Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 11, No. 3, 2024

Research on Object Strikes in Construction based on Hidden Hazard Correlation Analysis

Zhifeng Zhao [1], Xinyu Liu [1], Yuanyuan Feng [2]

[1] Xi'an Shiyou University, Xi'an, Shannxi, 710065, China
[2] Xi'an University of Science and Technology, Xi'an, Shannxi, 710054, China

Abstract: The safety of building construction is significantly impacted by object striking incidents, and social network analysis can be applied to analyze the correlation between potential hazards to mitigate associated risks. In this study, the focus is on assessing the construction safety of projects undertaken by Anjian Group. The traceability method was employed to identify 33 safety hazards, forming the basis for the establishment of a comprehensive safety hazard model. We used Ucinet 6 software to generate a safety hazard correlation map for object strike accidents in construction projects. The analysis encompassed holistic evaluation, cohesive subgroup analysis, and degree centrality analysis. The findings revealed that material flying out and falling hanging objects exhibited the highest degree of centrality. Consequently, emphasis should be placed on enhancing protective measures in these specific areas to ensure an optimal safety framework. This systematic approach integrates both the theoretical and practical aspects of safety hazard analysis in the context of construction projects, contributing to the overall enhancement of construction site safety.

Keywords: Construction Safety; Object Strike; Social Network Analysis; Countermeasures and Measures.

1. Introduction

The rapid economic growth in China has propelled significant advancements in the construction industry, accompanied by a myriad of security concerns. While China has made notable strides in safety management, an objective evaluation reveals insufficient investment in safety protocols within construction projects, resulting in a subpar safety standard. The consequence of this deficiency is evident in the high frequency of safety accidents, leading to substantial losses in national assets and endangering personal safety. Consequently, the imperative of ensuring and enhancing construction safety has emerged as a pivotal topic within the realm of construction safety.

In response to this pressing issue, the author initiates a safety analysis focused on object striking accidents within the building construction projects undertaken by Anjian Group. Employing the social network analysis method, the study aims to discern correlations between safety hazards, specifically exploring the primary hazards that precipitated the aforementioned accidents. The overarching goal is to furnish insights and strategic countermeasures for enhancing risk management practices within the construction industry.

2. Theory of Social Network Analysis

Social network analysis serves as an investigation into social structures, delineating intricate connections among social units through network diagrams characterized by specific structures. This analytical approach utilizes specialized theories and methods. Based on causal relationships, networks formed by individuals can be broadly categorized into undirected and directed networks. Undirected networks signify individuals with no discernible connections, while directed networks depict causally connected individuals. [1].

The initiation of social network analysis entails a threefold analysis: examination of the overall network structure, identification of cohesive subgroups, and evaluation of network centrality. The primary centrality indices include degree centrality and intermediate centrality. Key indicators encompass Density, Cohesion, Average Shortest Path, Degree Centrality, Node Betweenness, and Intermediate Centrality Distribution. Larger values of Network Density and Average Shortest Path denote closer interpersonal connections, whereas higher cohesion signifies more intricate relationships. Degree Centrality reflects direct associations between individuals.

Social network analysis involves constructing a matrix representing relationships between individuals, with "0" and "1" indicating the absence or presence of connections. This matrix, where rows and columns represent individuals, facilitates the study of connections. Importantly, this method extends beyond closed-loop networks, proving valuable in exploring causal relationships within non-closed-loop networks and thereby guiding research in accident chain dynamics.

3. Using Social Network Analysis to Analyze Object Strikes

3.1. Establishment of Safety Hazards

The traceability method is applied retrospectively to identify causes related to object striking incidents in Anjian Group's building construction projects. This method facilitates a comprehensive analysis by allowing bidirectional tracing – analyzing accidents based on outcomes and working backward to infer potential accidents from underlying causes. A total of 33 potential hazards are identified and categorized, encompassing aspects such as construction personnel, tools and equipment, and environmental factors. These hidden safety hazards, revealed through the traceability method, are systematically presented in Table 1, offering valuable insights into the safety challenges inherent in Anjian Group's construction activities.

Utilizing the traceability method, we achieved a comprehensive identification of 33 potential hazards associated with object striking accidents in Anjian Group's construction projects. These hazards have been systematically classified into distinct categories, encompassing facets such as construction personnel, tools and equipment employed in construction, and environmental factors. The resulting breakdown, available in Table 1, elucidates the multifaceted nature of these hazards and their interrelation, specifically in the context of the object striking accident within Anjian Group's construction activities. The tabulated information serves as a structured reference, offering insight into the latent safety risks embedded in the construction processes undertaken by Anjian Group.

Table 1. Selected safety hazards associated with object strikes

Safety Hazard No.	Description of Safety Hazards
A1	Non-compliance with indiscriminate dumping
A2	Unauthorized cross-cutting operations
A3	Personal error
A4	Failure to check and correct safety devices in a timely manner
A5	Failure to wear helmet properly
A6	Improper operation
A7	No qualifications
A8	Inadequate command coordination
A9	Unauthorized operation
A10	Failure to use the safe passage
A11	Command error
A12	Not concentrating on the main point
B1	Inadequate protection of the four openings and five critical edges
B2	Insecure placement of objects
B3	Failure of safety devices
B4	Wire rope breakage
B5	Equipment malfunction
B6	Fail to securely tie
B7	Overloading
B8	Equipment breakdown operations
B9	Quality defect
B10	Unauthorized operation of machinery
B11	Equipment jamming, illegal stabbing
B12	Material does not meet processing requirements
B13	Failure to configure qualified safety nets
C1	Strong breeze
C2	Violent attack
C3	Poor vision
D1	Falling objects
D2	A pendant falls
D3	Personnel underneath a sling
D4	Material flying out
D5	Object strikes

3.2. Building a Network of Relationships for Safety Hazards

In the examination of 33 safety hazards, a systematic classification has been employed, categorizing them into distinct types denoted as A: unsafe human behavior; B: unsafe state of objects; C: environmental factors; and D: comprehensive factors. The establishment of a safety hazard model is predicated on these classifications, where each hazard is represented as a unique entity in a safety hazard association network diagram. The presence of a connecting line between two entities signifies a relationship, and the directionality of the connecting line conveys nuances in the influence between the respective hazards [6].

The safety hazard association network diagram is conceptualized as a directed network, characterized by three primary relationship types: a→b, b→a, and a ↔ b. Specifically, a→b denotes that the occurrence of hazard a can precipitate the manifestation of hazard b; conversely, b→a suggests that hazard b can lead to the occurrence of hazard a.

The notation a ↔ b signifies a bidirectional influence, indicating that hazards a and b mutually impact each other. Noteworthy safety hazard associations are delineated in Table 2, further elucidating the intricate interplay between different safety hazards.

Table 2. Partial Safety Hazard Correlation

affiliate relationship	Description of Safety Hazards	Description of Safety Hazards	Relationship description
A2→D1	A2:Unauthorized cross-cutting operations	D1:falling objects	Illegal human crossings can lead to falling objects
B4→D2	B4:Wire rope breakage	D2: A pendant falls	Wire rope breakage can lead to falling objects
C1→C3	C1:Strong breeze	C3:Poor vision	Strong winds can cause poor visibility for construction workers
A11→D3	A11:Command error	D3:Personnel underneath a sling	A command error can cause a person to appear under a sling
B12→D4	B12:Material does not meet processing requirements	D4:Material flying out	Failure to process materials in accordance with requirements can cause objects to fly out
A3 ↔ A9	A3:Personal error	A9: Unauthorized operation	Individual operational errors can lead to unauthorized operations, because unauthorized operations can lead to individual operational errors for psychological reasons
B9→B11	B9:Quality defect	B11:Equipment jamming, illegal stabbing	Defects in the quality of the equipment can lead to jamming

3.3. Data Analysis

We use Ucinet 6 software to construct the safety hazard correlation network diagram of Anjian Group's building construction project about object striking accidents as shown in Fig. 1.

Within the network diagram, distinct entities are denoted by different letters, categorizing all individuals into four principal color-coded categories: red, yellow, blue, and green. Each color corresponds to a specific hazard category—red representing unsafe human behavior, yellow denoting environmental factors, blue signifying the unsafe state of objects, and green representing comprehensive factors. The connecting lines, featuring arrows, between individual entities serve to indicate the nature of the relationships among them [7].

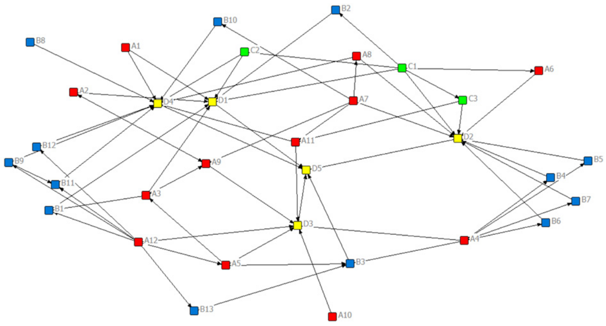

Fig 1. Safety hazard association network diagram

3.3.1. A Holistic Analysis of the Network of Safety Hazard Relationships

The safety hazards relationship network for Anjian Group's building construction project, specifically addressing object striking accidents, encompasses 33 hazards and 61 connecting lines. The network density, calculated at 0.0616, indicates sparse connections among individuals, suggesting a lack of extensive interconnections between safety hazards [8].

The average shortest path of the network, quantified at 1.533, serves as a metric reflecting the degree of interaction between safety hazards. A smaller average shortest path value suggests a higher likelihood of interaction among safety hazards. Furthermore, the network analysis reveals a correlation coefficient of 1.0000, a network rank of 0.9744, a network efficiency of 0.9395, and a network centrality of 0.2077, providing comprehensive insights into the overall characteristics of the safety hazard association network.

3.3.2. Analysis of Cohesive Subgroups

Initially, all data undergo a "2-valued" transformation, wherein values greater than 0 are assigned 1, and values less than or equal to 0 are assigned 0. Subsequently, a component analysis is conducted with a specified "n" value of 4. The resulting R-squared value of 0.602 indicates a highly satisfactory fit, signifying the effectiveness of the analytical process [9]. The procedural steps for analyzing cohesive subgroups are elucidated in Figure 2.

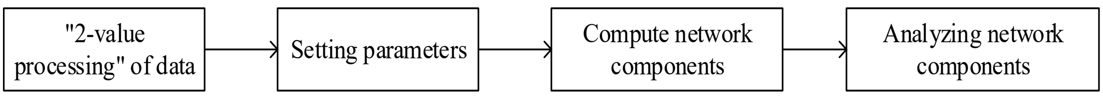

Fig 2. Steps in the analysis of cohesive subgroups

The results show that this safety hazard association network diagram contains 16 subgroups, details of the subgroups are shown below in Figure 3 and Table 3.

Each cohesive subgroup within the safety hazard association network represents an interconnected pathway among its internal members, essentially constituting an accident chain with the potential to lead to specific incidents. In the context of Anjian Group's building construction project, a total of 16 cohesive subgroups have been identified, signifying the existence of 16 distinct accident chains, for example, Faction 2: A11→B10, which indicates that the operator's unauthorized operation may be caused by the human's command error; Faction 9: A2→A3, which indicates that there is a personal operation error due to the construction personnel's unauthorized operation; Faction 13: C1→C3→A6, which indicates that the operator's vision will become blurred due to the strong wind, and finally the construction personnel will operate improperly; Faction 13: C1→C3→A6, which indicates that the operator's vision will become blurred due to the strong wind, and finally the construction personnel will operate improperly; Faction 14: C1→C3→A6, which indicates that the construction personnel's operation is not safe due to the strong wind. Faction 13: C1→C3→A6, indicates that strong winds will make the operator's vision become blurred, which will eventually cause the operator to operate improperly; Faction 14: A7→A8, indicates that the operator is not qualified enough, so it will lead to improper command and coordination.

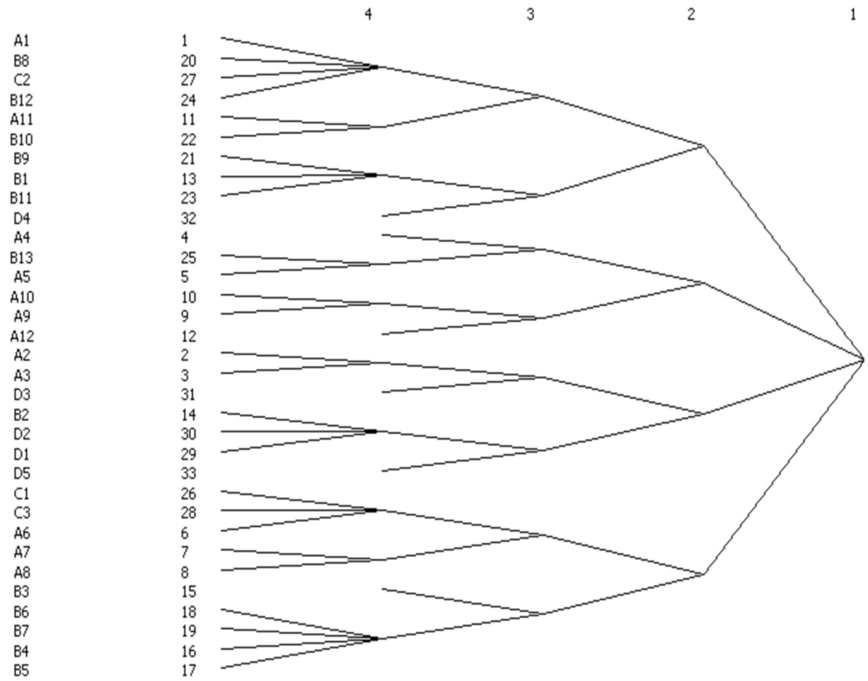

Fig 3. Cohesive subgroups of Anjian Group's building construction projects

Table 3. Cohesive subgroups in networks

subgroup	Safety hazards contained in subgroups
1	A1 B8 C2 B12
2	A11 B10
3	B9 B1 B11
4	D4
5	A4
6	B13 A5
7	A10 A9
8	A12
9	A2 A3
10	D3
11	B2 D2 D1
12	D5
13	C1 C3 A6
14	A7 A8
15	B3
16	B6 B7 B4 B5

3.3.3. Degree-centeredness Analysis of Safety Hazards

The degree centrality analysis for safety hazards in Anjian Group's building construction projects, as presented in Table 4, reveals notable findings. D2 (falling of suspended objects) and D4 (flying of objects) exhibit the highest centrality, underscoring their significance as hazards contributing to the occurrence of falling objects and airborne materials. Subsequently, D1 (falling from height) emerges as the third most critical hazard in object striking accidents. Within the domain of human unsafe behaviors, A12 (carelessness) demonstrates the highest centrality, implying a substantial association with safety hazards. To enhance accident prevention measures, there is a recommendation to bolster safety education initiatives targeted at mitigating carelessness among construction workers during operational activities [10]; In the category of unsafe states of objects, B3 (failure of safety devices) stands out with the highest centrality, suggesting its pivotal role in reducing the probability of safety accidents. Ensuring the proper functioning of safety devices during potential hazards can significantly contribute to accident prevention in the construction process. Furthermore, environmental factors, notably C1 (strong wind), exhibit the highest centrality, indicating a frequent occurrence of safety accidents during strong wind conditions. To minimize the likelihood of safety accidents in such scenarios, it is recommended that construction operations be promptly halted when facing strong wind environments [11].

Table 4. Anjian Group building construction project study in the degree center degree

a safety hazard	centrality	a safety hazard	centrality	a safety hazard	centrality
B8	3.125	A2	6.25	A3	12.5
A10	3.125	A1	6.25	A11	12.5
B7	6.25	C3	9.375	D5	15.625
B6	6.25	C2	9.375	A7	15.625
B5	6.25	B9	9.375	C1	18.75
B4	6.25	B11	9.375	A4	18.75
B2	6.25	B1	9.375	D3	21.875
B13	6.25	A8	9.375	A12	21.875
B12	6.25	B3	12.5	D1	25
B10	6.25	A9	12.5	D4	31.25
A6	6.25	A5	12.5	D2	31.25

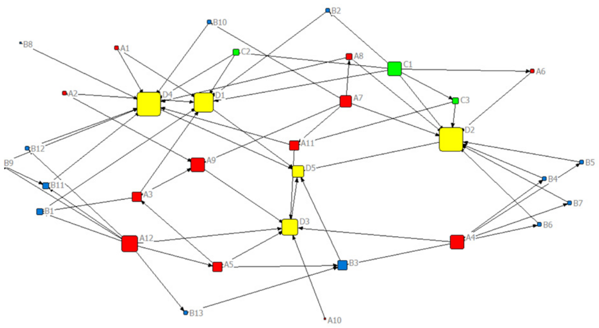

Fig 4. Centrality analysis diagram

An analysis diagram, grounded in centrality measures, has been crafted to elucidate the degrees of centrality for each safety hazard in Anjian Group's building construction projects, as illustrated in Figure 4. Within this network diagram, diverse safety hazards are denoted by unique alphanumeric identifiers, and distinct colors serve to categorize hazards into various types—red for human unsafe behaviors, yellow for comprehensive factors, blue for unsafe states of objects, and green for environmental factors. This color-coded system enhances clarity in discerning hazard categories within the network. In this visual representation, the interconnections among safety hazards are depicted through black lines equipped with arrows, symbolizing the relationships among various hazards. These connections vividly showcase the underlying factors contributing to each hazard and highlight the intricate interplay between different hazards. The strategic use of arrows emphasizes the directionality of these connections, providing valuable insights into the causal relationships among safety hazards. The adoption of this centrality-based analysis diagram not only facilitates a comprehensive understanding of the relative importance of each safety hazard but also presents the complex web of interactions within Anjian Group's building construction projects. This academic approach enhances the clarity and coherence of the information presented, contributing to a more insightful interpretation of the safety hazard network [12].

4. Security Countermeasures

Based on the above analysis, safety measures are proposed for key hazards as shown in Table 5.

The following security precautions are proposed based on the preceding analysis:

1)It is imperative to rigorously enforce all safety regulations to empower employees to overcome complacency. Strengthening safety education initiatives is crucial to instill a robust safety mindset, fostering a profound commitment to personal safety [13].

2)During construction activities, all tools must be securely stored in designated areas to prevent accidental falls and potential injuries resulting from tool-related incidents.

3)Construction workers should refrain from indiscriminate throwing of materials or debris. A structured approach, such as wrapping materials or passing them with care, must be adhered to during the construction process.

4)Rationalizing the construction sequence is paramount. Enhanced organization and coordination among construction personnel from different units are essential to mitigate risks associated with vertical operations.

5)During template dismantling, proper supervision and guidance are essential. Simultaneous dismantling from both sides should be enforced to prevent the risk of falling templates and subsequent injuries [14].

6)The lifting of both large and small components necessitates a meticulous classification of tools. Specifically, for larger parts, the utilization of carabiners or hook anti-decoupling devices is mandated to ensure secure lifting. Conversely, smaller pieces should be lifted using buckets or cages. Adherence to the "ten do not hang" lifting operations guidelines is paramount, strictly prohibiting any deviations from these established protocols. Any violations of the stipulated lifting procedures are expressly forbidden to maintain a safe and compliant working environment [15].

Table 5. Corrective measures for key safety hazards

a safety hazard	Corrective measures for safety hazards
A1, A12	Strengthen the safety awareness of construction workers, each employee must be conscientious and careful
A2, A3, A6	Enhancement of skills training for construction personnel
A4	Specialized safety device inspectors should be available prior to the start of any construction work
A5	Equip every employee with a helmet, which must be worn before construction work can be carried out.
A7	Strictly in accordance with the qualifications of the qualification for the placement of jobs
A8, A11	Each commanding officer should have frequent training and, where appropriate, two commanding officers
A9	A system of rewards and penalties can be used to incentivize employees to reduce work violations
A10	Regularly educate employees on safety, paying special attention to the safe passage during the construction process
B1	Installation of protective railings and fences at four openings and five verges
B2	During the construction process, each item should be securely placed, with a fixed location for each item.
B3	Regular safety inspections for each type of safety device
B4	Before the commencement of all types of lifting operations, timely inspection of all types of appliances and machinery in use
B5	Regular safety inspections of all types of equipment
B6, B7	In the lifting operation, in strict accordance with the lifting of the ten do not hang for lifting operations
B11, B12	In the process of material mixing, etc., in strict accordance with operating procedures
B13	Enhancement of safety protection during the construction process, including the safety of personnel and the use of various safety devices
C1, C3	No construction work in the event of inclement weather, timely suspension of
A1, A12	Strengthen the safety awareness of construction workers, each employee must be conscientious and careful
A2, A3, A6	Enhancement of skills training for construction personnel
A4	Specialized safety device inspectors should be available prior to the start of any construction work
A5	Equip every employee with a helmet, which must be worn before construction work can be carried out.
A7	Strictly in accordance with the qualifications of the qualification for the placement of jobs
A8, A11	Each commanding officer should have frequent training and, where appropriate, two commanding officers
A9	A system of rewards and penalties can be used to incentivize employees to reduce work violations
A10	Regularly educate employees on safety, paying special attention to the safe passage during the construction process
B1	Installation of protective railings and fences at four openings and five verges
B2	During the construction process, each item should be securely placed, with a fixed location for each item.
B3	Regular safety inspections for each type of safety device
B4	Before the commencement of all types of lifting operations, timely inspection of all types of appliances and machinery in use
B5	Regular safety inspections of all types of equipment
B6, B7	In the lifting operation, in strict accordance with the lifting of the ten do not hang for lifting operations
B11, B12	In the process of material mixing, etc., in strict accordance with operating procedures
B13	Enhancement of safety protection during the construction process, including the safety of personnel and the use of various safety devices
C1, C3	No construction work in the event of inclement weather, timely suspension of

7)Airborne workspaces, such as bridges, ramps, and springboards, demand regular cleaning and maintenance by specialized personnel. The prohibition of debris accumulation is vital to prevent potential falls and injuries.

8)Machinery and equipment utilized in construction activities should meet stringent quality standards. "Sick" equipment that fails to meet maintenance criteria should be strictly prohibited from use.

9)Personnel involved in construction operations must possess a comprehensive understanding of equipment characteristics and operational essentials. Specialized training and assessment, culminating in the acquisition of a competence certificate, should be mandatory before assuming duties.

5. Conclusion

1)The social network analysis method has been employed to scrutinize the safety hidden danger associations within the object striking accidents occurring in the building construction project of Anjian Group. Utilizing Ucinet 6 software, a safety hidden danger association network diagram has been meticulously constructed, revealing a total of 33 safety hidden dangers within the project. The network's density, quantified at 0.0616, signifies a sparse connection between safety hazards, indicating a lack of close interconnections within the network. Further examination of the network reveals an average shortest path of 1.533, indicative of a low degree of interaction between safety hazards. This measurement underscores that the pathways connecting different safety hazards are relatively short, contributing to a reduced overall network interaction.

2)The amalgamation reveals the presence of 16 cohesive subgroups, characterized by an R-squared value of 0.602, signifying a robust fit. A holistic examination of the safety hazard relationship network culminates in a centrality analysis diagram. Within this diagram, the highest centrality is identified for hazards associated with materials flying out and hanging objects falling. This underscores the critical importance of prioritizing protective measures in these specific areas. In response to these key findings, corrective measures are proposed for addressing the identified safety hazards in the building construction projects of Anjian Group. The emphasis on material containment and prevention of hanging objects falling highlights targeted interventions to enhance safety protocols and reduce the associated risks. This strategic approach is crucial for fostering a safer working environment within the construction projects.

3)In the analysis of object striking accidents, it's acknowledged that the collection of safety hazards may not be exhaustive due to time and experience constraints. Additionally, there is a recognition that numerous safety factors impact building construction projects. For future research endeavors, there is an opportunity to expand the research data directly building upon the foundation laid in this paper. The aim is to consider as many influencing factors as possible, thereby facilitating a more comprehensive investigation.

References

[1] Cheng Lianhua, Xue Siting, Cao Dongqiang. Risk transmission and control measures of high-altitude operation in building construction based on social network analysis[J]. Science Technology and Engineering,2022,22(20):8995-9003.

[2] Guo Zhonghua. Research on Safety Hazard Inspection of Construction Project Based on Network Theory[D]. University of Science and Technology Beijing,2018.

[3] Liao Pinchao, Guo Zhonghua, Ding Jiawei. Spatial–temporal Interrelationships of Safety Risks with Dynamic Partition Analysis: A Mechanical Installation Case[J]. KSCE Journal of Civil Engineering,2018,22(5).

[4] Shen Zupei, Wang Yao, Gao Jia. Consequent-antecedent retrospective table for human errors[J]. Journal of Tsinghua University (Science and Technology),2005,(06):799-802.

[5] Li Jue, Han Mei. Social network analysis of falling accidents based on EAST and STAMP[J]. Journal of Changsha University of Science & Technology(Natural Science),2021, 18 (01):49-57.

[6] Cheng Lianhua, Xue Siting, Cao Dongqiang. Risk Transmission and Control Measures of High-altitude Operation in Building Construction Based on Social Network Analysis[J]. Science Technology and Engineering, 2022,22(20):8995-9003.

[7] Transforming inherent safety risk in the construction Industry: A safety risk generation and control model[J]. Sooyoung Choe, Fernanda Leite. Safety Science. 2020(C).

[8] Hu Tianhui, Liu Sanya, Su Zhu. Research on Comparison and Integration of Synchronous and Asynchronous Interaction Patterns for Learners--Based on Social Network Analysis and Multiplex Network Analysis[J].e-Education Research,2022,43 (05): 53-60.

[9] Zhu Jing. M construction company Construction Safety Management Evaluation and Countermeasure Research[D]. Yangzhou University,2020.

[10] Wang Dan, Guan Ying, Jia Qian. Research on propagation path of construction workers' unsafe behavior based on social network analysis[J]. Journal of Science and Technology, 2018, 14(09):180-186.

[11] Zhou Xuefeng. Research on Safety Management of Key Parts in Construction Engineering Based on BIM and VR Technology [D]. China University of Mining and Technology, 2021.