A Systematic Review of The Causal Loop Accident Causes in the Construction Industry

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***Abstract*—Workplace safety is a crucial aspect of construction project success. Numerous studies indicate that the construction industry has one of the highest occupational hazard rates. In the context of safety, achieving zero accidents in construction projects is often seen as a hallmark of project success. It is well known that accidents in construction can be attributed to various factors or a combination of them. This study aims to investigate the root causes of accidents in the construction industry through a systematic and comprehensive review of existing literature. Using relevant studies as a dataset, this research identifies the most frequently cited accident causes and explores the interrelationships among these factors. This research gathered relevant articles to build the dataset through several steps. First, an advanced search was conducted using the "Web of Science" and "Science Direct" databases to locate articles related to workplace accidents in the construction industry. In the second step, titles, abstracts, and keywords were screened. Third, full-text screening ensured the selection of articles for the dataset. The final data collection step involved a snowball search technique to broaden the scope of articles. A total of 69 articles were gathered and analyzed in detail. The causes of work-related accidents were classified into 20 categories (T1-T20). According to the review analysis, the top five accident causes, based on the number of articles mentioning them, are as follows: 'worker capabilities' and 'safety culture' ranked first and second, each cited by 75% of the articles. Third and fourth were 'worker action and behavior' and 'project management' with 68.8%, while 'other factors' ranked fifth at 62.5%. Causal loop analysis revealed that 'safety culture' influences and is influenced by other factors, including risk management, site conditions, worker action and behavior, safety policy, project management, work scheduling, worker capabilities, construction process, equipment condition, equipment usability, and direct supervision. These findings underscore the necessity of integrating safety culture with other accident causes, as their interlinkages significantly contribute to the risk of construction accidents.**

***Keywords*—safety culture, construction accidents, accident causes, systematic review**

I. Introduction

Worker accidents are a potential issue that all employees may face, with construction accidents being particularly concerning due to their high fatality rates. As highlighted by Abukhashabah *et al.,* construction sites account for the highest percentage of injuries compared to other industries [1]. A significant aspect of workplace injuries involves disabilities and life-threatening scenarios [2]. Typically, an accident or incident refers to an unintentional event that results in harm, injury, or damage [3, 4]. Such incidents place a considerable burden on both workers and organizations, leading to financial losses [3] and negatively impacting the long-term economic stability of employees, their families, employers, and related stakeholders [5].

The construction sector is recognized as one of the most hazardous industries, with high rates of injuries and fatalities [6–9]. The elevated risk of accidents in construction compared to other occupations makes it one of the most dangerous fields [4, 10]. According to a report by the International Labor Organization, the construction industry is among the sectors with the highest risk of accidents [11]. Taiwan's Labor Health and Safety Act defines a major occupational accident as one causing injury to three or more individuals or resulting in at least one fatality at the time of occurrence [12]. Additionally, due to the intense nature of construction work, construction sites are considered highly dangerous [13]. Mohan *et al*. categorize accident zones into two types: those occurring within the construction site and traffic-related accidents [14].

Construction accidents can lead to permanent disabilities, fatalities, and project delays [5]. In developing countries, occupational health and safety hazards in construction are reported to be 10 to 20 times higher than in industrialized nations [15]. Moreover, injuries and deaths in the construction industry are estimated to cost approximately 10 billion USD annually [2]. As such, construction accidents require significant attention and should not be underestimated.

Several factors contribute to construction accidents, including personal, business, and social factors [5]. Zerguine *et al.* [16] emphasize that human and physical factors play a major role in workplace accidents. While

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advanced construction project management can yield substantial benefits, it also requires sustained vigilance. For example, Jo *et al.* [5] reported that while accelerated construction projects offer advantages, they can also introduce high levels of pressure and risk, leading to potentially severe consequences. Therefore, identifying the main causes of accidents through thorough analysis is critical to effective accident prevention programs. This study aims to provide new insights into construction accidents.

Many studies analyze construction accidents using historical data, including official national records. Some research explores construction accidents through interviews and surveys with construction workers, particularly safety experts. Others focus on case studies examining construction companies, project types, specific incidents, and their root causes. This research aims to offer a unique and detailed perspective on construction accidents by reviewing articles from various academic databases. The primary objective is to identify the accidents discussed and uncover their underlying causes.

II. Research Method

A. Dataset Collection

Aligned with the research objectives regarding construction accidents, the targeted dataset summarizes a selection of articles that discuss both construction accidents and their underlying causes. Wuni *et al.* [17] employed a study analysis review to examine critical success factors in the construction industry by utilizing various databases such as Web of Science, Google Scholar, and the Google search engine.

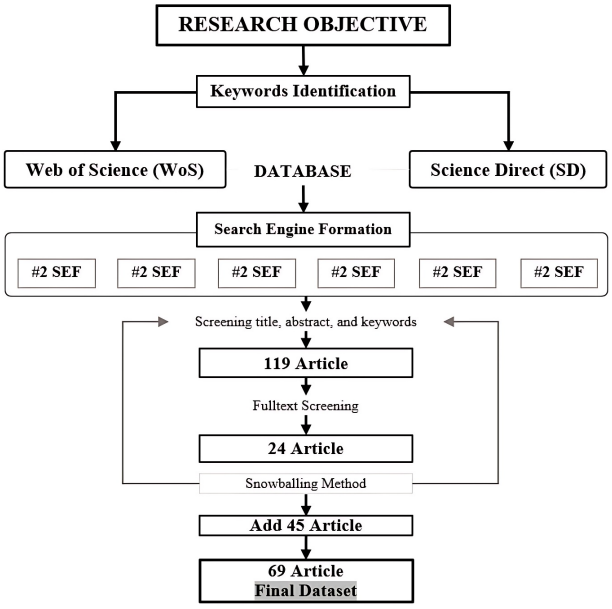

Fig. 1. Flowchart of dataset collection.

This study utilizes the Web of Science and ScienceDirect databases to ensure the inclusion of high-index articles in the dataset. The dataset collection process is illustrated in Fig. 1.

By employing systematic search techniques, a selection of relevant articles was gathered. Additionally, the "snowballing" method was utilized to expand the dataset's scope and enhance both its quantity and validity. The final dataset used in this study consists of 69 articles.

B. Review Process

The dataset of articles was analyzed comprehensively. Key information extracted from the dataset is presented as an overview representation. Subsequently, an in-depth analysis was conducted on the causes of construction accidents, which serve as the focus of this research. Various causes of workplace accidents were examined to produce a causal loop analysis. The causal loop analysis provides an overview of how each factor is interconnected with others.

The results of the causal loop analysis offer a new perspective on the occurrence of construction accidents, particularly by examining the causes discussed in each article within the dataset. These findings will be presented as recommendations to stakeholders in the construction industry to enhance safety standards.

III. Results and Analysis

A. Article Dataset

The article dataset utilized in this study, gathered through the search method outlined in Fig. 1, with a total of 69 articles in the dataset, all of which have been validated through a full-text screening process.

B. Dataset Pivotal Information

Fig. 2 provides a comprehensive bibliometric overview of 69 analyzed articles, highlighting their academic contributions and collaborative trends within the field. Over 26 years (1997–2023), these articles collectively garnered 2,391 citations, with an average of 5.52 citations per article, showcasing their academic impact. The total number of keywords identified in the articles is 310, reflecting a diverse range of topics. On average, the articles are 10.25 years old, which may indicate a mix of foundational studies and recent developments. With contributions from 240 authors, the dataset exhibits a high degree of collaboration, as only two articles were single-authored, emphasizing the cooperative nature of research in this domain. Furthermore, the total average citation counts of 381.09 points to these articles' substantial influence within their respective fields.

The high average age of 10.25 years indicates that many articles have had sufficient time to accrue citations, contributing to the total citation count of 2,391. However, the relatively low average citation per article (5.52) suggests that while the field has produced impactful work, some articles may have limited visibility or niche relevance. The presence of 310 total keywords highlights a wide scope, suggesting an interdisciplinary or multifaceted approach to the research. The predominance of co-authored articles, with only two single-authored contributions, underlines the importance of collaboration in producing impactful studies, likely leveraging diverse expertise to address complex research questions. This

dataset provides valuable insights into the field's research dynamics and academic influence.

Fig. 2. Pivotal information.

C. Causes of Construction Accidents

Fig. 3 shows two data series, "By Year (%)" and "By Articles (%)", across 20 categories labeled T1 to T20. The blue bars represent the percentage distribution of a metric calculated annually, while the orange bars represent the same metric as calculated based on articles. The percentages for both metrics are displayed above the bars for each category, providing a clear visual comparison.

In the chart, categories like T1, T2, and T19 show the highest percentages for the "By Year" metric, reaching up to 75%. In comparison, the "By Articles" metric also shows significant contributions in these categories but remains consistently lower than "By Year". Conversely, certain categories like T4, T5, and T10 exhibit very low percentages for both metrics, suggesting minimal contributions in these areas. Notably, several middle categories, such as T8 and T11, maintain uniform percentages for both metrics.

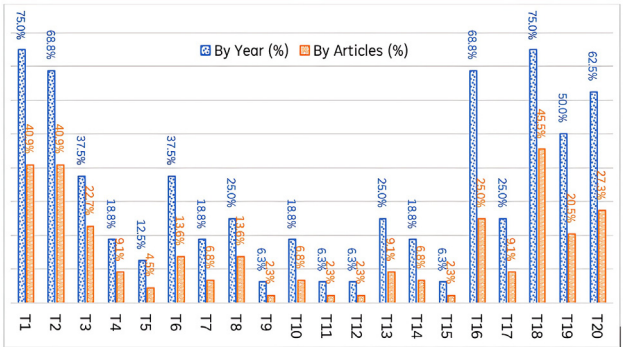

Fig. 3. Pivotal information.

Fig. 3 reveals that "By Year" percentages are generally higher than "By Articles" percentages across most categories. This trend suggests that the annual metric may capture broader or more aggregated contributions compared to article-specific data. Categories with high percentages in both metrics, such as T1, T2, and T19, likely represent dominant themes or areas of significance in the dataset. Conversely, categories with low values across both metrics might reflect lesser relevance or importance.

The disparity between the "By Year" and "By Articles" metrics indicates a potential skew in how the data is distributed over time versus by articles. This could be due to differences in data sources, focus areas, or the broader scope of annual metrics. Categories showing consistent or uniform percentages (e.g., T8, T10, T11) may reflect a baseline trend, while those with high variability, such as T1 and T2, could warrant further investigation to understand their unique contributions.

D. Causal Loop Analysis

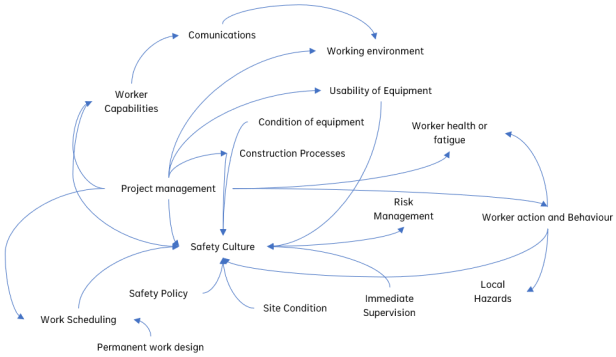

Fig. 4. Causal loop analysis.

The causal loop technique is utilized in this study to examine the factors contributing to construction industry accidents. It is well understood that construction accidents arise from specific factors or a combination of several causes. This causal loop analysis provides an overview of AC (summarized from the article dataset) for each cause of construction-related accidents, as shown in Fig. 4.

Worker actions, direct supervision, and risk management are identified as key contributors to construction accidents [18]. Additionally, worker capabilities, such as experience levels, play a significant role in accident occurrences [19]. Procedural errors by workers are one of the primary causes of construction site accidents, with worker mistakes often considered the root cause [20]. Factors like safety culture (including regular training), risk management, and housekeeping contribute significantly to injuries and fatalities on construction sites [21]. Worker behavior, such as substance abuse, increases the likelihood of accidents [22]. Improved understanding of construction tasks among workers enhances job quality and minimizes errors [19]. Migrant workers often face language barriers and lack safety training, which are significant factors in fatal falls [23]. Young workers with less than four years of experience are at a higher risk than experienced employees [19], whereas older workers tend to have better training and certifications [24].

Safety managers and supervisors are responsible for improving safety conditions at construction sites. Risk management is essential to identify hazards and implement appropriate safety systems [25]. Safety supervisors must accurately report historical accident data to prevent injuries and fatalities [1]. Safety training for both workers and management staff is critical to minimizing accidents [26, 27]. The presence of safety leaders tasked with direct supervision, including the proper use of personal protective equipment (PPE), enhances site safety [28]. Increased supervision of workers in low-visibility situations, such as through the use of reflective vests, helps reduce accidents [29].

Unsafe behavior is identified as the leading cause of 71% of construction accidents based on historical data analysis [30]. Mitigation is a vital management strategy for improving safety conditions [15]. This includes collecting and analyzing data to prevent future incidents [31]. Effective measurement of safety conditions and mitigation strategies can significantly lower accident rates [31]. Proper mitigation, aligned with workers' cultural attitudes, combined with risk management analysis, helps supervisors implement optimal safety systems [32].

Training and certification programs enhance workers' capabilities on construction sites [33]. Well-designed safety training programs save lives, improve productivity, and reduce costs [34]. These findings indicate that project management should prioritize experienced workers and provide regular training for all staff [33, 35]. A strong safety culture positively influences the performance of construction organizations and project management [36]. Emphasizing training and safety procedures is essential to reduce accident rates [37].

Working hours also affect workers' conditions [35]. The International Labour Organization (ILO) sets standards for optimal working hours, but management must monitor and control workers' well-being. Safety supervisors should consider programs to help workers maintain concentration and motivation throughout their shifts. Standards should be developed based on the unique requirements of different building categories [35]. Government policies and regulations play a crucial role in improving construction safety [8]. Authorities should consider project scale and contractors' safety records during the tender process [6]. Government regulations offer an opportunity to enhance safety [38]. Close collaboration between designers, clients, and contractors is necessary to minimize on-site injuries [34]. Comprehensive accident investigations help establish effective safety systems. Risk monitoring procedures are also required to encourage preventive measures [39].

Hazardous site conditions are among the leading causes of construction accidents [20]. Effective communication among workers is essential to ensure coordination and a safe working environment [20]. Providing personal protective equipment, site supervision, and safety training are critical elements in preventing fall-related accidents [40]. Management's awareness of safety measures must be reinforced through effective training for new employees [12].

Based on the analysis results, several key aspects must be considered to enhance construction safety levels, namely management and supervision, training and certification, site conditions, and the role of policies and regulations.

IV. Conclussion

The study highlights several critical factors contributing to construction industry accidents and emphasizes addressing them to improve safety levels. Using causal loop analysis, the research identifies key contributors, such as worker actions, direct supervision, and risk management, as well as individual factors like worker experience, procedural errors, and unsafe behaviors. The role of safety culture, including regular training, risk management, and proper housekeeping, is underscored as essential in reducing injuries and fatalities. Additionally, the study points to specific risks associated with migrant and young workers, who face unique challenges, such as language barriers and limited experience.

The research also stresses the critical role of safety managers and supervisors in creating safer work environments through risk identification, accurate reporting, and direct supervision of personal protective equipment usage. Unsafe behaviors account for a majority of construction accidents, further emphasizing the need for effective training and mitigation strategies. Regular training and certification programs are found to not only save lives but also enhance productivity and reduce costs while fostering a strong safety culture that benefits overall organizational performance.

Government policies and regulations, alongside collaborative efforts between designers, clients, and contractors, are identified as pivotal in ensuring construction safety. The study recommends monitoring workers' conditions, adhering to international working hour standards, and tailoring safety measures to specific project requirements. Investigations into past accidents and risk monitoring procedures are highlighted as essential for preventive measures.

In conclusion, improving construction safety requires a multifaceted approach focused on management and supervision, training and certification, site conditions, and the implementation of robust policies and regulations. By addressing these aspects, the construction industry can significantly reduce accident rates, enhance worker well-being, and ensure sustainable project execution.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, B.M. & W.T.C.; methodology, Y.-H.H. & B.M.; software, B.M.; validation, Y.-H.H.; formal analysis, B.M. & W.T.C.; investigation, B.M.; resources, Y.-H.H. & W.T.C.; data curation, B.M.; writing—original draft preparation, B.M. & W.T.C.; writing—review and editing, W.T.C.; visualization, B.M.; supervision, W.T.C. & Y.-H.H.; project administration, B.M. All authors have read and agreed to the published version of the manuscript.

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