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Dilemmas and Solutions for Sustainability-Based Engineering Ethics: Lessons Learned from the Collapse of a Self-Built House in Changsha, Hunan, China

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Abstract: With the rapid development of engineering construction in China, especially the emergence of large-scale engineering projects and self-built residential houses, ethical issues in engineering have become increasingly prominent. Engineering ethics encompass the moral issues within engineering practice. Currently, engineering ethics in China is in its early stages, due to a lack of practical experience and a comprehensive set of ethical norms and operational systems. To effectively prevent and control safety issues in self-built housing projects, and to avoid accidents, this paper firstly focuses on the causes of the collapse of self-built houses in Changsha on 29 April 2022, from the perspective of engineering ethics. By utilizing the meanings and relevant theories of engineering ethics, this paper analyzes the three ethical dilemmas involved in the collapse of self-built houses: the ethical dilemma faced by engineers, the dilemma of government credibility, and the dilemma of engineering ethics education. Subsequently, recommendations are proposed to address these dilemmas, focusing on enhancing engineers' ethical perspectives, improving government credibility, and strengthening engineering ethics education. Finally, an analysis and decision-making model is constructed based on the Civil Code of the People's Republic of China. The research findings of this paper have certain reference significance for ensuring the safety of residential buildings, which can effectively motivate governments, owners, designers, constructors, managers, and users to actively develop and promote high-quality sustainable buildings.

Keywords: engineering ethics; ethical dilemmas; potential solutions; collapse of self-built house; engineering ethics education

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1. Introduction

Over the past two decades, driven by China's rapid socio-economic growth, industries such as construction, transportation, and energy have undergone a significant transformation. These sectors have shifted from resource-intensive and low-output practices to a more advanced and sustainable development paradigm. However, due to various factors, the quality of engineering projects varies greatly, leading to the occasional occurrence of collapse accidents, such as the collapse of Tuojiang Bridge in Fenghuang County, Hunan Province, in 2006 [1]; the collapse of Jiujang Bridge in Foshan City, Guangdong Province, in 2007 [2]; the collapse of Yangmingtan Bridge in Harbin City, Heilongjiang Province, in 2012 [3]; the platform collapse of a power plant in Fengcheng City, Jiangxi Province, in 2016 [4]; the collapse of Zijin Bridge in Heyuan City, Guangdong Province, in 2019 [5]; and the Jiaxin Hotel collapse in Quanzhou City, Fujian Province, in 2019 [6]. The occurrences of these engineering accidents not only result in significant economic losses but also pose severe threats to the personal safety and well-being of the general public. On 29 April 2022, at 12:24 p.m., a particularly severe residential self-built house collapse accident occurred in Changsha City, Hunan Province, China (Figure 1). This accident resulted in the tragic loss of 54 lives, with 9 individuals sustaining injuries, and a direct economic loss of CNY 90,778,600 [7].

Figure 1. Photo of the collapsed building, Changsha, China (Reprinted/adapted with permission from Ref. [7]. Wang et al., *Int. J. Environ. Res. Public Health*, published by MDPI, 2023).

Scholars have conducted highly effective research on these engineering safety accidents. Some scholars have explored technical research on engineering safety [8–13], while others have analyzed the accidents themselves, such as causes and prevention measures. Pfatteicher [14] stated how the engineering profession struggled to transform an unspeakable disaster into a powerful, if painful, lesson about the meaning of ethics in engineering through the collapse of two elevated walkways in the lobby of Hyatt Hotel. Wang et al. [7] presented the process and rescue operations of a self-built house and performed a detailed cause analysis based on analytic hierarchy process (AHP). Zheng et al. [15] proposed a digital-twin-based investigation method to elucidate the potential causes and mechanisms of a collapse accident, thus remediating future structural collapse and enhancing the resilience. Yan and Kim [16] presented a stage model of a building collapse accident and gave a comprehensive conceptual framework of information technology support for the management of construction accidents (ITSMCA), which aligns the information technology (IT) with different stages of the collapse accident. Chen and Qiao [6] explored the factors influencing recent construction collapse accidents by utilizing a sample of 355 reports on building collapse accidents in China from 2012 to 2022. Ma et al. [17] present a study conducted regarding the self-built house collapse accident in Changsha, China, that occurred on 29 April 2022, with a focus on leveraging Sina Weibo (a Twitter-like microblogging system in China) comment data.

In 1987, the concept of sustainable development was officially introduced [18]. A professional engineer ought to have responsibility with regard to supporting basic principles of sustainable development, and sustainability should be included in the paramountcy clause [19]. Tziner and Persoff [20] looked at some of the factors that link the notions of ethics, justice, and corporate social responsibility (CSR), with an eye to their theoretical underpinnings and complexities and their relationship to the efficient and sustainable operation of sustainable performance management (with aspecial emphasis on CSR). Brauer [21] included sustainability in the paramountcy clause as a way of rectifying the current disregard for social justice issues in engineering codes. Miller and Brumbelow [22] performed a survey of new civil engineering students to determine their opinions on the relative importance of sustainability in the professional practice of engineering. It is found that they viewed sustainability very favorably and generally prioritized people-centric societal objectives above planet-centric and prosperity-centric priorities. Mares-Nasarre et al. [23] developed a systematic method to identify the level of awareness in students about the sustainability and ethics of civil engineering bachelor's degree students. Boateng [24] explored building collapses at the cross-cutting edges of urban sustainability and the socio-economic and political-cultural influences of vulnerability for the phenomenon—in a departure from the traditional conceptualization of the phenomenon as an 'engineering' problem. Chin et al. [25] presented the incident background, management measures taken after the incident, and a brief discussion of the causes of the Foundation Pit Collapse on June 8, 2019, in Nanning, China. Mentis and Papadopulos [26] evaluated unsafe buildings, facades, balconies, and sidewalks during a 15-year follow-up through a case study in Athens, Greece. Shakib et al. [27] briefly assessed the fire-induced progressive collapse of the Plasco building incident from different perspectives. Ayodeji [28] investigated the causes and consequences of building collapse in Nigeria using historical data from 1974 to 2006 and also proffered some solutions.

However, a few scholars argue that ethical reflection on engineering accidents is crucial. Ferjencik [29] summarized Kletz's approach to accident investigations, pointing out that his approach has some gaps that sometimes need to be addressed. Haghighattalab et al. [30] investigated engineering ethics and its gap within accident analysis models. Sulaima et al. [31] presented a case study on the Hotel New World tragedy; after the analysis and evaluation were performed, duty ethics and right ethics were found to be more relevant to the collapse of Hotel New World case compared to the other ethical theories. There are different views on engineering ethics related to building collapse accidents. Engineering ethics is a scientific study that encompasses the moral values, practical issues, and problem-solving strategies involved in all aspects of engineering practice. It not only includes ethical issues at the technical level of engineering activities, such as investment decisions, design, construction, and supervision, but also addresses ethical issues at the non-technical level, such as operation, management, social impact, and the ecological environment. It is evident that ethics, science, technology, students, study, and research appear with high frequency. Sustainability-based ethics research has been widely discussed and implemented in several fields related to engineering, including engineering ethics [32], the creditability of government [33,34], and engineering ethics education [35–37].

Consequently, some scholars have conducted research on engineering ethics from the perspective of engineers. Generally, engineers' ethical responsibility is considered to be greater or more significant than their professional responsibilities. Lovrin and Vrcan [38] emphasize the importance of ethics in decision-making for engineers and the need to consider more than just profit. They argue that when things go wrong, there is always an ethical dimension. Engineers are expected to not only solve technical design problems but also adhere to broader norms and meet societal expectations. However, these expectations can sometimes push engineers towards unethical or even illegal behavior [39]. Abdul-Rahman et al. [40] studied clients' perspectives on professional ethics for civil engineers and identified the causes of unethical conduct. They also developed two models for disciplinary procedures to address such behavior, specifically within the construction industry. Grunwald [41] proposed a transparent framework that enables the analysis of ethical dimensions in engineering goals. Woo [37] stated that engineering accidents are directly or indirectly related to engineering practices and technology. In such situations, engineers cannot shift responsibility onto the general public. Instead, engineers must take accountability for accidents within the context of the science and technology society of the time. Sobrino [42] advocated for improving design practices to enhance the quality of bridges and contributed to a better world by utilizing engineers' knowledge, creativity, and ethical considerations. Tscheon [43] conducted a survey on engineers' sense of values and found that practicality and economic efficiency are the most important factors when making decisions for the future. Baxter [44] stated that the Inter-Disciplinary Ethics Applied Centre at the University of Leeds launched a 10-year ethics-based plan to help the UK engineering profession better serve the public interest. However, the stakeholders of engineering responsibility should not be limited to engineers alone. It includes a larger community in engineering. This engineering community comprises scientists, designers, constructors, project owners, decision-makers, managers, and users. The shared ethical responsibility in engineering accidents refers to the collective duty of all parties in the community to uphold ethical principles such as fairness and justice.

Government credibility is a critical factor that determines the legitimacy and the relationship between the government and its citizens. It reflects the government's ability to propose and implement appropriate solutions fairly, efficiently, and with integrity, especially in the context of managing the distribution of interests among various individuals in society after acquiring public authority. Consequently, the level of government credibility fundamentally gauges its performance in fulfilling its responsibilities. However, recent significant events, such as public health crises and engineering failures, have led to a deterioration in public trust and confidence in both government institutions and professionals. Professional ethics, such as ethical codes and guidelines, is seen as a kind of remedial approach [45,46]. To investigate how government credibility and social morality work in a public health emergency, Xiang et al. [47] explored the relationships among the following variables: willingness to quarantine, perception of the epidemic, willingness to engage in outdoor activities, government credibility, and public morality. Ku [48] conceptualized the impact of news credibility in evaluating government trust and also studied whether the type of media using government news influenced government trust. Mishra et al. [49] dealt with the impact of security standards and policies on the performance and credibility of e-government. Sohn [50] identified the relationship between government trust and risk perception of Mad Cow Disease (MCD). Jung [51] recognized an individual central department of the government as an object that can be branded and then studied the impact of the central department's brand equity on the credibility of the government. Li et al. [52] analyzed the rules and characteristics of government media in disseminating information on public emergencies and tried to find ways and means to improve government media's communication power and credibility. Fan and Kim [53] sought to identify how media types and source types play a role in the credibility of news in China' s political environment. It can be observed that Korean scholars have conducted in-depth research on government credibility, primarily focusing on public health incidents. However, there has been limited exploration of the relationship between government credibility and engineering ethics.

Engineering ethics education can help engineers develop proper professional ethics and values, enhance their ethical awareness, and foster a sense of professional responsibility. Currently, the field of civil engineering is witnessing a growing interest in the study of engineering ethics, and implementing engineering ethics education has become an important measure to improve the moral and ethical standards of engineers. Current research on engineering ethics education focuses on four aspects. Firstly, there is an emphasis on the importance of conducting engineering ethics education from a macro perspective. Typical researchers in this area include Billingto [54], Simpson et al. [55], Bairaktarova and Woodcock [56], Colby and Sullivan [36], Morrison and Wallace [57], and so on. Secondly, there is a focus on the development of training programs and curriculum reform. Typical researchers in this area include Atesh [58], Bird and Sieber [59], Li and Fu [60], Martin et al. [61], Huaquisto-Cáceres et al. [62], and so on. Some researchers concentrate on studying teaching methods, such as Haws [63], Chung [64], Sochacka et al. [65], Swartz [66], and so on. Additionally, some scholars, such as Bielefeldt et al. [67–70], Yin and Zhang [71], Zhong et al. [72], and so on, argue that engineering ethics education should be tailored to students from different majors.

Based on the above analysis, it is found that few scholars have conducted engineering ethics analyses specifically for major safety accidents like building collapses. From the perspective of engineering ethics, this paper firstly provides a detailed introduction to the process, causes, and rescue efforts of the self-built house collapse accident in Changsha. Subsequently, drawing on the implications of engineering ethics and relevant theories, the three major ethical dilemmas involved in self-built house collapse accidents are analyzed, namely, the ethical dilemma faced by engineers, the dilemma of government credibility, and the dilemma of engineering ethics education. Then, suggestions for resolving the ethical dilemmas in engineering are proposed, focusing on enhancing engineers' ethical perspectives, improving government credibility, and strengthening engineering ethics education. Finally, an analysis and decision-making model is constructed based on the Civil Code of the People's Republic of China.

2. Materials and the Self-Built House Collapse Accident in Changsha

2.1. Safety Status in the Field of Housing and Municipal Engineering in China

According to data from the Ministry of Housing and Urban-Rural Development of the People's Republic of China [73], from 2015 to 2023, there were a total of 5870 production safety accidents in the field of housing and municipal engineering in China, resulting in 6759 deaths. There were 176 major and above accidents, with a death toll of 703. The specific data are shown in Table 1 and Figure 2. Table 2 illustrates typical accidents of building collapses.

Table 1. Overview of numbers of accidents and deaths in the field of housing and municipal engineering in China, 2015–2023 (Data from Ministry of Housing and Urban-Rural Development. https://zlaq.mohurd.gov.cn/ (accessed on 2 July 2024)).

Year	Number of Accidents	Number of Deaths	Number of Major Accidents *	Number of Deaths in Major Accidents
2015	442	554	22	85
2016	634	735	27	94
2017	692	807	23	90
2018	735	841	22	87
2019	786	921	24	110
2020	695	798	22	89
2021	736	823	16	68
2022	564	640	12	52

* According to Article 3 of the Regulations on Reporting and Investigation of Production Safety Accidents issued by the State Council of China (implemented on 1 June 2007), production safety accidents are generally classified into the following levels based on the casualties or direct economic losses they cause: extraordinarily major accidents, major accidents, significant accidents, and general accidents. Accidents that are major and worse refer to those that result in the death of three or more people, or injuries to ten or more people, or direct economic losses exceeding CNY 10 million.

Table 2. Overview of building collapses in China.

Date	Building Name	Place	Fatalities /Injuries	Cause of Collapse
29 December 2014	Gymnasium of High School affiliated to Tsinghua University	Beijing	10/4	Construction mistakes
16 May 2019	Factory 1#, 148 Zhaohua Road	Shanghai	12/13	Design errors, Construction mistakes
20 May 2019	Steel building	Baise, Guangxi	6/87	Illegal contracting, Design errors, Construction mistakes, Rain and wind
27 June 2019	Building 7#, Lotus Riverside View Garden	Shanghai	1/0	Construction mistakes
8 July 2019	Shenzhen Sports Center	Shenzhen, Guangdong	3/3	Construction mistakes
7 March 2020	Xinjia Hotel	Quanzhou, Fujian	29/42	Construction mistakes (illegal enlargement)
29 August 2020	Juxian Restaurant	Linfen, Shanxi	29/28	No professional design, illegal enlargement
19 June 2021	Self-built house	Chenzhou, Hunan	5/7	No professional design, Construction mistakes
12 July 2021	Four Seasons Open Source Hotel	Suzhou, Jiangsu	17/5	Construction mistakes

Table 2. *Cont.*

Date	Building Name	Place	Fatalities /Injuries	Cause of Collapse
16 July 2021	Rest Hall	Yongan, Fujian	8/2	Design errors, Construction mistakes
23 November 2021	Lakeside Hotel	Jinhua, Zhejiang	6/6	Design errors, Construction mistakes
29 April 2022	Self-built house	Changsha, Hunan	54/9	No professional design, Illegal enlargement
23 July 2023	Gymnasium of No. 34 Middle School	Qiqihaer, Heilongjiang	11/0	Construction mistakes

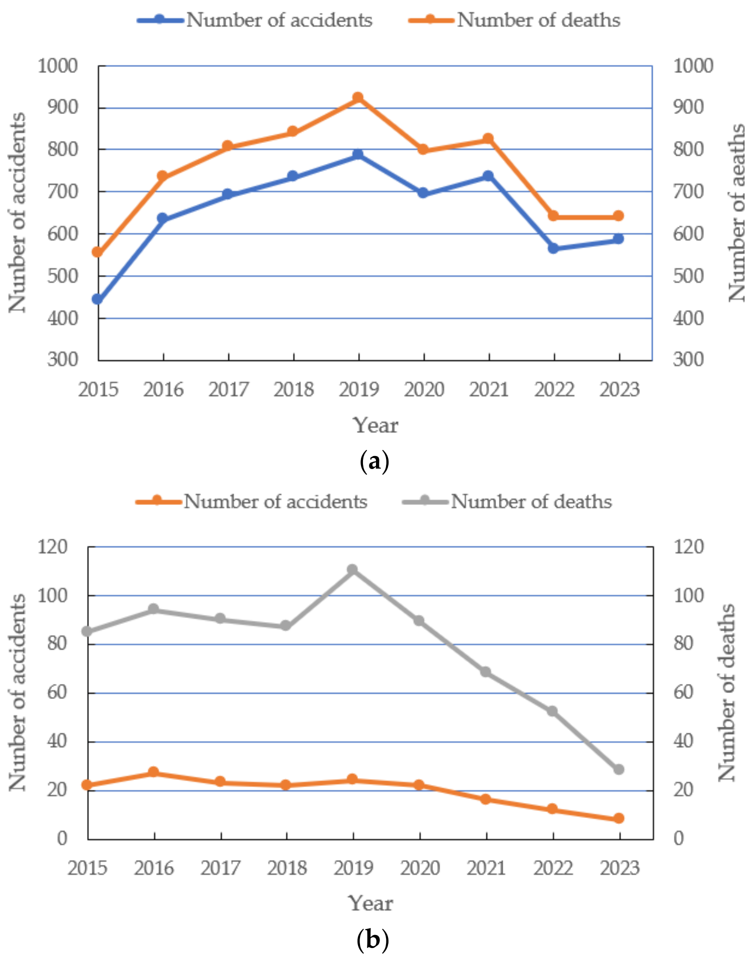


Figure 2. Safety accident statistics in the field of housing and municipal engineering in China, 2015–2023. (Data from Ministry of Housing and Urban–Rural Development. https://zlaq.mohurd.gov.cn/ (accessed on 2 July 2024)) (**a**) Accidents. (**b**) Major and larger accidents.

2.2. Process of the Self-Built House Collapse Accident in Changsha

On 29 April 2022, a self-built house in Wangcheng District, Changsha City, Hunan Province, collapsed. The building was located adjacent to the North Gate of Changsha Medical University. The house had a total of eight floors (partially nine floors) with a construction area of 1401.3 m^2. The first to sixth floors were used for rental businesses, including restaurants, milk tea shops, private cinemas, and hotels. The seventh and eighth floors were used for the residence of the owner and his family. The sequence of events during the accident is presented in Table 3.

Table 3. Process of the self-built house collapse accident in Changsha, Hunan.

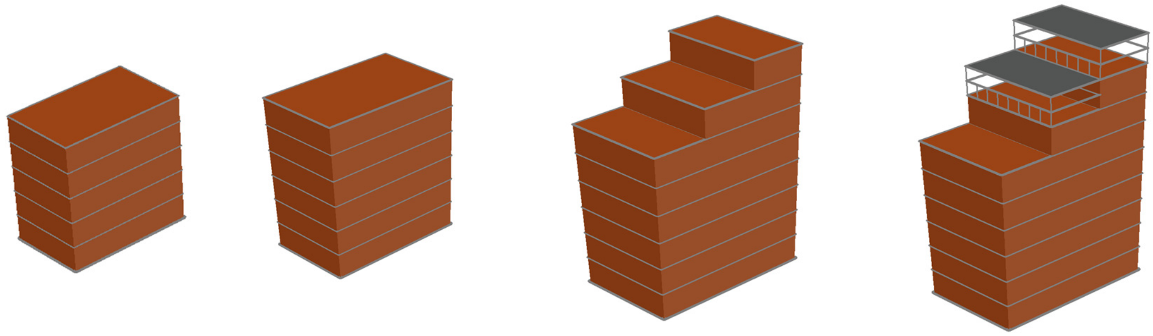
Date	Time	Description
28 April 2022	20:00 p.m.	On the second floor, the staff of the restaurant noticed that a concrete column on the eastern side, as well as the adjacent wall tiles, had become detached. The plaster on the wall had cracked, and the concrete at the base of the column had been crushed, with exposed and bent reinforcing bars.
29 April 2022	10:15 a.m.	A supporting U-steel beam on the second floor (purchased by the owner in July 2019 to reinforce the column that had developed cracks) had undergone severe deformation, creating a gap of approximately 50 mm from the wall.
29 April 2022	11:50 a.m.	The owner went out to purchase construction materials in preparation for further reinforcement.
29 April 2022	12:19 p.m.	The exterior wall at the southeast corner, where the first and second floor ring beams meet, exhibited peeling plaster, exposed bricks, and outward bulging, signifying the onset of wall deformation. Neighbors and the village group leader present at the scene advised the owner to evacuate, but their attempts to persuade were unsuccessful.
29 April 2022	12:21 p.m.	The eastern wall of the restaurant on the second floor made abnormal noises, and objects fell from the ceiling and the eastern exterior wall. The restaurant manager promptly urged two staff members and three diners to leave.
29 April 2022	12:24 p.m.	The entire building collapsed in a sink-like manner, taking approximately 4 s.

A total of 63 individuals were trapped inside the involved building after the accident, including 50 undergraduates, 11 employees of businesses and other members of the community, and the owner and his family (2 individuals). The accident resulted in a loss of 54 lives, with 44 of them being undergraduates.

2.3. Causes of the Self-Built House Collapse Accident in Changsha

According to the official accident investigation report [74], it was determined that the direct cause of the accident was the poor construction quality, structural inadequacy, low stability, and low bearing capacity of the original five-story (partially six-story) building that violated regulations. After illegally adding additional floors to a total of eight stories (partially nine stories), the load significantly increased, causing the east-side columns and walls on the second floor to exceed their ultimate load-bearing capacity. These components experienced compressive failure, which continued to develop, ultimately resulting in the overall collapse of the building. Prior to the accident, despite clear signs of collapse, the owner refused to take advice and did not implement emergency evacuation measures, which contributed significantly to the high number of casualties. The process of illegal construction and expansion of the building is illustrated in Figure 3.

The original five-story building constructed by the owner, who violated laws and regulations, had inherent deficiencies in its quality. In 2003, the owner built a three-story house. In July 2012, the three-story building was demolished and replaced with a five-story (partially six-story) building, without specific location details, which are not provided in Figure 3a. However, the involved owner, without fulfilling any approval procedures or obtaining any permissions, hired a retired construction worker from a building company to hand-draw the design drawings and personally procured construction materials. Moreover, the construction was carried out by an unqualified and mobile construction team. In the construction process, self-mixed concrete with high levels of sand and silt content and low strength was used, particularly the minimum compressive strength of the concrete used in the three columns on the east side of the second floor, which was only 4.3 MPa, significantly lower than the required 20 MPa [75]. The compressive strength of the mortar used in the masonry of the walls on the first and second floors was only 0.4 MPa, which fell far below the required 2.5 MPa [76]. The building adopted a masonry structure, in which the walls and columns constructed with solid blocks and mortar served as the primary load-bearing components. While the first floor had solid walls, the walls from the second to fifth floor improperly used hollow or cavity walls, which had low load-bearing capacity and were no longer in compliance with the Code [76].



(a) (b) (c) (d)

Figure 3. The process of illegal development of the involved building. (**a**) Original house (July 2012). (**b**) Heightened to six stories (September 2014). (**c**) Heightened to eight stories (July 2018). (**d**) Steel roof added.

(1) The owner illegally expanded the building to a total of six floors. After its initial construction as a partially six-story building, it was later expanded to become a complete six-story structure, as shown in Figure 3b. The exact time of this expansion is unknown, but the schematic diagram was drawn based on data from Baidu Maps in September 2014.
(2) In addition, the owner again violated laws and regulations by further expanding the building to a total of eight floors, exceeding its maximum load-bearing capacity. In July 2018, without fulfilling the necessary construction procedures, the owner once again employed the retired construction worker from the above-mentioned construction company to hand-draw design drawings. They personally procured construction materials and organized an unqualified and mobile construction team to carry out the construction. The additional floors were added, resulting in a structure going from six to eight stories, as shown in Figure 3c. The added three floors adopted a frame structure, with columns, beams, and floor slabs made of cast in situ reinforced concrete. The total load created by the additional structural elements, such as the newly added walls, increased by 46%, significantly increasing the load on the lower floors' columns. The maximum increase in load on the second-floor east-side column was 71%, exceeding its limit load-bearing capacity by 18%. Furthermore, the overall stability of the building was compromised due to the chaotic arrangement of the structural system. Some columns were misplaced vertically, leading to a structural imbalance. The first and second floors were designed with a single-span, large-space layout, resulting in fewer transverse walls. On the other hand, the third to eighth floors were divided into multiple small rooms, with more transverse walls and higher floor loads. The second floor became the weakest layer structurally and was most vulnerable to damage due to its limited resilience against collapse.
(3) The owner illegally and unlawfully added a steel roof, as shown in Figure 3d. The specific timeline of this addition is unknown.
(4) The owner failed to effectively address significant safety hazards. In July 2019, a network of cracks up to 0.6 m long appeared on the concrete column of the eastern wall on the second floor. The owner, following the advice of the retired worker from the aforementioned construction company, purchased two U-steels for additional

support, but this did not completely eliminate the safety hazards. In March 2022, further issues arose with the deformed support U-steels, the detachment of wall tiles, and worsening deformation of the support U-steels. The owner did not take any action to rectify these issues. On 12 April 2022, a testing company, entrusted by the hotel operator in the implicated property, conducted a so-called inspection without bringing any testing equipment and relied solely on taking photographs. On 13 April 2022, they issued a false inspection report for the hotel, classifying it as Bsu grade, stating that it was basically intact and could be used as a hotel without any problems and affirmed its structural safety. On 22 April 2022, the renters informed the owner that the deformation of the support channel steels had worsened, with a maximum gap of approximately 15 mm from the wall. However, the owner still took no measures until the accident occurred.

(5) The involved parties failed to take immediate emergency evacuation measures. Over 2 h before the accident, the bending and deformation of the support U-steels on the second floor intensified, reaching approximately 50 mm, indicating a collapse was imminent. In particular, around 30 min before the accident, the retired worker from the construction company, upon the owner's request for an on-site inspection, deemed the house unsafe for continued occupancy. Despite this, the owner insisted on further reinforcement and did not organize the evacuation of individuals residing or dining in the house. Just 5 min before the accident, facing a significant risk of collapse, the owner still neglected to promptly notify evacuation, thus missing the final opportunity for occupants inside the house to escape and avoid major casualties.

2.4. Rescue of the Self-Built House Collapse Accident in Changsha

Following the occurrence of the accident, immediate emergency responses were initiated. A prompt organization and mobilization of rescue forces were carried out. Notably, the Hunan Provincial Fire Rescue Corps deployed a total of 1132 armed police personnel, who were equipped with over 3300 sets of diverse apparatus and gear, to effectively manage and address the retrieval and rescue operation. Simultaneously, the National Health Commission and Hunan Province expedited the deployment of medical and healthcare professionals, who were tasked with providing prompt medical treatment and psychological counseling.

The circumstances surrounding this accident posed a complex and multifaceted environment, thereby compounding the challenges encountered during the rescue operation. The structural collapse of the housing resulted in a cascade-like compression, rendering the equilibrium exceptionally precarious. Moreover, an additional burden of approximately 150 tons, representing an intact roof spanning six stories that had been casted as a single unit, exerted further strain on the affected site. Consequently, any attempt to disturb the situation risked triggering destabilization, which could potentially imperil both trapped individuals and members of the rescue team. Another perilous factor involved the convergence of severely damaged buildings situated proximal to the collapsed housing. These compromised structures posed an imminent threat of collapsing onto the rescue area, endangering the lives of both those trapped and those engaged in the rescue efforts. Given these hazardous impediments, rescue personnel confronted substantive operational limitations. The restricted scope of the operational area was confined to the southern direction, with multiple individuals beneath the wreckage. As a result, the usage of heavy machinery and extensive tools is not suitable.

Given the extremely complex and hazardous rescue environment, the rescue personnel utilized advanced life detection equipment and various types of excavation and support equipment. They were simultaneously excavating, reinforcing, and searching, striving against time to establish a life passage for rescue. Regardless of the cost, they made every effort to search and rescue those in distress. After a grueling and intense rescue operation lasting 158 h, the on-site search and rescue work concluded at 3:03 a.m. on 6 May 2022. All 10 individuals displaying signs of life were successfully rescued (with the exception of the owner, who passed away after receiving medical treatment for 11 days due to severe injuries), and all deceased individuals were located.

3. Dilemmas of Engineering Ethics

The collapse of self-built residential houses in Changsha, Hunan, is a particularly significant safety accident caused by multiple factors, involving deep-seated ethical issues and moral dilemmas. After providing a detailed overview of the collapse of self-built residential houses in Changsha, it is crucial to analyze the causes of the building collapse with respect to various aspects that are significant in engineering ethics. However, there is currently limited scholarly research on the ethical study of building collapses.

3.1. Identification of Ethical Dilemmas

Accurately identifying potential engineering ethics dilemmas is a prerequisite for effectively addressing these ethical challenges. A moral dilemma occurs when individuals are faced with a moral choice that involves deciding between two valuable but mutually exclusive options. It is also referred to as a moral quandary. However, choosing between good and evil, or between good and non-good, does not typically cause rational confusion. It is when one has to choose one good over another and abandon the other that a moral dilemma arises. The term dilemma implies difficulty because choosing one good over another can leave a person in a state of dilemma. Unfortunately, the ethical dilemmas faced by the development of engineering technology have been consistently overlooked. The main ethical issues existing in current engineering construction include the technical, interest, and responsibility dilemmas faced by engineers, the lack of government credibility and social trust, and the inadequate education on engineering ethics.

Engineers must adhere to ethical guidelines and have a strong sense of social responsibility, correct values, interests, and a strong ethical conscience in order to consciously assume the ethical responsibility of safeguarding the common interests of humanity. In reality, as engineers gain more advanced technological knowledge, their responsibilities also expand. Initially, their responsibilities were limited to individuals and the company, but now they extend to the public and society. They also face more ethical dilemmas, technological ethics, interest ethics, and responsibility ethics.

The level of government credibility can be observed through its actions in fulfilling its responsibilities. News media serve as a conduit for conveying official voices, and these voices should inherently be trustworthy. However, if there is concealment of sudden events and inadequate disclosure of information, it will inevitably invite continuous doubt, foster the spread of rumors, and further destabilize society. When the government, experts, and authorities become untrustworthy, the public develops a pervasive sense of skepticism. They lack a sense of security and cannot obtain the desired truth through legitimate channels, thus seeking answers in online discourse. Public opinion on the internet tends to believe in bad news while distrusting government or official clarifications and explanations. When this set of game rules collapses, it leaves behind a tremendous black hole of trust.

Education on engineering ethics is not only a necessary path to cultivate engineers with ethical values but also a crucial requirement for achieving sustainable social development. However, the research on engineering ethics in China started relatively late and is still in its early stages. There is insufficient emphasis on the interdisciplinary nature of engineering ethics education, and some universities even fail to offer related courses. Neglecting the education and guidance of students' ideological consciousness has resulted in many college students lacking awareness and concepts of engineering ethics, and there is a detachment between theoretical and practical aspects in the teaching process. Furthermore, engineering ethics education lacks a long-term educational mechanism, and the construction of disciplines and talent pools lags behind. Although these institutions can produce a large number of technical personnel, they cannot guarantee the cultivation of engineers with a sense of social responsibility and noble moral qualities. It is imperative to strengthen engineering ethics education and cultivate high-quality engineering professionals.

3.2. Ethical Dilemmas Faced by Engineers

3.2.1. Dilemma of Technological Ethics

The dilemma of technological ethics refers to ethical dilemmas arising from conflicts between roles and obligations. Engineers play multiple roles in engineering practice, and the obligations of some roles may clash, resulting in ethical dilemmas. Loyalty to the employer is a fundamental ethical guideline for engineers. The professional ethical guidelines for engineers require them to adhere to high standards of quality and safety, placing the safety, health, and welfare of the public as a priority. Choosing loyalty to the employer at the expense of the interests of the majority, sacrificing the interests of the majority for the benefits of a few, would contradict engineering ethical principles. When the interests of the company conflict with the interests of the public, engineers face an ethical choice between loyalty to the company and responsibility to the public.

Currently, most self-built houses suffer from insufficient construction funds and outdated technology. There is a lack of a comprehensive design, construction, and management supervision system, resulting in significant resource consumption, a lack of scientific and technological rigor, and variably increased safety hazards. In the collapse of the self-built house in Changsha, the design drawings were hand-drawn by retired personnel from the architectural company, and the construction was carried out by unqualified individuals. There were no on-site supervisors or acceptance personnel, and the construction had undergone multiple unauthorized expansions. Prior to the accident, four management personnel and two technical personnel were severely derelict in their inspection duties. On the one hand, as engineers, they should prioritize the public's health and welfare and consider the safety of the house with the utmost importance, providing impartial evaluations of the safety conditions. On the other hand, as employees of the company, they bear the responsibility of generating profits for the enterprise. Firstly, in pursuit of the company's profits, they obtained the certificate of qualification of inspection and testing institution and the certificate of qualification of construction project quality testing institution through improper means. Secondly, they falsified the on-site inspections of the involved house and did not conduct the appraisal activities in accordance with the regulation [77] and other standards. The erroneous ethical choices made by these personnel directly resulted in the occurrence of the collapse accident.

3.2.2. Dilemma of Interest Ethics

The ethical dilemma of conflicting interests and values is referred to as dilemma of interest ethics. The basic requirement of interest ethics is to reasonably coordinate the interests of all participating parties and address the issue of fairness in engineering benefits. The main approach is to use ethical and moral constraints to address the interests of all parties, ultimately achieving a balance of benefits and a fair and unified system. Engineers must possess ethical and moral awareness and should not be swayed by certain interests to engage in actions that compromise engineering and construction safety. They should seek benefits for both the company and individuals while safeguarding the public interest. However, in engineering practice, engineers often face challenges in making ethical choices and trade-offs concerning social ethical responsibilities.

A conflict of interest refers to a situation where employees have a personal interest that may prevent them from fulfilling their obligations to their employer. Conflicts of interest can manifest in numerous ways, with the most common cases encompassing bribery, kickbacks, and interests in other companies. The revised version of 2019 from National Society of Professional Engineers (NSPE) clearly states that engineers should not directly or indirectly accept valuable compensation from others. They should act as honest agents serving their employers or clients and avoid conflicts of interest. Ethical issues in engineering decision-making, design, construction, and management have attracted significant attention. Examples include arbitrary changes to design plans during construction, the unauthorized substitution of substandard materials by on-site construction personnel, the dereliction of duty by supervision personnel, unreasonable demands from the administrative department and project owners, chaotic project management resulting in compressed timelines, and illicit financial transactions and corrupt practices. The collapse of the Tuojiang Bridge in Fenghuang County, Hunan Province, in August 2007, leading to 64 fatalities and 22 injuries, was due to bribery received by personnel from the administrative department and contractors involved in the construction, unauthorized changes to the original design and construction plans, subpar construction quality failing to meet design requirements, a reckless rush to meet project deadlines, and inadequate supervision and quality control, which left serious safety hazards in the project and resulted in significant economic losses. If at any stage of design, construction, supervision, or evaluation, engineering professionals had come forward to identify and promptly demand rectification of the issues, the collapse accident could have been completely avoided [1].

Most self-built houses are renovated based on the decisions of owners or tenants, who often prioritize their individual interests and disregard their social responsibilities. Additionally, relevant housing safety assessment agencies should have a sense of responsibility and fulfill their duties by thoroughly examining architectural designs and construction quality and providing trustworthy and credible inspection reports to safeguard the lives and properties of the people. In the case of the self-built house collapse in Changsha, according to the official investigation report, the owner illegally expanded and added structures, the inspection company obtained qualification certificates through illegal means, inspectors falsely claimed qualifications, the elevator installation company violated regulations, government departments failed to effectively remove illegal buildings, market operators engaged in unlicensed operations, inspection agencies falsified results, and the illegal installation and use of elevators were not properly penalized. These various factors ultimately led to the occurrence of the collapse accident.

3.2.3. Dilemma of Responsibility Ethics

The dilemma of ethical responsibility refers to the dilemma of determining the responsible entity. Ethical responsibility is at the core of engineering ethics, focusing primarily on the subjective and behavioral values, emphasizing the individual's sense of responsibility, correct evaluation of behavior value, and the assumption of responsibility. The correctness of moral values and the awareness of responsibility are closely related to a sustainable and safe development. In engineering ethical responsibility, starting from an individualistic perspective, engineers are the sole responsible entities. However, from a holistic perspective, the responsible entities include not only engineers but also all participants in the entire engineering practice, such as project owners, constructors, supervisory units, and relevant government administrative departments.

In light of the recent issues with self-built houses, owners and tenants should also possess a sense of social responsibility. In the self-built house collapse accident in Changsha, the individuals involved, relevant government officials, inspection agencies involved, experts and personnel from the participating inspection companies who conducted qualifications on-site evaluations, and the unit lending qualifications all received punishments. Fourteen responsible persons were punished for suspected crimes of serious responsibility accidents and providing false certification documents, according to the Criminal Law of the People's Republic of China. The owner, who suffered serious injuries and died after unsuccessful rescue efforts, will no longer be held criminally accountable. As for government officials, some individuals were found to have performed their duties insufficiently or were suspected of corruption, resulting in disciplinary actions imposed by the Party or the transfer to judicial organs. Regarding the involved inspection companies, administrative penalties were imposed on the inspection companies. Additionally, three individuals were penalized for suspected actions of lending qualifications.

3.3. The Dilemma of Government Credibility Deficiency

3.3.1. Lack of Public Trust in Engineering Quality

Frequent engineering quality issues and the resulting accidents caused by human factors have transformed engineering quality into not just a technical problem, but also a societal problem. Theoretically, there is comprehensive supervision over engineering projects. However, in practice, some quality supervision departments often lack robust mechanisms for supervisory management. Instead, they prioritize their own interests, resulting in regulatory gaps and allowing non-compliant projects to slip through the cracks. In the collapse of self-built houses in Changsha, the owner engaged in illegal construction and occupied the collapsed buildings, while the testing company falsified on-site inspections. Relevant government departments neglected supervision throughout the entire process, failing to diligently fulfill their responsibilities for routine monitoring and inspections. They did not effectively prevent or rectify the illegal and non-compliant acts of demolishing and rebuilding the implicated houses in 2012, nor did they prevent or rectify the additional construction in 2018.

Numerous cases of quality problems leading to accidents due to lack of supervision have raised concerns among the public. However, even without the advanced science and technology we have today, structures built in the past could withstand the test of time, such as the Wuhan Yangtze River Bridge completed in 1957. In contrast, the Wuhan Baishazhou Bridge, built in 2000 with an investment of CNY 1.1 billion, has been in a state of constant maintenance and repairments, requiring an average of two repairments per year. This has significantly negative social and environmental impacts. During the restoration in 2008, there were even instances of illegal subcontracting of maintenance projects, pointing to deep-rooted corruption behind the cycle of deterioration and repairment. Despite technological advancements, building quality continues to be doubtful, and accidents seem to have become an inevitability rather than a coincidence. It is crucial that engineering quality issues receive the attention they deserve from everyone.

3.3.2. The Decline of Government Credibility

Government credibility is a specific manifestation of the government's legitimacy and its relationship with the public. It refers to the government's ability to propose appropriate solutions in the allocation of interests among social individuals after acquiring public power and to implement them through fair, efficient, and clean means to gain the trust of the general public. Since the reform and opening-up policy from 1978, the tremendous changes in China's economy and social environment have become important reasons shaking the government's credibility. The contradiction between the demand for fairness mechanisms and an open environment triggered by economic globalization and the relatively backward function of the Chinese government has caused dissatisfaction among the people. The market mechanism has also led to acts of power alienation, such as corruption and unfair competition, which have worsened people's evaluation of the government. The lag in reforming China's institutional system has made it difficult to implement credit protection mechanisms, and the gradual increase in people's political awareness, as well as the continuous expansion of channels for expressing public opinion, have posed significant challenges to the government's credibility in China.

After the building collapse accidents in Quanzhou, Fujian (7 March 2020), and Xiangfen, Shanxi (29 August 2020), the central government instructed immediate investigation into safety hazards associated with such buildings and prompt rectification of identified loopholes to prevent mass casualties at the root. However, the following main problems were observed at various levels of government, Hunan Province, Changsha City, and Wangcheng District, during the self-built house collapse accident in Changsha on 29 April 2022: (1) delayed and superficial deployment of special inspections on illegal construction and irregular approvals, with an attitude of mere perfunctoriness; (2) mutual avoidance and shirking of responsibilities among government departments during the routine supervision of illegal construction and renovation of self-built houses; (3) over the past ten years, from 2012 to date, multiple large-scale campaigns were organized by government at all levels in Hunan Province, Changsha City, and Wangcheng District to rectify self-built houses, but the work was lax, insincere, and carried out as a formality; (4) government departments exhibited weak enforcement against violations, tolerating and neglecting misconduct, thereby encouraging more people to engage in illegal activities; (5) the chaotic management of housing inspection agencies resulted in all 79 inspection reports issued by the involved companies since their establishment being falsified; (6) uncontrolled planning and construction of self-built houses without obtaining planning permits, lacking professional design and completion acceptance, and posing significant risks in terms of building and fire safety. The occurrence of these problems has to varying degrees contributed to the decline in government credibility.

3.4. The Dilemma of Engineering Ethics Education

3.4.1. Insufficient Emphasis on the Interdisciplinary Nature of Engineering Ethics

Engineering ethics is a field that is based on both the humanities and technological education, relying on other disciplines as its foundation. Essentially, it is an intersection between philosophy and engineering. With the development of science and technology, there has been an increasing emphasis on science and technology in China while neglecting the humanities. However, engineering education is inseparable from humanities education. Engineering education provides knowledge to understand and transform the world, while humanities disciplines provide principles, thoughts, and methods. The two are interdependent and cannot be separated. If engineering ethics education does not gain recognition in society, its research and practice will struggle to develop because the public's awareness of engineering ethics directly influences and restricts the development of engineering ethics education. Engineering students who only focus on their professional studies lack knowledge in the humanities and social sciences. In complex situations, they are unable to make informed decisions. The current educational model fails to reflect the interdisciplinary nature of the field, resulting in narrow perspectives and a lack of problem-solving abilities among students.

3.4.2. Detachment between Theory and Practice in Engineering Ethics Education

Professors of philosophy and ethics who are involved in engineering ethics education often lack practical engineering experience. The teaching method commonly used in the classroom relies on theoretical interpretations, without effectively integrating engineering theory with actual engineering examples. Additionally, there is a lack of analysis and inspiration from engineering case studies in the classroom, and the design of course content fails to reflect the unique nature of engineering. Engineering ethics education should aim to address real-world issues through theoretical education, stimulating students' innovative capabilities, and helping them develop independent thinking and problem-solving skills, rather than resorting to empty moral preaching.

There is a detachment between theory and practice in higher education, but it is essential to prioritize the professional qualities of engineering practitioners in real-life situations. It is necessary to strengthen social oversight on the professional ethics of engineers, implement effective professional ethics education, employ the power of public opinion to regulate the behavior of engineers, and enhance the overall professional ethics of engineers as a whole. The collapse accident of the self-built house in Changsha, Hunan, highlights the existence of false inspection reports and irregular certification practices by testing companies, indicating a low level of professional ethics among the personnel involved in testing.

3.5. The Collapse of the Condominium Building in Florida, US

On the early morning of 24 June 2021, a partial collapse occurred in a 12-story condominium in Florida, USA. By 23 July 2021, the fire and rescue authorities declared the search for the victims' remains had concluded, confirming 98 fatalities. This accident is considered one of the most severe public safety events in the U.S. in recent years [78,79].

Possible causes include illegal construction by the developer on the top floor in 1981, uneven settlement leading to structural instability, decades-long seawater intrusion causing structural damage in the underground garage, and even sea level rise due to climate change. The collapsed building was completed in 1981, according to Miami's city safety regulations, the building had undergone a series of safety certifications and inspections by local authorities in the preceding months. However, the inspection report indicated that the building's condition was "very typical" for its age, with no "life safety hazards" identified, and no concerns raised about its structure. Following the collapse, the approval process for state and federal government rescue resources took 16 h, with the first rescue team arriving on the scene only 16 h after the accident. The number of subsequent rescuers was insufficient to meet the demands for timely and effective rescue operations.

Questions arise about why the condominium suddenly collapsed; whether the design, construction, management, and inspection were compliant with regulations; why the rescue efforts were so slow; and who should be held accountable. Moreover, what measures should be taken to prevent similar collapses in the future? The federal and Florida state governments have yet to provide clear answers, and even when the investigation report is expected, experts claim it could take years. Some scholars have analyzed the collapse, with Lu et al. [78] studying the overall performance and key components of the collapsed building based on design codes (GB 50010 [75] and ACI-318 [80]) and Kong and Smyl [81] analyzing the collapse event using publicly available social media video clips. However, the ethical dilemmas arising from this collapse still require further reflection.

4. Solutions of Engineering Ethics

4.1. Enhancing the Ethical Perspectives of Engineers

The responsibility of engineers is inherently limited and remains so even as their technological capabilities advance. However, the scope of their responsibility has expanded from initially being accountable to oneself and the company to being responsible to the public and society. With this expansion, engineers face more ethical dilemmas. Scientific and technological advancements themselves have inherent value biases, and even if engineers use technology without misuse or abuse, ethical issues can still arise. Furthermore, conflicts that may arise between multiple roles can put engineers in ethical quandaries, and the collective nature of responsibility also adds to the challenges faced by engineers. Therefore, when engineers collectively engage in problematic behavior along with other societal entities, how do we address issues of responsibility? Who should bear the responsibility, and what kind of responsibility should be assumed when tracing the events of history? These questions warrant our reflection.

4.1.1. Enhancing Public Participation in Engineering Decision-Making

To alleviate the ethical dilemmas faced by engineers, Smith et al. [82] proposed giving critical attention to corporate social responsibility (CSR) and role ethics as a means to help engineers think critically about the ethics of their professional practice. Incorporating discussions on role ethics and CSR explicitly into engineering ethics teaching and learning would be beneficial. Engineering decision-making involves addressing numerous ethical issues, and two primary ethical questions arise within the context of engineering decision-making: who participates in the decision-making and how decisions are made. Mitcham [83] argued that engineering ethics is not solely the concern of experts but rather a matter for everyone in this era.

Prior to making decisions, the project's goals, design concepts, technical feasibility, and potential issues and challenges should be objectively disclosed, and the public should be encouraged to voice diverse opinions. This approach benefits decision-makers by considering alternative perspectives, obtaining comprehensive information, effectively identifying problems, and facilitating improvements in design proposals. In some cases, it can even prevent the implementation of erroneous solutions. Encouraging public participation fosters the scientific and democratic nature of engineering decision-making and maximizes the realization of public interests. Experts often overlook the direct interests of the public during the decision-making process, but public involvement can effectively prevent such situations. The public has the right to participate in engineering decision-making to safeguard their own interests. Public participation and technological assessment serve as vital components of the engineering decision-making process and represent effective means for engineers to overcome their ethical dilemmas.

4.1.2. Effective Implementation of Technical Assessment in Engineering

Technical assessment in engineering involves predicting and analyzing the future development trend of technology to evaluate the feasibility of an engineering project from a technical perspective. It involves assessing potential risks associated with the application of technology in advance and developing appropriate solutions to avoid adverse consequences. A project is likely to succeed if the technology is secure at the technical level and ensures safety during its use. Conversely, if the technology is not viable, the project is unlikely to be successful. Engineering technical assessment encompasses two aspects: first, the feasibility of the technology, and second, the comprehensiveness and integrity of the technology. These two aspects are mutually interactive and complementary. Therefore, engineering technical assessment requires considering both aspects together. The focus of technical assessment lies in conducting comprehensive and anticipatory evaluations of a particular solution, which helps overcome the dilemma faced by engineers.

4.1.3. Establishing a Sound Legal and Ethical Framework for Engineering

In recent years, China has gradually been paying more attention to engineering ethics issues and has promulgated relevant laws and regulations. However, a more comprehensive system has yet to be established, leading to difficulties in ensuring the safety needs of engineers. Often, when engineers are faced with conflicts between ethical responsibilities and practical demands, they are unable to make brave decisions. Furthermore, government enforcement plays a crucial role in safeguarding the rights and interests of engineers and serves as a guarantee for moral construction in various sectors of society.

When faced with issues such as cutting corners in engineering projects, if engineers choose to report the problems to the company, they lack relevant laws to rely on when the company chooses to turn a blind eye and prioritize cost efficiency. If they turn to the safety supervision department for help, it may be futile if the department acts irresponsibly or forms an interest group with the company, and engineers may even face retaliation. To protect the basic interests of engineers, it is necessary to establish a sound legal and liability system, strengthen the reliability of government oversight, and create a favorable environment for ethical practices in engineering. This will enable engineers to speak up and further enhance their ethical awareness.

4.2. Promoting Credibility of Government

Understanding how to promote the government's adaptability to changing times and reshape its credibility has become an urgent issue that needs to be addressed. Building a service-oriented government is a rational approach to reshaping the credibility of government. In our opinion, to build a service-oriented government and reshape the credibility of government, the following aspects need to be considered.

4.2.1. Deepen Administrative System Reform and Establish a System of Government Credibility

In response to the current issues of functional dislocation, overlapping responsibilities, and detachment of power and responsibility in government departments, it is necessary to clearly define the division of labor and establish rules for the exercise of power in future reforms. The goal is to establish a large departmental system with an integrated unity of power and responsibility and to establish mechanisms for coordination and cooperation between departments. Simultaneously, it is essential to strengthen the construction of leadership teams at all levels and continuously optimize internal supervision mechanisms. Improvements should be made to the administrative hearing system, the information disclosure system, the government credit system, and the accountability system, with a focus on institutional innovation and the establishment of a government credit system.

4.2.2. Actively Mobilize the Power of the Media and Create a Healthy Ethical Discourse Environment in Engineering

In the face of emergencies, government departments should attach importance to information at all levels after a crisis outbreak. They should promptly communicate with the public through various channels and provide rolling updates. This continuous effort strengthens transparency and emphasizes public opinion guidance, thus avoiding the adverse effects of misinformation resulting from information deviation. It also provides conditions for subsequent government response measures, preventing the weakening of government credibility due to panic. In the modern society with comprehensive internet coverage and the highly influential role of public opinion, the unique function of media in public opinion supervision is increasingly evident. The role of the media is to disseminate real-time information about engineering projects to the public. Therefore, the media can fully exert the supervisory role of public opinion, promote the improvement of technical proficiency in the engineering sector and related institutions, have a significant impact on the ethical environment of engineering construction, and consequently enhance government credibility.

4.2.3. Adhere to the Concept of Public Nature and Service and Establish a People-Centered Philosophy

Government departments at all levels should regard the needs of the public as the guiding principle for providing services. Through performance evaluation and social feedback, they should assess the government's service capabilities and make improvements accordingly. The people-centered work philosophy requires the government to prioritize the fundamental interests of the people, avoid causing losses to their interests due to decision-making errors, and refrain from inconveniencing their production and livelihoods due to inappropriate work methods. It is crucial to firmly establish an image of serving the people.

The collapse of self-built houses in Changsha is a typical accident that exposed the long-accumulated contradictions in the economic and social development of Changsha. The related issues are relatively widespread in the street where the accident occurred, as well as in Wangcheng District and Changsha City. The accident investigation team reviewed more than 2800 documents, conducted over 20 site surveys and visits, and interviewed 225 individuals. They organized experts in planning, construction, and law to conduct research and demonstration and released the accident investigation report in a timely manner. The report disclosed the details and causes of the accident and identified the main problems existing within the party committees, governments, and relevant departments at various levels such as Hunan Province, Changsha City, and Wangcheng District. The report also promptly clarified the specific responsibilities of the parties involved in the accident, provided handling suggestions for relevant units and responsible individuals, and summarized the main lessons learned from the accident. These efforts effectively prevent the recurrence of similar accidents and greatly enhance government credibility.

4.3. Strengthening Engineering Ethics Education

While intensifying research and exploration in the field of engineering ethics, it is important to place emphasis on the education of engineering ethics and integrate it into general education to promote the ethical development of engineers. This will play a positive role in enhancing engineers' value rationality in engineering practice, enabling them to approach the relationship between engineering, nature, and society in a fair, just, and objective manner. Engineering ethics education is essentially about teaching students how to make ethical choices and how to comprehensively evaluate engineering practices. Sustainable development, as a prevailing concept, aims to promote holistic human development, overall societal progress, and the protection of the natural environment as ultimate goals. It can provide practical content and direction for ethics education in engineering in higher education institutions.

4.3.1. Adding Engineering Ethics-Related Courses to the Curriculum

Engineering ethics education includes formal education and informal education. Formal education refers to the ethical education provided within the formal education system for government officials, professionals in the industry, and university staff. Many universities abroad offer courses in engineering ethics. Informal education includes public opinion guidance, policy guidance, legal constraints, and cultural upbringing.

In the 1970s, engineering ethics became a mandatory course in the United States, along with the emergence of economic ethics and business ethics. It has since developed into a relatively sound scientific system. Only by incorporating engineering ethics into the curriculum system can an institution attain accreditation from the Accreditation Board for Engineering and Technology (ABET). Engineering professional organizations in Germany, Japan, and France have developed specific ethical standards and made significant achievements in the study of engineering ethics.

The Accreditation Board for Engineering and Technology (ABET), the Japan Accreditation Board for Engineering Education (JABEE), and the European Federation of National Engineering Associations (FEANI) have all established strict training objectives for engineering students. For a long time, China has lacked a long-term education mechanism and policy support for engineering ethics education for university students. It was not until June 2007, when the China Engineering Education Accreditation Association and the Education Quality Assessment Center of the Ministry of Education issued the National Engineering Education Accreditation Standards (Trial), that the basic quality standards for engineering education were officially established. Tsinghua University was one of the first domestic universities to offer courses on engineering ethics education. After nearly a decade of development, other universities such as Beijing University of Science and Technology, Southwest Jiaotong University, Hohai University, and Fuzhou University have also gradually introduced engineering ethics-related courses.

China should prioritize the education of engineers' professional ethics on an equal footing with technical expertise. More universities should be encouraged to offer standardized engineering ethics education courses. The establishment of course curriculum should also emphasize interdisciplinary approaches. Additionally, engineering ethics content should be incorporated into both core courses and general education courses for science and engineering students, enabling them to gain theoretical knowledge and enhance their understanding of professional ethics for engineers.

4.3.2. Strengthening Engineering Ethics Education in Engineering Practice

In order to enhance engineering ethics education in engineering practice, it is necessary to address the mismatch between traditional education's emphasis on theory and the requirements of the engineering profession. Engineers need to broaden their understanding of disciplines and improve their ability to anticipate and mitigate engineering risks through practical experience. In the teaching of engineering ethics, it is important to provide students with theoretical knowledge while emphasizing engineering ethics codes. By integrating engineering case studies with theoretical knowledge, the potential risks in engineering practice can be analyzed, and specific challenges that may arise can be explained. Students should be trained to analyze real-life problems using relevant theories of engineering ethics to make appropriate judgments. Practical activities should be incorporated to apply the knowledge gained. Schools should strive to provide opportunities for students to engage in real-world engineering activities, including participation in engineering design and management, to enhance their practical skills and cultivate their awareness of engineering ethics and social responsibility. It is also crucial for students to recognize the significant impact of engineering activities on human life and societal development.

The self-built house collapse accident in Changsha serves as a warning that disregarding the objective laws of development and pursuing rapid progress can lead to disasters. This accident, where the owner violated construction regulations, the inspection company issued fraudulent reports, and government oversight was inadequate, reflects the widespread non-standard practices in the field of self-built houses, which inevitably lead to accidents.

4.3.3. Strengthening Professional Ethics Training for Practitioners

It is of utmost importance to strengthen professional ethics training for practitioners as it can help enhance the overall competence and professional conduct of engineering professionals. The main goal of higher engineering education is to cultivate talents capable of engaging in advanced engineering technology for the country. Currently, China has a vast number of engineering and technical personnel, but their overall quality is not yet high, and there is a significant gap in technical levels compared to foreign counterparts. It is therefore necessary to further enhance the professional competence of engineering practitioners. In addition to possessing extensive theoretical knowledge, solid practical skills, and excellent technical abilities, engineers should also strive to improve their moral character, cultivate ethical qualities, and enhance their overall competence and professional ethics.

It is important to establish a more comprehensive engineer training and employment system, creating a relatively stable and professional workforce to address the current situation of employing the majority of practitioners on a temporary basis without proper formal training. Therefore, increasing the emphasis on vocational ethics education and strengthening the moral cultivation of engineers has become an essential choice.

4.4. Solutions Taken after the Collapse Accidents

The occurrence of collapse accidents highlights the ethical issues in engineering. To address these engineering ethics dilemmas, it is essential first to establish a sound legal framework for engineering ethics and enhance government oversight to ensure that engineers are willing to take responsibility. Next, it is crucial to continuously promote engineering ethics education to enhance the professionalism and moral awareness of engineering personnel. Ultimately, a community of ethical responsibility in engineering that enforces accountability at all stages should be built. Both the Chinese and U.S. governments have made similar efforts in institutional development.

4.4.1. The Self-Built House Collapse Accident in Changsha

The investigation report on the self-built house collapse in Changsha, Hunan, indicates that the involved owners and relevant enterprises exhibited various violations and illegal behaviors. The Hunan provincial government, along with the Changsha city and Wangcheng district authorities, faced issues such as delayed centralized governance deployment, a simplistic approach to handling inspections, mutual shirking of daily regulatory responsibilities, inadequate seriousness in investigation and rectification, weak enforcement against violations, chaotic management of housing inspection agencies, and a loss of control at the source of self-built house planning and construction.

On 30 April 2022, the State Council of China called for lessons to be learned from the self-built house collapse accident, urging comprehensive inspections for various safety hazards. It directed relevant departments to immediately carry out safety risk inspections for self-built houses and to take strict legal action against unauthorized construction and changes to the main structure of buildings to prevent similar collapses. In response to the prominent issue of building safety in China, the government emphasized the need to expedite the research and improvement of building safety management systems, establish a building inspection system, and enhance safety guarantees throughout the entire life cycle of buildings. Furthermore, it called for the establishment of a housing pension system to address the funding sources for the maintenance of existing buildings and the introduction of a housing quality insurance system to further improve the engineering quality and safety regulatory mechanism through market-oriented means.

On 27 May 2022, seven departments of the Changsha municipal government jointly issued the Operational Measures for the Ten Safety Management Guidelines for Commercial Self-Built Houses in Changsha. This document covers five main areas: the safety assessment of houses, the handling of safety hazards, the improvement of approval procedures, standardized management practices, and the strengthening of daily supervision. The operational measures stipulate that new self-built houses should not be constructed within urban and county planning areas. New rural self-built houses are limited to three stories or less. For self-built houses that are three stories or more (including three stories) and have a building area exceeding 300 square meters, as well as houses within resettlement areas, they must be included in the basic construction program management. Any newly constructed self-built houses that do not comply with planning and approval requirements are prohibited from being approved.

4.4.2. The Condominium Building Collapse in Florida, US

In the spring of 2022, the Florida legislature passed the Florida Condo Safety Act, which mandates that all condominium buildings that are three stories or taller and located within three miles of the coastline must undergo inspections by qualified engineers or architects if they are 25 years old or older, with compliance required by the end of 2024. Additionally, condominiums that are over 30 years old, are three stories or taller, and are located more than three miles from the coastline must also be inspected. The law further requires condominium associations to reserve sufficient funds by 2025 to ensure the necessary maintenance for preserving the structural integrity of the buildings. Besides the newly introduced inspection and reserve fund requirements, the regulation requiring the installation of automatic sprinkler systems in condominium buildings six stories or taller will come into effect on 1 January 2024. The implementation of these laws and regulations will undoubtedly help ensure building safety to some extent.

4.5. The Ethical Analysis and Decision-Making Model for Engineering Failures

On 1 January 2021, the Civil Code of the People's Republic of China came into effect. Article 1252 of the Civil Code specifically delineates two scenarios in which building collapse may occur due to defects in quality and defects unrelated to quality, respectively. Where a building, structure, or another type of a facility collapses or subsides and causes damage to another person, the project owner and the constructor shall assume joint and several liability, unless they can prove that there is no quality defect. Where the damage is due to the fault of another responsible person, the project owner or constructor who has made compensation has the right to indemnification against the responsible person. Where a building, structure, or another type of facility collapses or subsides and damage is thus caused to another person due to the fault of the owner, manager, user, or a third person, the owner, manager, user, or the third person shall bear tort liability [84].

This paper, based on the Civil Code of the People's Republic of China, integrates the subject, object, and ethical issues of engineering into a system model for research and decision-making on ethical problems in engineering collapses [85], as illustrated in Figure 4. The multi-party stakeholders of the engineering community, including the government, project owner, constructor, owner, manager, user, a third person, and the public, constitute the system's subject. The relationships between these subjects are characterized by interaction and negotiation. The entire life cycle of the engineering project serves as the system object, with ethical issues encompassing various stages, including planning, design, construction, operation, repairment, maintenance, and demolishment. The research and decision-making on engineering ethical issues represent the interactive action between the subject and object of the system, emphasizing the micro-dimension and problem-oriented approach in specific engineering practices.

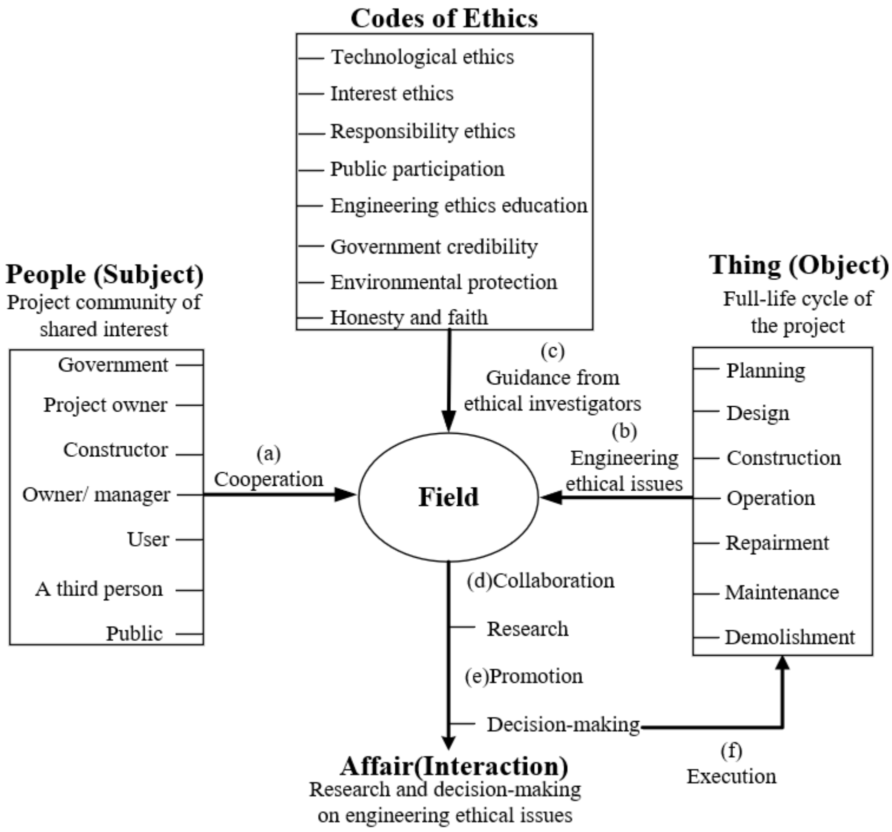


Figure 4. The ethical analysis and decision-making model for engineering failures.

Within this model, the diverse stakeholders of the engineering community address ethical issues that arise during the various stages of the project lifecycle, forming a field of study. Under the guidance of ethicists and researchers adhering to ethical standards, including ethical values (technical ethics, interest ethics, and responsibility ethics), public participation, engineering ethics education, governmental credibility, environmental protection, and honesty, collective wisdom is leveraged to assist decision-makers in formulating solutions acceptable to all parties and to promote the implementation of solutions across the various processes of the engineering lifecycle. This iterative process is expected to enhance the awareness of engineering ethics among the entire society, aid in the identification of ethical issues in engineering, assist in mastering and applying the basic norms of engineering ethics, and improve the ability to make decisions and address ethical problems in engineering.

5. Conclusions

In this paper, a concise but comprehensive investigation of the causes of building collapses, accident rescue efforts, existing engineering ethics dilemmas, and solutions to overcome ethical dilemmas is presented. By combining the case of the self-built house collapse accident in Changsha with engineering ethics theory, this paper conducts ethical reflections on the accident, analyzes the ethical dilemmas faced by the development of engineering technology based on practice, and draws lessons from the accident. It also proposes solutions to help overcome ethical dilemmas. Some potential solutions, such as enhancing engineers' ethical perspectives, improving government credibility, and strengthening the education on engineering ethics, may help address the shortcomings of the existing engineering ethics framework and their related social, economic, and environmental issues. Finally, an ethical analysis and decision-making model for engineering failures is proposed based on the Civil Code of the People's Republic of China. Aimed at guiding the deeper development of engineering technology in China, this has significant theoretical research implications and practical value for the development of engineering projects.

In general, engineers need to collaborate with ethicists, social scientists, and experts from other fields to solve complex ethical problems. This interdisciplinary collaboration can promote knowledge exchange and the collision of ideas between different domains. We hope that this research could provide some insights for future studies on engineering ethics, helping various stakeholders, including engineers, to better understand the ethical issues of technological development and find innovative ways to address these dilemmas.

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