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Analysis of Characteristics of Fire Incident on 24 July 2021 in Jilin Province, China

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Abstract: At 15:48 on 24 July 2021, a fire accident occurred in Changchun City, Jilin Province, China, resulting in 15 deaths and 25 injuries. After the accident happened, Jilin Province comprehensively organised an emergency rescue, saving more than 100 trapped people. Given the dangers posed by these events, it is recommended that we must strengthen our risk awareness. Combined with the general background and scene of the fire, in this study, we analysed the causes of the accident and described the on-site rescue actions. The direct cause of the accident was an arc fault, and the indirect cause was the dereliction of duty in the laying and installation of the circuit and the subsequent fire supervision. From our case analysis of electrical fires in public buildings, we found that electrical failure, human factors (illegal operation), ageing and short circuits of wires, poor contact of wires, and ignition of other combustibles by electrical appliances are the main factors causing electrical fire accidents in public buildings. To avoid serious fire accidents caused by arc faults, we proposed suggestions to reduce or prevent electric fire accidents caused by arc faults.

Keywords: electrical fire; rescue measures; incident; circuit fault

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1. Introduction

With the economy development in recent years [1,2], a large number of buildings were constructed in China [3,4]. China consumes a large amount of power. In 2021, the power consumption in China was 8312.8 billion kWh, a 10.3% year-on-year increase from 2020 and 14.7% from 2019. Consequently, the safety hazards and risks in building power distribution systems are also sharply rising, and the incidence of electrical safety accidents is increasing. Failures and improper treatments in building power distribution are affecting the normal operation of the system, leading to damage, and endangering human health. The occurrence of major accidents such as explosions or fires can result in varying degrees of casualties and huge economic and property losses. The most dangerous accident in these buildings is fire. Building electrical fires results in the most social harm [5], the highest casualties, and the most serious property loss. Arc faults are the primary cause of electrical fires. As such, studies on arc faults are needed. From a technical point of view, three common AC arc faults occur in building distribution systems: grounding, parallel, and series faults.

The electric power industry is important in a country [6]. However, the improper use of electrical energy or maintenance of circuits may lead to safety hazards. In contemporary society, when the focus is modern urban construction, the maintenance and construction of infrastructure in older urban areas are sometimes ignored, creating risks and posing challenges, such as fire and power safety and maintenance, for infrastructure construction and maintenance in some areas (Xu, 2020). The troubleshooting and meditating of potential safety hazards due to electrical fire risks (such as leakage, short circuit, and circuit overload)

are essential. Electrical accidents occasionally occur, which seriously threaten human safety but cause catastrophic damage to surrounding buildings and traffic facilities. Table 1 lists the casualties caused by electric fires in China in recent years. For example, on 1 October 2020, a major fire accident occurred in an ice sculpture hall in Yingze District, Taiyuan. The electronic components caught fire and ignited combustibles because of a continuous short circuit. On 15 December 2005, a fire disaster in central hospital, Liaoyuan County, Jilin Province caused 37 deaths, 95 injuries with direct economic losses of 8.22 million yuan [7]. The cause of the accident was the distribution room cable short circuit fault ignited combustibles. At 22:49 on 20 September 2008, the Dance King Club in Longgang District of Shenzhen caught fire, resulting in 44 deaths and 64 injuries [8]. The direct economic loss reached 70 million yuan. The immediate cause of the accident was that stage lighting and fireworks caught fire at the same time.

Table 1. Casualties of electrical fire accidents in various regions of China in recent years.

Date	Site	Casualties	References
15 December 2005	Liaoyuan Country of Jilin Province	37 deaths and 95 injuries	[7]
20 September 2008	Shenzhen County of Guangzhou Province	44 deaths and 64 injuries	[8]
5 February 2017	Taizhou County of Zhejiang Province	18 deaths and 18 injuries	[9]
18 November 2017	Beijing	19 deaths and 8 injuries	[10]
25 August 2018	Haerbin County of Heilongjiang Province	20 deaths and 23 injuries	[11]
22 June 2020	Shenzhen County of Guangzhou Province	2 deaths	[12]
25 September 2020	Dongguan County of Guangzhou Province	3 deaths	[13]
1 October 2020	Taiyuan County of Shanxi Province	13 deaths and 15 injuries	[14]
23 February 2021	Shenzhen County of Guangzhou Province	4 deaths	[15]
25 February 2021	Fuzhou County of Fujian Province	6 deaths and 7 injuries	[16]

Our main purpose in this study was to explore the specific causes of fires caused by circuit failure, the rescue actions taken by various departments, and other causes of heavy casualties. On this basis, we constructed some suggestions for future power safety, infrastructure, and equipment maintenance.

2. Materials and Methods

2.1. Overview of Fire Event

Figure 1 depicts the scene of the fire disaster. At approximately 15:40 on 24 July 2021 a fire accident occurred in Changchun City (Figure 1a), Jilin Province (Figure 1b) [17]. The accident occurred at the intersection of Jincheng Street and Yinfeng Road in Jingyue District, Changchun City, Jilin Province. A lighting circuit on the upper part of the studio leaked electricity through its metal pipe and ignited the surrounding combustible fake-plant decoration materials.

The three-story building that subsequently caught on fire was shared by Jilin Remote Logistics Co., Ltd. and Li's Wedding Dress Dream City. These storage and logistics sites are often large, storing large amounts of goods with high economic value, high personnel density, high fire risk, and pose difficulties for firefighting (see Figure 2). After a fire starts, it rapidly spreads in all directions and produces a large amount of smoke (see Figure 3). Finding the fire source is difficult, so these fires burn for a long time, which can lead to the collapse of buildings. In the case situation, the second and third floors were studios, and the internal rooms were complex (see Figure 4). Even under normal circumstances, it was difficult for customers to find exits within a short time (see Figure 5). The fire broke out at 4 p.m. that day, and black smoke was emitted from the scene, which could be seen several kilometres away.

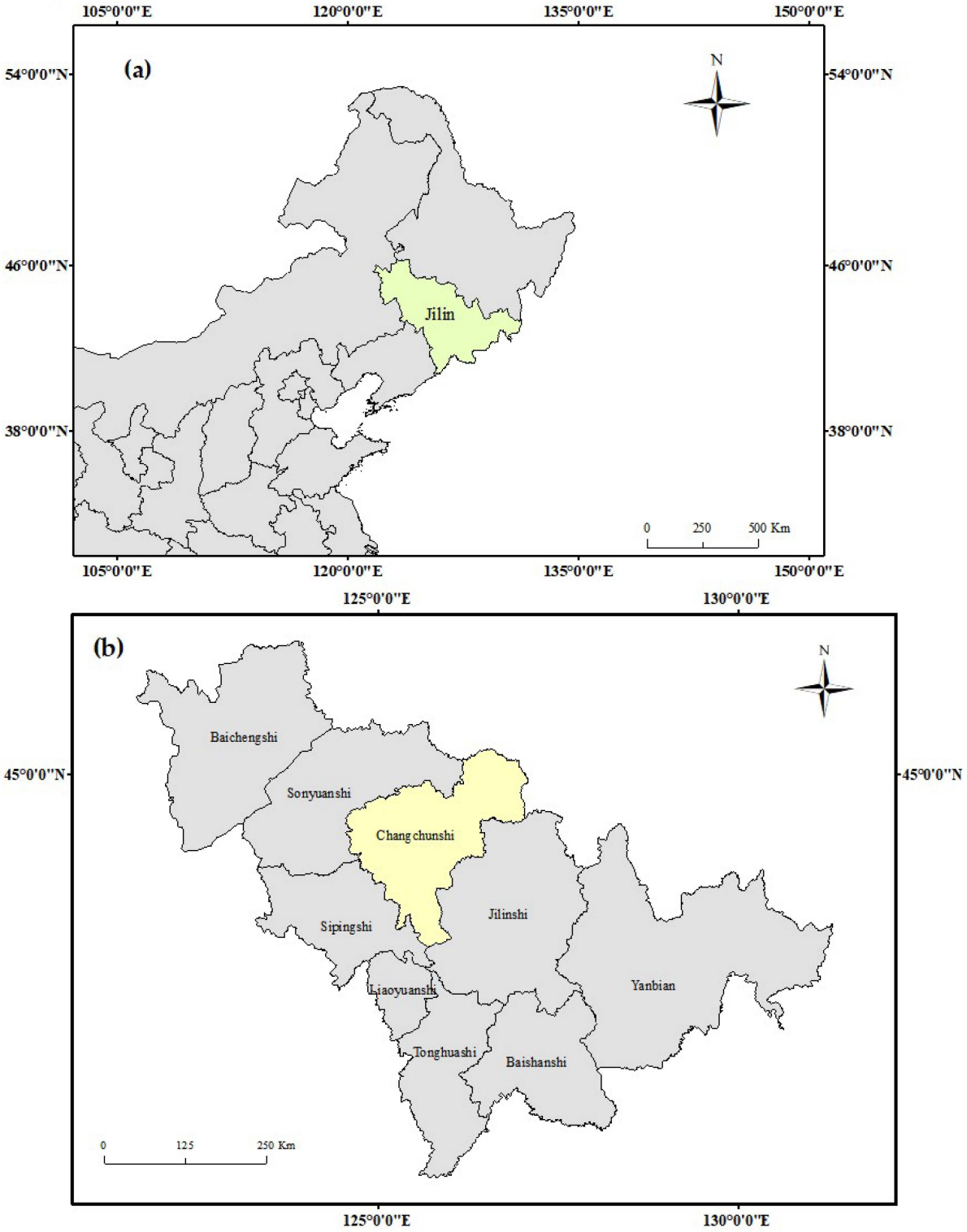

Figure 1. Location of the fire site: Jilin Province in China; disaster site of Changchun Prefecture in Jilin Province (from the (**a**) to the (**b**)).

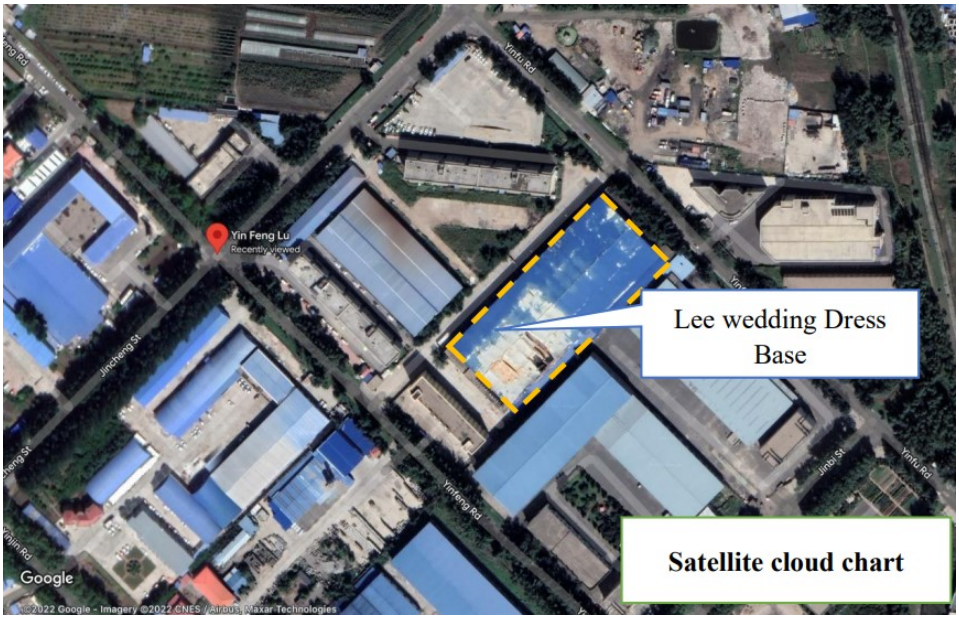

Figure 2. Electrical fires: complete picture of the incident (from Google map).

Figure 3. Electrical fires: burned buildings (picture source: [18]).

There were also many people trapped at the upstairs window awaiting help. Some residents, who rushed to the rescue, placed ladders beside the windows to help them escape. At 20:00 h on 24 July 2021, it was preliminarily verified that 14 people had been killed, 12 were seriously injured, and 14 suffered ordinary bone injuries and trauma. The on-site search and rescue were completed at 5:00 h on 25 July. The fire caused 15 deaths and 25 injuries, and the identities of all the 15 victims were confirmed. As of 11:00 on 25 July, 24 wounded were hospitalised. Among them, it was 15 from the China Japan Friendship Hospital of Jilin University while it was 9 from the second branch of the first hospital of Jilin University. From the outside, the fire building had two floors, but contained three floors inside. Mr. Liu, a survivor of the accident, said that the complex layout of the building

probably prevented people from escaping. The governor, who attended the meeting and made a speech, made specific arrangements for accident disposal and the rescue work. All departments across the province should draw inferences from this incident and address both the symptoms and root causes, investigate and rectify potential safety hazards in various fields, and consolidate measures to fill weaknesses, to ensure public safety and maintain harmony and stability of the society.

Figure 4. Electrical fires: Messy Wires on Photography base roof (picture source: [19]).

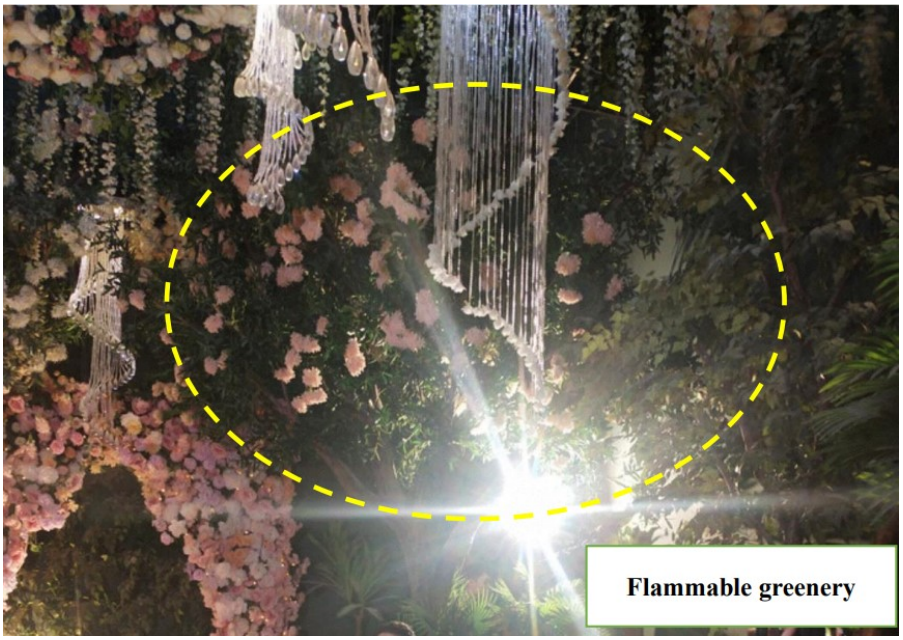

Figure 5. Electrical fires: combustible decorations in the wedding dress shop (picture source: [20]).

2.2. Rescue

On 24 July 2021, the Jilin provincial government established the Provincial Emergency Management Department, Provincial Fire Rescue Corps, and Provincial Public Security Department, Provincial Branch of Commerce, Provincial Branch of housing and urban coastal

rural development, and the Provincial Department of natural resources. The "7–24" major fire accident investigation team of Li's Wedding Dress Dream City in Changchun, Jilin Province (hereinafter referred to as the accident investigation team) in accordance with the regulations on the reporting and handling of production safety accidents (Order No. 493 of the State Council) and other laws and regulations. It comprised personnel from the Provincial Federation of trade unions and Changchun municipal government, and it invited the intervention of the Provincial Commission for Discipline Inspection and Supervision.

At 15:48 on 24 July, the command centre of the Changchun fire rescue detachment received an alarm. Responders from Juye Street, South Fourth Ring Road, Jinbao Street, Xinlicheng fire station, and Centrino small station arrived at the scene at approximately 15:58. The on-site commander immediately organised the rescue operations and simultaneously reported the situation to the fire brigade. Subsequently, the provincial, municipal emergency management departments and fire rescue institutions immediately launched an operation, quickly mobilised 21 fire stations and dispatched a construction machinery brigade, 80 fire engines, and 402 commanders and fighters to the scene (see Figure 6). The entire service headquarters at the general and detachment levels were dispatched, and a front headquarters was established at the accident site. The whole rescue process is hard to deal with. Based on the operational principle of "saving people first, putting out fire scientifically and ensuring safety", the front headquarters organised five external rescue teams, nine internal attack search and rescue teams, six firefighting teams, and two demolition teams to divide the fighting forces into four combat sections: east, south, west, and north. The commanders and fighters effectively controlled the fire controlled at approximately 18:30. At 19:28, all the open fires were extinguished. By 5:00 on the 25th, six search and rescue teams were set up to complete five rounds on the scene "Carpet" search and rescue work (see Figure 7). During the firefighting and rescue operation (see Figure 8), more than 100 people were evacuated from the affected building, while more than 350 people were evacuated from the residential building in the downwind direction, which minimised casualties and property losses and ensured the safety of rescuers (see Figure 9).

Figure 6. Emergency rescue teams: rescue teams in Jilin Province (picture source: [21]).

Figure 7. Emergency rescue teams: rescue medical staff (picture source: [22]).

Figure 8. Emergency rescue teams: firefighting equipment (picture source: [23]).

Figure 9. The fire rescue is continuing (picture source: [24]).

3. Analysis and Discussion

3.1. Analysis

After the accident, the fire department made a thorough investigation into the cause of the fire [25]. The results of the survey show that the electrical fire accident was caused by the leakage of lighting lines, breakdown of threading metal pipes, and ignition of the surrounding combustibles [26]. The temperature of the contact point of the conductor owing to poor contact causes severe heating at the contact point of the conductor and increases the resistance of the contact point, which exacerbates the heating [27]. The heated conductor in turn heats the external plastic insulation material of the conductor near the contact point, which greatly reduces its insulation capacity and causes electric leakage [28]. The roof of the wedding shop was difficult to find in the first place because the roof was covered by inflammable materials such as green plants. Its fire extinguishing mechanism is as follows: (1) vaporization, heat absorption, and radiation blocking [29]; (2) smoke and dust removal, surface infiltration; (3) three-dimensional movement, horizontal fire extinguishing. Fire extinguishing agent is famous for water and cheap materials; the fire extinguishing mechanism is cooling and asphyxiation, the fire extinguishing effect is good, it is not easy to reignite after fire; under the condition of water supply guarantee, it can be reused, applicable to the wedding dress shops and other shops related to fabric [30]. In serious cases, an electric arc occurs, causing an electrical fire. Most of the wires in the wedding dress shop were old and damaged. Due to poor contact of wires, it is easy to leak through the insulation layer and cause a fire. The circuit layout of the wedding dress shop was extremely disordered, with intertwined lines. Furthermore, there were no electrical design drawings and the electrical construction did not meet the specifications [31]. Polyurethane foam was used for thermal insulation in violation of regulations, and fire prevention treatment was not performed, resulting in the rapid spread of the fire [32]. In addition, the local government departments did not perform their assigned duties, but only supervised and inspected the approved construction projects, and neglected the long-standing illegal reconstruction and expansion of Li's Wedding Dress Dream City. The inventory of "two violations" was not conducted thoroughly, the hidden dangers of Li's Wedding Dress Dream City were not detected, and there were deficiencies in investigation and rectification [33]. Owing to single person law enforcement in the fire supervision and inspection department, the rectification of hidden dangers was not monitored, items requiring rectification were overlooked, and law enforcement was incomplete.

The analysed reasons were established in very popular standards, e.g., National Fire Protection Association (NFPA) [34], FMGlobal [35], Australian Standards (AS) [36]. These three standards have made relevant provisions on the importance of fire protection and how to prevent the occurrence of fire, which will be listed as follows:

NFPA: NFPA75 [34] specifies the requirements related to construction, including the division of areas by building materials with strong fire resistance during construction, and the fire resistance rating and distribution of refractory materials. NFPA75 allows the development and use of documented fire risk analysis to determine the requirements, e.g., installation and use of automatic detection system. Most jurisdictions in the United States enforce these requirements. The minimum acceptable level of wall, ceiling, and floor finishes in full sprinkler and non-sprinkler equipment areas as defined in NFPA101 life safety code [37]. The existing fire detection and suppression systems are also required to be evaluated and tested as necessary to maintain compliance with applicable codes and standards.

FMGlobal: FMGlobal's philosophy is that most losses are preventable. Promote loss prevention through scientific knowledge. Engineering provides cost effective solutions to reduce risk. Among them, FMappoval4880 [35] specifies the level 1 fire performance requirements of building panel components or indoor finishing materials, with specific height installation requirements and flammability levels.

Australian standards: AS1670 [36] has detailed provisions on the design, installation, and commissioning of fire detection, alarm, control, and intercom systems. In the specification

AS2118, the automatic sprinkler system provides an important fire rating for the building structure by minimizing the possible impact of major structural fire [38]. When designing the sprinkler system, it is necessary to consider the interaction between the sprinkler system and other building fire safety systems to maximize protection and provide the best method for the overall goal of fire safety.

3.2. Weather Condition

Changchun experiences a continental climate. The annual average temperature, maximum temperature, minimum temperature, and sunshine time are 4.8 °C, 39.5 °C, −39.8 °C, and 2688 h, respectively. In summer, the southeast wind prevails, and moisture supplemented by the Bohai Sea also passes through. The average annual precipitation is 522–615 mm. The average temperature during the hottest month (July) is 23 °C (see Figure 10. Data from https://www.tianqi.com/qiwen/city_changchun/, accessed on 28 April 2022). The fire occurred in late July. The temperature was high, and the plasticity of the indoor wire insulation layer and snake skin metal pipe was significantly enhanced. The risk of electric leakage was caused by heating owing to the resistance. Figure 10 shows the monthly maximum and minimum average temperatures in the Changchun Jingyue Development Zone for 2021.

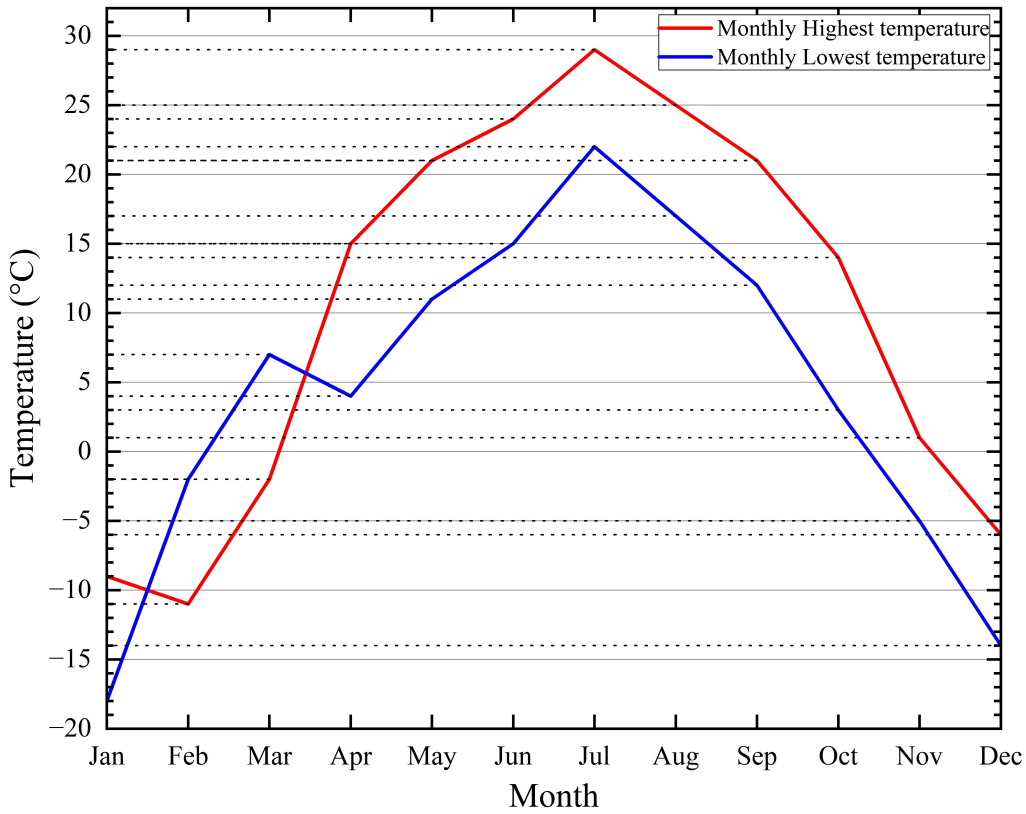

Figure 10. Annual average temperatures in the Changchun Jingyue Development Zone for 2021.

3.3. Main Factors behind the Fire

The fire caused by an arc fault resulted in serious casualties and property losses, with a total of 40 casualties (25 dead and 15 injured) and property losses of more than 37 million yuan, which attracted extensive attention from the society. Other factors that affected the severity of the accident are explored.

1. Leakage

(a). The insulation layer of the wire may be damaged by external forces. Leakage may occur when the damaged part of the wire makes contact with a conductive object [39].

(b). The voltage may exceed the rated range. The insulating skin of the wire resembles the water pipe wall. It can withstand a certain rated voltage (generally marked on the wire surface). When the actual voltage exceeds the rated voltage, the insulating skin breaks down and the current slips away along the position where the breakdown occurred. Therefore, at the point of use, the actual voltage must be lower than the rated voltage of the wire.

(c). Wire aging: a wire has a certain service life that depends on its quality and service environment. Generally, it may be used for 10–20 years. When the wire insulation is aged, its insulation strength gradually declines, and breaks down to a certain extent, resulting in leakage or short circuits.

2. Structural safety

The main body of the building was a steel structure, 138.5 m long, 54.6 m wide, and 12.75 m high. Its area was 12,681.96 m^2 and fire resistance rating was grade III. Steel structures typically lose their bearing capacity at 450–650 °C and deform significantly, resulting in the bending of steel columns and beams. Consequently, their further usage is not possible because of excessive deformation.

3. Illegal construction

Li's Wedding Dress Dream City built additional floors in violation of regulations and expanded the construction area [40]. The distance of the evacuation passage was too long [41]. The elevation of the original building was changed outdoors and additional rooms were added. Without relevant approval, there was a "congenital" hidden danger in the unit. Li's wedding dress company changed the industrial plant to commercial use without authorisation, built auxiliary buildings in violation of regulations, occupied the fire spacing, built solid walls, and closed the fire truck access, which affected rescue and emergency evacuation.

3.4. Perspective Managerial Measurement

Problems associated with electrical systems are becoming increasingly prominent. An increasing number of fires are caused by electrical faults and improper operation of electrical equipment, which not only cause casualties but also large-scale and long-term power outages, resulting in immeasurable economic losses [42]. Therefore, it is necessary to accurately grasp the characteristics and causes of electrical fires and propose some prevention strategies for electrical fires by considering countermeasures and making efforts to implement them [43]. In the latest version of national code for automatic fire alarm system, new requirements and operation methods appear in the debugging of automatic fire alarm system [44]. Therefore, we should recognise the characteristics of electrical fires, strengthen their prevention and control, avoid their occurrence, and ensure the safety of life and property by adequate publicity and increasing awareness for fire prevention, selecting qualified electrical facilities, increasing efficiency in fire supervision and management, regularly inspecting, and repairing electrical equipment, and installing various protective devices.

1. Strengthening equipment management: Electrical faults may be prevented by strengthening equipment management and prohibiting the installation of defective or low-quality equipment. After installing the electrical equipment, single equipment commissioning and joint commissioning tests must be conducted in turn. Finally, during project acceptance, the quality of the construction must be thoroughly inspected.
2. Daily maintenance and regular overhaul: Proper daily maintenance of line equipment is essential. Dust and stains on the surface of equipment lines must be removed and equipment lines must be restored to their best operating state to prevent electrical faults and fire accidents.
3. Strengthen the protection of key parts: To prevent the occurrence of common electrical faults, such as short circuits, electric leakage, overload operation, and poor contact, protective measures must be adopted for the key parts of the building electrical system.

When the system malfunctions, the corresponding protective action is automatically executed to cut off the connection between the faulty part and the system or restore the normal operation of the equipment line.

4. Fault simulation analysis and prevention: Consider that most electrical failures have a pattern, fault simulation analysis tests can be conducted in advance to simulate the operation status and process of the electrical system under different working conditions. Based on the simulation analysis results, the conditions for occurrence, causes, and specific effects of various electrical faults and building electrical fire accidents can be accurately determined. Furthermore, targeted preventive measures can be adopted and emergency accident response schemes can be formulated.
5. Online equipment monitoring and automatic fault identification: According to the latest regulations of the power fire monitoring system, the functions of the monitoring equipment should meet the self-test function, operation level, fault alarm function, monitoring alarm function, muffler function, and reset function [45]. Online devices comply with relevant regulations and can automatically and effectively identify faults. For example, some electrical faults exhibit obvious characteristics in the early stages. There is a time difference between the formation of gas faults and the occurrence of electrical building fires. If an electrical fault is detected and resolved within the time period, the loss caused by the fault can be effectively controlled to avoid building fires.
6. Building an early fire warning platform: An early fire warning platform based on the Internet of Things can be developed. Sensors may be arranged in the indoor and outdoor areas of the building to continuously monitor and collect information regarding the temperature, air humidity, and air composition. When the collected data reach the standard, early warning can be issued in time to avoid the occurrence or spread of fire.
7. Improving technical specifications and management systems: It is necessary to regularly improve and supplement the relevant technical specifications of the electrical engineering, equipment operation, and maintenance management systems of the building to provide clear guidelines for activities, such as equipment installation, commissioning and operation, maintenance, fault diagnosis, and repair.
8. Personnel management: Personnel are primarily responsible for conducting activities such as electrical equipment installation and electrical operation and maintenance. If the professional quality of the staff is low, or they lack safety awareness, new potential safety hazards will occur, and the probability of electrical fire accidents and electrical faults will increase.
9. With the development of technology, artificial intelligence (AI) management and monitoring achieves active analysis and identification, reduces the labour cost of enterprises, and improves work efficiency. AI is used to develop theories, methods, technologies, and application systems for simulating, extending, and expanding human intelligence [46]. There are various AI technologies that can be used for management and monitoring, including deep learning neural networks [47], long-term and short-term memory (LSTM) [48] and deep learning- [49] enhanced neural networks with an alternative activation function tanhlu. Shen et al. (2022) used deep learning to develop remarkable innovations in shield machine energy consumption [50], ground settlement [51], shield tunnelling performance [52], moving trajectory [53], and safety risk assessment [54]. Shen et al. superimposed grid search and k-fold to predict geological characteristics according to shield operation and shield tunnelling time series prediction [55,56]. Shen et al. [57] predicted the grouting diameter, grouting differential evolution [58–60], controlled drainage, and built models using the Long Short Term Memory method to simulate the characteristics of soil. Elbaz et al. [49] combined a genetic algorithm with Group Method of Data Handling to predict tool life. Similarly, the application of artificial intelligence in power management will be more extensive. Zhao et al. [61] published a circuit fault diagnosis method based on deep learning algorithm. Chen et al. [62] also published a multi-agent particle swarm

optimization algorithm for power system fault diagnosis. Artificial Intelligence technology for intelligent management is expected to be an important research topic in the future.

4. Concluding Remarks

This study reports on an electrical fire accident in Jilin Province, China, on 24 July 2021. Based on the preliminary investigation and analysis of the fire, the following conclusions were drawn:

1. A devastating fire broke out in Li's wedding dress city in Jilin Province, killing 15 people and wounding 25. The electric leakage in the upper part of the photo studio was caused by a combustible lighting line, and the electric leakage around the photo studio was caused by a combustible lighting line.
2. Li Family Wedding Dream City illegally expanded the building area, built auxiliary buildings without authorization, and closed the fire truck channel. These illegal constructions affected the postdisaster firefighting, rescue and emergency evacuation. This illegal behaviour of construction indicated that the establishment of a more perfect safety management department and supervision system is necessary.
3. Prevention is the key to electrical fire events. This study proposed some suggestions for preventing electrical fires. These include strengthening awareness on fire prevention and establishing fire prevention awareness, selecting qualified electrical facilities and increasing efficiency in fire supervision and management, applying advanced electrical technology to detect fire hazards in time, regularly checking and repairing electrical equipment, and installing various protective devices.

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