information provides the possibility to carry out this research. In recent years, it has become a current trend to study discipline development trends, research status, and research hotspots through the method of scientific knowledge graphs (Feng Changgen et al., 2018; Li Jie et al., 2017; Li Jie et al., 2018). This paper is based on the literature data collected by CNKI in the safety field of accident trees, and uses the powerful tool of scientific knowledge map to systematically analyze the domestic safety research of accident trees, in order to fully understand the current research status of accident trees in the domestic safety field. As well as the theme trends, provide help for the research of accident tree safety in our country.

2. MATERIALS AND METHODS

Taking the CNKI database with the most comprehensive collection of domestic scientific and technological documents as the data source, the subject search was carried out through "SU=('accident tree'+ 'fault tree')* 'safe'", and scientific papers, conference news, solicitation notices, etc. were excluded Documents that are not related to the application of the accident tree analysis method in safety were finally obtained, which were published in various journals between 1978 and 2018 on the subject of accident trees and safety, and the search results were saved in the Refworks format.

This study uses scientific measurement methods and knowledge map technology to analyze and visualize the collected literature data. Using a new generation of scientific and technological text mining and visualization system-CiteSpace5.0 software. It is an information visualization software developed by Professor Chen Chaomei of Drexel University based on JAVA language. The software can perform multiple, time-sharing and dynamic visual analysis of scientific and technological text data, and intuitively display a certain science The relationship between the development process of the field and the knowledge structure (Li Jie and Chen Chaomei, 2016)

3. RESULTS AND DISCUSSION

3.1. Paper Output Analysis

The application of the fault tree analysis method in the security field is a manifestation of the application of the method in the field, and the change in its number directly reflects the application of the fault tree analysis method in the field of safety science. From the perspective of the entire time span (Figure 1), the period from 1978 to 2002 was in the embryonic stage of safety research on accident trees. Since 1978, the first literature on the use of accident tree analysis in the field of safety appeared. In the next 24 years The output of mid-year literature has been below 25, which is at a low output level. With the gradual development of the research on the fault tree analysis method, the application of the fault tree analysis method in the security field has become more and more mature. The period from 2003 to 2016 is a period of rapid growth in research. During this period, the output of papers basically maintained a steady growth. In 2003, the research on the application of accident trees in the field of safety showed a rapid growth trend. The annual output of that year reached 48. This is twice the output in 2002. In 2009, it ushered in significant growth again, with an annual output of 111 articles, more than twice the output in 2003. From 2009 to 2018, the output of papers remained at a

high level, basically at more than 110 papers. In 2017, it reached a peak of 164 papers in a single year, reflecting that the fault tree analysis method has become a relatively popular application in the security field. One of the many analytical methods that reflects its importance in the security field. The output of 147 papers in 2018 was not much different from the output of the previous year, and it remained at a relatively high level of papers, reflecting that the research of the fault tree analysis method in the security field has entered a stable period.

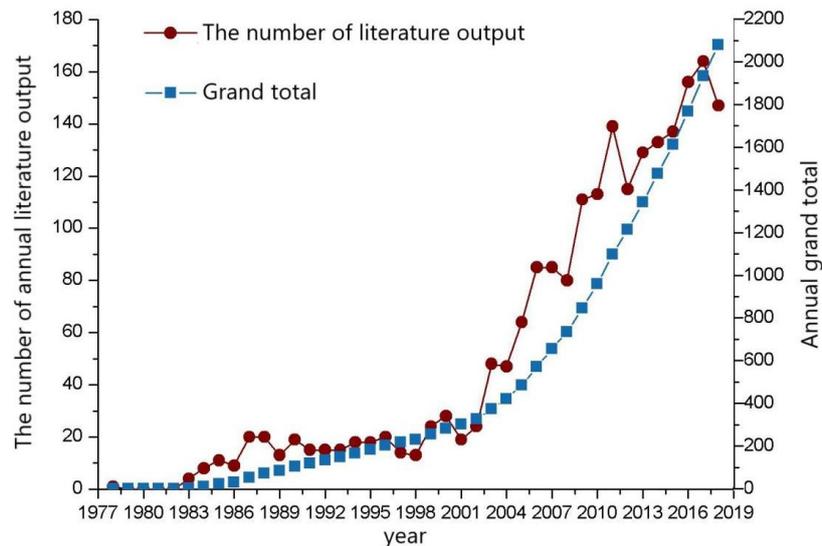


Figure 1. Paper output of fault tree safety

3.2. Author Collaboration Analysis

In order to study the application of accident tree analysis by domestic scholars in the field of security, CiteSpace was used to analyze 2081 accident tree safety analysis documents from 1978 to 2018 by author's cooperation network. The number of articles published in the cooperation network ranked the top ten The authors are shown in Table 1, and selected the top 10 network size rankings for key analysis. As shown in Figure 2, combined with Table 1 and Figure 2, 9 of the top 10 authors in the number of posts have not appeared on the Internet. Among the top 10 authors' collaboration networks, this shows that there is less collaboration between authors with a high volume of articles and other scholars. The main reason is that the research directions of the authors and their affiliated research institutions are different, such as those of Liaoning Technical University. Cui Tiejun and Ma Yundong are based on the theoretical research of the fault tree analysis method of improved space fault tree (Cui Tiejun and Ma Yundong, 2015; Cui Tiejun and Ma Yundong, 2014); Huang Zhiqiu of Nanjing University of Aeronautics and Astronautics combines the fault tree analysis method and the component status to the software modeling, It is used for fault analysis in software (Wu Zhipeng et al., 2015); Dong Yu of Shandong Institute of Business and Technology combined the fault tree and analytic hierarchy process to the accident analysis in construction (Yang Yuting et al., 2018). Among the many cooperative networks, Wang Wencai has used the fault tree analysis method to conduct safety research with the largest number of documents, reaching five. The author's network research with him at the core mainly includes the safety production of metal mines, the safety of tailings, and mines. Blasting safety and other mining production safety (Wang Wencai et al., 2010 a,b,c), which is also related to his own research direction mining safety; the author with the second most published articles is Yuan Run, with the largest cooperation network with him as the core, and his team is mainly based on The Institute of Plasma Physics, Chinese Academy of Sciences, was established in September 1978. Its predecessor was the "Hefei Controlled Thermonuclear Reaction Research Experimental Station". It is mainly engaged in high-temperature plasma

physics, magnetic confinement nuclear fusion engineering technology and related high-tech research and Development. Yuan Run’s team mainly researches safety issues such as nuclear fusion reactor reliability analysis and nuclear power plant risk assessment based on the fault tree method (Wang Jiaqun et al., 2011; Wu Yican et al., 2011), and independently developed the probabilistic safety analysis software RiskA calculation engine based on the probability algorithm of the fault tree quantitative analysis. To speed up the probability calculation speed. Taking the whole figure 2 together, the author's cooperation network using the fault tree analysis method in the security field is relatively scattered, and the cooperation between the networks is less. The main reason is that the research objects of each cooperation network are different. The cooperation between them is mainly focused on the collaboration of authors within the same research institution.

Table 1. Top 10 authors of domestic accident tree safety analysis literature published from 1983 to 2018

Rank	Author	Research institute	The number of literature
1	Cui Tiejun	Liaoning Technical University	7
2	Hang Zhiqiu	Nanjing University of Aeronautics and Astronautics	5
3	Ma Yundong	Liaoning Technical University	5
4	Dong Yu	Shandong Technology and Business University	5
5	Wang Wencai	Inner Mongolia University of Science&Technology	5
6	Wang Yujie	Wuhan University of Technology	4
7	Song Wenhua	Tianjin Polytechnic University	4
8	Fan Jianchun	China University of Petroleum	4
9	Zhang Laibin	China University of Petroleum	4
10	Yuan Run	Chinese Academy of Sciences	4



Figure 2. Author's cooperation network diagram

3.3. Analysis of Cooperation between Institutions

In order to study the application of the accident tree analysis method in the security field by various institutions, we used CiteSpace to conduct an institutional cooperation network analysis of 2081 Fault tree analysis papers from 1978 to 2018, and selected the top 10 networks in scale to analysis, as shown in Figure 3. It can be seen from Figure 3 that the cooperation network with the School of Resources and Safety Engineering of Central South University as the core is the largest. A total of 24 documents have been published. The research mainly includes the fault tree analysis in industrial safety, mining safety, construction safety and accident safety theoretical system. Application, 8 of which are the research of the fault tree analysis method in

the field of industrial safety. Through the establishment of the fault tree model with different industrial accidents as the top incident, it can cause various industrial accidents such as LNG storage tank fire, crane safety hazards and The factors of electromagnetic pollution are analyzed by fault tree to determine the main factors affecting the accident. The second largest network size is a collaborative network with the School of Land and Resources Engineering at Kunming University of Science and Technology as the core. A total of 17 documents have been published. Its research mainly includes mining safety and industrial safety. Among them, 13 documents are the fault tree analysis method in mining safety. There are few researches on accident safety theory, such as dam failure of tailings pond and mining ventilation accidents. Because the scope of application of the fault tree analysis method is extremely wide, and the research objects of each research institution are also different, the research institution cooperation network of the fault tree safety analysis is relatively scattered, mainly focusing on the cooperation between two research institutions, and the cooperation of multiple institutions less. Table 2 shows the other top research institutions in terms of publication volume.

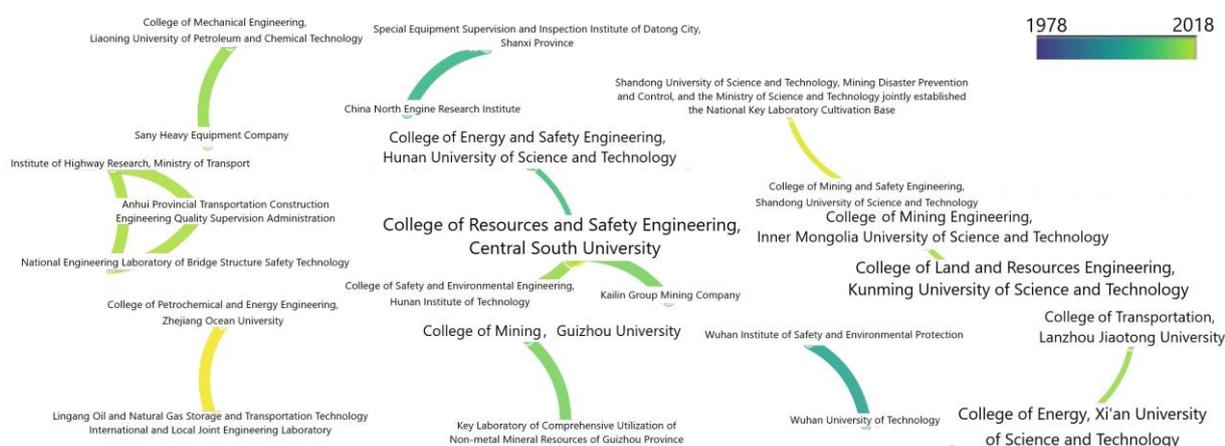


Figure 3. Fault Tree Safety Sub-Research Institution Cooperation Network

Table 2. China's top 10 research institutions in the number of domestic accident tree safety analysis paper published from 1983 to 2018

Rank	Research institute	The number of literature
1	College of Resources and Safety Engineering, Central South University	13
2	College of Land and Resources Engineering, Kunming University of Science and Technology	9
3	College of Civil and Environmental Engineering, University of Science and Technology Beijing	8
4	College of Mining Engineering, Inner Mongolia University of Science and Technology	8
5	College of Computer and Technology, Nanjing University of Aeronautics and Astronautics	8
6	College of Safety Science and Engineering, Liaoning Technical University	8
7	College of Energy and Safety Engineering, Hunan University of Science and Technology	7
8	College of Energy, Xi'an University of Science and Technology	6
9	College of Resources and Safety Engineering, China University of Mining and Technology	6
10	College of Engineering, China University of Geosciences	6

3.4. Keyword Co-occurrence Analysis

Keyword co-occurrence analysis is the analysis of keywords provided by authors in the data set. Use CiteSpace to analyze the keyword co-occurrence network of 2081 accident tree safety analysis journal documents, select the node type as Keyword, and obtain the keyword co-occurrence network as shown in Figure 4. (The larger the character, the higher the word frequency).

Keywords are extracted from the literature by the author and can reflect the content of the article, usually including research direction, research content, research methods, etc. If the same keywords are frequently used by different authors in the same field, this can reflect the research hotspots in the field. As shown in Figure 4, as the search term of the research topic, "Fault Tree" ranks first in terms of keyword frequency. Other high-frequency keywords appearing in the figure include "Safety evaluation" (445 times), "Risk assessment" (139 times), "Safety system engineering" (131 times), "Minimum cut set" (96 times), "Structural importance" (83 times), "Minimum radius set" (58 times), "Fire explosion" (45 times), "Safety checklist" (40 times), "Analytic Hierarchy Process" (39 times), "Bayesian network" (24 times), "Gas explosion" (22 times), etc., which all represent the research hot spot of fault tree safety analysis. Categorize the top keywords. From the perspective of research methods, in the research of safety analysis, the accident tree analysis method is often combined with analysis methods such as analytic hierarchy process and safety checklist method to assist in the completion of accident analysis. Use the fault tree model to complete the qualitative analysis of the accident, and then use the hierarchical analysis to complete the statutory index weights to complete the quantitative analysis. The use of multiple analysis methods can improve the results of the accident analysis; from the perspective of the research object, it can be found that the accident tree in the safety field Applications are mainly concentrated in gas explosions, fires, coal mines and other major accidents with complex and huge systems and more serious accident hazards and consequences. The fault tree analysis method can start from the occurrence of the top event (Accident), and through the deductive method, the complex system is integrated. Decompose layer by layer, find all the direct and indirect factors that may cause the accident, and make a systematic analysis of the cause of the accident; from the perspective of the research process, the fault tree research needs to determine the minimum cut set or minimum path set to complete Qualitative analysis of the accident, and then analyze the structural importance coefficient to complete the quantitative analysis, so "Minimum cut set", "Minimum radius set", "Structural importance" will also be high-frequency keywords in the literature of accident tree safety analysis appear.

Table 3. High-frequency keywords in the fault tree literature

Number	Key words	Word frequency	Number	Key words	Word frequency
1	Safety Evaluation	445	11	Safety checklist	40
2	Risk assessment	139	12	Analytic Hierarchy	39
3	Security System	131	13	Process	32
	Engineering		14	Mine safety equipment	30
4	Minimum cut set	96	15	Elementary event	30
5	Structural importance	83	16	Reliability	24
6	Analytical method	78	17	Bayesian network	22
7	Minimum radius set	58	18	Gas explosion	21
8	Precaution	53	19	Source of risk	21
9	Accident	52	20	Evaluation method	19
10	Fire explosion	45		Safety measures	

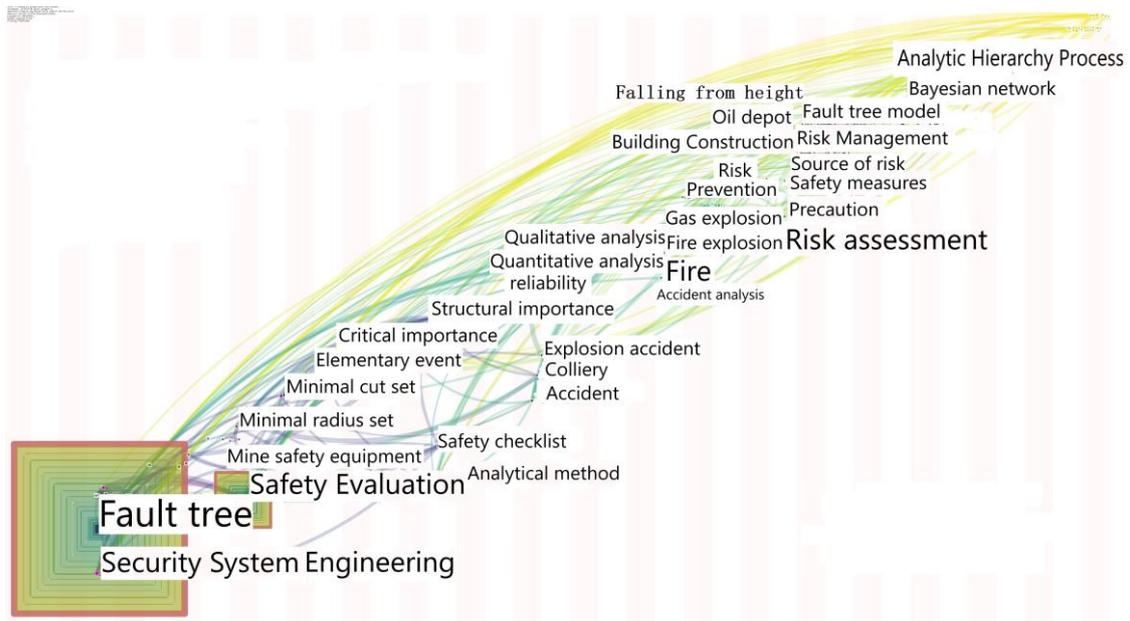


Figure 5. Keyword time zone diagram for fault tree safety research



Figure 6. Keyword mutations in fault tree safety research

4. CONCLUSION

Through the analysis of Citespace data visualization software on the application of fault tree analysis in the security field, the following conclusions can be drawn.

1) The fault tree analysis method can be divided into three stages according to the size of the annual literature output: the budding period (1978-2003), the rapid growth period (2004-2016), and the stable period (2017-2018).

2) The number of scholars who use the fault tree analysis method for research is relatively large and the research direction is relatively wide, but the cooperation between the authors is relatively scattered, mainly concentrated on the cooperation with the authors in the institution,

among which the research team with Yuan Run and Wang Wencai as the core. The network is large. The research team of the former is based at the Institute of Plasma Physics, Chinese Academy of Sciences, mainly researching the reliability analysis and risk assessment of nuclear reactors, and the latter is mainly researching mining safety.

3) The research institutions using the fault tree analysis method are mainly concentrated in Central South University, Kunming University of Science and Technology and Beijing University of Science and Technology. Among them, the cooperation network of institutions with Central South University as the core is the largest, with 13 articles published, and the main research directions are Research on the theoretical system of industry, mining, construction safety and fault tree models. Because the scope of application of the fault tree is extremely wide, and the research direction and research focus of each institution are different, there is less cooperation among multiple institutions, and mainly based on cooperation between two institutions.

4) Through the analysis of the high-frequency keywords in the literature, it is found that the application theme of the fault tree analysis method is mainly focused on "Safety evaluation", which is widely used in accident scenarios such as mining safety, fire and explosion, and gas explosion. The combined application of fault tree analysis and other methods mainly involves Analytic hierarchy process, Bayesian network, etc. The current research hotspot is mainly the comprehensive application of fault tree analysis and Bayesian network.

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