

A Review on Higher Education of Fire Safety in China

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Abstract

Along with the rapid urbanization and economic growth in China over the last four decades, higher education in Fire Safety Science and Engineering has been developed and changed significantly. This work systemically reviews the origin and evolution of fire safety higher education history in China, from Fire Protection Technology (before the 1980s) to Fire Safety Science and Engineering (1985-2010s) and to Human-Oriented Public Safety and Smart Firefighting (2010s-today). The scopes of fire safety discipline are discussed by introducing the requirements of firefighters, registered professional fire protection engineers and safety engineers in China. The courses and curriculum in fire safety higher education in representative universities are introduced and compared in detail. By comparing their undergraduate and postgraduate programmes, we explain the context of fire safety education in different universities. From a historical viewpoint, we review the unique features and the diversity developed in different institutes, based on the evolution of programme documents and first-hand teaching materials. This review aims to introduce the systems of fire safety-related higher education in China to the world and encourage more international collaboration with the Chinese fire safety community in the future.

Keywords: *Fire Science; Fire Protection Engineering; Education Programme; Public Safety; Course and Curriculum; Engineering License*

Abbreviations

CSE	Certified Safety Engineers	MEM	Ministry of Emergency Management
CFPE	Certified Fire Protection Engineers	MoE	Ministry of Education
CPAPA	Chinese People's Armed Police Force Academy	MND	Ministry of National Defense
CPPU	China People's Police University	MPS	Ministry of Public Security
CSU	Central South University	PRC	The People's Republic of China
CUMT	China University of Mining and Technology	SEE	Safety Evaluation Engineering
EI	Engineering Index	SCI	Science Citation Index
GDP	Gross Domestic Product	SKLFS	State Key Laboratory of Fire Science
JCR	Journal Citation Reports	USTC	University of Science and Technology of China

1. Historical overview of fire safety in China

This history of human beings fighting against fire started long before our civilization mastered the use of fire [1]. Fire, as Earth's natural process, is both friend and foe to the human race, having influenced our social development and success as a species, yet it remains a serious threat to human life [2]. Our ancestors intentionally or unintentionally considered fire prevention and firefighting in their daily lives and explored the laws, codes, and empirical methods to ensure fire safety. In the Chinese language, the character of 'disaster' is a direct combination of fire (火) and flooding (氾) or fire (火) and house (厶) with, as shown in Fig. 1a. This reflects the historical memory of having fire as a primary disaster in the long Chinese history.

Like most other civilizations, the building materials of Chinese architecture developed from mainly thatch and wood to stone and brick, dominated in ancient times [3], gradually reducing the fire risk. Nevertheless, timber materials are still needed in most historic building construction and decoration, so they are vulnerable to fire. Arguably, this is one of the key reasons that not many historical buildings are reserved in China today, compared to Europe. The first professional fire brigade in China can be traced back to 1,000 years ago, during the Northern Song Dynasty [4], and it was formed to deal with the high fire risk of high-density wooden buildings in urban areas. Other professional firefighting troops, called patrol camps (军巡铺) and defence corners (防隅), are dedicated to fire prevention, checking, and suppression. For example, the night patrols in ancient China would yell slogans "dry weather, mind fire" (天干物燥, 小心火烛) in the street at night to remind residents to be careful about using fire and candles in a dry weather.

Fire safety measures, training, and regulations have been developed throughout Chinese history to protect life and property from fire. For example, the high-rise "Fire Watch Tower" (望火楼) was built back in the 1100s in large cities to monitor fire accidents (Fig. 1b). Ancient fire brigade also developed the "water dragon" (水龙) (Fig. 1c) which was a prototype of the modern fire truck. The "Chi Wen" animal-like figures stretching out their tongues (left of Fig. 1d) were the earliest anti-lightning devices (避雷针) started in the Han Dynasty (206 B.C.–220 A.D.) and also developed into iron tongues, which are non-grounding devices to be installed on the cornices of some of the Palace's halls to eliminate the risk of fire from lightning. The grounding anti-lightning devices similar to modern anti-lightning devices (right of Fig. 1d) [4] starts in the early Qing Dynasty in the 1600s, which connect each tongue of "Ji Shou" (also symbolize best wishes) along the roof, pillar, all the way down to the earth. Formal institutions like fire stations and fire brigades have always been part of the local government. Together with volunteers like firefighting associations or clubs and water bureaus, historically, there has been a strong fire service in ancient Chinese cities.

The fire protection measures were also reflected in the design of the city and building. For example, the concept of a fire alley (防火巷) was required in the design of the community (Fig. 1e) as the early form of emergency evacuation path. The stepped gable (or horse-head wall, 马头墙) was adopted in ancient townhouses (Fig. 1f), which acted as firebreaks to prevent the fire spread between adjacent buildings [5,6]. Along with technological development and countless fire accidents [7,8], people continuously took lessons about fire protection and firefighting from their predecessors. Their knowledge of empirical fire protection technics and fire safety concepts was gradually gained and transferred from one generation to the next,

although many were lost in history. This should be the early form of fire safety training and education in China and other civilizations.

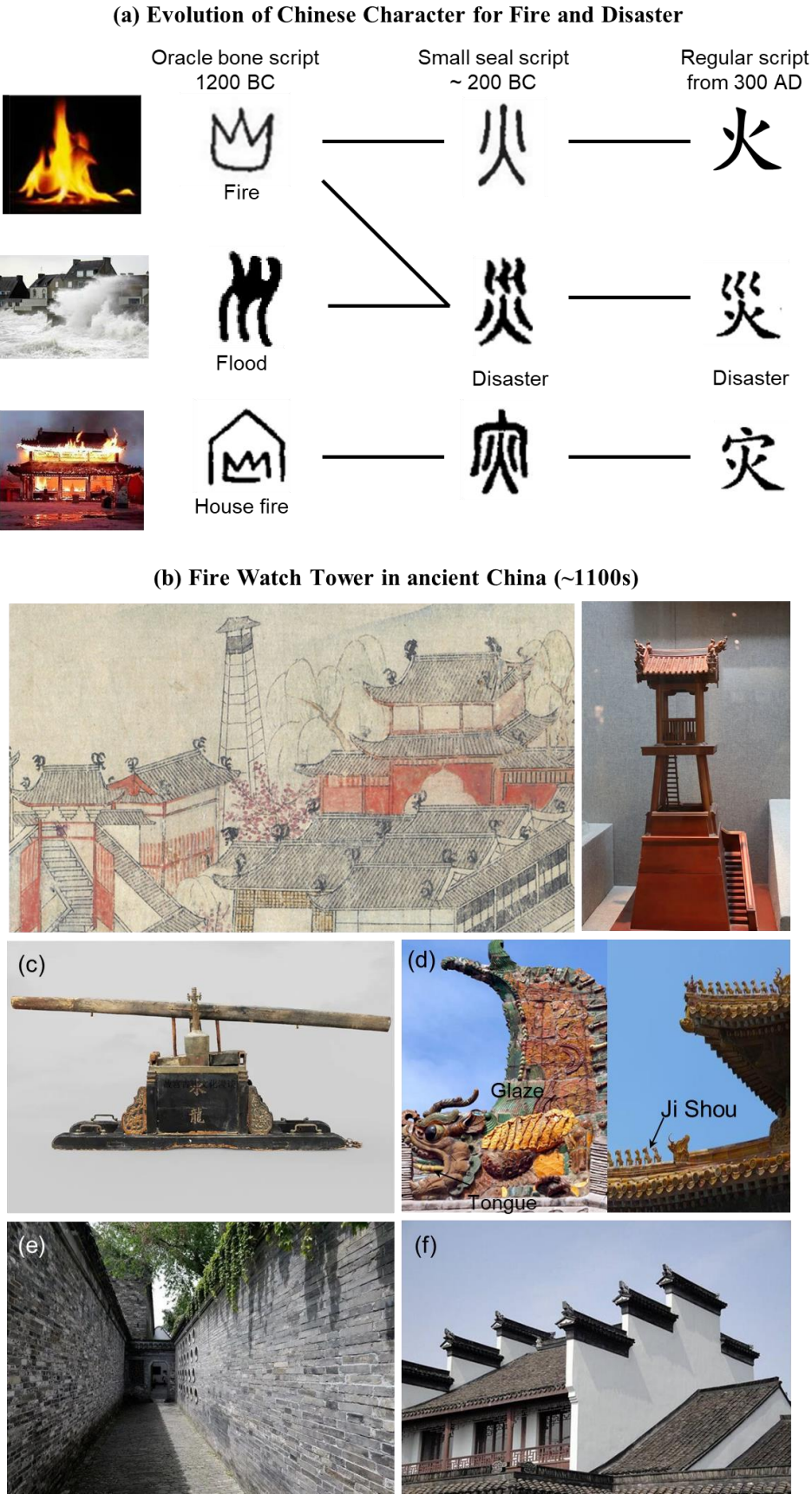


Fig. 1. (a) The evolution of the character of ‘fire’ and ‘disaster’ in the Chinese language, and the typical fire

service in the ancient time (b) the high-rise Fire Watch Tower (望火楼), (c) water dragon (水龙), (d) anti-lightning devices (避雷针), (e) fire alley (防火巷), (f) stepped gable (马头墙).

After the industrial and scientific revolution, new industries, massive urbanization, and rapid population growth have become the major driven force of fire accidents [9]. Nevertheless, the improvement of fire safety technology, management, public education, and awareness also helps reduce fire risk and hazards. Figure 2 presents (a) the number of fire accidents and fire death, (b) the Gross Domestic Product (GDP) and direct fire losses, and (c) the ratio of the direct fire losses and firefighting expenditure to GDP from 1950¹ until the present. Noticeably, in the early days of China, only large accidents were counted, and the reliability of fire data was not high. Note that wildland fire services departments in China are historically separated from the urban fire services, but they belong to the National Forestry and Grassland Administration. Thus, the statistics in Fig. 2 do not include the losses and costs of wildland fires. Terms of the budget for firefighting expenses (Fig. 2c), were first published when the Fire and Rescue Department was moved from the Ministry of Public Security (MPS) to the Ministry of Emergence Management (MEM) in October 2018 [10]. Therefore, the data are limited, and only three data points are shown in Fig. 2c. It is also worth noting that the population in China is almost tripled from 0.55 billion in 1950 to 1.43 billion in 2022.

As shown in Fig. 2a, the number of fire accidents can be generally divided into three growth stages. The first increase started from 1950 to the nearly 1980s and remained relatively stable. Then, there was a sudden growth from 1990 to the early 2000s. The third increase occurred in 2011-2014, but fire death has continuously decreased since 1978, despite the population growth. The first-stage growth of fire accidents stimulated the requirement and technology of fire protection [6,7,11], as well as the founding of four National Fire Research Institutes (discussed more in Section 2.1).

The low fire accident period between 1980 to 1996 may be attributed that the industry prompted the emergence of formal fire safety education and management after the 1980s, mainly in vocational education for workers and higher education institutes for engineers and managers. The need for fire safety eventually established a discipline of fire safety engineering in higher education and created the professions of fire protection engineers and safety engineers (discussed more in Section 2.2). The third growth was mainly caused by the change in statistical methods and more transparent information through the Internet. Many big and eye-tracking fire accidents also promoted people-oriented public safety and information technology (discussed more in Section 2.3).

¹ The People's Republic of China (PRC) was established in 1949.

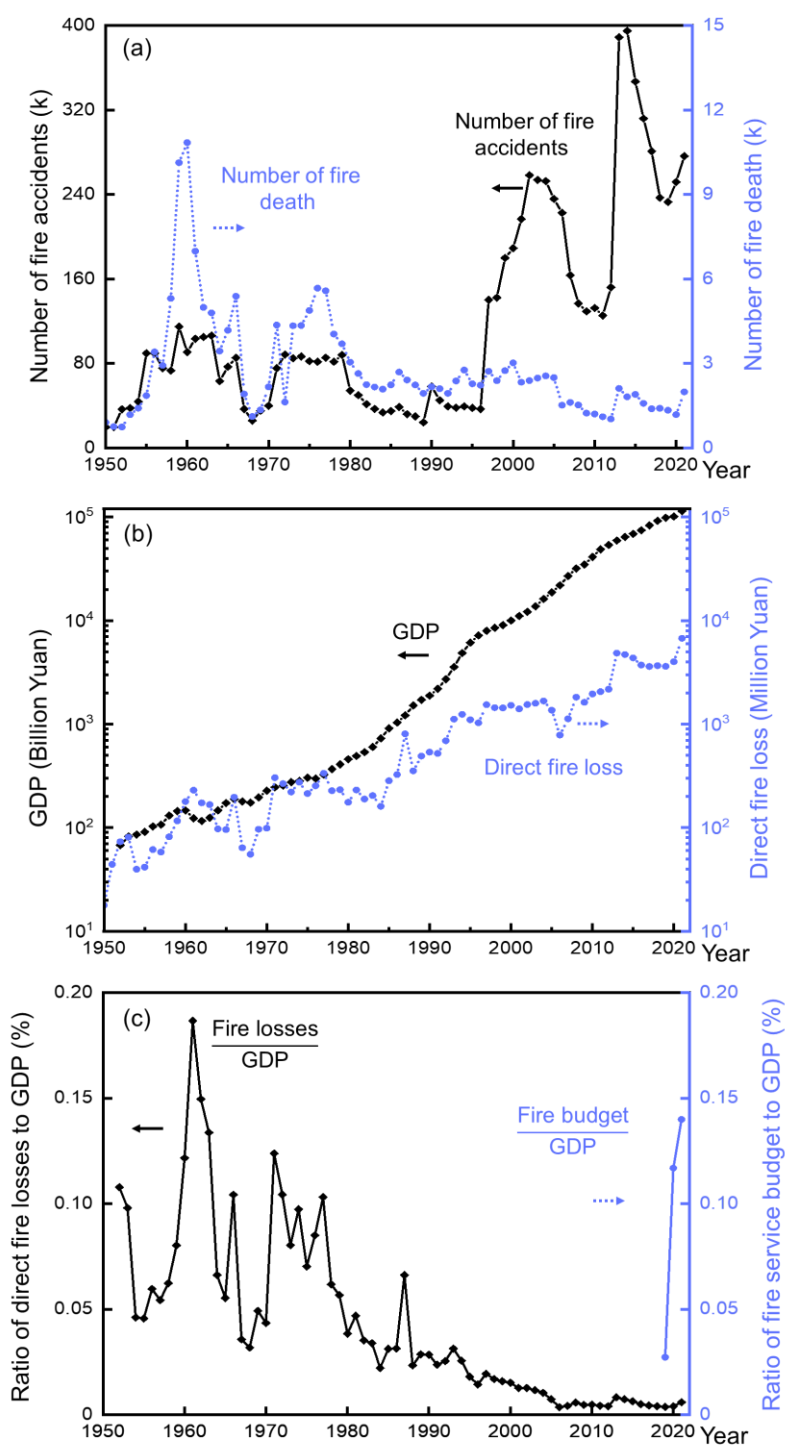


Fig. 2. (a) Number of fire accidents and fire death, (b) GDP and direct fire losses, and (c) ratio of the direct fire losses and fire-service budget to GDP from the early 1950s (excluding wildland fire).

Figure 2b shows that the growth of GDP in China clearly exceeds that of the direct fire loss. Therefore, the ratio of the direct fire losses to GDP overall decreased from the peak in 1962 with some fluctuations until now in Fig. 2c. After the fast social and economic development over the last four decades, the GDP per capital in China is approaching US\$13,000 in 2022. Public awareness of fire safety also increased significantly with transparent reporting on social media. The related government budget has witnessed a tremendous increase recently, as shown in Fig. 2c.

2. Fire safety higher education in China

Regarding higher education (i.e., post-secondary education or tertiary education) in China, there are two milestones, the restoration of the college entrance examination in 1977 and the change in education plan from the specified 2nd-level sub-discipline to a more general 1st-level discipline around 2010. For the development of the fire safety higher education system in China, it can be divided into three periods, (I) before the 1980s, characterized by the concept of “fire protection”, (II) from 1985 – 2010s, characterized by the concept of “fire safety science and engineering”, and (III) 2010s – today, characterized by the concept of “human-oriented public safety and smart firefighting”.

Figure 3 presents the more detailed historical evolution in these three periods, as well as the changes in fire-safety and firefighting-related institutions and policies in China. Like most other counties, there are very few dedicated higher education programs in modern China on wildland fire, so they are not reviewed here.

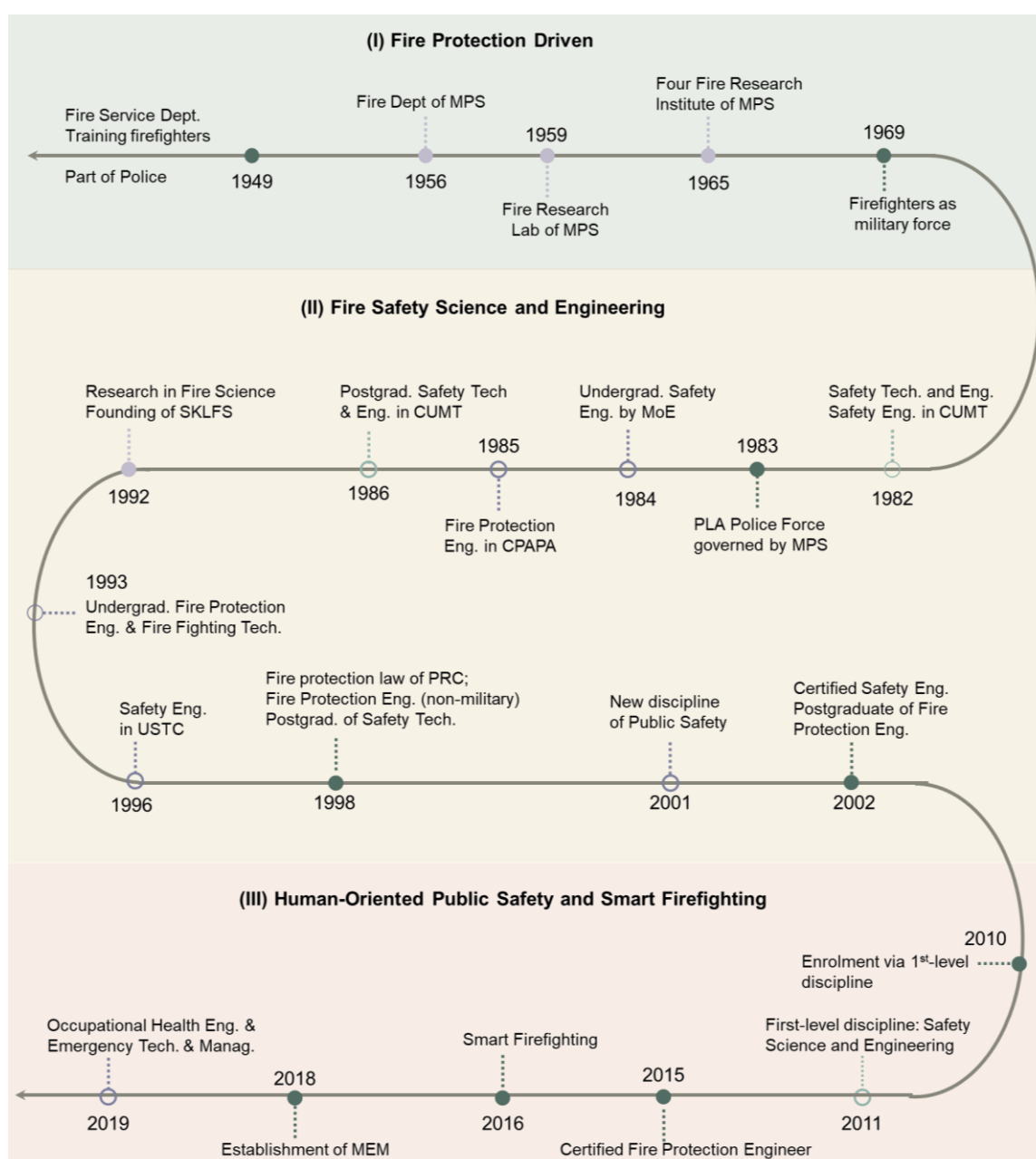


Fig. 3. Three key historical developments of the higher education of fire safety in China.

2.1. Before the 1980s

Before the establishment of the People's Republic of China in 1949, there is no formal higher education in fire safety. By then, the concept of fire safety was still not well-established worldwide. The local governments in China set up fire service departments that were responsible for recruiting and training firefighters. At that time, firefighters are identified as “police” belonging to the Ministry of Public Security (MPS). Since 1949, Chinese higher education has gradually adopted the Soviet system that aims to train high-level specialized scientists and engineers within a short time. Such a higher education system has two features,

- (1) Dividing universities into more specialized colleges and institutions. That is the reason why there are many universities in China named after the name of discipline, such as mining, geosciences, petroleum, chemical technology, etc. (see Table 1). Many of these colleges changed to universities with a more general name in the 1990s. For those that keep their particular name today, they are also comprehensive universities that include most of the major disciplines.
- (2) Dividing major disciplines into more detailed and narrowed 1st, 2nd, and 3rd disciplines or sub-disciplines. Even today, the scope of schools and departments in Chinese universities is still quite specialized. For example, the discipline of Mechanical Engineering in the western university is often distributed into five schools in a typical Chinese university, namely, Mechanical Engineering, Mechanics, Thermal Engineering, Control Engineering, and Instrument Engineering.

In the 1950s and 1960s, such a Soviet-like higher education system indeed promoted rapid economic development and industrialization.

In 1963, the Ministry of Education (MoE) issued the first version of the *General Catalogue of Engineering Disciplines for Undergraduates of Higher Institutions* [12]. It outlined 373 academic majors from 10 categories of disciplines, namely, engineering, agriculture, forestry, medicine, education, arts, science, economics, politics, and sports [13]. On the one hand, this catalogue overemphasized engineering disciplines with massive narrow specialities. On the other hand, it neglected some disciplines (e.g., political science and law, etc.) and even abolished sociology, psychology, anthropology and so on for ideological reasons [12]. In this version, there was no discipline or major related to fire or fire safety in the Chinese higher education system. It is mainly because, at that time, fire safety engineering and science were still in the very early stage and were not considered separate disciplines globally.

Along with the rapid economic development in the early 1960s, the annual fire incidents, death toll, and ratio of direct fire losses to GDP in China also increased to a peak (see Fig. 2a and c) [11]. In 1956, MPS established the Fire Department and proposed to set up a fire research institute to support fire protection in China. Then, a group of engineers and researchers was gathered to engage in fire protection design and research [4]. In 1959, the Fire Research Laboratory of MPS was formally established in Beijing. The laboratory was the prototype of a later fire protection research institute. During that period, there were big advances in fluid mechanics and combustion that provided a theoretical foundation for developing the fire safety discipline [7].

In 1963, this Fire Research Laboratory was expanded to the Fire Research Institute of MPS. Then, it was relocated from Beijing to Sichuan, and renamed as Sichuan Fire Research Institute of MPS in 1965. In the same year, another three Fire Research Institutes were established in Tianjin, Shanghai, and Shenyang. The

establishment of these four Fire Research Institutes marked China's early research and development in fire protection areas. Their mission is to conduct applied research and develop new technologies for fire prevention and protection. It is also consistent with the development of fire protection research and industry in many other countries [14]. In 1969, the fire services were moved to the Ministry of National Defense (MND), and since then, they were identified as a part of the "military" until the 2010s.

Overall, there was only limited applied research on fire protection and no formal fire safety higher education in China before the 1980s. In that period, the fire protection strategy considered fire as an accidental and isolated case, so fire extinguishing was the main strategy for firefighting. Fire prevention mainly focused on the establishment of a professional fire brigade, the inspection of fire risks, and the invention of fire detection and fire-fighting equipment, as well as the formulation of various firefighting regulations. Accordingly, the fire safety research focused on fire protection and firefighting technology. In addition, by analysing a large number of fire incident data and summarising the statistics of fire occurrence, some research had also contributed to the upgrade of fire safety regulations and codes.

2.2. 1985 – 2010s

Since the Chinese economic reform in 1978, there is another round of rapid industrialization and urbanization. The fast-economic development triggered a rapid increase in fire incidences. For example, there were 91,000 fire incidences in 1986 (see Fig. 2a), and the ratio of the direct fire losses to GDP in 1987 had reached another peak (see Fig. 2c). These massive fire incidents proved that the increase in fire protection efforts, fire research, and firefighting manpower alone was insufficient. A fire safety higher education system is needed to gain a better understanding of natural fire phenomena, train professionals in fire safety design, engineering and management, and develop new firefighting technologies. Since 1998, existing laws are updated, and new laws are issued in a regular base to improve the entire legal system in China, including those related to Fire Safety and Higher Education [15,16]. The government of all levels and fire departments have made great efforts to promote fire science research, education, and public awareness.

Since the restoration of the college entrance examination in 1977, higher education in China has developed dramatically, which promoted the development of fire-related majors and programmes. In 1983, to develop fire safety education, a study group was sent to the Soviet Union to study fire protection engineering and management [17]. In 1985, the first undergraduate programme in Fire Protection Engineering was established in the Chinese People's Armed Police Force Academy (CPAPA)². This marked the start of higher education for fire protection engineering in China.

In 1993, two undergraduate programmes, Fire Protection Engineering (082001) and Firefighting Technique (082002), were first listed in the *General Catalogue of Engineering Disciplines for Undergraduates of Higher Institutions* issued by the MoE, but they were only available in various police academies. In July 1998, universities started to establish the programme of Fire Protection Engineering, such as the China University of Mining and Technology (CUMT) in 2001 (discussed more in Section 4.2), Nanjing Tech

²Chinese People's Armed Police Force Academy (CPAPA) is now renamed to the Chinese People's Police University (CPPU). See more discussions in Section 4.5.

University in 2002 (discussed more in [Section 4.4](#)), and Central South University (CSU) in 2004 (discussed more in [Section 4.3](#)). Graduates are awarded Bachelor of Engineering (BEng) in Fire Protection Engineering (083102K) in the latest *General Catalogue of Engineering Disciplines for Undergraduates* since 2020.

In addition, Safety Engineering (082901), as a fire safety-related discipline, was listed in the *General Catalogue of Engineering Disciplines* for the first time in 1984. Many universities with a strong background in Fire Engineering, Engineering Thermophysics, Mining and Chemical Engineering have established Safety Engineering programme that offers many fire safety-related courses. For example, undergraduate students could choose Safety Engineering as their major at the University of Science and Technology of China (USTC) in 2001 (discussed more in [Section 4.1](#)), CUMT in 1982, Nanjing Tech in 1990, and CSU in 2003, and they were awarded BEng in Safety Engineering. Since 2004, the National Professional Qualification Examination for Certified Safety Engineers (CSE), which is similar to the Chartered Engineer (CEng) in the UK and Professional Engineer (PE) in the US. To obtain this license, applicants have to take written exams that are held annually, plus a higher education degree related to safety engineering and certain years of related working experience. The exam covers the safety codes and technologies for fire, explosion and other hazards [18].

In terms of fire-safety postgraduate education in China, MoE listed the discipline of *Safety Technology and Engineering* as a 2nd-level sub-discipline under the 1st-level discipline of *Geological Exploration, Mining, and Petroleum* in 1982 [19]. In 1986, CUMT was qualified as one of the first units to grant a doctoral degree in *Safety Technology and Engineering*. The discipline was later upgraded as an independent 1st-level discipline of *Safety Science and Engineering* after the amendment to the Catalogue in 2012 [20,21]. Since then, postgraduates in the fire safety area have been awarded the Master of Science (MSc) and Doctor of Engineering (DEng, equivalent to PhD) in Safety Science and Technology.

In China, MoE also allows universities to set the name of the 2nd-level sub-discipline under the 1st-level engineering discipline, as long as it has a similar scientific basis while having a different emphasis. For example, CSU and many other universities that have a strong background in civil engineering have a postgraduate programme that focuses on fire safety. They can award the MSc and PhD degrees in Fire Protection Engineering (2nd-level sub-discipline) under the 1st-level discipline of Civil Engineering [17]. During this period, USTC led the fundamental research on fire science in China, and eventually established the State Key Laboratory of Fire Science (SKLFS) in the early 1990s. The increasing fire research activities and deeper understanding of fire safety science also promoted fire engineering education, the applications of fire engineering methods, and the upgrading of fire safety regulations

Since the 1980s, the development of fire engineering education in China has referred to a lot of experience in the US and UK [22,23], but the traditional Soviet higher education of a very detailed Engineering Catalogue (Levels 1, 2, and 3) still played a role. One unique feature is that most universities in China consider fire safety education as a branch of Civil Engineering, Safety Engineering or Engineering Thermophysics programmes rather than an independent or multi-disciplinary programme.

2.3. 2010s – today

The fire safety engineering programme of many higher education institutions has further grown with an

emphasis on many specific fire safety issues, like mining, chemical process, building, *etc.* Another milestone during this period is the establishment of the Certified Fire Protection Engineer (CFPE) in 2015 [18], which is similar to the Fire Protection of PE in the US, and result in the removal of building fire protection from CSE. It is now an independent engineering license, apart from the CSE. Noticeably, the social pressure from the Tianjin Port Fire and Explosion in 2015 (173 deaths) [24,25] played an important role.

On the other hand, the rapid economic developments and the improvement of living standards also set higher requirements and expectations on fire safety. Driven by climate change, the Earth's ecosystems tend to suffer more frequent hazards like extreme weather and severer wildfire [16,26]. A systematic conception of safety is urgent to break the boundaries between diversified industries and establish more general and basic theories of public safety. Education on fire safety in China has promoted the concept of safety and set a solid foundation for the establishment of a new discipline of *Public Safety* since 2001 [27]. *Public Safety* is a human-oriented concept to systematically protect people from various hazards such as accidents (e.g., fire and explosion), natural disasters (e.g., earthquake and hurricane), public health incidents (e.g. Covid-19), and social security incidents (e.g., terrorist attacks).

Another milestone during this period is the establishment of the Ministry of Emergency Management (MEM) (<https://www.mem.gov.cn/>) in 2018. The MEM and Departments of Emergency Management in local governments are systematically responsible for an emergency response from natural disasters and safety accidents in work, prevention and reduction of natural disasters, to the safety supervision [28]. Since then, all fire services in China have been moved from the MPS (as armed police forces) to the MEM (as civilian servants), as discussed more in [Section 4.5](#). In addition, the concept of public safety has also received significant attention, such as the establishment of emerging engineering disciplines of Occupational Health Engineering (082903T), and Emergency Technology and Management (082902T) in 2019 [29,30], and the 2nd-level sub-discipline National Security (1402) under the 1st-level discipline of Interdisciplinary in 2021 [31].

To meet these new demands, the training objectives of fire education are gradually reformed to promote systemic thinking skills and master the basic theories of safety. Over the past 20 years, many universities have been exploring and practising general education in a larger category of disciplines. Specifically, universities allow undergraduate students of similar majors and disciplines within the same department or across different departments to take the same general courses in their 1st and 2nd years [32]. From the 3rd year, students will choose a specific major according to their interests under the principle of two-way selection [33]. The disciplines related to fire safety are always belonged to a larger category, like Engineering Science in USTC, Safety Science and Engineering in CUMT, and Civil and Safety in CSU. Nevertheless, for most universities, it is still not an easy task for undergraduate students to change their major after enrolment, mainly because all disciplines have different entrance scores.

More recently, driven by the fast development of big data, artificial intelligence, the Internet of Things, Web 3.0, etc., the concept of *Smart Firefighting* or *Intelligent Fire Safety* is emerging. The education of fire science and technology in China is towards achieving the safety and resilience of the community, city, and society. Under the information age, Smart Firefighting is based on the fast collection, transmission, and processing of massive information to improve fire safety, emergency response, and firefighting efficiency [16].

To meet these new demands, the higher education of Fire Safety is expanding the scope of courses and promoting more multi-disciplinary training. For postgraduate research students, their research also goes beyond conventional fire science and engineering to address smart urban resilience and apply new technologies to fire protection systems and firefighting.

3. Scopes of Fire Safety Education

3.1. Higher-education programmes

Higher education in fire safety science and engineering consists of a three-level academic degree education system, i.e., bachelor, master, and doctor in engineering. The high diploma and associate degree are relatively rare in China for very specialized topics like fire safety. In terms of the length of study, undergraduate education takes four years. A master's degree usually requires two to three years. Specifically, the Master of Science (MSc) includes a significant research component and a thesis, so it is more like the Master of Philosophy (MPhil) in the UK. The Master of Engineering (MEng) is more practical and towards professional education, although it also takes at least 2 years. A doctoral degree takes three to six years, focusing on research.

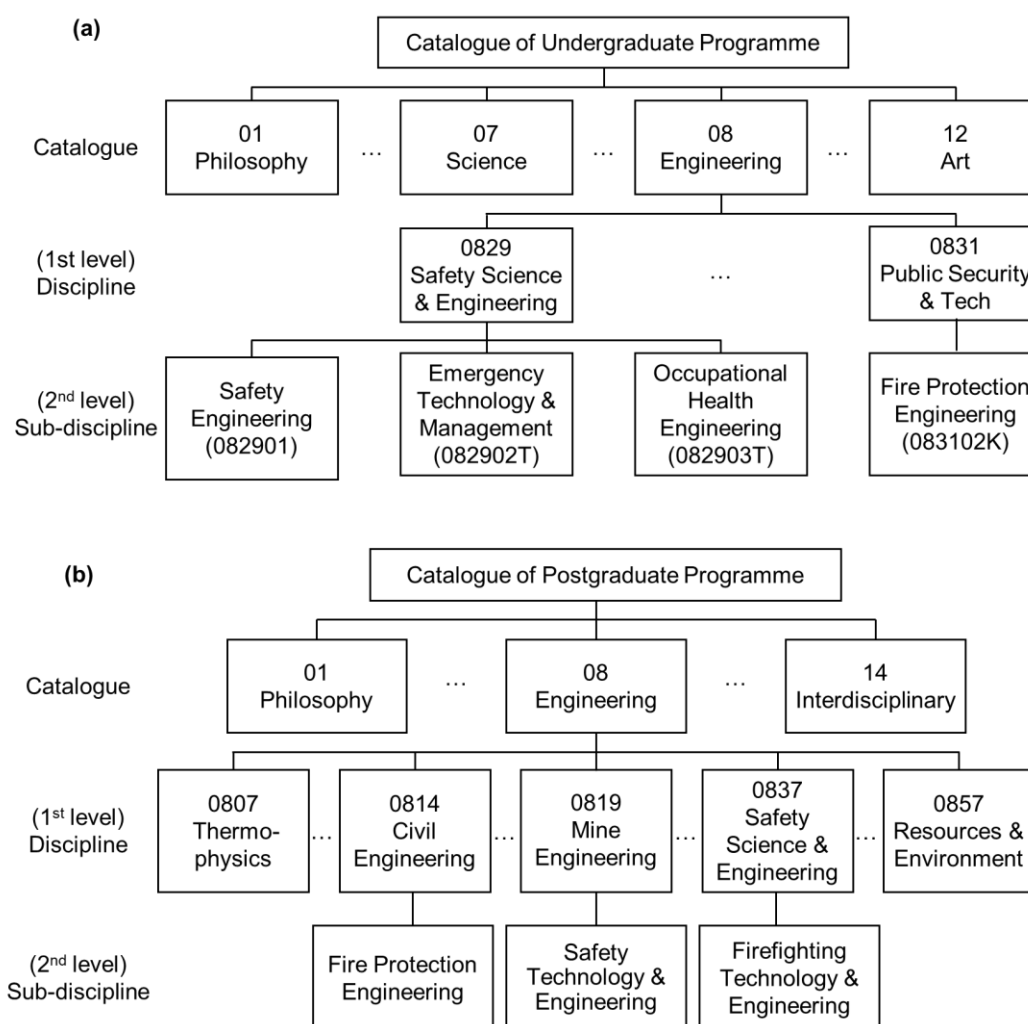


Fig. 4. MoE Catalogue of (a) undergraduate and (b) postgraduate programmes in China for fire safety-related disciplines and sub-disciplines.

The undergraduate education focuses on basic knowledge and the primary capabilities to conduct research and technical work in fire safety-related areas. The undergraduate programme follows the *Catalogue of Undergraduate Programs in Ordinary Higher-learning Institutions* (see Fig. 4a). It outlined 717 academic disciplines from 12 major categories, i.e., philosophy (01), economics (02), law (03), education (04), literature (05), history (06), science (07), engineering (08), agriculture (09), medicine (10), administration (11), and art (12). There are four fire safety-related sub-disciplines,

- (1) *Fire Protection Engineering* (083102K), was first listed in 1985 and by 2022 has been offered in 21 universities,
- (2) *Safety Engineering* (082901), was first listed in 1984 and has been offered in 169 universities,
- (3) *Emergency Technology and Management* (082902T), was first listed in 2019 and has been offered in 35 universities,
- (4) *Occupational Health Engineering* (082903T), was first listed in 2019 and has been offered in 5 universities.

The first one is under *Public Security and Technology* (0831), and the latter three are under *Safety Science and Engineering* (0829). The quality of sub-disciplines is judged by Engineering Education Professional Certification and Washington Agreement [34]. In recent years, MoE listed the National First-Class Undergraduate Programmes for *Fire Protection Engineering* in 4 universities and *Safety Engineering* in 47 universities, as highlighted and sorted by their first letter in Table 1.

Table 1. Fire-related National First-class Undergraduate Sub-disciplines

	2019	2020	2021
Fire Protection Engineering	China People's Police University	Central South University	China University of Mining and Technology, Beijing
		Xi'an University of Science and Technology	
	Anhui University of Science and Technology	Beijing University of Chemical Technology	Capital University of Economics and Business
	Beijing Institute of Technology	China University of Geosciences, Beijing	China Jiliang University
	Central South University	Chongqing University	China University of Geosciences, Wuhan
	Changzhou University	Dalian University of Technology	China University of Labor Relations
	China University of Mining and Technology, Beijing	Fuzhou University	Guizhou University
	China University of Mining and Technology, Xuzhou	Hunan Institute of Technology	Shanghai Maritime University
	China University of Petroleum, Beijing	Heilongjiang University of Science and Technology	Shenyang Jianzhu University
	China University of Petroleum, East China	Kunming University of Science and Technology	South China University of Technology
Safety Engineering	Henan Polytechnic University	Liaoning Technical University	Southwest Jiaotong University
	Hunan University of Science and Technology	Nanjing University of Science and Technology	Wuhan University of Science and Technology
	Nanjing Tech University	Northeast University	Zhengzhou University
	North China Institute of Science And	North China University of	

Technology	Science and Technology
Shandong University of Science and Technology	North University of China
Taiyuan University of Technology	Qingdao University of Science and Technology
University of Science & Technology Beijing	Tianjin University of Technology
Wuhan University of Technology	University of Science and Technology of China
Xi'an University of Science and Technology	University of South China
	Xinjiang University
	Zhejiang University of Technology

The master's education aims to master fundamental theories in fire safety science, integrate specialized knowledge, and develop research capability and professional skills. The doctoral education focuses on original research related to fire safety. In China, postgraduate education follows the *Catalogue of Disciplines for Degree Awarding and Educational Programs* (Fig. 4b). It is released by the State Council Committee on Academic Degrees and MoE and is updated every ten years. According to the latest version in 2021 [21], there are 14 categories, namely, Philosophy (01), Economics (02), Law (03), Education (04), Literature (05), History (06), Science (07), Engineering (08), Agriculture (09), Medicine (10), Administration (11), Military Science (12), Art (13) and Interdisciplinary (14). Under these categories, there are 113 (1st-level) disciplines and 380 (2nd-level) sub-disciplines. The fire-related discipline is mainly the 1st-level discipline of *Safety Science and Technology* under the Engineering Category.

In China, both master's and doctoral degrees have academic and professional degrees. This paper refers to the academic degrees (i.e., Master of Science in Engineering and PhD in Engineering) unless specified. The fire-related postgraduate programmes are often under the 1st-level disciplines of *Safety Science and Engineering* (0837), *Mining Engineering* (0819), *Civil Engineering* (0814), *Power Engineering and Engineering Thermo-physics* (0807). Some universities set 2nd-level sub-disciplines programmes of *Safety Technology and Engineering* (under *Mining Engineering*), *Fire Protection Engineering* (under *Civil Engineering*), and *Firefighting Technology and Engineering* (under *Safety Science and Engineering*). The 2nd-level sub-disciplines programmes can be set by an individual university, but their degree is under 1st-level discipline. The fire-related professional postgraduate programme is under the 1st-level discipline of *Resources and Environment* (0857), issued in 2019 (see more in Table S1).

MoE of China has a percentile-based ranking for all 1st-level disciplines [35] every five years, after a thorough Degree Program Review of faculties, resources, research, teaching and reputation. Most higher education institutes choose to participate in this review, so it provides a good reference. The fourth round of the Degree Program Review was conducted in 2016, and it ranked the universities of Safety Science and Engineering as two A+ (top 2%), three A- (5%~10%), five B+ (10%~20%), five B (20%~30%), five B- (30%~40%), six C+ (40%~50%), five C (50%~60%) and five C- (60%~70%). The universities rated as B and above are shown in Table 2. The fifth round of the Degree Program Review in 2022 has not been published

by the completion of this paper.

Table 2. The fourth round of the Graduate Degree Program Review in Safety Science and Technology, where * is enlisted in the First Class Academic Discipline Construction Plan [36].

University Code	University Name	Rating
10290	China University of Mining and Technology*	A+
10358	University of Science and Technology of China*	A+
10460	Henan Polytechnic University	A-
10533	Central South University	A-
10704	Xi'an University of Science and Technology	A-
10003	Tsinghua University	B+
10007	Beijing Institute of Technology	B+
10008	University of Science and Technology Beijing	B+
10291	Nanjing Tech University	B+
11414	China University of Petroleum	B+
10147	Liaoning Technical University	B
10361	Anhui University of Science and Technology	B
10424	Shandong University of Science and Technology	B
10491	China University of Geosciences	B
10611	Chongqing University	B

3.2. Courses

Fire is an uncontrolled combustion process that involves combustion chemistry, material, thermodynamics, fluid mechanics, heat transfer and associated fire modelling [37–39]. The energy release of unwanted fire will damage the building environment and structures, so it also involves structural engineering and fire services systems. The study of fire also involves safety science, e.g., evacuation, public safety, emergency response, and statistics in fire incidents. The latest concept of smart firefighting covers an even larger scope, such as information science, artificial intelligence algorithm, the Internet of Things, robotics, virtual reality, and communication technology.

Compared to the history of civil and mechanical engineering, fire safety science and engineering is still emerging discipline. It studies the occurrence and behaviours of fire, the theory and technology of fire prevention, and firefighting strategies to minimize fire threats to human beings [40,41]. The education in fire protection engineering discipline (or sub-discipline) should at least involve (but not be limited to) combustion science, structural mechanics, safety science, and computer science (Fig. 5a) [23]. On the other hand, some disciplines, like Mine Engineering, Civil Engineering, Chemical Engineering, Safety Engineering, Engineering Thermophysics, and Environmental Engineering, also offer some fire safety-related courses.

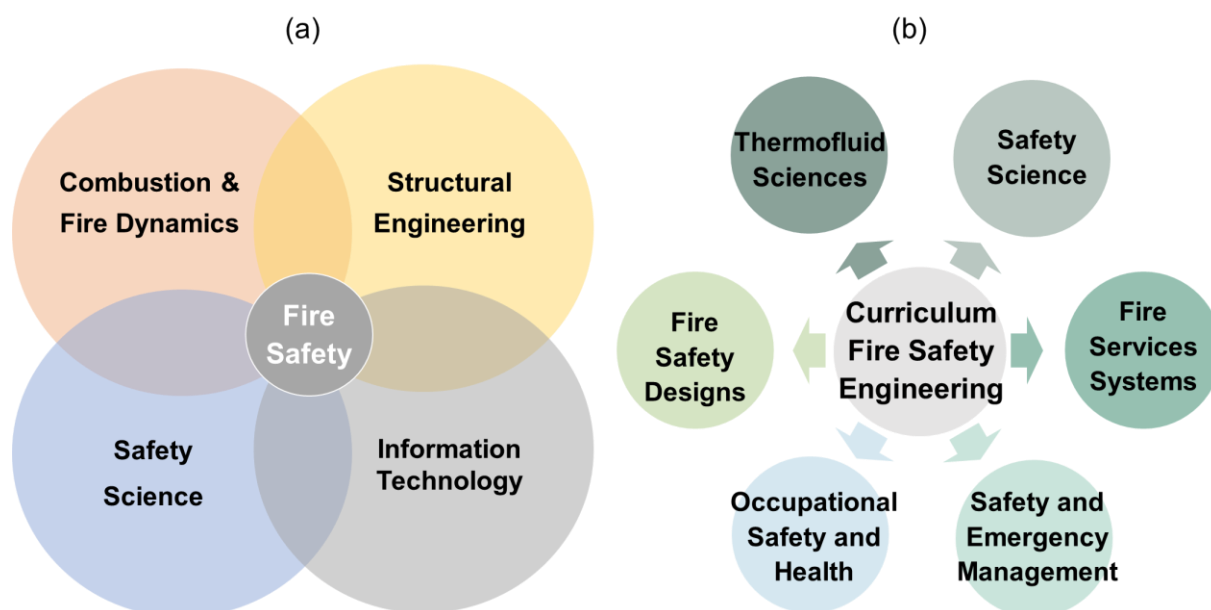


Fig. 5. (a) Discipline distribution and (b) curriculum of Fire Safety Engineering.

The higher education of engineering curriculum in China consists of three components, (1) general courses, (2) specialized (or major) courses and (3) practical training. In each component, courses can be further classified into foundation, core, and elective courses. The curriculum of Fire Protection Engineering follows the same principle.

- (1) The general courses generally include political theories, morality and ethics, employment guidance, physical education, and some general skills, such as literature, language, math, and computer applications. Most of these courses are arranged in the first two years of a four-year BEng programme.
- (2) Major foundation courses (Fig. 5b) mainly cover basic engineering concepts, especially,
 - Thermofluid, such as *Fundamental Fluid Mechanics*, *Thermodynamics*, *Heat Transfer*, *Combustion*, etc.
 - Safety Science, such as *Safety System Engineering*, *Safety Principles*, *Public Safety Theory and Methods*, *Safety Economics*, *Safety Psychology*, etc.
- (3) The major core and elective courses include:
 - Fire Safety Engineering, such as *Fire Science/Dynamics*, *Principle of Building Fire Safety Design*, *Water Supply and Drainage Engineering Design*, *Smoke Prevention Project*, *Fire Alarm and Linkage Control*, *Fire Safety Detection Technology*, *Firefighting Technology and Management*, *Industrial Fire and Explosion Prevention*, *Structure Fire Resilience*, *Fire Investigation and Failure Analysis*, *Security Information Engineering*, *Electrical Fire Protection*, *Fire and Explosion of Chemical and Hazardous Chemicals*, *Performance-based Fire Protection Design Building*, etc.
 - Fire Services Systems, such as *Fire Regulations*, *Fire Management*, *System Optimization Theory and Method*, *Fire Risk Assessment and Insurance*, etc.
 - Occupational Safety and Health, such as *Personal Protection*, *Health Toxicology*, *Prevention and Control of Occupational Health Hazards*, *Occupational Health Management*, *Occupational Injuries and Occupational Diseases*, etc.

- Emergency and Information Management, such as *Risk management and evaluation*, *Emergency Decision-making and Command*, *Emergency Response and Rescue*, *Emergency Strategy*, *Public Safety Monitoring*, *Public Safety Prediction and Early-warning*, *Smart Firefighting*, etc.

(4) Practical-training courses aim to develop the students' capability of applying knowledge and technology in their future work, such as the basic computational design of fire services systems, and performance-based design in fire engineering, etc. Building fire safety design always contains four subjects, *Fire Protection Engineering of Buildings*, *Water Fire-extinguishing Engineering*, *Smoke Prevention and Exhaust Engineering of Buildings*, *Automatic Fire Alarm and Linkage Control*.

Note that even with the same programme name (e.g., Fire Protection Engineering), the curriculum of major and practical-training courses can vary a lot in different universities. In China, the curriculum mainly depends on the university's history, strengths, and training objectives. For example, if the university historically focuses on mining technology, then the curriculum is most related to the mining process and safety (discussed more in [Section 4](#)). The sequence of courses in the curriculum reflects the progression of knowledge. In general, common courses and disciplinary or major foundation courses were mostly offered in the first and second years, while major-core and practice-oriented courses often took place in the third and fourth years.

3.3. Teaching materials and textbooks

Teaching materials and textbooks, as a key component of each discipline and programme, are the most basic and useful resources for both teachers and learners. The compilation of teaching materials into a textbook not only needs years of teaching experience but also continuous teaching innovation and academic research. Good textbooks facilitate teaching activities by providing detailed technical content and homework questions and also promote research in this area by allowing the junior researcher to enter a new field quickly.

In China, the first textbook on fire safety area is the *Introduction to Fire Science*, published by USTC Press in 1995 (in [Fig. 6](#)) and authored by Profs. Weicheng Fan, Qingan Wang, Fenghui Jiang, and Jianjun Zhou from USTC. This book summarized the fundamental theories of fire science in eight chapters, *i.e.*, (1) *Introduction to Fire Phenomena*, (2) *Fundamentals of Flow and Heat Transfer in Fire*, (3) *Ignition and Fire Spread*, (4) *Fire Smoke*, (5) *Fire Statistics and Hazard Analysis*, (6) *Computer Simulation of Fire Phenomena*, (7) *Experiments in Fire Science*, And (8) *Deterministic and Random Fire Behaviour* [42]. This textbook covers both fire dynamics based on mathematic models and statistical analysis of fire incidences. The targeted audience includes senior undergraduates, masters, and doctoral postgraduates. This textbook was recommended by the State Education Commission for the discipline of Engineering Thermophysics.

Later in 2004, Prof. Weicheng Fan also led the writing of another textbook, *Methodology of Fire Risk Assessment*. This book mainly clarifies the basic and applied theory for assessing fire risk based on the dual theory of random and deterministic fires. Prof. Fan's latest book in 2013, *Introduction to Public Safety Science*, summarizes the fundamental theory and methodology of safety science and public safety.



Fig. 6. Examples of teaching materials or textbooks of fire safety-related sub-disciplines and disciplines.

As initiated by the National Higher Education Committee in 2004, a group of distinguished scholars and experts have co-authored and edited a series of university textbooks in safety science and engineering. So far, this book series has more than 30 textbooks, all published by China Machine Press (listed in Table S3). Similar initiation for textbooks of Fire Safety Science and Engineering started in 2008. More than 20 textbooks have been published by China Machine Press, covering the fundamentals of fire dynamics, fire protection technologies, and fire safety management. Other publishers, such as the Science Press, China University of Mining and Technology Press, and Chemical Industry Press, also published fire-related textbooks. For example, the Chinese translation of Prof. James Quintiere’s Fundamentals of Fire Phenomena was published by Chemical Industry Press in 2010.

Some other good textbooks in other disciplines that are related to fire safety and receive awards are also mentioned here, such as “Safety Technology and Management of Hazard Chemicals” (National Textbook Award) published by Chemical Industry Press, “Thermal Risk Assessment of Chemical Substances” (Outstanding Youth Science Library Award) by Science Press, and Water Fire-extinguishing System published by CUMT Press, *etc.* (listed in Table S3). These diverse textbooks reflect that the development of fire safety higher education in China is towards Safety Science (or a greater concept of Public Safety) and multidisciplinary areas.

3.4. Graduates and job markets

Since the early 2000s, the labour system in China has changed to “market-oriented mutual choices between graduates and employers”. Before the 2000s, the system was a “state-planned distribution of graduates” that assigned jobs to university graduates based on their major [12]. Today, higher education in fire safety science and engineering aims to provide talents to the job market who fit the needs of industry and society [43]. Graduates are expected to master the fundamental theories of fire safety, develop engineering skills in technology application, and acquire a broad multidisciplinary knowledge related to fire and public safety.

As China is a big country, the job market for graduates in the fire-related discipline varies from university to university and from city to city. Using the data of all graduates with a BEng in Fire Protection Engineering

from Nanjing Tech during 2015–2020, the distribution of their first job after graduate is state-owned companies (31.33%), private companies (33.29%), research institutes (0.37%), government (3.92%), and postgraduate study (31.09%). In terms of geographic distribution, about 55% of graduates stayed in Jiangsu Province because Nanjing is the capital of Jiangsu, and 7% went to Shanghai, because Shanghai is only a 2-h train away. Another 4% went to Guangdong Province, 3% to Zhejiang Province, and 2% to Beijing, all of which have a higher level of economic development. Because of the recent big social demand and wide scope of different jobs for fire-related graduates, the initial employment rate for graduates in the fire discipline is much higher than in other conventional engineering disciplines like mechanical engineering.

3.5. Professional license

In China, there are five fire-related professional licenses (or certificates), (a) Firefighter, (b) Fire Facility Operator, (c) Emergency Rescuer, (d) Certified Fire Protection Engineer (CFPE), and (e) Certified Safety Engineer (CSE). The covers of their licenses are shown in Fig. 7. Note that the license of CSE in China covers all safety-related expertise (like fire and explosion protection of hazardous chemicals), but it no longer covers building fire safety, since the establishment of CFPE in 2015. The Certified Fire Protection Engineer is specialized in building fire safety design and analysis.



Fig. 7. The cover pages of the certificates for (a) Firefighter, (b) Occupational Qualification Certificate (OQC) of Fire (Services) Facility Operator or Emergency Rescuer, (c) Certified Fire Protection Engineer (CFPE), and (d) Certified Safety Engineer (CSE) in China.

The certificate of firefighter (Fig. 7a) is a professional ID like the police ID and membership of the National Comprehensive Fire Rescue Team, issued by the Political Department of MEM. The education requirement for firefighters is a secondary school or higher, and everyone is required to pass the basic writing test, physical fitness test, interview, psychological evaluation, and health examination. Their work covers every aspect of firefighting, such as controlling and suppressing the fire, fire rescue, building firebreaks to prevent structure-to-structure fire spread, and cooling the structure to prevent structural failure [45,46]. However, they are also required to handle other fire-unrelated missions like handling hazardous chemicals and rescuing trapped people. Essentially, the requirements and working contents for firefighters in China are similar to most other countries.

The certified fire (services) facility operator and emergency rescuer both have the Occupational Qualification Certificate, issued by the Ministry of Human Resources and Social Security. The minimum education level for these certificates is the secondary school or higher. There are five levels of skill qualification, depending on the working years and operational skills requirements. The skill level can be distinguished by the colour of these occupational qualification certificates, that is, green for Level 5 (Junior), blue for level 4 (intermediate), red for level 3 (senior, see Fig. 7c), brown for level 2 (technician), and dark red for level 1 (senior technician).

The fire (services) facility operator is a work permit who is engaged in the operating, maintenance, and testing of fire-fighting facilities for buildings or structures. The person is required to pass the basic writing test and firefighting operation skill assessment test. The emergency rescuer is a work-permit who addresses and resolves different emergencies, including but certainly not limited to fire accidents, to ensure public safety and health. The Emergency Rescuer candidate should pass the assessment by the Emergency Rescue Occupational Skills Appraisal Station. The assessed skills and expertises include disaster and incident investigation and search skills, strategic safety planning, on-site real-time risk assessment, basic first-aid skills, etc. Essentially, the requirements and working contents for emergency rescuers in China are similar to most other countries.

Table 3. The requirements of education background and working experience in the fire safety before the qualification exams of Certified Fire Protection Engineer (CFPE).

Education background	Total working experience (in Fire Safety) [year]		
	Fire Protection Eng.	Fire Protection Related Eng.	Other Disciplines
High Diploma	6 (4)	7 (5)	8 (6)
Bachelor Degree	4 (3)	5 (4)	6 (5)
Two Bachelor Degrees	3 (2)	4 (3)	5 (4)
Master degree	2 (1)	3 (2)	4 (3)
Doctoral degree	1 (1)	2 (2)	3 (3)

The license of certified engineers in China, has relatively strict entrance requirements, and all require a series of written exams. For a fire protection engineer, he or she has to pass three examinations, (1) *Fire Safety Technical Practice*, (2) *Comprehensive Ability of Fire Safety Technology*, and (3) *Fire Safety Case Study*, to obtain the license of Level-1 CFPE (Fig. 7b). Nevertheless, not everyone can sign up for these exams. They must have no crime record and meet certain education background plus a minimum number of years fire-safety-related working experience, as summarized in Table 3 [44].

Currently, about 46 institutions in China offer the High Diploma (or 2-year Junior College Degree) in Fire Protection Engineering, and 21 institutions can award the (4-year) bachelor's diploma. The full list can be found on the China Higher Education Student Information (CHSI) website. A number of engineering and management disciplines are considered to be related to Fire Protection Engineering, as shown in Table 4.

Table 4. Disciplines that are considered related to Fire Protection Engineering.

Engineering Disciplines	Management Disciplines
Safety Eng., Chemical Eng. and Tech., Electrical Eng. & Automation, Electronic Information Eng., Telecommunications Eng., Computer Sci. and Tech.;	Management Sci, Industrial Eng., Eng. Management.
Architecture, Urban Planning, Civil Eng., Building Environment and Equipment Eng., Water Supply and Sewerage Eng.;	

Those who have passed the examinations of CFPE must be registered before they can practice in the name of a CFPE. The continuing professional development (CPD) of a registered CFPE shall not be less than 20 hours cumulatively each year. Specifically, the annual training should contain at least 4 credited hours for fire safety codes, laws and professional ethics, 12 credited hours for fire technical standards, and 4 credited hours for fire safety management. The practice scope of CFPEs contains fire technical consultation and fire safety assessment, fire safety management and technical training, fire facility inspection and maintenance, fire monitoring and inspection, technical analysis of fire accidents, and other fire safety technical work that is stipulated by the MPS.

Since 2015, the national professional qualification examination for the CFPE has been held once every year [18]. The CFPEs are divided into two levels, the Level-1 certificate is recognized nationally wide, and the Level-2 certificate is recognized within one province. Comparatively, Certified Safety Engineers (CSEs) are divided into Senior CSE (based on working experience and contribution), Intermediate CSE (after passing the national examination) and Assistant CSE (after passing the provincial examination).

For any fire service company or organization in China, a minimum number of two CFPEs (at least one Level-1 CFPE) is required, based on the regulation on the operational conditions of fire protection and technical service [45]. Fig. 8 presents the annual numbers of applicants and qualified engineers for Level-1 CFPEs and Intermediate CSEs in recent years. For both CFPE and CSE exams, there are about 20,000 people who can pass the exam annually, but the number of applicants for CFPE is nearly 6-8 times that of CSEs. Therefore, the success rate is extremely low, about 2% for CFPE and 15% for CSE. Although a large portion of applicants only signs up for the exam while never taking the exam, it demonstrates a huge market demand for CFPE in China.

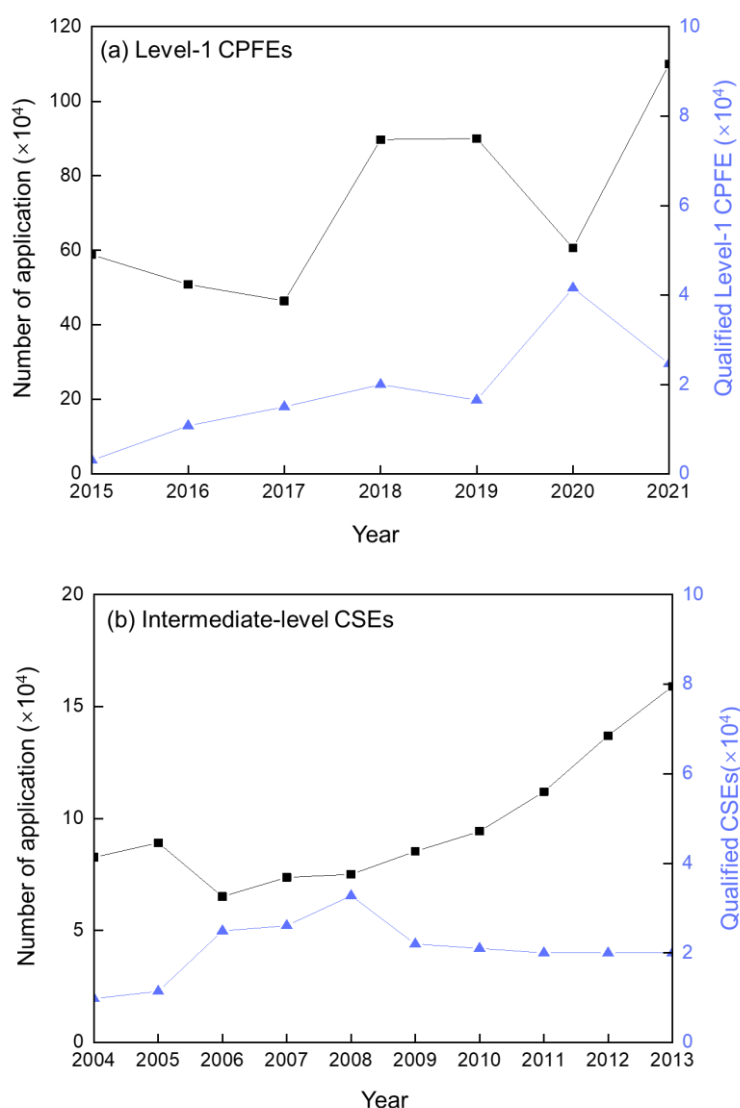


Fig. 8. Annual numbers of applicants and qualified engineers for (a) Level-1 Certified Fire Protection Engineer (CFPE), and (b) Intermediate-level of Certified Safety Engineer (CSE).

4. Higher-Education Case Studies

A comparison of the historical development and the scope of fire safety education in various universities can tell us more details about the trends and features in the Higher Education of Fire Safety Science and Engineering in China. This section reviews the fire safety higher education at seven institutions, namely, the USTC (featuring fire safety science), CUMT (featuring mining safety), CSU (featuring transportation safety), Nanjing Tech (featuring industrial-process safety), CPPU (featuring fire protection technology and firefighting), and The Hong Kong Polytechnic University (featuring building fire system and uniqueness under “One Country, Two Systems”).

4.1. University of Science and Technology of China (USTC)

The University of Science and Technology of China (USTC) is only of the top elite universities in China that ranks as a top-10 university in any of the university rankings. USTC set up the State Key Laboratory of Fire Science (SKLFS) back in the early 1990s, motivated by the rapid increase in fire losses and an urgent

need to build national key science and technology research system. The detailed history and development of SKLFS can be seen in [46]. Since then, SKLFS has served as China's central base for fundamental and applied research on fire safety science. Prof. Weicheng Fan, a professor of engineering thermo-physics in combustion, is the founder of SKLFS and fire safety higher education in China. Many outstanding fire researchers graduated from USTC (see <http://en.sklfs.ustc.edu.cn/main.htm>). Compared to other institutions, USTC has three major uniquenesses,

- (1) USTC aims to educate top talent in cutting-edge, interdisciplinary science and technology, so it is recognized as the “Cradle of Scientists” in China. The programs and courses at USTC are engaged in cultivating students with a solid foundation in mathematics, physics, and chemistry.
- (2) USTC is an organization belonging to the Chinese Academy of Sciences, while most other top universities are under MoE.
- (3) SKLFS has a long and proud tradition of providing outstanding fire research and comprehensive education in the fire-related field. The mission of SKLFS is to study fire dynamics & key technologies of fire safety, train qualified personnel to satisfy the growing national demand in fire science, and make strategic or forward-looking contributions to national fire safety.

Driven by the fire research in SKLFS, USTC started to offer courses and programs on fire safety engineering first in the discipline of Engineering Thermophysics, and later in 1996, these courses are offered under the discipline of Safety Engineering. At USTC, undergraduate education in Fire Safety Engineering is mainly offered by the Department of Safety Science and Engineering under the School of Engineering Science. SKLFS is a research institution inside USTC (equivalent to a school) that offers postgraduate education in Fire Science and awards the MSc and PhD in Safety Science and Technology. In terms of research, SKLFS focuses on (but is not limited to) the following topics:

- (1) Fire safety of urban public service buildings and building complexes,
- (2) Fire safety in navigation, spaceflight, and plateau atmosphere,
- (3) Fire safety in the use of new energy (such as hydrogen energy and Lithium-ion battery),
- (4) Wildland and Urban Interface (WUI) fires,
- (5) Evolution of multiple urban disasters (including fire) with their prevention and protection.

Currently, there is one undergraduate degree program —— Safety Engineering (4 years, full-time, BEng) [47] that covers the fire safety engineering discipline from 2001. In actuality, the related undergraduate program was studied in the department of thermal science and energy engineering in 1996. After the major "Safety technology and engineering" is approved in 2001, the grade 1996 changed and choose Safety Engineering as their major in 5th grade in 2001. Since 2002, the undergraduate programme had been changed from 5 years to 4 years. In recent years, about 18 students will be admitted to this programme from the discipline split-flow (at the end of the second year) of classified “Engineering Science” enrollment from secondary school. The student quota of the bachelor's programme is 160.

All courses in the programme are summarised in [Table S4](#) (2022 version). It is worth noting that the general courses in basic or applied mathematics, physics, and chemistry are highly abundant. The major required (16 credits) and elective courses (8.5 credits) only account for 15% of the total credits, and all fire

safety-related major courses have been summarised in Table 5. There are three fire safety-related compulsory courses in Table 4, and *Fundamentals of Fire Science* include 54 hours of lecture and 6 hours of tutorial activities, and *Fire Detection and Control Engineering* include 48 hours of lecture, 6 hours of laboratory, and 6 hours of seminar. Four out of nine elective courses are also offered to preliminarily outline the basic theories and technical principles of fire prevention and control in industrial or building areas. It is noticeable that *Viscous Fluid Dynamics* and *Experimental Diagnostic Methods on Thermal Hazards* have been sorted as elective courses to further support the solid thermofuild foundation, which fits with the USTC characteristics of science. In Year 4, students will conduct an 8-credit *Graduation Thesis* Project with an academic supervisor for 2 semesters. 100% of students will choose research topics related to fire dynamics and modelling, guided by professors in SKLFS. After graduation, students receive a bachelor's degree in safety engineering, and 90% of graduates will further their studies in domestic and international universities.

Table 4. All fire safety-related courses in undergraduate and postgraduate Fire Safety Engineering in USTC, where the normal subject has 2 credits [2'] if not specified, and each unit is normally 20 hours of lecture, seminar, lab, or tutorial activities.

Program	BEng in Safety Engineering	MSc in Safety Engineering	PhD (Doctor in Engineering Science)	
			Integrated training mode of master-doctor	Doctoral training mode
Department	Department of Safety Science and Engineering in the School of Engineering Science	SKLFS	SKLFS	SKLFS
Student No. per year [#]	18	87 (average of 2017-2021)	43 (average of 2019-2021)	3+17 (average of 2019-2021)
Courses in fire safety	Year 3 Combustion [4'] Fundamentals of Fire Science [3'] Fire Detection and Control Engineering [3'] Industrial Fire and Explosion Prevention (elective), The Design on Building Fire Protection and Prevention (elective), Fire Investigation and Failure Analysis (elective)	Compulsory Subjects: Fundamental of Fire Phenomena [3'] Core Elective Subjects: Principle and Application of Fire Extinguishing Technology [3'], Fire Chemistry [3'], Theory of Fire plume, Flame-Retardant Principle and Technology [3'], Frontier of Fire Safety Engineering Technology, Foundation of Preparation and Application of Safety Engineering Materials [3'], Energy Fire Safety Theory and Methodology [3'], Principles of Chemical Safety Analysis [3'], Introduction to the Safety of Hazardous Chemicals, Thermal Spontaneous Combustion Theory and Its Application [2'], Performance-Based Fire Design Methodology, Fire Signal Detection and Processing [3'], Fundamentals of Personnel Evacuation Dynamics	Compulsory Subjects: Fundamental of Fire Phenomena [3'] Public Safety Science or Safety Culture [3'], Preparation and Application Basis of Smart Safety Materials or Numerical methods for safety engineering [3'] Core Elective Subjects*: Principle and Application of Fire Extinguishing Technology [3'], Fire Chemistry [3'], Theory of Fire plume, Flame-Retardant Principle and Technology [3'], Frontier of Fire Safety Engineering Technology, Foundation of Preparation and Application of Safety Engineering Materials [3'], Energy Fire Safety Theory and Methodology [3'], Principles of Chemical Safety Analysis [3'], Introduction to the Safety of Hazardous Chemicals, Thermal Spontaneous Combustion Theory and Its Application [2'], Performance-Based Fire Design Methodology, Fire Signal Detection and Processing [3'], Fundamentals of Personnel Evacuation Dynamics	Compulsory Subjects: Public Safety Science or Safety Culture [3'], Preparation and Application Basis of Smart Safety Materials or Numerical methods for safety engineering [3'] Core Elective Subjects**
	Year 4 An Introduction to Building Fire Safety Engineering (elective)			
Total Credits	16 (compulsory) + 8.5 elective	12+	16+	4+
Full-time study period	4 years	3 years	5~8 years for a PhD	3-5 years for a PhD

*Postgraduate courses offered by various colleges of the university (outside their cultivation program) can be counted as professional elective courses of their major.

**Postgraduate courses offered by Professional courses of master's courses and various colleges of the university (outside their cultivation program) can be counted as doctoral credits.

Postgraduate training in safety science and engineering was first offered the fire safety engineering courses in 1998. The programme covers four major research directions, namely, Fire Dynamics, Key technology of fire prevention, Theory and methodology of fire safety engineering, and Theory and methodology of public safety and emergency management. In recent years, USTC further offers courses in Public Safety, such as emergency planning, emergency decision-making, and human evacuation.

Postgraduate education can be classified into (1) the master programme (35-credit), (2) the integrated program of master-doctor (45-credit), and (3) the regular doctoral program (12-credit) [47]. The postgraduate programme admitted about 60 students per year in the early 2010s, and the intake number has further increased to 97 since 2020. To enter the postgraduate programme, students can be recommended by their undergraduate school (i.e. enrolled without national examination) or take the national college entrance examinations. By the end of the second year, about 50~65% of students will be transferred to the doctoral programme, after passing the doctoral qualification assessment. The normal study period for a PhD is 5~8 years in total. The remaining students belong to the master training mode to apply for graduation in their third year. Only a limited number of master's graduates from some other university can enter SKLFS for the PhD degree (3 from the average of 2019-2021), and there are also a small number of part-time PhD students every year.

Table 5 presents all fire safety-related compulsory courses and elective courses to be served students' multiple learning needs in various fire safety research. The all course table of the postgraduate programme can be found in Table S5. Postgraduate courses that those students take outside their cultivation program can be counted as professional elective courses of their major. There are also either-or (pick one of two) compulsory courses, like *Public Safety* [3'] or *Safety Culture Studies* [3'], *Fundamentals of Smart and Safe Materials* [3'] or *Numerical Methods for Safety Engineering* [3'], to apply for the doctorate.

The thesis research is conducted throughout the entire postgraduate training. The research proposal should be completed within the third or fourth semester of the master's education or at the end of the second or beginning of the third semester after entering the doctoral programme. The mid-term inspection for doctoral students should be carried out one year after the research proposal approval. The pre-defence of the dissertation of doctoral students is a necessary part of post-graduate education and is organized by its degree program in March and September every year. The same review group consisting of at least five academics (including at least three full professors who have previous PhD supervision experience) will check the research proposal, mid-term inspection, and pre-defence processes. Finally, PhD candidates need to pass the final thesis oral exam hosted by 5 external examiners.

For awarding an MSc degree, the student needs to publish one research paper in the 'Core Journals of China'. For awarding a PhD degree, the candidate needs to publish at least one paper in JCR Q1/Q2 journals [48], or two papers in JCR Q3/Q4 journals (or journals in Engineering Index (EI)). The postgraduates (MSc and PhD) are awarded in *Engineering Thermophysics* before 2001, *Safety Technology and Engineering* from 2001 to 2012, and *Safety Science and Engineering* from 2012 until now.

The majority of master graduates from USTC will work as professional engineers in the fire safety area, such as government departments, facility management companies, and engineering consulting companies. Doctoral graduates will more likely be engaged in the interdisciplinary fields related to fire safety engineering

in colleges or research institutes.

4.2. China University of Mining and Technology (CUMT)

The predecessor of the China University of Mining and Technology (CUMT) was the Jiaozuo School of Railroad and Mines founded by Peking Syndicate Limited in 1909, and it was renamed the China Institute of Mining and Technology in 1950. It becomes the first mining institution of higher education and enjoys a high reputation in the areas of mine construction, work safety, ecological restoration, and management engineering relating to exploration, development, and utilization of coal energy. CUMT also established the CUMT-Beijing Campus in 1997, which stated its independent operation under the name of China University of Mining and Technology-Beijing in 2003.

Currently, education in Fire Safety is mainly offered by the School of Safety Engineering (see <http://safe.cumt.edu.cn/main.htm>), which grew out of the mine ventilation and safety research of the coal mining department at Beijing Institute of Mining and Technology founded in 1952. Based on the discipline of safety science and engineering, the School of Safety Engineering was formally established in Nov 2007. They offer fire safety-related courses for BEng, MSc, and PhD degrees.

Currently, there are three undergraduate degree programs (4 years, full-time, BEng) that are related to the fire safety engineering discipline, (1) BEng in Safety Engineering, (2) BEng in Fire Protection Engineering, (3) BEng in Occupational Health Engineering, which can date back to 1982, 2001, and 2020, respectively. In 2007, about 120 students were admitted from secondary school with 60 safety engineers and 60 fire protection engineers, while about 180 students with 150 safety engineers and 30 fire protection engineers in 2013. Since 2017, these undergraduate programmes were all enrolled in the major categories of safety science and engineering discipline. These relevant majors are admitted through voluntary choice after the students have completed the general courses at the end of the second year of study. The school recommends that no more than 120 people in the safety engineering of mine safety, no more than 35 people in the safety engineering in industrial safety, no more than 39 people in fire protection engineering, and no more than 30 people in occupational health engineering. In 2022, about 190 students were admitted to the undergraduate programme from secondary school, and 95, 35, 38, and 22 were admitted to safety engineering of mine safety, safety engineering of industrial safety, fire protection engineering, and occupational health engineering, respectively. The student quota for all the bachelor's programmes is 176.5.

1) BEng in safety engineering courses was first offered by the mine ventilation and safety sub-discipline, which was set up in 1982 and renamed safety engineering in 1994 [49]. It recognized as the major for Educating Excellent Engineers for the 21st Century World since 2013. Engineering education professional certification is passed and implemented in 2015 and 2018 (three-year validity). This programme covers three main course modules, namely, mine safety, industrial safety, and emergency technology and management. Fire safety is part of the discipline of mine and industrial safety. Subjects related to fire safety engineering include a 3-credit compulsory combustion fundamental course and a 3-credit elective course, like mine fire for mine safety, and fire protection for industrial safety in [Table 6](#).

Table 6. All fire safety-related courses in undergraduate and postgraduate Safety Engineering in CUMT where the normal subject has 2 credits [2'] if not specified, and each unit is 16 hours of lecture, seminar, lab, and tutorial activities.

Program	BEng			MSc		PhD in Safety Science and Engineering	
	Safety Engineering	Fire Protection Engineering	Occupational Health Engineering	Safety Science and Engineering (Academic)	Resources and Environment (Professional)	bachelor-to-doctorate	doctoral training
Department	School of Safety Engineering						
Student No. per year[#]	Mine & Industrial Safety (120- & 35-)	39-	30-	120		12	
Courses in fire safety	Year 3 Combustion Theory [3'], Mine fire prevention and control (elective) for mine safety, and Fire Protection Engineering [3'] (elective) for industrial safety	Year 3: Combustion Theory [3'], Fire Dynamics [3'], Fire Protection Engineering of Buildings [3'], Fire-resistant Design of Building Structure [2'], Water Fire-extinguishing Engineering [3'], Smoke Prevention and Exhaust Engineering of Building, Automatic Fire Alarm and Linkage Control [2'], Electrical Fire Protection, Fire Regulations, Fire Investigation, Fire Rescue Technology and Equipment (elective), Modern Fire-extinguishing Technology (elective), Fire Risk Assessment and Insurance (elective), Fire and Explosion of Chemical and Hazardous Chemicals (elective), Urban Public Safety and Fire Planning [1.5'] (elective), Introduction to Smart Fire Protection [1.5'] (elective), Fire Numerical Simulation [1'] (elective), Building Fire Hazard Investigation (elective), Course Design of Fire Protection Engineering of Buildings [1'], Course Design of Water Fire-extinguishing Engineering [1'], Course Design of Smoke Prevention and Exhaust Engineering of Building [1'], Course Design of Automatic Fire Alarm and Linkage Control [1']	/	Compulsory Subjects: /	Compulsory Subjects: /	Compulsory Subjects: /	Compulsory Subjects: /
	Year 4 Fire Numerical Simulation [1'] (elective)	Year 4: Fire Protection of Underground Engineering (elective), Performance-based Fire Protection Design Building (elective), Fire Engineering Construction and Management [2'] (elective), Fire Facility Construction and Inspection [3'] (elective), New Energy Firefighting Technology and Management (elective), Ship and Offshore Platform Firefighting Engineering (elective), Nuclear Power Plant Firefighting Engineering (elective), Forest Firefighting Engineering (elective), Case Analysis of Building Firefighting [3'] (elective), Fire Smoke detection and Analysis (elective)	0	Core Elective Subjects: Mine Fires [1'], Building Fire Prevention [1'], Fire Dynamics, Emergency Rescue and Management [1']	Core Elective Subjects: Fire Protection Engineering Practice in Underground Engineering [1'], Mine Fire Prevention Technology and Engineering Practice [1'], Emergency Rescue and Management Case Analysis [1']	Core Elective Subjects: Fire Protection Engineering Practice in Underground Engineering [1'], Mine Fire Prevention Technology and Engineering Practice [1'], Emergency Rescue and Management Case Analysis [1']	Core Elective Subjects: Fire Protection Engineering Practice in Underground Engineering [1'], Mine Fire Prevention Technology and Engineering Practice [1'], Emergency Rescue and Management Case Analysis [1']
Total Credits	3 +3/4 elective	28+10.5 elective	0	6+ (elective)	8+ (elective)	8+	2+
Full-time study period		4 years		3~4 years	2~3 years	5-7 years	4-6 years

2) The second BEng programme in Fire Protection Engineering started to enrol the undergraduate in 2001 and engaged in the fire protection of buildings and urban underground spaces (see more in [Table S6](#)). The programme offers fire safety-related professional courses, containing 9 compulsory subjects (24-credit) and required 5.5-credit from six elective subjects in [Table 6](#). There are some extended courses to underground engineering, forest fire engineering, and firefighting engineering of new energy, nuclear power plant, ship and offshore platform, etc. A minimum of 5 credits (elective) is required to further broaden the students' professional skills and technical knowledge. Four building fire safety designs always will be conducted in Year 3. It is a group project in which students are required to design the fire safety facilities of the buildings or urban underground spaces, guided by supervisors from the university and industry.

3) The third BEng programme in Occupational Health Engineering is started in 2020 and engaged in recognizing, evaluating, and controlling occupational disease and injury in the workplace. The programme offers 22.5-credit compulsory courses and 13.5-credit elective courses to cover three main disciplines, occupational health, occupational medicine, and occupational safety. The health effects of exposures related to firefighting have been a major interest of occupational health investigators. Until now, no fire-related occupational health course has been established.

In Year 4, students will conduct an 11-credit individual *Graduation Design* Project with an academic supervisor for one semester. About 30% of students will choose research topics related to fire dynamics, fire modelling, or performance-based fire protection, guided by professors in coal mine fire prevention and fire safety disciplines.

In terms of postgraduate education, the School of Safety Engineering has offered a Master of Engineering in *Safety Technology and Engineering* since 1986, upgraded to *Safety Science and Engineering* in 2011 based on the 2011 version of the *Discipline Catalogue of Academic Degree Awarding and Talent Training* [50]. About 120 students per year were admitted into the master's programme in recent years, which includes academic and professional masters awarded in Safety Science and Engineering or Resources and Environment, respectively, with about a three-year study period. About 12 students per year have been admitted into the doctoral programme in recent years. Relying on the *National Engineering Research Center for Coal Gas Control*, *Key Laboratory of Gas and Fire Control for Coal Mines*, *Jiangsu Key Laboratory of Fire Safety in Urban Underground Space*, and *National Professional Center Laboratory of Basic Research of Mine Gas and Dust Control Technology*, the programme covers eight research topics:

- (1) Underground Space Ventilation and Air Conditioning,
- (2) Coal and Rock Dynamics and Coal-gas Control,
- (3) Fire and Explosion,
- (4) Safety Monitoring and Control,
- (5) Dust Control and Occupational Health,
- (6) Urban Public Safety,
- (7) Emergency Rescue and Safety Management,
- (8) Fire Safety Engineering.

The academic graduates will be awarded an MSc or PhD in Safety Science and Engineering, after

completing 33 (22+ course study) or 27 (13+ course study) credits, respectively, while professional graduates awarded an MSc in Resources and Environment, after completing 45 (24+ course study) credits. Research and professional masters, and PhD in Safety Science and Engineering all offer fire-related elective courses, on building, mine, underground or chemistry fire prevention and emergency rescue, as shown in Table 6.

In recent years, about 10% of students will conduct their thesis in fire safety areas, depending on professors' research interests and funding situation. The research proposal needs to be completed within the third semester of the master's or doctoral education. The mid-term inspection for doctoral students should be carried out two times within the sixth semester. The blind peer review system is a necessary part of PhD dissertations in March and September every year. The same review group consisting of at least three doctoral supervisors will track and check the research proposal and mid-term inspection. Finally, the PhD candidate needs to pass the final thesis defence hosted by five external examiners. There is no extra-scientific paper required for the award of MSc and PhD, but the candidate needs to pass the Academic Innovation Ability Inspection and Evaluation by five external examiners ($\geq 2/3$ PhD supervisors).

The majority of master graduates will work as professional engineers in the mine safety, industrial and fire safety areas, such as government departments, facility management companies, and engineering consulting companies, while the doctoral graduates will prefer to engage in the interdisciplinary field of safety science and engineering in colleges or research institutes.

4.3. Central South University

Central South University was established through the merger of the former Hunan Medical University, Changsha Railway University, and Central South University of Technology on April 29, 2000. Here, the foundation of safety (fire) engineering and fire protection engineering back in 1956 and 2002, respectively. Safety engineering is inherited from the Central South University of Technology, with a strong accumulation in Mining and Metallurgy. Fire protection engineering is derived from the Changsha Railway University, with a powerful foundation in civil engineering and architecture. These two sub-disciplines both offer courses related to fire safety engineering in BEng, MSc, and PhD three-level academic degrees. The undergraduate admissions of these two sub-disciplines (safety engineering and fire protection engineering) belong to the category of civil and safety from secondary school.

Currently, education in *Safety Engineering* is mainly offered by the Department of Safety Science and Engineering, affiliated with the School of Resources and Safety Engineering. The safety engineering sub-discipline originates from the Department of the Mine Ventilation and Safety in 1956, and enrolled undergraduate and postgraduate students in 2003 and 1998, respectively. Each year, about 80 students are admitted to the undergraduate programme mainly from the discipline split-flow (at the end of the first year), and the graduates will be awarded the BEng degree in *Safety Engineering*. This programme aims to cultivate students who are proficient in the fundamental safety system theory, and the accident prevention and control of various fields, such as mining, metallurgy, construction, and chemical industry. Fire safety is involved in fire and explosion accidents in related fields. There are two elective courses related to fire safety focusing on combustion fundamentals and fire protection (Table 7). For individual *Graduation Design Project*, about 20%

of students will choose research topics related to fire risk assessment or modelling, guided by professors in mining or industry safety discipline. In terms of taught postgraduate education, there are five directions, namely,

- (1) Basic Theory Research of Safety Science,
- (2) Safety and Emergency Management,
- (3) Control of Geotechnical Disasters,
- (4) Environmental Safety Control of Metal Mining,
- (5) Workplace Occupational Safety and Health.

The programme admits about 50 students per year in recent years. In terms of fire-related courses of the MSc programme, 3 courses (6-credit) are required to choose from 6 discipline foundation requisites containing *Emergency Management and Rescue* [2'], and 2 courses (4-credit) are required to choose from 8 core elective subjects containing explosion theory and fire science. In recent years, about 20% of students will conduct their thesis in fire research areas, depending on the supervisor's research interests and funding situation. The PhD programme admits about five students per year, but no one has engaged in a fire-related thesis in recent years.

The education in fire safety is offered by the Department of Fire Protection Engineering, affiliated with the School of Civil Engineering. The Department of Fire Protection Engineering was established based on the *Institute of Disaster Prevention Science and Safety Technology* in 2004. Education in fire protection engineering started to enrol undergraduate and postgraduate students in 2004 and 2002, respectively. CSU is currently the only college that includes three levels of undergraduate, master's, and doctoral education in Fire Protection Engineering in China.

Each year, about 60 students are admitted to the undergraduate programme, mainly from the discipline split-flow (at the end of the first year), and the graduates will be awarded a BEng degree in *Fire Protection Engineering* after completing 180 credits. The BEng course (see more in [Table S7](#)) consists of three modules, i.e., the basic module of fire science, engineering design and safety knowledge, the technology module of fire protection engineering, and the expansion module of fire protection knowledge.

1) The basic module mainly contains compulsory courses like thermal and fluid science and engineering design.

2) The technology module of fire protection engineering contains compulsory courses, on the fire safety design, maintenance and management of the building, and elective courses on fire protection engineering of equipment and construction.

3) The expansion module of fire protection knowledge mainly contains elective courses, on city fire planning, intelligent building, structure fire-resistant design, flame-retardant technology, forest Fire, electrical fire, fire risk assessment, and fire insurance.

There are some courses like *Structural Mechanics*, *Design Principles of Concrete Structures*, *Housing Architecture*, *Urban Fire Planning*, etc. to further strengthen the basic theories and technical principles of fire prevention and control in civil and building structures. Course Design of four building fire safety, fire engineering budge and comprehensive experiments of building fire protection always will be conducted in Year 3. It is a group project in which students are required to design the fire safety facilities of civil, buildings or urban underground spaces, guided by supervisors from the university and industry.

Table 7. All fire safety-related courses in undergraduate and postgraduate at CSU, where the normal subject has 2 credits [2'] if not specified, and each unit is 16 hours of lecture, seminar, lab and tutorial activities.

Program	BEng in Safety Engineering	MSc in Safety Science and Engineering	PhD in Safety Science and Engineering	BEng in Fire Safety Engineering	MSc in Fire Safety Engineering	PhD in Fire Safety Engineering
Department	Department of Safety Science and Engineering, School of Resources and Safety Engineering			Department of Fire Protection Engineering, School of Civil Engineering		
Student No. per year [#]	80	50	5	60	25-30	3
Courses in fire safety	Year 3 Combustion and Explosion Theory [2.5'] (elective) Year 4 Fire Protection Engineering [1'] (elective)	Compulsory Subjects: / Core Elective Subjects: Explosion Safety Theory, Fire Science, Emergency Management and Rescue	/ Year 2 Fire-Control law and Regulations Year 3 Combustion Science [3'], Comprehensive Experiments of Combustion [1'], Principle of Building Fire Safety Design [3'], Fire Protection, Water Supply and Drainage Engineering Design [3'], Smoke Prevention Project [2.5'], Fire Alarm and Linkage Control [3'], Fire Protection Engineering Budget, Design of Smoke Prevention and Control Engineering [1'], Course Design of Fire Alarm and Linkage Control [1'], Course Design of Fire Engineering Budget [1'], Course Design of Building Fire Protection Design [1'], Course Design of Fire Protection, Water Supply and Drainage Engineering [1'], Course Comprehensive Experiments of Building Fire Protection [0.5'], Production Practice of Fire Engineering [3'], Fire Protection Equipment and Technology (elective), Construction Technology of Fire Protection Engineering (elective), Introduction to Intelligent Building (elective), Fire Investigation (elective) Year 4 Fire Numerical Simulation Technology, Computer Practice of Fire Numerical Simulation Technology [1'], Comprehensive Experiments of Building Fire Automation [0.5'], Electrical Fire Prevention Technology (elective), Fire Risk Assessment and Insurance (elective), City Fire Planning [1.5'] (elective), Forest Fire [1.5'] (elective), Flame-Retardant Materials and Technology [1.5'] (elective), Principles of Structure Fire Resistant Design (elective), Intelligent Fire Protection [1.5'] (elective)	Year 2 Fire-Control law and Regulations Year 3 Combustion Science [3'], Comprehensive Experiments of Combustion [1'], Principle of Building Fire Safety Design [3'], Fire Protection, Water Supply and Drainage Engineering Design [3'], Smoke Prevention Project [2.5'], Fire Alarm and Linkage Control [3'], Fire Protection Engineering Budget, Design of Smoke Prevention and Control Engineering [1'], Course Design of Fire Alarm and Linkage Control [1'], Course Design of Fire Engineering Budget [1'], Course Design of Building Fire Protection Design [1'], Course Design of Fire Protection, Water Supply and Drainage Engineering [1'], Course Comprehensive Experiments of Building Fire Protection [0.5'], Production Practice of Fire Engineering [3'], Fire Protection Equipment and Technology (elective), Construction Technology of Fire Protection Engineering (elective), Introduction to Intelligent Building (elective), Fire Investigation (elective) Year 4 Fire Numerical Simulation Technology, Computer Practice of Fire Numerical Simulation Technology [1'], Comprehensive Experiments of Building Fire Automation [0.5'], Electrical Fire Prevention Technology (elective), Fire Risk Assessment and Insurance (elective), City Fire Planning [1.5'] (elective), Forest Fire [1.5'] (elective), Flame-Retardant Materials and Technology [1.5'] (elective), Principles of Structure Fire Resistant Design (elective), Intelligent Fire Protection [1.5'] (elective)	Compulsory Subjects: Computational Fluid Dynamics, Frontier of Fire Protection Engineering, Disaster Prevention and Mitigation Engineering, Advanced Combustion, Numerical Heat Transfer, Principle and Application of Engineering Thermodynamics, Structural Analysis and Design for Fire, and Safety Engineering Principle; Core Elective Subjects: Fire-retardant and Fire-extinguishing Technologies, Fire Dynamics, Fire Protection Assessment Technology, Safety and Fire Protection for Intelligent City, Structural Fire Engineering-Theory and Application, and Ventilation Engineering	
Total Credits	0 +3.5 elective	0+6 elective	0	31.5+ 19.5+ (elective)	14+4 (elective)	4+4 (elective)
Full-time study period	4 years	3-5 years	4-6 years	4 years	3-5 years	4-6 years

In senior year, students will conduct a 16-credit individual *Graduation Design* Project with an academic supervisor for 1 semester. 100% of students will choose research topics, such as fire designs (fire protection design, smoke prevention and exhaust system design, fire extinguishing system design, automatic fire alarm system design) in architecture, tunnels and underground spaces, and special research on performance-based fire protection design, guided by professors in disaster prevention and mitigation in civil engineering.

In terms of postgraduate education, the *Institute of Disaster Prevention Science and Safety Technology* has offered a self-determined degree-conferring program in a master's and doctoral degree in *Fire Protection Engineering* since 2002, which is a 2nd-level sub-discipline under the first-level civil engineering discipline. About 25-30 students per year are admitted into the master's programme in recent years, including academic and professional destination masters with a three-year study period. The doctoral programme admits about three students per year in recent years. The graduates will be awarded an MSc or PhD in *Fire Protection Engineering*, after completing 26 or 16 credits, respectively. The programme covers four research topics, the fire spread mechanism and prevention and control technology for tunnel and underground space fires, structure fire technology for major projects, fire-extinguishing theory and key technology of new fire-extinguishing agents and equipment, and big data-based smart fire fighting and major disaster early-warning technology.

MSc and PhD in *Fire Protection Engineering* offer compulsory courses, containing discipline foundation requisites on computational fluid, combustion, and disaster prevention and mitigation, and major courses on fire structural analysis and design or thermodynamics and safety principles. And the elective courses are offered on fire protection applied to fire-retardant and fire-extinguishing, structural building, and intelligent city. MSc and PhD in *Fire Protection Engineering* require a total of 26-credit, 10-credit discipline foundation requisites, 4-major courses, 4-credit elective subjects; and a total of 19-credit, 4-credit discipline foundation requisites, 2-major courses, 4-credit elective subjects, respectively.

The research proposal needs to be completed within the third or fourth semester of the master's or doctoral's education. The mid-term inspection for doctoral students should be carried out one year after the research proposal approval. The blind peer review system is a necessary part of PhD dissertations in March and September every year. The same review group consisting of at least five persons (including at least three doctoral supervisors with senior professional titles) will track and check the research proposal and mid-term inspection. Finally, the PhD candidate needs to pass the final thesis defence hosted by five external examiners. One EI/SCI paper or one patent (invention) is required for the award of MSc. For a PhD student, three SCI-indexed papers, or two SCI-indexed papers plus two EI-indexed papers, or one SCI-indexed paper and two patents (invention) are required.

The majority of master's graduates will work as professional engineers in the fire protection area, such as government departments, facility management companies, and engineering consulting companies, while the doctoral graduates will prefer to engage in the interdisciplinary field of fire protection engineering in colleges or research institutes.

4.4. Nanjing Tech University

Nanjing Tech University started to offer courses and programmes on safety engineering and fire protection

engineering back in 1990 and 2002, respectively. Nanjing Tech was built by the combination of Nanjing University of Chemical Technology and Nanjing Institute of Architecture and Civil Engineering in 2001. Compared to the other higher education in Fire Safety, there are two major differences,

- (1) Due to the strong background in chemical technology and rapid industrialization in the Jiangsu region, the programmes and courses at Nanjing Tech focus on industrial fire protection and emergency rescue.
- (2) The programmes offer unique advantages for the integration of production and education, aiming to support the application-oriented senior engineering that could break the gap between innovation education and practical use of knowledge. Professional technical personnel can engage in safety engineering (especially chemical process safety), safety supervision, and management to serve regional economic and social development.

In Nanjing Tech, the education in Fire Safety Area is mainly offered by the College of safety science and engineering (see http://cces.Nanjing_Tech.edu.cn/index.htm), which was renamed the School of Urban Construction & Safety Engineering in 2015. They offer fire engineering courses in BEng, MSc, and PhD three-level academic degrees. Currently, there are two undergraduate degree programs (4 years, full-time, BEng) that cover the fire safety sub-discipline, (1) BEng in Safety Engineering and (2) BEng in Fire Protection Engineering. The student quota of the bachelor's programme is 170. All courses in different programmes are summarised in [Table S8](#).

BEng in Safety Engineering first offered safety engineering courses in specialist qualification in 1990, and established an undergraduate engineering program in 1994. It has been recognized as the major for Educating Excellent Engineers for the 21st Century since 2011. Engineering education professional certification is passed and implemented in 2014 and 2020 (six-year validity). Thus, the graduates of this programme will be exempt from *Fundamentals of Safety Production Technology*, when they later apply for the CSEs. From 2015, about 150 students will be admitted to this programme from secondary school, with about 30 students (1994~) and 60 students (~2014).

This programme mainly focuses on industrial safety, including (but not limited to) industrial fire. It covers four main directions, namely, fundamental safety system theory, safety design, risk analysis, and safety management of the chemical industry. Subjects related to fire safety in [Table 8](#), include the fundamental combustion, and the fire safety of feedstock, reactor and chemical equipment. To improve the ability of students' engineering practice, some courses like accident investigation, safety assessment, and electrical safety were taught by off-campus part-time adjuncts with practical experience to enrich the engineering education.

The students will do three subjects' course design in *Safety Assessment* [2'], *Safety Design of Chemical Process* [2'], and *Ventilation, and Dust Cancellation in Industry* [2'] in Semester 1 of Year 4. It is a group project in that students are required to design the fire safety facilities or assess the fire and explosion of hazardous chemicals, guided by supervisors from the university and industry. In Year 4, students will conduct a 12-credit individual *Graduation Design Project* with an academic supervisor for two semesters. About 30% of students will choose research topics related to performance-based fire protection of a chemical process, guided by professors in the industrial safety discipline.

The second BEng programme in Fire Protection Engineering is a relatively new program, started in 2002 and motivated by the severe fire hazards with the economy booming and the increasing fuel demands of industries. About 60 students will be admitted to this programme from secondary school from 2014, and about 30 students were admitted from 2002 to 2013. The programme aims to clarify the fire dynamics and fundamentals of fire protection from “why do fires happen”, “how do fires grow” and “what can be done to prevent fires”. The programme offers 39-credit compulsory courses and 17-credit elective courses to cover three main disciplines, building fire protection design, industrial fire protection design, and fireproofing of structural engineering (see more in [Table S8](#)). All fire safety-related compulsory and elective courses have been summarised in [Table 8](#).

The students will be required to complete four building fire safety designs and architecture foundation designs in Year 3~4. It is a group project in which students are required to design the fire safety facilities of the buildings or industrial plants, guided by supervisors from the university and industry. In Year 4, students will conduct a 13-credit individual *Graduation Design Project* with an academic supervisor for 2 semesters. About 100% of students will choose research topics related to fire dynamics, fire modelling, or performance-based fire protection, guided by professors in fire safety and industrial fire safety disciplines.

Table 8. All fire safety-related courses in undergraduate and postgraduate of Nanjing Tech, where the normal subject has 2 credits [2'] if not specified, and each unit is 16 hours of lecture, seminar, lab, and tutorial activities.

Program	BEng		MSc		PhD
	Safety Engineering	Fire Protection Engineering	Safety Science and Engineering (Academic master)	Resources and Environment (Professional master)	Safety Science and Engineering
Department	College of Safety Science and Engineering				
Student No. per year[#]	150	60	20	100	10+5 (Joint Training with University of Surrey)
Courses in fire safety	Year 2 Security Technology of Dangerous Chemicals	Year 2 Fire Management, Industrial Fire Safety (elective), System Safety Engineering (elective)	Compulsory Subjects: /	Compulsory Subjects: /	Compulsory Subjects: /
	Year 3 Combustion & Explosion Theory [3'], Chemical Process Safety, Safety Design of Chemical Process	Year 3 Combustion Theory [3'], Fire Dynamics [3'], Building Fireproof Engineering, Smoke Control Engineering, Water Supply System of Fire Protection [3'], Fire detection Technology, Performance-Based Design of Fire Engineering, Fire Investigation [3'] (elective), Theory and Practice of Fire Engineering Budget [3'] (elective), Installation and Acceptance of Fire Protection Systems (elective), Building Construction and Safety Management (elective), Disaster Psychology (elective), Public Health Emergency Management (elective), Advances in Fire Science [1'] (elective), Architecture Technology Foundation Design [1'], Design on Fire Protection Engineering of Buildings [1']	Core Elective Subjects: Safety Design of Building Fireproof [1'], Combustion & Explosion Theory and its Progress [1'], Fire Simulation [1'], Flame Retarding and Fire Suppression Technologies [1']	Core Elective Subjects: Safety Design of Building Fireproof [1'], Flame Retarding and Fire Suppression Technologies [1']	Core Elective Subjects: /
	Year 4 Course Design of Safety Assessment, Course Design of Safety Design of Chemical Process, and Ventilation, and Course Design of Dust Cancellation in Industry	Year 4 Experiments of Fire Engineering [3'], Fire Risk Assessment (elective), Flame Retardant Material & Technology (elective); Artificial Intelligence in Data Mining: Theory and Applications (elective), Design on Smoke Prevention and Exhaust Engineering of Buildings [1'], Design on Water Fire-extinguishing Engineering [1'], and Design on Automatic Fire Alarm and Linkage Control			
Total Credits	9 +0 elective	29+17 elective	0+4 (elective)	0+2 (elective)	0+0
Full-time study period		4 years	3~5 years	3~5 years	4-8 years

In terms of taught postgraduate education, the College of safety science and engineering has offered a Master of Engineering in *Safety Technology and Engineering* since 1998, upgraded to *Safety Science and Engineering* in 2011 based on the 2011 version of the *Discipline Catalogue of Academic Degree Awarding and Talent Training* [50]. The programme admitted about 25-30 students per year in the early 2010s, and the annual intake number increased to 120 in recent years, which includes academic and professional destination masters with about a three-year study period. Relying on the four Provincial and Ministerial Key Laboratories (*Jiangsu Key Laboratory of Urban and Industrial Safety*, *Jiangsu Key Laboratory of Intrinsically Safe Technology of Hazardous Chemicals*, *Key Laboratory on Chemical Process Safety Control of China Petroleum and Chemical Industry Federation*, and *Key Laboratory of Chemical Process Safety Production of the MEM*) under the College of safety science and engineering, the programme covers five disciplines, namely,

- (1) fire and explosion hazard and disaster prevention technology,
- (2) hazardous chemicals and chemical process safety,
- (3) safety monitoring and hazard detection techniques,
- (4) theory for evaluating occupational safety and health risks,
- (5) public safety and emergency management of major accidents.

Currently, the research is mainly engaged in new energy, industrial, urban, and wildland fire prevention from the perspective of fire and explosion accidents.

The student quota of the postgraduate programme is 28 (academic master) and 32 (professional master). The fire safety-related courses of the academic and professional master's are involved in 4-credit and 2-credit elective courses in Table 8, respectively. Professional masters should take a 6-credit professional practice than academic masters. Every student should take the graduate dissertation to conduct the research under the guidance of a faculty member, and about 50% of students will choose a fire-related dissertation, *e.g.*, hydrogen, battery, building, or wildland fire. Before getting MSc, the student needs to publish one EI/SCI paper, or one (invention) patent, or two (model utility) patents.

Nanjing Tech has also offered Doctoral programmes in safety science and engineering since 2003 and upgraded to safety technology and engineering in 2011, the same as the master's degree. The programme admitted ~10 students per year and additionally added 5 Joint Training of Doctoral Students with the University of Surrey in 2020. A total 12-credit is required, and there is no fire safety-related course in the course setting list. In recent years, about 3-5 new PhD students will conduct their thesis in fire research areas, depending on professors' research interests and funding situation. The normal study period of a full-time PhD student is 3 ~ 4 years. The PhD student has implemented a process assessment, which contains the opening report, mid-term check, and final thesis defences. The mid-term confirmation exam is required to be hosted by three internal examiners before half-time of their normal study period. Finally, the PhD candidate needs to pass the final thesis oral exam hosted by five external examiners, plus publishing at least one JCR Q1/Q2 paper [48], or two JCR Q3 papers, or four JCR Q4 papers.

4.5. China People's Police University (CPPU)

The predecessor of China People's Police University (CPPU) was the Chinese People's Armed Police

Force Academy (CPAPA) founded in April 1981. CPPU is subordinate to the MPS and mainly undertakes the education and training of commanders or officers for border control, fire control, very important person protection, and UN (United Nations) peacekeeping operations. Compared to the other higher education in Fire Safety engineering, there are two major differences,

- (1) CPPU serves the needs of the national security strategy to train professional firefighters rather than engineers. Its development is mainly subject to Chinese fire protection regulations, standards, and systems.
- (2) The graduates not only master the knowledge of fire protection but also have strong combat operations in fire control and fire fighting.

They offer fire-related courses in BEng and MSc degrees, back in 1985 and 2003, respectively. There are three important inter-departmental adjustments during the development of higher education in Fire Protection Engineering at CPPU.

1) In 1985, the Armed Police Headquarters merged the fire department of Langfang Armed Police College into Xi'an Armed Police Technical College to establish the department of Fire Management and the Department of Fire Protection Engineering. Department of Fire Management has recruited serving cadres (two-year college degree) and outstanding soldiers (three-year college degree) within the army to train the cadres that are good at fire command and management. The Department of Fire Protection Engineering has enrolled a four-year undergraduate from secondary school to train professional and technical personnel in fire protection.

2) The above two fire-related departments in Xi'an Armed Police Technical College were re-introduced to CPAPA, and its department of Fire Management was renamed the department of Fire Command with two three-year college sub-discipline, Fire Fighting Command and Fire Management. The department of Fire Protection Engineering consists of four four-year undergraduate majors, namely, Fire Cause Identification, Fire Extinguishing Technology, Fire Prevention Engineering and Information Engineering. It enrolled about 200 undergraduate students and 100 college students every year. Since 1999, the enrollment of junior college students has been expanded, and the technical secondary school degree in domestic fire protection has been gradually cancelled. The number of undergraduate students in the Department of Fire Protection Engineering even peaked at 1000-2000, driven by the function of the national fire protection agency and job requirements.

3) In 2018, the fire brigades transferred their identity from "military and police" in the public security organs to "civilian" in the emergency management department. According to the transfer of the public security fire department from MPS to the newly formed MEM, the CPAPA was renamed CPPU. At the same time, the Department of Fire Protection Engineering was renamed the School of Fire Protection Engineering, including three majors, namely, Fire Protection Engineering, Fire Investigation, and Electronic Information Engineering. Then the Department of Rescue Command was renamed School of Rescue Command, including three majors, namely, Fire Command, Emergency Rescue Command and Technology, Nuclear, Biological and Chemical Fire-fighting. From then on, "the planned distribution of graduates based on the government's orders" is replaced by the "market-oriented mutual choices between graduates and employers".

Currently, about 120, 40, and 70 students are admitted to the undergraduate programme from secondary school, and the graduates will be awarded the BEng degree in Fire Protection Engineering, Fire Investigation,

and Electronic and Information Engineering (Smart Firefighting), after completing 182-credit (161-credit in-class teaching and 21-credit extra-curricular practice).

The undergraduate professional courses of Fire Protection Engineering (see more in [Table S9](#)) contain the 58-credit fire-related compulsory courses and 6-credit elective courses in [Table 9](#). It educates the students to use their expertise to help groups or organizations diagnose fire risks and set up safety precaution plans. The undergraduate professional courses in Fire Investigation contain 42-credit fire-related compulsory courses and 6-credit elective courses. Fire Investigation aims to train the ability to solve analytical problems combined with a background in engineering and firefighting. The undergraduate professional courses in Electronic and Information Engineering (Smart Firefighting) contain the 7-credit fire-related compulsory courses. It focuses on the proper analysis of smart-fire data based on artificial intelligence to deliver information and a real-time monitor of the evolution of fire environments and hazards. It is noticeable that there are many experimental or practical training for live firefighting and fire rescue.

Table 9. All fire safety-related courses in undergraduate and postgraduate of CPPU, where the normal subject has 2 credits [2'] if not specified, and each unit is 16 hours of lecture, seminar, lab, and tutorial activities.

Program	BEng in Fire Protection Engineering		Electronic and Information Engineering (Smart Firefighting)	MSc
	Fire Protection Engineering	Fire Investigation		Safety Science and Engineering
Department	School of Fire Protection Engineering			
Student No. per year [#]	~ 120	~ 40	~ 70	40-50
Courses in fire safety	Year 2 Safety Systems Engineering (33% practice) [3'], Housing Architecture (25% practice) [4']	Year 2 Fire Protection Engineering (25% practice) [4'], Building Firefighting Installation (17% practice) [3']	Year 3 Fire Protection Engineering (13% practice) [4'], English for Smart Fire	Compulsory Subjects: Fundamentals of Fire Phenomena, Risk Assessment: Theory and Methods, Numerical Simulation of Fire Processes, Safety and Emergency Management, Frontiers of Safety Science and Technology
	Year 3 Combustion Fundamentals of Fires [4'], Fire and Rescue Technology Training (100% practice), Firefighting Strategies and Tactics (33% practice), Fire Investigation (33% practice), Thermodynamics and Heat Transfer [3'], Building Firefighting Installation [3'], Practical Training of Building Firefighting Installation (50% practice) [1'], Smoke Management Systems in Building, Fire Risk Assessment (25% practice), Chemical Safety Technology Engineering (25% practice) [3'], Electrical Control Technology of Fire (42% practice) [3'], Fire Protection of Hazardous Chemicals (25% practice), Fire Regulation (25% practice) [4'], English for Fire Engineering, Burning Behavior and Evaluation of materials (elective), Safe Evacuation (25% practice) (elective), Fire Numerical Simulation (75% practice) (elective), Fire Insurance (elective)	Year 3 Combustion Fundamentals of Fires (19% practice) [4'], Fire and Rescue Technology Training (100% practice), Firefighting Strategies and Tactics (25% practice), Fire Evidence, Fire Investigation (29% practice) [3.5'], Fire Evidence Identification (25% practice) [4'], Fire Patterns (25% practice) [4'], Fire Image Technology (43% practice) [3.5'], Analysis and Identification of Special Fire (37.5% practice) [4']. Fire Risk Assessment (25% practice) (elective), Case Study of Fire Investigation (elective), Disaster scene rescue technology (elective)	Year 4 Application Development and Practice of Smart fire (100% practice) [1']	Core Elective Subjects: Special Fire Protection Design and Assessment, Detonics, Theoretical Model and Application of Safe Evacuation, Study on Building Fire Protection Code, Fire Extinguishing Technology and Engineering, Smoke Prevention and Exhaust Engineering, Monitoring Technology of Smart fire Fighting, Planning and Design of Smart fire Fighting, Industrial Fire Prevention and Control, Public Fire Management, Study on Public Fire Policy
	Year 4 Building Fire Protection (50% practice) [4'], Industrial Fire Protection (25% practice) [4'], Electrical Fire Protection and Fire Controlling System (25% practice) [4'], Fire Management (25% practice) [4'], Smart Fire Fighting (elective), Fire Patterns (elective)	Year 4 Fire Management, Industrial Fire and Explosion Mechanisms, English for Fire Investigation, Rescue Technology of Chemical Accident (elective), Firefighting & Rescue Command (elective)		
	Total Credits	42+6 elective	7+0 elective	10+6 (elective)
Full-time study period	58+6 elective	4 years		3 years

Professional and simulated laboratories with unique CPAPA features, such as *National Simulated Virtual Experiment & Teaching Center for Fire Control*, *MPS Key Laboratory for Fire Fighting & Rescue Techniques*, and *Material Evidence Identification Center for Fire Accident* are established to assume the practice and training of the firefighting, rescue activities, or combat training drills in fires. Standardized physical training and practical skills training in firefighting run throughout the undergraduate training cycle, but are not counted as credits. In Year 4, students will conduct a 6-credit individual *Graduation Design* Project with an academic supervisor for 12 weeks. About 100% of students will choose research topics related to performance-based fire protection of buildings and underground spaces, guided by professors in fire protection engineering.

In terms of postgraduate education, the School of Fire Protection Engineering has offered a self-determined degree-conferring program in a Master of Science in *Safety Technology and Engineering* since 2003, upgraded to *Safety Science and Engineering* in 2011. About 40-50 students per year are admitted into the master's programme in recent years with a three-year study period. The graduates will be awarded an MSc in *Safety Science and Engineering*, after completing 32 credits. This programme covers three main disciplines, namely,

- (1) Fundamentals of Fire and Explosion
- (2) Fire Safety Technology and Engineering
- (3) Safety and Emergency Management

MSc in Safety Science and Engineering offers 10-credit fire-related compulsory courses and the 6-credit elective courses in [Table 9](#).

For the thesis research, the research proposal needs to be completed within the third semester of the master's education. The mid-term inspection for master's students should be carried out during the fifth semester of the master's education. The blind peer review system is a necessary part of dissertations in March and September every year. All courses and training programs in the training plan, and the final thesis defence should be completed or passed. One journal or conference paper related is required for the award of MSc. Almost all students will conduct their thesis in practical fire protection engineering, depending on professors' research interests and funding situation. The majority of MSc will work as professional engineers in the government departments of the fire protection area.

4.6. The Hong Kong Polytechnic University (PolyU)

The Hong Kong Polytechnic University (PolyU) started to offer courses and programmes on fire (safety) engineering back in 1981 (British Colony Era). Due to historical reasons, the programmes and courses at PolyU are inherited from the UK higher-education system. Despite gaining more diverse characteristics since the handover in 1997, they are overall quite different from the higher education systems in mainland China, in terms of programme niches, course contents, and teaching modules. Nevertheless, the development trend of engineering education is similar worldwide, that is, adding more elements of labs, design and research projects, internships, and service learnings. Compared to the mainland higher education in Fire Safety, there are two major differences:

- (1) The local fire services regulations, standards, and systems in Hong Kong are different from those in the mainland because of the constitutional principle of “One Country, Two Systems”. The courses will emphasize the local regulations and practices in Hong Kong.
- (2) The programmes aim to support students’ future registration of professional engineers. The evaluation of Registered Engineer in Hong Kong is inherited from the UK chartered engineer system, which requires more accredited courses, training, working experience, and exams than the mainland. The Registered Engineers are not mutually recognized between HK and the mainland.

At PolyU, the education in Fire Safety Area is mainly offered by the Department of Building Services Engineering that is recently renamed the Department of Building Environment and Energy Engineering (BEEE) in 2021 (see <https://www.polyu.edu.hk/beee/>). PolyU offers fire engineering courses in Higher Diploma (closed in 2022), Bachelor of Engineering (BEng), Master of Engineering (MEng), Master of Science (MSc), Master of Philosophy (MPhil), and Doctor of Philosophy (PhD). All programmes are taught in English.

Currently, there are two undergraduate degree programs (4 years, full-time, BEng) that cover the fire safety engineering discipline, (1) **BEng (Honours) in Building Sciences and Engineering (BSE)** [51] and (2) **BEng (Honours) in Structural and Fire Safety Engineering (SFSE)** [52]. The first BSE BEng programme has an old name of Building Services Engineering (1981 - 2021) by following the convention of the British engineering discipline. It has been accredited by the Chartered Institution of Building Services Engineers (CIBSE), UK and the Hong Kong Institution of Engineers (HKIE) “Scheme A Graduate Training” [53] since 1989. Thus, the graduates of this programme will be recognised when they later apply for the Chartered Engineer (CIBSE) or the Registered Engineer (HKIE Building Services Division). Each year, about 30 students (freshmen) will be admitted to this programme from the secondary school, and another 30 students will be admitted in Year 3 with a Higher Diploma or an Associate Degree (i.e., senior in-take). Thus, in total 60 students graduate from this programme per year. Since 1997, this programme has also offered a 4-year part-time study mode that allows local fire practitioners with higher diploma/certificate and fire officers to upgrade their academic qualifications and become professional fire engineers [54].

This programme covers four main disciplines, namely, building environment, building energy, building facility management, and building safety. Fire safety is part of the discipline of building safety. Subjects related to fire safety engineering include *Fire Services* in Year 3 and *Fire Engineering Safety Management* in Year 4. Each subject has 3 credits, and each credit includes 13 hours of lecture, laboratory, seminar, and tutorial activities. The students will do a subject of *Building Services Systems Design* in Year 3 with 2 credits in Semester 2 and 2 credits in Summer Semester 3. It is a group project in that students are required to design the fire service systems, guided by supervisors from university and industry. In Year 4, students will conduct a 6-credit individual *Capstone Research Project* with an academic supervisor for 2 semesters. About 10 students will choose research topics related to fire dynamics and modelling, guided by professors in building safety discipline. All courses in different programmes are summarised in [Table 10](#).

Table 10. Summary of programs and courses on fire safety offered by Hong Kong Polytechnic University (PolyU), where the normal subject has 3 credits [3'] if not specified, and each unit is 13 hours of lecture, seminar, lab, and tutorial activities.

Program	BEng in Building Sciences and Engineering (BSE)	BEng in Structural and Fire Safety Engineering (SFSE)	MSc in Fire and Safety Engineering (FSE)	MEng/MSc in Building Services Engineering	MPhil and PhD
Department	BEEE	BEEE and CEE	BEEE	BEEE	BEEE
Student No. per year [#]	24 + 30	30	60	40/40	3-5
Applicant No.					
Courses in fire safety	Year 3 Fire Services Building Services Systems Design [4'] Year 4 Fire Engineering Safety Management, Fire Science (elective), Capstone Research Project [6']	Year 2 Integrated Project for Fire Engineering Year 3 Human Psychology & Physiology Year 4 Fire Science, Active Fire Protection Systems Analysis, Passive Fire Protection Systems Analysis, Ethics, Law, Regulations and Standards for Construction and Fire Safety, Structural Resilience and Fire Risk Management Design Project for Structural & Fire Engineers [4'], Project for Structural & Fire Engineering [6']	Compulsory Subjects: Fire Dynamics, Fire Engineering Systems Core Elective Subjects: Computational Fire Modelling for Building Design, Legislation Aspects of Fire Safety Management, Design Considerations for Fire Safety Management, Accident Prevention, Hazard Assessment and Control, Safety Management Systems and Safety Auditing, Dissertation [9']	Compulsory Subjects: Fire Engineering Systems Core Elective Subjects: Legislation Aspects of Fire Safety Management, Dissertation (Fire Research) [9'] *Students can take any course from MSc in FSE as elective	Elective Subjects: Fire Science and Fire Safety Engineering
Total Credits	6 - 18	34	15 - 21	0 - 15	0 or 3
Full-time study period	4 years	4 years	1 year	1 year	2 years for MPhil. 3-4 years for PhD
Accreditation	HKIE Building Services Discipline	HKIE Structural Discipline and Fire Discipline	HKIE Fire Discipline (Partial Accreditation)	HKIE Building Services Discipline (Partial Accreditation)	-

[#]Average over the last 3 years.

The second SFSE BEng programme is a new program, started in 2020 and offered jointly by the Department of Building Services Engineering (BEEE) and the Department of Civil and Environmental Engineering (CEE). The programme aims to seek full accreditation of the programme by HKIE, and graduates of this programme will then be qualified for “Scheme A Graduate Training” of both the Structural Discipline and Fire Discipline of HKIE. Because of the growing demand for Fire Engineering Professionals to face the new challenges, the HKIE Fire Discipline was established in November 2005, while the Fire Division was subsequently formed in June 2008. The SFSE BEng programme is the only programme in HK that satisfies all course requirements of HKIE Fire Discipline. The detailed course list of BEng in Structural and Fire Safety Engineering (SFSE) can be found in [Table S10](#).

The student quota of the SFSE programme is 30. Ten subjects (34 credits) related to fire safety engineering are offered, i.e., *Integrated Project for Fire Engineering* in Year 2; *Human Psychology & Physiology* in Year 3; and *Active Fire Protection Systems Analysis, Passive Fire Protection Systems Analysis, Fire Science, Design Project for Structural and Fire Engineers, Individual Project for Structural and Fire Engineering, Ethics, Law, Regulations and Standards for Construction and Fire Safety, Structural Resilience and Fire Risk Management* in Year 4. For the 4-credit Design Project and 6-credit Individual Project, 10-15 students will choose the design of fire services systems and fire research, respectively. The minimum Grade Point Average (GPA) requirement for the First-Class Honour is 3.6 out of 4.3.

In terms of taught postgraduate education, the BEEE department has offered a **Master of Science (MSc) in Fire and Safety Engineering (FSE)** since 2000 [55]. The programme admitted about 25-30 students per year in the early 2000s, and the annual intake number increased to 40 in recent years. In terms of fire-related courses, the FSE MSc programme offers two Compulsory Subjects (Fire Dynamics and Fire Engineering Systems) and another five Core Elective Subjects in fire modelling, design, safety management, and regulation. Students can choose to take the 9-credit dissertation and conduct fire research under the guidance of a faculty member, but only a small portion of students will choose the dissertation. Most of the students in this programme are part-time and from HK locals who have years of working experience and various academic backgrounds. As they have full-time jobs, most of them will take 2-3 years to complete the required courses. The normal study period for full-time students is one year. Students with a GPA of 3.6 or higher out of 4.3 will be honoured as Distinction.

Currently, the FSE MSc programme alone is insufficient to get full accreditation of the HKIE Fire Discipline. Nevertheless, most of the students have a BEng degree in Building Services Engineering, Mechanical Engineering, Fire Safety Engineering, and Civil Engineering. Thus, this MSc programme provides top-up courses for these students to satisfy the “Scheme A Graduate Training” of the HKIE Fire Discipline. The BEEE department also offers another two master's programmes, **MEng and MSc in Building Services Engineering**. The students in these programmes can also choose courses in fire safety discipline as their electives. Some master students will also choose the 9-credit dissertation in fire research, particularly for those who intend to pursue PhD in fire science and engineering areas. The majority of BEng, MSc, and MEng graduates from these programmes will work as professional engineers in the fire safety area, such as engineering consulting companies, construction contractors, real estate developers, facility management

companies, and government departments.

PolyU has offered research postgraduate programmes (MPhil and PhD) since the late 1980s before it became the university in 1994. Fire safety science and engineering is an important research area in the discipline of Building Safety and Resilience. PolyU's first Doctoral graduate in fire research is Dr Nai-Kong Fong in 1991. By 2022, more than 30 PhD and MPhil students from BEEE (BSE before 2021) Department are graduated with a thesis in fire research. The PolyU PhD student is required to take 1-2 PhD subjects from any department, and the only PhD subject on fire is *Fire Science and Fire Safety Engineering* offered by BEEE Department. In recent years, about 3-5 new PhD students will conduct their thesis in fire research areas, depending on professors' research interests and funding situation. The normal study period of a full-time MPhil student is 2 years. The normal study period of a full-time PhD student is 4 years or 3 years if the student holds an MPhil or equivalent (a postgraduate research degree with a dissertation as an award requirement). The normal study period of part-time students doubles that of the full-time programme. The PhD student is required to pass the confirmation exam hosted by two internal examiners before half-time of their normal study period, and the student can choose to change to the MPhil programme based on the suggestions from the exam committee. Finally, PhD candidate needs to pass the final thesis oral exam hosted by two external examiners. Like most of the universities in the US and Europe, there is no extra publication requirement for the award of a PhD degree.

4.7. Feature comparisons

The undergraduate course units are always divided into five-course categories, namely, general, major foundation, major core, major elective, and practical training courses. In a student's learning and development journey, the sequence of courses is from general, major foundation, major core, to major elective, interspersed with practical training. The undergraduate course units of five-course categories in Safety Engineering are summarized and compared among four presentative universities in Fig. 9. Safety Engineering in USTC provides 42% general courses and 24% major-foundation courses, which is much higher than the other three universities. It is attributed that USTC more focus on cultivating students with a solid foundation in mathematics, physics, chemistry, and engineering. It is a tradition in USTC to offer more and deeper foundation courses because most of their student will participate in research projects in their undergraduate and eventually enter postgraduate programmes in China or overseas. On the other hand, USTC provides 10% major-core courses and 8.5% major-elective courses that allow students to apply physical principles to solve practical fire-engineering problems.

Safety Engineering in USTC focuses on fire research and comprehensive education in the fire-related field. While Safety Engineering concentrates on Coal-Mining Safety in CUMT, Metal-Mine Safety in CSU, and Chemical Safety in Nanjing Tech, based on the development history and recent service application. Compared to USTC, most of the undergraduates from these universities will work in the industry as professional engineers, so more specified and practical courses are offered. From Fig. 9, the proportions of five-course categories in course units stay nearly the same. It is worth noting that fire-related major foundations are always the same courses, like *Combustion (& Explosion) theory*, *Fundamentals of Thermodynamics* and

Heat Transfer (or split into *Engineering Thermodynamic* and *Heat Transfer*), *Safety System Engineering*, etc. And the above courses are taught in Year 2 or Semester 1 of Year 3. These major foundations in various universities are inclined to choose the same textbooks, like *An introduction to combustion concepts and application* (annotated by Qiang Yao, Tsinghua University Press), *Fundamental of Thermodynamics and Heat Transfer* (compiled by Xuexue Zhang, Higher Education Press), *Combustion Theory* (compiled by Changkun Chen, China Machine Press).

Curriculum of Safety Engineering

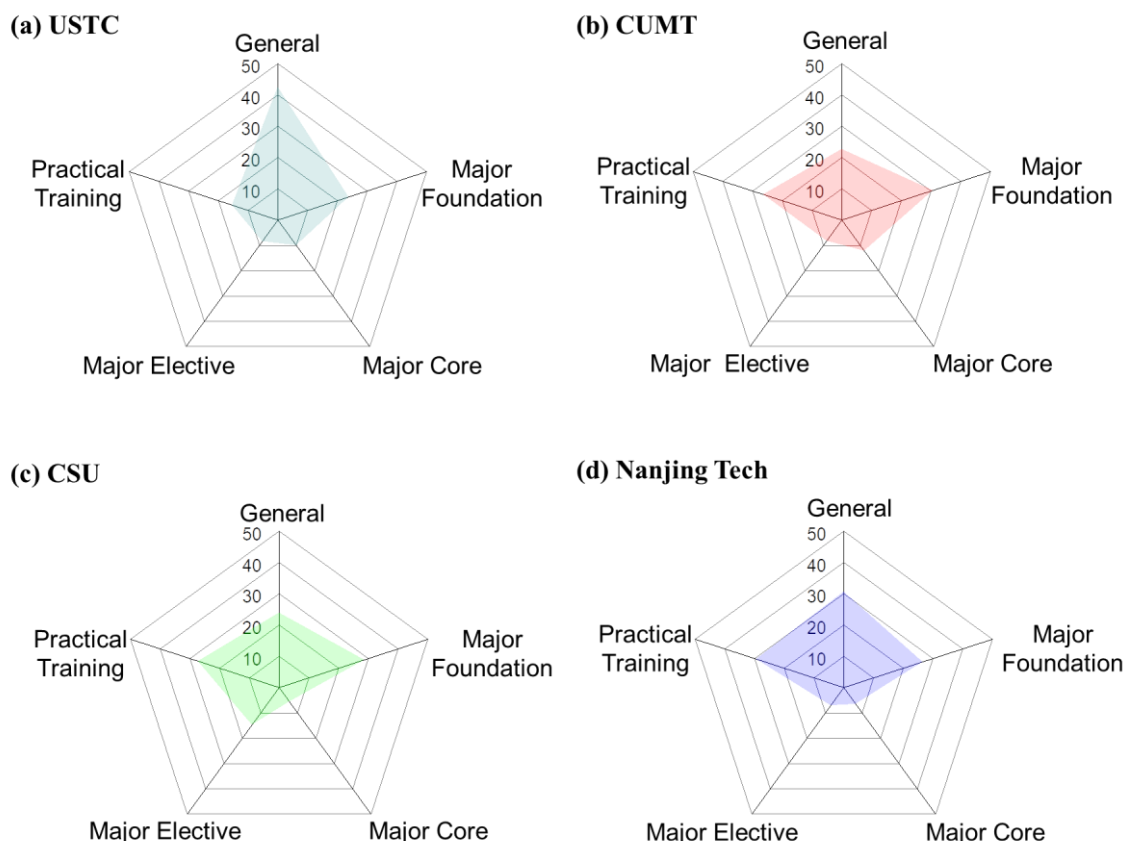


Fig. 9. Comparing unit numbers of the general, major foundation, major core, major elective, and practical training courses in Safety Engineering for (a) USTC, (b) CUMT, (c) CSU, and (b) Nanjing Tech.

Curriculum differences are mainly existed in the major core and major elective, based on academic research background. Thus, there are many courses applied to the foundation safety in mining, industrial ventilation, or the prevention of industrial disasters. One course may have multiple or various requirements in different universities. For example, *Industrial Fire and Explosion Prevention*, *Chemical Safety Protection*, or *Safety Technology of the Chemical Industry* is the major elective in USTC, CSU and CUMT, but there are refined industrial fundamental courses (like *Security Technology of Dangerous Chemicals*, *Chemical Process Safety*, *Industrial Hazards and Prevention*) in Nanjing Tech. And various teaching materials are chosen based on their industry publishers. In terms of CUMT, CSU, and Nanjing Tech, a consensus has also been reached that only 2-3 specialized fire courses are offered in the education of Safety Engineering, despite massive self-ignited fires and explosions in underground mines and fires in hazardous chemicals. It may be because the programme of Safety Engineering needs to be more distinguished from the programme of Fire Protection

Engineering in their university.

Similar comparisons for the undergraduate programmes of Fire Protection Engineering are presented in Fig. 10. Fire Protection Engineering at CPPU focuses on training practical firefighters of fire rescue agencies rather than engineers. It provides 37% general courses, 19% major-foundation courses, 6% major-core courses, and 7% major-elective courses to cultivate students with (but not limited to) conceptual explanations of fire dynamics and many fire protection strategies. It also provides 31% practical training with combat operations in fire control and firefighting. It is worth noting that their physical training requirements are similar to military schools, but the daily physical training does not count for credit.

Curriculum of Fire Protection Engineering

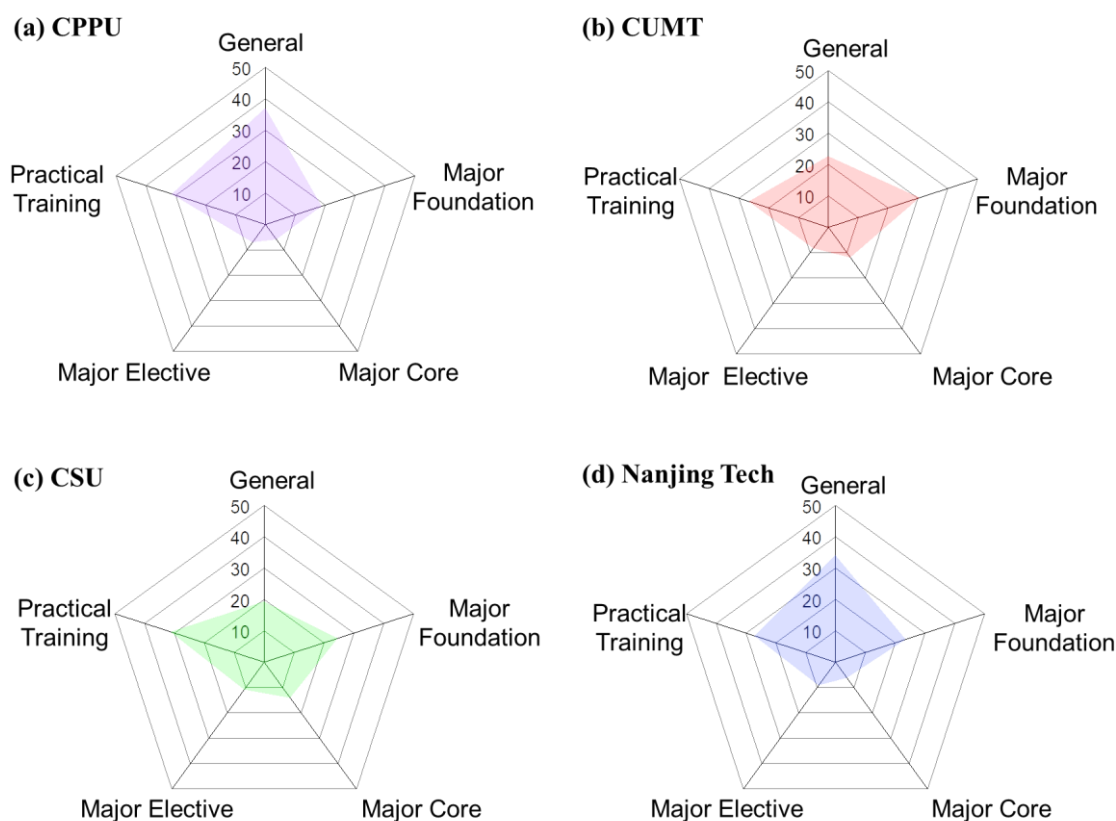


Fig. 10. Comparing undergraduate unit numbers of the general, major foundation, major core, major elective, and practical training courses in Fire Protection Engineering for (a) CPPU, (b) CUMT, (c) CSU, and (d) Nanjing Tech.

Universities such as CUMT, CSU and Nanjing Tech, with a strong background in Mining and Chemical Engineering, have established both the Safety Engineering programme and Fire Protection Engineering programme. As the license of CFPE only requires knowledge of building fire safety, most courses in these universities mainly focus on building fire safety and prevention, which fits well with the competency framework for fire safety engineering in the western university [56]. Overall, the curriculums of every fire protection engineering college are at a higher coincidence level than that of safety engineering. The six major courses (in Section 3.2) of Fire Protection Engineering are summarized and compared among five presentative universities in Fig. 11. The major courses of USTC are also involved as they mainly focus on fire research and comprehensive education in the fire-related field, even though with the name Safety Engineering. The ratios

were counted by the credit weighting of compulsory and elective courses. Thermofluid courses in variable universities are usually the same and 12 ± 3 credits at the above schools, despite that presented in different proportions, which is also consistent with the western university. Courses on fire safety engineering have the highest ratio of all major course, which mean the major courses and related course designs are always the same. The undergraduates are always the textbooks published by China Machine Press (listed in Table S2).

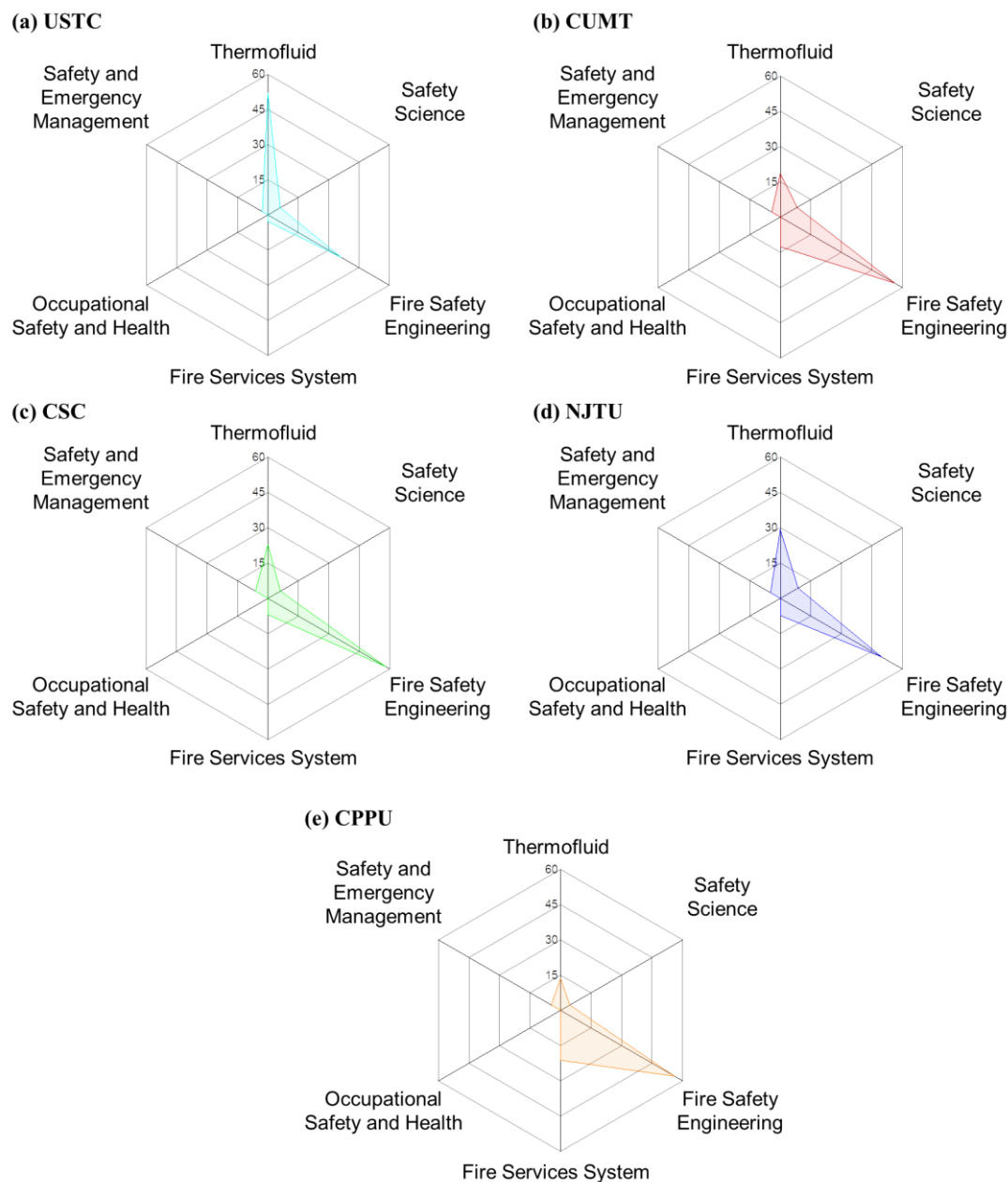


Fig. 11. Comparing six major courses (Thermofluid, Safety Science, Fire Safety Engineering, Fire Services System, Occupational Safety and Health, and Emergency and Information Management Section 3.2) of Fire Protection Engineering for (a) USTC, (b) CUMT, (c) CSU, (d) Nanjing Tech, and (e) CPPU.

The ratios of safety science, fire services system, and safety and emergency management are nearly the same and represent the equivalent recognition of these topics in various universities of Fire Protection Engineering. Occupational Safety and Health is an important topic in fire safety, but is not set up the related course in Fire Protection Engineering. Nevertheless, these universities also offer courses on coal mine fires,

fire hazards in chemicals, and industrial fires, because of their strong research background in these areas. Although the various discipline direction, some major electives, like *Fire Numerical Simulation*, *Fire Investigation*, and *Fire Risk Assessment*, are also the same and taught in Year 3 or Year 4. Limited to the different accident scenarios by different professions, the above teaching materials are always written by the teacher themselves, and being formed the related materials.

Although all these institutes became comprehensive universities a few decades ago, very detailed training programmes adopted from the Soviet system in the 1950s still influenced the development of higher education in China. The required number of credits in mainland China is way more than in PolyU or an average western university. Due to the individual characteristics of professional construction, many courses cover very specific topics and techniques, resulting in heavy loads for both teachers and students. In addition to the remaining influence of the Soviet system, another reason is that the system of continuous professional training in the industry has not been fully established in China, so the university has to share these parts of the education and training in the undergraduate programme. Moreover, the number of professors in a department of a typical university in China is at least three times more than their equivalent in a western university. And the number of students who attend a school or university is almost four times more than their equivalent in a western university. And the student–faculty ratio was brought to 12.84:1 in 2021 [57], which reaches the general international level of 14:1. Compared with the western universities, regulated and dogmatizing graduation assessments of undergraduates and postgraduates are also partially responsible for the heavy course load in both undergraduate and postgraduate education.

5. Conclusions and Future perspectives

In the past four decades, higher education in Fire Safety Science and Engineering has developed and changed significantly, along with the rapid urbanization and economic growth in China. The higher education development of fire safety science and engineering in China also suggests the evolution of concepts and techniques from fire protection (before the 1980s) to fire safety science and engineering (1985-2010s) and human-oriented public safety and smart firefighting (2010s-today).

The scopes of fire safety discipline are discussed by introducing the requirements of firefighters, fire facility operators, emergency rescuers, registered professional fire protection engineers and safety engineers in China. The foundation and major courses in fire safety higher education in representative universities are introduced in detail. By comparing their undergraduate and postgraduate programmes, we explain the context of fire safety education in different universities. From a historical viewpoint, we review the unique features and diversity developed in different institutes, based on the evolution of programme documents and first-hand teaching materials.

Despite the current fire safety majors definitely cannot be set up perfectly according to different demands of fire protection and usually lag due to the limited amount of resource reserve (such as faculty and teaching materials) and available teaching hours of colleges and universities, which are not able to cover all areas. The conflicts between the diversified segmentation of market demand and the limited cultivation and supply ability of colleges and universities have already been influencing and continue to influence the development of the

discipline of fire safety science of colleges and universities.

Meanwhile, the technical developments and structural changes in society will influence the role of fire safety engineering. The primary task of the first university education should be to learn how to collect and assimilate new knowledge during the whole professional career or lifelong learning and prepare the methodology for formulating and solving qualified technical tasks. This review aims to introduce the systems and features of Fire Safety higher education in China to the world and encourage more international collaboration with the Chinese fire safety community.

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Declaration of competing interest

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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