

Application Research on Safety Assessment of Old Elevators

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Abstract

According to statistical data, China currently ranks first in the world in terms of elevator holdings, annual production, and average annual growth. Among them, the number of elevators that have been in use for more than 15 years has exceeded 800,000, and those older than 20 years have surpassed 170,000. Due to prolonged use and wear and tear, these aging elevators face a higher probability of malfunctions. In the event of a safety accident, they pose a direct threat to the lives of residents. Therefore, it is particularly urgent and important to carry out safety assessments on aging elevators in use, aiming to comprehensively identify potential risks and propose targeted safety countermeasures to effectively reduce safety risks. This paper elaborates on the workflow of elevator safety assessments and clarifies the specific requirements for risk evaluations, aiming to provide useful references and guidance for future elevator inspection work.

Keywords

Old elevators, safety assessment, risk analysis.

1. INTRODUCTION

Recently, a shocking elevator accident occurred in a residential area in Guizhou Province, where an elevator abnormally ascended from the 11th floor to the 28th floor, severely injuring a 7-year-old boy with multiple fractures throughout his body. The image of accident scene is shown in Fig.1 and the image of rescue is shown in Fig.2. Preliminary investigations suggest that the accident may be related to a fault in the elevator's brake, and this elevator has been in service for nearly 15 years, categorizing it as outdated equipment. In recent years, such elevator accidents have been frequent nationwide, posing a significant threat to public safety. Elevators, as indispensable vertical transportation tools in modern life, often have severe safety consequences when they malfunction. According to statistics, with the accelerated urbanization process in China, the total number of elevators in the country has surpassed the 11 million mark, nearly equivalent to the combined total of elevators in all other countries globally. Particularly noteworthy is that by the end of this year, the number of outdated elevators in service for over 15 years will climb to 900,000, a substantial figure that undoubtedly heightens the risk of elevator accidents.



Figure 1. Image of accident scene



Figure 2. Image of rescue

Reviewing the report on the safety status of special equipment nationwide released last year by the State Administration for Market Regulation, elevator accidents accounted for 19.72% of all special equipment accidents in 2023, with a significant proportion involving outdated elevators. These statistics serve as a warning that the safety issue of outdated elevators has become a social problem that cannot be ignored. In light of this, to ensure the safety of the people and effectively reduce the risks posed by outdated elevators, conducting comprehensive safety assessments on them is particularly urgent and important [1].

2. REASONS FOR ELEVATOR SAFETY ISSUES

The safety problems of old elevators in use are becoming increasingly prominent, mainly manifested in: First, due to excessive wear of mechanical parts and aging of electronic components, the failure rate is high, resulting in frequent malfunctions or inability to operate; Secondly, due to the backward design, manufacturing and installation technology in the early days, the safety performance indicators of elevators are underground, and some safety performance indicators cannot meet the requirements of current safety technical specifications and standards, resulting in many potential safety hazards; Thirdly, some spare parts that need to be replaced and were produced in the early days are no longer produced, making it difficult or even impossible to purchase them, resulting in the failure to effectively repair and replace parts with potential safety hazards [2].

Therefore, it is necessary to conduct safety assessments on outdated elevators, determine their risk levels and categories, and propose measures to reduce risks.

3. SAFETY ASSESSMENT OF ELEVATORS

The core of safety assessment lies in using the concept of risk assessment to systematically identify and examine potential risk points. This process is not only about discovering risks, but more importantly, taking corresponding measures to reduce these risks to an acceptable level, thereby ensuring the safe operation of elevators [3].

3.1. Definition of safety assessment

Safety assessment is a professional service in which an assessment agency ensures the safety of elevators based on the requirements of the client. This process involves in-depth inspection of key aspects such as elevator equipment itself, use management, and daily maintenance, to identify and analyze possible risks and hidden dangers. Through this detailed risk analysis and assessment, the assessment organization proposes both reasonable and feasible safety countermeasures to effectively address the identified risks.

3.2. The process of safety assessment

The general process of safety assessment is outlined as follows: Firstly, an organization or individual with a need must submit a written request to a safety assessment agency, requesting

a safety assessment for a specified elevator. Upon receiving the request, the assessment agency will immediately begin formulating a detailed work plan. The assessment team will conduct a site survey and organize in-depth discussions among experts subsequently. At this stage, they will clearly categorize the identified issues into risk categories and propose a series of comprehensive improvement suggestions accordingly [4]. The assessment agency will consolidate all information and compile a detailed safety assessment report ultimately. The process diagram of assessment is shown in Fig.3.

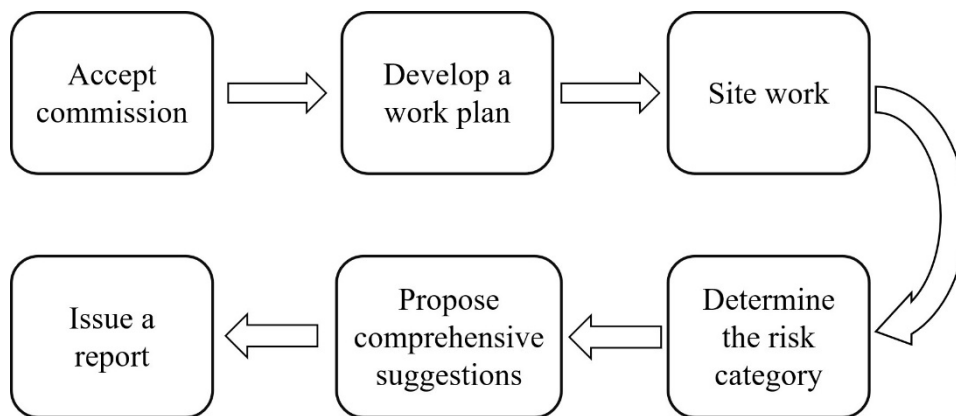


Figure 3. Process diagram of assessment

3.3. Risk estimation

For each evaluation item related to the equipment itself, the assessors evaluate the identified scenarios based on the severity of the injury and the probability level of occurrence to determine the risk level.

1) Injury severity

When evaluating risks, we should consider the potential impacts on personal safety, property, and the environment comprehensively, based on the objectives and specific contexts of the risk assessment. On this basis, for the potential injuries that may occur in a particular scenario, their severity should be assessed with reference to Table I.

Table I. Injury Severity

Severity	Description
1-High	Death, system loss, or severe environmental damage
2-Medium	Serious injury, severe occupational diseases, major system or environmental damage
3-Low	Minor injury, less severe occupational diseases, secondary system or environmental damage
4-Negligible	No injury, occupational disease, or system or environmental damage

2) Probability of injury occurrence

By comprehensively considering the established factors such as the probability of the scenario occurring, the frequency and duration of exposure to danger, as well as the possibility of influencing, avoiding, or limiting harm, the probability of harm occurring can be assessed.

Based on the consideration of these factors, the probability level of harm occurrence should be classified with reference to Table II.

Table II. Probability Level

Probability	Description
A-Frequently	Occur frequently during the service life
B-Probably	Occur several times during the service life
C-Occasionally	Occur at least once during the service life
D-Rarely	May occur during the service life
E-Impossible	The probability is almost zero

3) Risk level

The risk level can be determined by comprehensively measuring both the severity and probability grades, as shown in Table III.

Table III. Risk Level

Probability level	Severity			
	1-High	2-Medium	3-Low	4-Negligible
A-frequently	1A	2A	3A	4A
B-Probably	1B	2B	3B	4B
C-Occasionally	1C	2C	3C	4C
D-Rarely	1D	2D	3D	4D
E-Impossible	1E	2E	3E	4E

4) Risk category

Once the risk level has been assessed and determined, the next step is to conduct a risk evaluation to judge whether appropriate protective measures are needed to reduce the risk level. This evaluation process will be based on the assessed risk level and will achieve an accurate definition of the risk by identifying the corresponding risk category, as shown in Table IV.

Table IV. Risk Category

Risk category	Measures taken
I	Protective measures need to be taken to reduce risks
II	A review is needed to determine whether further protective measures are required to reduce risks, taking into account the practicality of solutions and social value
III	No measures need to be taken

5) Risk evaluation

By combining the risk level and risk category, one can obtain the risk assessment grade, as shown in Table V.

Table V. Risk Evaluation

Risk category	Risk level	Measures taken
I	1A, 1B, 1C, 1D, 2A, 2B, 2C, 3A, 3B	Protective measures need to be taken to reduce risks
II	1E, 2D, 2E, 3C, 3D, 4A, 4B	A review is needed to determine whether further measures are required to reduce risks, taking into account the practicality of solutions
III	3E, 4C, 4D, 4E	No measures need to be taken

3.4. Propose risk reduction measures

If the risk category is classified as Class I or II, appropriate protective measures need to be selected to deal with it. After the implementation of protective measures, it is necessary to conduct a risk analysis to verify whether the risks have been effectively reduced to a safe level, confirm that no new risks have been generated, and that the remaining risks do not need further reduction [5].

Reducing risks through design means to meet the safety performance requirements of elevators is a strategy that integrates safety solutions directly into the equipment functional design stage without the need for additional safety guards. Therefore, it is also known as direct safety technical measures. These measures mainly include: firstly, adopting appropriate design structures to maximize the avoidance or reduction of potential hazards; secondly, reducing the need for operators to enter hazardous areas through design, thereby limiting their exposure to risks; and finally, combining these two methods for better safety outcomes.

When intrinsic safety measures are unable to effectively avoid or adequately control hazards, it is necessary to carefully plan various safety protective devices during the overall design stage of elevators. These devices must be manufactured, installed, inspected, and maintained strictly according to design requirements during the manufacturing, installation, and subsequent use stages to ensure safety [6].

If the hazards identified through the aforementioned methods cannot be eliminated or effectively reduced, it is imperative to clearly inform users of the residual risks associated with the device, system, or process. In response to these risks, the following measures should be taken:

1) Provide Information

Elucidate to users the existing risks and their potential consequences in detail, ensuring they are fully aware and cognizant of the risks.

2) Determine the Necessity and Scope of Training

Based on the nature of the risks, develop necessary training programs to ensure users acquire the skills and knowledge required for safe operation of the equipment or system.

3) Increase Warning Signs

Place warning signs in prominent locations to visually remind users of potential dangers.

For elevator components that have been identified as posing risks, our primary consideration is to eliminate or reduce these risks through repairs or adjustments. If the components have reached the scrap technical conditions specified in the GB/T 31821-2015 standard or the product's use and maintenance instructions, the corresponding elevator components must be replaced to fundamentally eliminate the risks. For elevators that comply with the standards at the time of manufacture but lack or do not meet the safety protection devices specified in current standards, we will propose specific plans to add or improve safety protection devices, taking into account factors such as risk categories, technical feasibility, and economic costs. This

will further enhance elevator safety and eliminate or reduce potential risks. In some cases, if the identified risks cannot be effectively eliminated or reduced through existing measures, we will clearly indicate these residual risks and recommend additional preventive measures. This may include strengthening elevator maintenance and monitoring, adding prominent warning signs, formulating and implementing special emergency response plans, etc. These measures aim to ensure rapid and effective response in the event of a risk, maximizing the safety of personnel and equipment.

Based on the risk categories, their quantities, the overall safety condition rating of the elevator, and the individual risk reduction measures already implemented, we need to comprehensively consider technical complexity and economic feasibility to propose reasonable suggestions for general repairs, major repairs, renovations, or replacements for the entire elevator system. For potential safety hazards in use management and routine maintenance, we also need to put forward targeted improvement suggestions. These suggestions aim to optimize the elevator's use management process and enhance the quality of routine maintenance, thereby ensuring the long-term safe operation of the elevator.

Through a comprehensive approach, we strive to enhance elevator safety from multiple levels and safeguard the lives and property of the people.

3.5. Issue a safety assessment report

The core content of a safety assessment report usually includes the purpose and basis of elevator safety assessment, detailed assessment content, professional assessment team composition, comprehensive overview of elevator equipment, assessment process and its main instruments and equipment, in-depth technical analysis, and comprehensive safety assessment conclusions. According to the specific requirements of the client and the characteristics of the project, the content of the safety assessment report can be adjusted and optimized accordingly.

4. RISK ASSESSMENT CASE

In November 2024, an inspection agency conducted a safety assessment on a freight elevator in an industrial park. The relevant information and technical parameters of the equipment are shown in Table VI.

Table VI. Basic Information of Elevator

Device name	Cargo lift	Manufacturing date	August 1, 2004
Rated load	2000kg	Rated speed	0.5m/s
Floors	3	Stations	3
Doors	3	Control mode	Selection system
Speed regulation method		Variable Voltage Variable Frequency	

4.1. On-site Risk Assessments

The issues found are illustrated in Fig. 4 to 9.

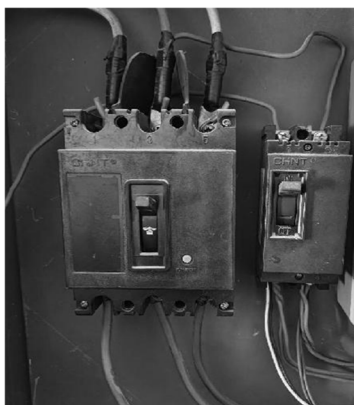


Figure 4. No misoperation protections



Figure 5. Oil leakage



Figure 6. Wheel groove wear



Figure 7. No electrical switch

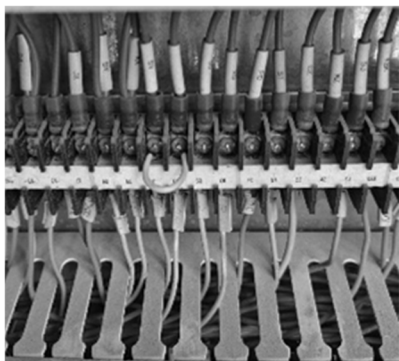


Figure 8. Shortcut the circuit



Figure 9. Electric relay damage

4.2. Summary of Evaluation Overview

Compile and tabulate the findings of the on-site evaluation, as shown in Table VII.

4.3. Overall Evaluation and Suggestions

Based on the safety assessment, the elevator is found to have 8 Category I risks and 7 Category II risks. Considering that the elevator was manufactured prior to the implementation of the TSG T7001-2023 (Regulation for Lift Supervisory Inspection and Periodical Inspection) safety technical specifications and is not equipped with the required Unintended Car Movement Protection (UCMP) device and Automatic Car Operation Protection (ACOP) systems, the cost of rectification would be significant, and there is no practical value in repairing or retrofitting it. Therefore, it is recommended to replace the entire elevator.

Table VII. Risk Assessment Table

NO.	Risks	Evaluation criteria				
1	No misoperation protections	The main switch should have stable open and closed positions, and be capable of being locked with a padlock when in the open position				
	Severity	2	Probability	D	Category	I
	Measures	Repair the main switch to ensure it can be locked with a padlock when in the off position				
NO.	Risks	Evaluation criteria				
2	Oil leakage of lift machine	The compartment divider surfaces, observation window covers, and other parts of the gear traction drive housing should be tightly connected to prevent any leakage of oil.				
	Severity	3	Probability	D	Category	II
	Measures	Identify the causes of oil leakage at the shaft end of the gearbox and perform repair				
NO.	Risks	Evaluation criteria				
3	Severe wear on the groove	The traction sheave groove is free from defects or abnormal wear.				
	Severity	2	Probability	D	Category	I
	Measures	Replace the traction wheel				
NO.	Risks	Evaluation criteria				
4	Lack of electrical switch	For removable manual winding handwheels, there is an electrical safety device that becomes operational at the latest when the handwheel is installed on the elevator drive machine.				
	Severity	3	Probability	D	Category	II
	Measures	Add an electrical safety device				
NO.	Risks	Evaluation criteria				
5	Shortcut the circuit	It is prohibited to bypass the electrical safety circuit of the elevator				
	Severity	2	Probability	C	Category	I
	Measures	Remove the short-circuit wires				
NO.	Risks	Evaluation criteria				
6	The phase sequence relay damage	The phase failure and phase sequence error protection functions of the phase sequence relay should be effective				
	Severity	3	Probability	D	Category	II
	Measures	Repair the phase sequence relay				
NO.	Risks	Evaluation criteria				
7	Not equipped with the Automatic Car Operation Protection	When the upward travel speed of the elevator car becomes uncontrolled, the Automatic Car Operation Protection device for upward travel should activate, causing the car to stop or at least reduce its speed to within the design range of the counterweight buffer.				
	Severity	1	Probability	C	Category	I
	Measures	Add the Automatic Car Operation Protection				
NO.	Risks	Evaluation criteria				
8	No Unintended Car Movement Protection	The Unintended Car Movement Protection device can promptly detect and take measures when the elevator car moves unexpectedly, in order to prevent harm to passengers				
	Severity	1	Probability	C	Category	II
	Measures	Add the Unintended Car Movement Protection				

5. SUMMARY AND PROSPECT

The government should actively formulate policies to intensify the safety assessment of aging elevators and increase government funding subsidies to support their renovation and upgrading, thereby enhancing the quality of life for residents.

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