safety

Review

Caught-In/Between Accidents in the Construction Industry: A Systematic Review

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Abstract: This systematic review examines caught-in/between accidents in construction, revealing complex safety challenges involving machinery errors, vehicle incidents, loading mistakes, and structural collapses. The analysis highlights significant risks, including heavy equipment rollovers, trench cave-ins, and material shifts, with injuries ranging from minor to fatal. Despite the critical nature of these accidents, existing research demonstrates notable gaps, particularly in understanding long-term worker health impacts, economic consequences, and nuanced risk factors. Most studies insufficiently explore correlations between worker experience, age, and accident susceptibility, while gender-specific risks remain poorly documented. Training inadequacies and safety protocol non-adherence emerge as primary contributors to these incidents. This review identifies a pressing need for standardized, comprehensive safety interventions that address technological, human, and organizational factors. Recommendations include stricter safety regulations, enhanced training programs, advanced safety technologies, and robust support systems for workers. By fostering a holistic safety culture and addressing research gaps, the construction industry can potentially mitigate caught-in/between accidents, ultimately protecting worker well-being and improving overall productivity.

Keywords: caught-in-between; accident; construction industry; systematic review; PRISMA

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1. Introduction

Numerous factors contribute to injuries sustained in the construction industry, which is dynamic and intricate. Construction accidents are frequent and can result in permanent disability and a high rate of fatality [1]. It is precarious due to the regular movement, assembly, disassembly, and modification of work surfaces, equipment, machinery, trenching, and scaffolding [2,3]. The danger of fatality is five times greater in the construction industry than in the manufacturing sector, while the probability of serious injury is two and a half times greater [4]. Except for the construction industry, every other sector has a lower rate of fatal injuries than the national average [2]. However, the level of risk varies according to the type of accident, location, and other relevant variables.

The construction industry is known for its high-risk environment, where 'caught-in' and 'caught-between' accidents pose serious threats to workers' safety. According to

Occupational Safety and Health Administration (OSHA) guidelines, 'caught-in' accidents involve crushing injuries due to entrapment between two objects, while 'caught-between' accidents occur when a worker is caught or compressed between moving and stationary objects [5]. This distinction was a foundational aspect of the methodology, influencing search terms, inclusion criteria, and analysis. These types of incidents are significant contributors to injuries and fatalities on construction sites. They account for a notable percentage of construction-related deaths each year. Tackling these safety issues is essential not only for protecting the lives and health of workers but also for maintaining the efficiency and success of construction projects. By prioritizing safety, we can create a safer and more productive industry for everyone involved.

Caught-in/between accidents is among the four fatal accidents that occur on construction sites and is ranked third in terms of construction worker fatalities, behind struck-by incidents. It was ranked third in 1980 (16%), 1985 (13.3%), and 1990 (9.3%) in the US [6]. It was also ranked third at 11.9% between 1997 and 2000 [7]. It is a mishap where the operator is caught between moving and stationary objects or components of the machine or between moving machine elements and the material [8,9]. It is also described as being most frequently related to equipment, trench cave-in, and materials accidents [10]. Addressing caught-in/between accidents is crucial for safeguarding worker safety, minimizing legal and financial risks, maintaining productivity, enhancing reputation, complying with regulations, and fulfilling ethical responsibilities within the construction industry.

Construction workers face life-threatening risks every day, with caught-in/between accidents representing one of the most dangerous yet often overlooked workplace hazards. This systematic review digs deep into the complex world of these accidents, aiming to unravel the hidden patterns and root causes that continue to put workers' lives at risk. By meticulously examining existing research, we hope to shed light on critical insights that could ultimately save lives and make construction sites safer. Our goal is not just to analyze the data but to understand the human stories behind these accidents and develop meaningful strategies that can prevent future tragedies.

The approach blends academic rigor with a genuine concern for worker safety, transforming cold statistics into a compelling narrative about protecting those who build our world. Through this comprehensive review, we strive to transform academic knowledge into practical solutions that can make an immediate difference in construction workplace safety. This paper aims to use a systematic review to identify the fundamental causes, trade workers involved, and associated construction activities of caught-in/between accidents in different countries. The findings are compared with 54 cases of fatal caught-in/between accidents in Malaysia between 2010 and 2019. Cross-sectoral literature pertaining to caught-in/between accidents in the construction industry was systematically retrieved from Scopus and Web of Science (WoS) databases.

2. Methodology

This section presents the step-by-step procedure employed in this study for the systematic review. In the complex and high-stakes world of construction safety, systematic literature reviews serve as critical navigational tools for researchers and safety professionals. These comprehensive studies are like detailed maps that guide us through the vast landscape of existing research, cutting through the noise and bias to reveal the most reliable and meaningful insights. By meticulously examining multiple studies with a structured and transparent approach, we can uncover hidden patterns, expose critical knowledge gaps, and draw more robust conclusions about workplace safety. This methodical process is not just about collecting data; it is about creating a clearer, more accurate picture of the challenges workers face and identifying meaningful strategies to protect those who put their lives on the line every day in the construction industry. However, the probability of bias in the selection of publications is a limitation of the systematic review methodology [11]. Various inclusion and exclusion criteria will be used to determine the reports to be included in the review, and the findings will be synthesized after thoroughly examining all published publications on the topic. Using inclusion and exclusion criteria, on the other hand, may result in omitting relevant papers that do not meet these criteria.

In the challenging realm of construction safety, our systematic review sets out to unravel the complex narrative of caught-in/between accidents. The review aims to go beyond surface-level statistics, diving deep into the human stories behind these workplace incidents. The research question is a carefully crafted lens, focusing on understanding not just the raw numbers, but the intricate details that define these dangerous workplace events. By examining the methodological approaches, case analyses, occurrence rates, primary sources, trade workers at risk, and the specific construction activities where these accidents frequently occur, this review seeks to paint a comprehensive and nuanced picture of a critical safety issue that directly impacts workers' lives and well-being.

2.1. Data Search

Scopus and Web of Science (WoS), two of the most extensive repositories of academic publications, were selected for their substantial scientific impact, facilitating the identification of relevant peer-reviewed journals and conference papers. [12]. To investigate caught-in/between accidents, the Scopus and Web of Science (WoS) databases were systematically explored, with the search encompassing records from their inception up to 25 December 2024. The search was conducted with precision and purpose, guided by carefully constructed Boolean operators that served as fine-meshed nets, capturing relevant research while filtering out extraneous information.

A comprehensive search strategy was developed using the following key search terms and Boolean operators: ("caught-in-between") AND ("caught between") AND ("construction" OR "construction industry") AND ("accident" OR "safety" OR "risk"). Each term was a key, designed to unlock the most relevant and meaningful research in our quest to understand and ultimately prevent these potentially fatal workplace incidents.

2.2. Inclusion and Exclusion Criteria

To understand caught-in/between accidents comprehensively, a rigorous framework was established to ensure the quality and relevance of the research. Inclusion criteria were meticulously designed to focus on the most impactful and meaningful studies, targeting peer-reviewed articles that specifically addressed construction safety and caught-in/between accidents.

English-language publications were prioritized to provide a clear window into critical research, focusing on empirical studies, compelling case reports, and thorough safety analyses. The aim was not to delve into abstract theories or speculative discussions but to gather actionable, real-world insights with the potential to enhance safety and save lives on construction sites.

The selection process was highly selective and precise. Publications were thoroughly screened, with emphasis placed on the engineering domain, particularly the construction industry. Priority was given to original research in peer-reviewed journals and conference papers that offered clear objectives and tangible methodologies. Non-English publications, theoretical works lacking practical data, and studies outside of the construction field were excluded to maintain focus and relevance. This targeted approach ensured the review's practical applicability, aligning it with the ultimate goal of protecting workers and preventing future incidents.

2.3. Search Results and Data Extraction

In line with Moher et al. [13], this study adopted the PRISMA approach to guide the systematic review process rather than the full PRISMA protocol, which requires a formal checklist and registration. The methodology followed the key principles of PRISMA, including defining review characteristics, applying search and eligibility criteria, screening relevant literature, and performing a structured data synthesis. This approach aligns with previous studies on occupational safety in the construction industry [14], ensuring a transparent and replicable selection of relevant literature.

The initial literature search yielded 28 potentially relevant studies from the Scopus database and 33 from the Web of Science (WoS) database. In addition, a manual search of references from published studies, relevant reviews, and prior meta-analyses identified four additional studies. Combining the results from both databases and additional searches resulted in a total of 45 unique peer-reviewed journal articles and conference papers. Out of these, 31 studies were screened. Following the screening of abstracts and conclusions, the full-text versions of 31 studies were retrieved and evaluated for eligibility. Of these, 18 studies satisfied the inclusion criteria and were subsequently incorporated into the systematic review (see Figure 1). The other 13 studies were excluded as they were either irrelevant or did not report on caught-in/between accidents in the construction industry.

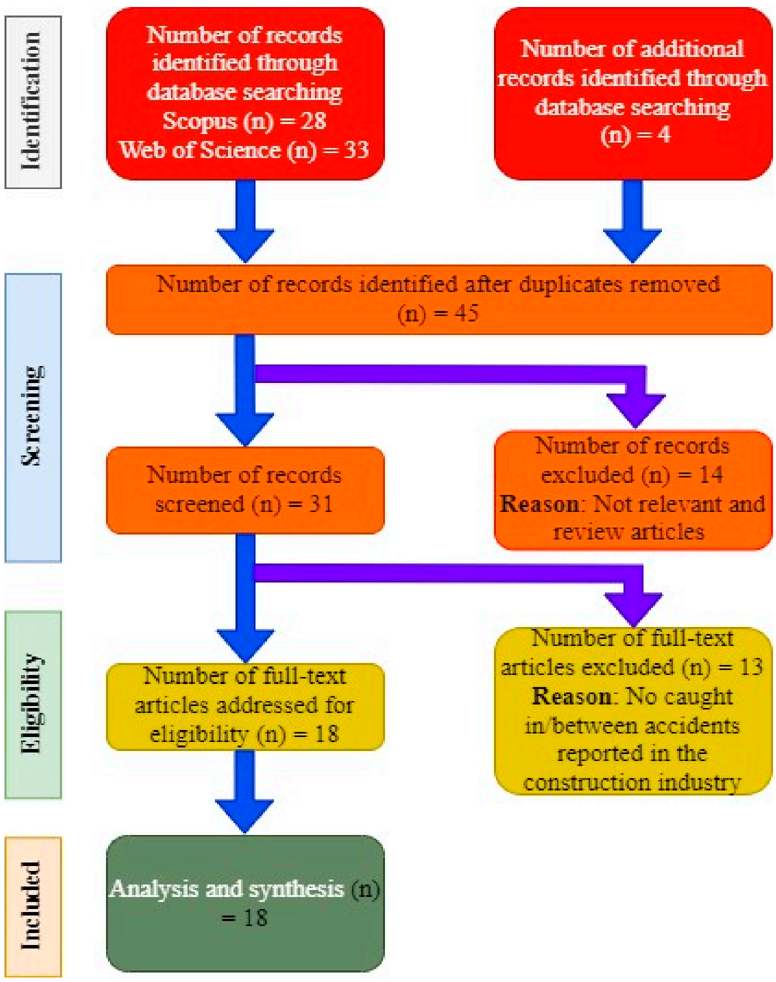

Figure 1. Scheme of the proposed systematic literature review approach [14] (modified and adopted).

This review is a call to action. It highlights the urgent need for contemporary studies that not only reflect the realities of today's construction environment but also drive the development of updated safety protocols. Our limited dataset is not a limitation; it is a compelling argument for immediate and focused research. Each of the 18 studies provides a fragment of insight, but together, they underscore the critical need to prioritize construction worker safety with the seriousness it deserves.

The story of caught-in/between accidents remains incomplete, awaiting deeper exploration. This review is only the beginning; it is a challenge to the research community to renew its focus and commit to meaningful action that safeguards the lives of construction workers.

2.4. Study Selection Process, Eligibility, and Quality Assessment

Our approach to study selection in systematic research was a meticulous, collaborative process, carefully designed to ensure precision and reliability. This three-stage method served as a rigorous filter, allowing us to identify studies with meaningful insights into caught-in/between accidents.

The first stage resembled panning for gold: an initial database search focused on eliminating duplicate studies to ensure each remaining record was unique and valuable. The second stage involved a focused review of titles and abstracts, quickly identifying studies aligned with our objectives. This step was crucial for narrowing the scope to research most relevant to construction safety and caught-in/between accidents.

The final stage was the most exacting: a comprehensive full-text review conducted with the care of forensic investigation. In our assessment of methodological rigor, two independent reviewers carefully evaluated each study using an adapted version of the Newcastle–Ottawa Scale (NOS). When disagreements arose between reviewers, they engaged in collaborative dialog to reach a consensus. In particularly challenging cases, a third reviewer served as an impartial arbiter to resolve remaining differences. This meticulous evaluation process strengthened the foundation of our research, contributing to a robust knowledge base for preventing workplace accidents and improving construction site safety.

The NOS framework encompasses three primary domains of evaluation: selection (4 points), comparability (2 points), and outcome (3 points). Studies could achieve a maximum score of 9 points, reflecting the highest methodological quality. Within our star-based classification system, studies garnering 7–9 stars were designated as high quality, those with 4–6 stars as moderate quality, and those receiving 0–3 stars as low quality.

The selection domain examined several critical elements: how well the exposed cohort represented the target population, the appropriateness of the non-exposed cohort selection, the reliability of exposure assessment methods, and evidence that the outcome was absent when the study commenced. Comparability focused on how effectively studies controlled for crucial variables in their design and analysis. The outcome domain assessed three key aspects: the rigor of outcome measurement, whether the follow-up period was sufficient, and the completeness of participant follow-up.

Our quality assessment revealed that one-third of studies (33.33%) achieved high-quality status, as detailed in Table 1. These exemplary studies demonstrated several strengths: they drew from multiple official data sources, incorporated sophisticated statistical analyses, provided international comparisons, employed trained inspectors for standardized data collection, accounted for multiple control variables, maintained secure mandatory reporting systems, and implemented reliable outcome assessment protocols.

Most studies (61.11%) achieved moderate quality ratings, distinguished by their use of large, representative datasets from credible sources, adequate follow-up periods, sound statistical approaches, and appropriate methodological frameworks. However, our analysis revealed that nearly all studies (88.89%) faced notable limitations. These included potential underreporting of incidents, insufficient non-exposed cohort comparisons, and inadequate controls for confounding variables.

Table 1. Quality assessment of the selected papers using Newcastle–Ottawa Scale (NOS).

Study ID	Author (s)	Selection (Max 4)	Comparability (Max 2)	Outcome (Max 3)	Total (Max 9)	Quality Level
Study 1	Chi and Wu [15]	4	2	2	8	High
Study 2	Hinze et al. [10]	2	0	1	3	Low
Study 3	Chi et al. [16]	3	0	2	5	Moderate
Study 4	McCann [17]	2	0	2	4	Moderate
Study 5	López et al. [18]	3	1	3	7	High
Study 6	Im et al. [19]	4	2	2	8	High
Study 7	McCann and Cheng [20]	3	1	2	6	Moderate
Study 8	Chi et al. [21]	3	1	3	7	High
Study 9	Chong and Low [8]	4	1	2	7	High
Study 10	Chi and Lin [22]	2	1	2	5	Moderate
Study 11	Chan et al. [23]	2	0	2	4	Moderate
Study 12	Prasetyo et al. [24]	2	1	2	5	Moderate
Study 13	Grant and Hinze [25]	3	1	3	7	High
Study 14	Yoon et al. [26]	2	0	2	4	Moderate
Study 15	Hatipkarasulu [27]	2	1	2	5	Moderate
Study 16	Eteifa and El-adaway [28]	3	1	2	6	Moderate
Study 17	Enshassi et al. [29]	3	1	2	6	Moderate
Study 18	Yamaguchi et al. [30]	3	1	2	6	Moderate

The absence of comprehensive follow-up data emerged as a significant methodological weakness, compromising our ability to track outcomes definitively. Additional limitations included reliance on a restricted set of court cases, insufficient baseline data, and the absence of prospective data collection methods. The studies' analytical depth and methodological sophistication were constrained by the absence of control groups and inadequate confounding variable adjustments—elements crucial for establishing generalizability and ensuring robust findings. These limitations informed our careful interpretation of the results.

2.5. Analytical Approach

In the complex landscape of research, our narrative synthesis approach was like weaving a rich tapestry from diverse threads of knowledge. Faced with studies that varied widely in methodology and focus, we did not see complexity as a challenge but as an opportunity for deeper understanding.

Our analysis was a journey of discovery, moving beyond simple data compilation to uncover the nuanced stories hidden within each study. We approached the research like detectives, looking for meaningful connections and underlying themes that might have been overlooked in more rigid analytical frameworks. By employing thematic analysis, we transformed seemingly disconnected pieces of research into a coherent narrative about caught-in/between accidents in the construction industry.

We carefully mapped out patterns and trends, tracing the subtle threads that connected different studies. Each research paper was not just a standalone document, but part of a larger conversation about workplace safety. Our goal was not just to summarize findings, but to create a comprehensive, holistic interpretation that could provide meaningful insights into these critical incidents.

This approach allowed us to see beyond the numbers and statistics to understand the human stories and systemic challenges that lie at the heart of caught-in/between accidents. By synthesizing these diverse perspectives, we aimed to create a more nuanced, comprehensive understanding that could ultimately contribute to improved safety practices in the construction industry.

2.6. Justification for Methodological Choice

In the realm of construction safety research, our decision to undertake a systematic literature review transcended mere methodology—it was a deliberate effort to uncover and address critical truths about caught-in/between accidents. This approach reflected our dual role as researchers and advocates, committed to building a comprehensive and unbiased understanding of these workplace hazards.

Our systematic review served as a meticulously crafted map, charting the diverse terrain of existing knowledge. By synthesizing insights from multiple sources, we created a panoramic perspective that extended beyond the limitations of individual studies. This process was not simply about compiling data; it was about constructing a cohesive narrative to uncover hidden patterns and extract critical insights.

Guided by a steadfast commitment to objectivity, we designed our methodology to mitigate biases that might influence conclusions. Each study was rigorously analyzed through a critical yet empathetic lens, recognizing that behind every data point lies the lived experiences and safety of real workers.

Ultimately, our approach aimed to illuminate gaps, not only within the research, but also in the broader understanding of workplace safety. By identifying these critical voids, we sought to inspire future investigations capable of bridging them, preventing accidents, and saving lives. This systematic review was not merely an academic exercise; it was a purposeful exploration, driven by a profound commitment to enhancing construction workplace safety.

2.7. Ethical Statement

This study adhered to the PRISMA approach for systematic reviews. The approval of an ethics committee or institutional review board is not required for systematic reviews and meta-analyses.

3. Findings

3.1. Publication Bias Assessment: Funnel Plot and Egger's Test

Publication bias is a significant threat to the validity of systematic reviews. To evaluate its presence, we utilized a combination of graphical (funnel plot) and statistical (Egger's regression test) methods, ensuring a comprehensive assessment of potential bias in the included studies. Analyses were performed using Origin and SPSS, respectively, with results being interpreted at a significance level of 0.05. The effect size and standard error were calculated using the formulas outlined in Equations (1) and (2). The results obtained are presented in Table 2.

$$Effect\ Size = \frac{Frequency\ of\ a\ specific\ cause}{Total\ injuries} \tag{1}$$

$$Standard\ Error\ (SE) = \sqrt{\frac{p(1-p)}{n}} \tag{2}$$

where p is the proportion of death in each group and n is the sample size.

Using the data in Table 2, a funnel plot was generated to visually assess publication bias (see Figure 2). The funnel plot demonstrated a symmetrical distribution of studies, suggesting no significant publication bias. However, the limitations of these methods are acknowledged, particularly in the context of a small number of included studies. Symmetry in the distribution of study results around the pooled effect size suggests minimal bias. Asymmetry in the plot can arise due to reasons other than publication bias, such as differences in study quality or methodology.

Table 2. Data showing effect size and standard error.

Study ID	Effect Size (Odd Ratio)	Standard Error
Study 1	0.079	0.010483695
Study 2	0.150	0.010855291
Study 3	0.087	0.010065538
Study 4	0.120	0.020430157
Study 5	0.150	0.002005924
Study 6	0.120	0.005006896
Study 7	0.120	0.014539310
Study 8	0.100	0.003101200
Study 9	0.210	0.009456953
Study 10	0.160	0.020754981
Study 11	0.110	0.016288390
Study 12	0.180	0.041918288
Study 13	0.130	0.023152083
Study 14	0.074	0.018372715
Study 15	0.210	0.069852786
Study 16	0.110	0.031288976
Study 17	0.11	0.015703487
Study 18	0.17	0.051597133

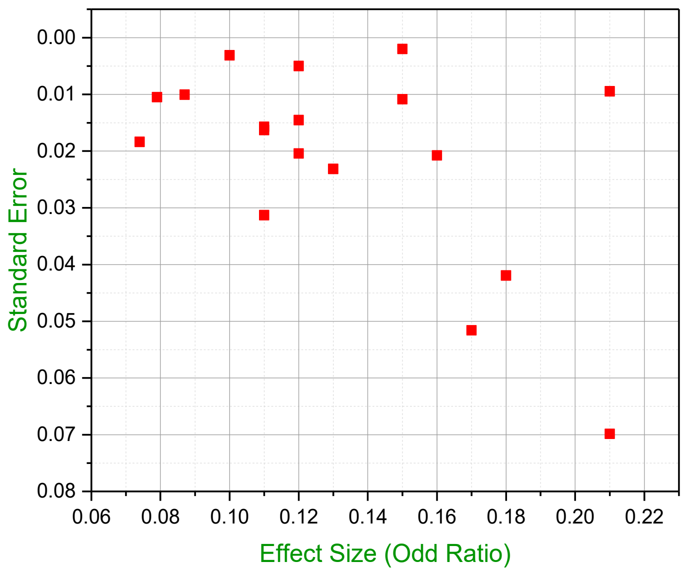

Figure 2. Funnel plot.

To statistically evaluate publication bias, we conducted Egger's test, which examines asymmetry in the funnel plot. A p-value greater than 0.05 indicates no significant evidence of publication bias. The necessary data for the test was calculated using Equations (3) and (4), with the results being summarized in Table 3. Equation (5) shows the linear model of the relationship between standardized effect size and precision.

$$Standardized\ Effect\ Size = \frac{Effect\ Size}{Standard\ Error} \tag{3}$$

$$Precision = \frac{1}{Standard\ Error} \tag{4}$$

$$Linear\ Model : Standardized\ Effect\ Size_i = \beta_0 + \beta_1 * Precision_i + \epsilon_i \tag{5}$$

where β_0 (intercept) is tested for significance to determine asymmetry.

Table 3. Data showing the standardized effect size and precision.

Study ID	Standardized Effect Size	Precision
Study 1	7.535511096	95.38621641
Study 2	13.81814638	92.12097584
Study 3	8.643353192	99.34888726
Study 4	5.873669987	48.94724989
Study 5	74.77850607	498.5233738
Study 6	23.96694479	199.7245399
Study 7	8.253486582	68.77905485
Study 8	32.24558236	322.4558236
Study 9	22.20588386	105.7423041
Study 10	7.708992844	48.18120527
Study 11	6.753276413	61.39342194
Study 12	4.294068498	23.8559361
Study 13	5.615045523	43.19265787
Study 14	4.027711745	54.4285371
Study 15	3.006322468	14.31582128
Study 16	3.515615212	31.96013829
Study 17	7.004813644	63.68012404
Study 18	3.294756707	19.3809218

The standardized effect size represents the effect sizes of the studies, adjusted to facilitate direct comparison across different studies. Precision, defined as the inverse of the standard error of the effect sizes, reflects the reliability of these estimates, with higher precision indicating more robust results.

In Egger's regression test, the intercept, which represents bias, is -0.88 with a p-value of 0.540. As the p-value is greater than 0.05, the intercept is not statistically significant, indicating no evidence of publication bias in the data. This suggests that the effect sizes do not systematically deviate from zero when precision is high. In contrast, the slope of the regression line is 0.14 with a p-value of 0.000. Because the p-value is less than 0.05, the slope is statistically significant, demonstrating a relationship between the standardized effect size and precision. Specifically, the results indicate that as precision increases, the effect size also tends to increase.

3.2. Definition and Classification of Caught-In/Between Accidents

Caught-in/between accidents often result in serious injuries, including fractures, amputations, crush injuries, and in severe cases, fatalities [22]. Prevention measures typically focus on engineering controls (e.g., machine guarding, safety barriers), administrative controls (e.g., training, safe work procedures), and personal protective equipment (PPE) to reduce the risk of such accidents.

A caught-in/between accident, also referred to as a caught-in or caught-between accident, is a workplace incident where a person is caught, trapped, or crushed between two or more objects [22]. These accidents typically occur in industrial settings, including construction sites, manufacturing facilities, agricultural operations, and warehouses.

Workers can be caught between moving machinery parts, such as gears, rollers, belts, or hydraulic systems [22]. For instance, a worker's clothing or body part might get pulled into a conveyor belt or become caught between gears during operation. Accidents can also happen when workers are trapped between heavy objects, such as building materials (e.g., concrete slabs, steel beams), collapsed structures, or vehicles (e.g., forklifts, trucks) [31]. Additionally, workers can become trapped in trenches or excavations due to cave-ins, soil collapses, or falling debris [32]. Objects falling from heights or improperly stored materials can also trap or strike workers below, leading to caught-in/between injuries [22]. Furthermore, workers can be caught between collapsing walls, roofs, or scaffolding structures [33]. Working in confined spaces with limited exit points can result in workers being trapped or caught if an accident occurs [34].

Caught-in/between accidents often result in serious injuries, including fractures, amputations, crush injuries, and in severe cases, fatalities [22]. Prevention measures typically focus on engineering controls (e.g., machine guarding, safety barriers), administrative controls (e.g., training, safe work procedures), and personal protective equipment (PPE) to reduce the risk of such accidents. Regular inspections, hazard assessments, and adherence to safety protocols are critical to minimizing the occurrence of caught-in/between accidents in workplaces.

3.3. Statistical Trends in Caught-In/Between Accidents over the Years

Caught-in/between accidents remain a persistent and significant cause of injuries and fatalities in the construction industry [22]. Despite technological advancements and safety measures, these incidents continue to occur due to complex factors including human error, equipment malfunctions, and inadequate worker training.

Regulatory bodies like the Occupational Safety and Health Administration (OSHA) track these accidents through annual reports, documenting detailed statistics on incident rates, circumstances, and underlying causes. The prevalence of caught-in/between accidents varies across different construction sectors, influenced by work nature, equipment types, and specific workplace hazards.

Regional variations in these accidents reflect differences in local regulations, economic conditions, and safety culture. Comparative and longitudinal studies provide critical insights into evolving safety practices, helping to identify effective intervention strategies and inform policy decisions.

A comprehensive analysis of research reveals multiple dimensions of caught-in/between accidents (see Table 4). Studies from diverse locations, including Taiwan, the USA, Spain, South Korea, Malaysia, Hong Kong, Qatar, Gaza Strip, and Japan, employed both quantitative and qualitative methodologies to examine these incidents. Key findings consistently highlight critical risk factors:

- High percentage of accidents related to equipment failures.
- Significant risks from trench cave-ins.
- Prevalence of poor safety practices.

Workers most frequently impacted include heavy machinery operators, machine operators, and general construction workers. The most common injury sources involve machinery, structures, and construction facilities, with high-risk activities such as crane maintenance, excavation, and earthmoving presenting notable challenges.

Table 4. Summary of the reviewed articles.

S/No	Author(s)	Location	Method(s)/Approaches Employed	Number of Cases Analyzed (Fatal (F) or Non-Fatal (NF) or Combination (C))	Percentage of Occurrence (%)	Primary Source/Agent	Top Three Trade Workers Involved	Essential Construction Activities Associated with Caught-In/Between Accidents
Study 1	Chi and Wu [15]	Taiwan	Quantitative approach using frequency distribution and cross-tabulation	1230 occupational fatality reports for 1989, 1990, and 1992. The construction sector had 53.82% of fatal occupational injuries. They also found that caught-in/between and clamped accounted for 7.9% of fatal accidents in the construction industry	7.9	The authors did not specify the main causes of caught-in/between accidents. However, they identified the following as the source of injury: structures and construction facilities, loading and unloading machinery, powered machinery, etc.	Not specified	Not specified by the authors
Study 2	Hinze et al. [10]	USA	Quantitative and qualitative analysis	The authors examined 1082 accidents from 1994 and 1995, as reported by OSHA	15	A total of 59% of caught-in/between incidents were equipment-related, and about 33% involved trench cave-ins. Few cases (8%) involved material, most of which were caused by the shifting or movement of materials that pinned workers against other objects or the ground	Machine operators	Crane maintenance
Study 3	Chi et al. [16]	Taiwan	Quantitative approach using Spearman's rank correlation coefficients and Cramer's V and Phi coefficients	They analyzed 784 work-related single fatalities that occurred in 1999 and 2000. They found that firms with less than 30 employees had a decreased probability of being caught-in/between and clamped and struck-by and -against fatalities	8.7	The authors did not specify the main causes of caught-in/between accidents. However, they identified the following as the source of injury: structures and construction facilities, loading and unloading machinery, powered machinery, etc.	Not specified	Not specified by the authors
Study 4	McCann [17]	USA	Quantitative approach using frequency distribution and cross-tabulation	The author identified and examined 253 heavy equipment-related deaths on construction sites within the excavation work industry from 1992 to 2002. The analysis revealed that caught-in/between (i.e., vehicle-related deaths) accounted for 12% of the total cases studied	12	Rollovers constituted the primary cause of death for heavy equipment operators. Meanwhile, for vehicle operators working on foot around their vehicles and for workers involved in vehicle maintenance, being run over by the vehicle or caught-in/between vehicle parts were identified as the primary causes of death	Heavy equipment operators (backhoes and trucks were involved in half of the deaths) and construction laborers	Excavation and deep foundation
Study 5	López et al. [18]	Spain	Quantitative and qualitative analysis	Based on a descriptive analysis of 1,630,452 construction accidents in Spain spanning from 1990 to 2000, the findings reveal a distribution among different severity levels. Specifically, 1,598,765 accidents (98%) were categorized as light accidents, indicating minor injuries or incidents. Serious accidents, accounting for 28,658 cases (1.8%), were categorized by more severe outcomes. Finally, 3029 accidents (0.2%) resulted in fatalities, highlighting the most severe consequence category among the analyzed incidents	14.6	The primary agents posing the highest risk in construction are scaffolding and ladders, modes of transportation, machinery or cranes, and lifting apparatuses. These elements are critical points of concern due to their potential to contribute significantly to accidents and injuries on construction sites	The authors did not specifically mention the kind of trade workers involved	Activities such as demolition, excavation, earthmoving, perforation, drilling, and the rental of construction or demolition equipment with an operator are integral parts of many construction projects. These activities involve significant risks due to the operation of heavy machinery, the manipulation of unstable structures, and the potential for accidents associated with equipment use

Table 4. *Cont.*

S/No	Author(s)	Location	Method(s)/Approaches Employed	Number of Cases Analyzed (Fatal (F) or Non-Fatal (NF) or Combination (C))	Percentage of Occurrence (%)	Primary Source/Agent	Top Three Trade Workers Involved	Essential Construction Activities Associated with Caught-In/Between Accidents
Study 6	Im et al. [19]	South Korea	Quantitative and qualitative analysis	Out of 10,276 deaths resulting from occupational injuries between 1997 and 2004, 4333 fatalities occurred in the construction industry. Specifically, 122 deaths (2.8% of total deaths) were due to being caught in machines, and 417 deaths (9.6% of total deaths) were caused by structural collapses	12.4	Equipment and machine-related causes are usually the source of injury and sometimes even death	Heavy truck drivers, construction operators Construction machinery fitters, operators, and mechanics Plumbers and pipefitters	Not specified by the authors
Study 7	McCann and Cheng [20]	USA	Quantitative and qualitative analysis	A total of 829 construction workers died in dump truck-related incidents between 1992 and 2007, an average of 52 deaths yearly. A total of 484 died on the construction sites. A total of 56 fatalities were related to the caught-in/between accidents	11.57	A total of 52.60% of these deaths were caused by vehicles, and failure to set brakes or lock out the vehicle or vehicle parts while working contributed to 21 of 26 maintenance worker deaths (81%)	Dump truck operators, maintenance workers, helpers, and others (vehicle drivers)	Demolition, excavation, and earthmoving, just to mention few
Study 8	Chi et al. [21]	USA	Quantitative and qualitative analysis	In the study examining 9358 accidents within the U.S. construction industry from 2002 to 2011, researchers found that 10% of these incidents, totaling 934 accidents, were classified as caught-in/between accidents	10	Worker misjudgment caused most of the fatalities	Crane and tower crane operators, heavy machinery operators, and various general construction workers are frequently involved in construction-related activities that pose risks of caught-in/between accidents	Not specified by the authors. A total of 19.3% (63) of fatalities caught-in/- between accidents (326) can be prevented by managing the required working activity and judgement or perception
Study 9	Chong and Low [8]	Malaysia	Quantitative and qualitative analysis	Out of 19,195 reported occupational accidents in Malaysia from 2005 to 2009, 1855 occurred within the construction industry. Specifically, incidents involving caught-in/between accidents were reported at a rate of approximately 371 times per year, totaling 1855 incidents over the five-year period	20	These accidents typically occurred due to workers being buried inside a hole or trench, often resulting from soil collapse that trapped them underground. This situation highlights the risks associated with excavation and trenching activities in the construction industry, where unstable soil conditions can lead to serious and potentially fatal incidents	The researchers did not mention the kind of trade workers that are involved in for this type of accident	Excavation/deep foundation trenches
Study 10	Chi and Lin [22]	Taiwan	Quantitative approach	They examined 312 caught-in/between fatalities resulting from machines and vehicles. They discovered that 16.3% are from the construction industry	16.3	The accidents were caused by unsafe behavior, unsafe environment, unsafe machinery, and unsafe management	The researchers did not also mention the kind of trade workers involved.	The authors did not indicate the essential construction activities associated with caught-in/between accidents reported in the article. They just generalized
Study 11	Chan et al. [23]	Hong Kong	Quantitative and qualitative approaches	They analyzed 9 fatal and 369 nonfatal construction accidents in the Hong Kong–Zhuhai–Macao Bridge (HZMB-HK) project from 2012 to 2017. They discovered that falling from height is a lethal accident, followed by being caught-in/between, and 1 out of 9 fatal accidents was caught-in/between	11.1	The accidents occurred due to the failure of a working platform or a lifting frame system	Handyperson/ Crane operator	Heavy equipment operations/ lifting of construction materials and equipment

Table 4. *Cont.*

S/No	Author(s)	Location	Method(s)/Approaches Employed	Number of Cases Analyzed (Fatal (F) or Non-Fatal (NF) or Combination (C))	Percentage of Occurrence (%)	Primary Source/Agent	Top Three Trade Workers Involved	Essential Construction Activities Associated with Caught-In/Between Accidents
Study 12	Prasetyo et al. [24]	Qatar	Quantitative approach using univariate analysis and cross-tabulation	The authors collected and analyzed 84 non-fatal occupational accidents from a ready-mixed concrete company in Qatar	17.9	The majority of work-related accidents (71%) of all of the analyzed cases are attributed to unsafe behavior, particularly due to improper use of PPE.	Not specified	Manual handling and walking around the sites. However, it is for all the analyzed concrete mixer accidents
Study 13	Grant and Hinze [25]	USA	Descriptive statistics were used to categorize the data	The Occupational Safety and Health Administration (OSHA) fatality and catastrophic incident related to truss work database was analyzed for the years inclusive of 1990–2009 (2011 incident resulting in 214 fatalities)	13	There is some evidence that deficient bracing techniques were responsible for a greater number of incidents. There are risks also associated with the movement and hoisting of materials	Essential and non-essential workers	Truss work in building construction projects
Study 14	Yoon, et al. [26]	South Korea	Risk Analysis Using the Man, Machine, Media, and Management Method	The authors extracted 203 cases from the 763 accident data points from the construction safety management integrated information (CSI)	7.39	The caught-in/between accidents were primarily caused by vehicle-based construction equipment and defective protective devices	Construction equipment drivers	General construction processes
Study 15	Hatipkarasulu [27]	USA	Quantitative approach using frequency analysis and cross tabulation	The author collected and analyzed 34 fatal accident data between 1 January 2018, and 31 December 2019 for concrete contractors	21	Structural collapse, pinned by equipment, and cave-in	Concreters	Demolition, earthwork, carpentry installations, cleanup, loading and unloading equipment
Study 16	Eteifa and El-adaway [28]	USA	Social Network Analysis (SNA)	The authors extracted data about accident causation from 100 case files	10.71	Human-related errors are a strong factor leading to caught-in/-between hazards. These include poor equipment handling, noncompetent individuals performing operations, poor handling of materials, not wearing PPEs, and not wearing seatbelts	Not specified by the authors	Mostly associated with construction equipment operations
Study 17	Enshassi, et al. [29]	Gaza Strip	Quantitative approach using frequency analysis and cross-tabulation	The authors collected and analyzed 397 construction fatal accident data between 1998 and 2003	11	Site congestion.	Not specified.	Not specified.
Study 18	Yamaguchi, et al. [30]	Japan (Chiba and Tokyo)	Descriptive epidemiological study	From the 4899 autopsies, 136 (2.8%) occupational accidental injury deaths (OAIDs) and 3926 (80.1%) non-OAID cases were extracted. A total of 53 of the OAID cases were from the construction industry	16.9	Mainly caused by transportation machinery such as cranes, conveyor belts, and other kinds of transportation or powered machinery	Heavy equipment operators	Mechanical operations such as transport equipment and crushers were typical

These findings underscore the urgent need for comprehensive safety improvements, including enhanced training programs, stringent regulatory compliance, and proactive risk management strategies to mitigate caught-in/between accident risks in the construction sector.

3.4. Number of Cases Analyzed

Studies on caught-in/between accidents across various countries and years reveal diverse methodologies and a wide range of analyzed cases, both fatal and non-fatal. The primary analysis method identified is the mixed-method approach, which combines quantitative and qualitative techniques and accounts for nearly 44.44% of all papers reviewed. In contrast, all other research methods collectively represent 55.56%. This indicates the need to encourage the use of additional tools and methods beyond just quantitative and qualitative approaches to better determine the ultimate predictors of caught-in/between accidents in the construction industry. Quality assessments revealed that the absence of comprehensive follow-up data emerged as a significant methodological weakness, compromising our ability to track outcomes definitively. The studies' analytical depth and methodological sophistication were constrained by the absence of control groups and inadequate adjustments for confounding variables—elements crucial for establishing generalizability and ensuring robust findings.

Numerous studies have highlighted the significant prevalence of occupational fatalities in the construction industry. An analysis of 1230 occupational fatality reports from 1989, 1990, and 1992 revealed that 53.82% of these fatalities occurred in the construction sector, with caught-in/between and clamped accidents accounting for 7.9% of fatal incidents. Similarly, from 1997 to 2004, 4333 out of 10,276 occupational fatalities occurred in the construction industry. Of these, 122 deaths (2.8%) were due to machinery-related caught-in accidents, while 417 deaths (9.6%) were caused by structural collapses.

Studies focusing on heavy equipment and machinery also underscore their contribution to construction fatalities. Between 1992 and 2002, 253 heavy equipment-related deaths within the excavation work industry were analyzed, with 12% being attributed to caught-in/between accidents involving vehicles. Another study on dump truck-related incidents from 1992 to 2007 recorded 829 construction worker deaths, with 56 fatalities being specifically linked to caught-in/between accidents.

In the U.S., a study examining 9358 construction industry accidents from 2002 to 2011 identified 10% (934 accidents) as caught-in/between incidents. Similarly, data from Malaysia between 2005 and 2009 showed that 1855 out of 19,195 occupational accidents occurred within the construction industry, with caught-in/between accidents being reported at an average annual rate of 371 cases. In Spain, a review of 1,630,452 construction accidents from 1990 to 2000 revealed that 98% were minor, while serious accidents and fatalities accounted for 1.8% (28,658 cases) and 0.2% (3029 cases), respectively.

Studies of specific projects further emphasize the risks associated with construction. An analysis of 378 accidents from the Hong Kong–Zhuhai–Macao Bridge project (2012–2017) found that falling from heights was the most common lethal accident, followed by caught-in/between incidents, which accounted for one of nine fatal accidents. In Qatar, 84 non-fatal occupational accidents from a ready-mixed concrete company revealed that 71% were caused by unsafe behavior, such as improper use of personal protective equipment (PPE).

Larger datasets provide a broader view of construction accident patterns. OSHA's fatality database for truss work, spanning 1990–2009, recorded 214 fatalities caused by catastrophic incidents, highlighting risks related to bracing techniques and material hoisting. Additionally, a review of 763 accidents from the Construction Safety Management Integrated Information (CSI) system in South Korea identified 203 cases of significant risk, primarily due to vehicle-based construction equipment and defective protective devices.

Accident causation studies provide critical insights into fatalities. An analysis of 100 case files using social network analysis (SNA) attributed many caught-in/between hazards to human errors, including poor equipment handling, lack of competency, and neglect of PPE usage. Similarly, a review of 4899 autopsies in Japan identified 136 occupational accidental injury deaths (OAIDs), with 53 of these occurring in the construction industry, primarily due to transportation machinery such as cranes and conveyor belts.

Small firms and specific worker roles also show distinct trends in construction accidents. A study of 784 single-fatality incidents from 1999 to 2000 indicated that firms with fewer than 30 employees were less likely to experience caught-in/between accidents.

Meanwhile, concreters faced elevated risks during activities such as structural collapses and earthwork, as demonstrated by an analysis of 34 fatal accidents in the U.S. concrete sector between 2018 and 2019.

3.5. Percentage of Occurrence

The proportion of caught-in/between accidents varies markedly across studies, reflecting disparities in regional safety standards, reporting practices, and industry conditions. These regional differences underscore the influence of local industry practices, regulatory frameworks, and safety cultures on the prevalence of these accidents.

3.6. Primary Source/Agent

Caught-in/between accidents in the construction industry arise from a complex interplay of equipment use, site conditions, and workplace environments. These incidents can occur through various mechanisms:

Equipment-related risks are prominent, with insufficient guarding on machinery playing a critical role. Conveyor belts, gears, rollers, and rotating equipment can trap workers in their moving parts [35]. Incorrect operation, maintenance failures, and equipment malfunctions—such as scaffolding or crane collapses—increase the potential for workers to become entrapped [36].

Spatial and environmental hazards further contribute to these accidents [37]. Trench and excavation cave-ins can trap workers, while overhead materials, falling debris, and hoisted equipment pose additional entanglement risks [7]. Structural collapses involving walls or roofs can pin workers between building components [31]. Confined workspaces with limited entry and exit points compound these dangers, especially in high-density work areas where multiple workers and equipment operate simultaneously [34].

Human factors significantly influence the occurrence of these accidents. Worker behaviors, perceptions, and organizational safety cultures play crucial roles. Common contributing elements include:

- Hazard misperception: workers often fail to recognize or underestimate task-specific risks, leading to potentially dangerous interactions with equipment and environments [38].
- Attentional challenges: workplace distractions such as noise, conversations, and multitasking can divert attention from critical safety protocols [39].
- Communication breakdowns: poor communication between workers, supervisors, and equipment operators can result in misunderstandings and unsafe practices [40].

Training deficiencies represent another critical factor [41]. Insufficient preparation in equipment operation, hazard recognition, and emergency procedures leaves workers vulnerable. The lack of ongoing training and infrequent safety refresher courses further exacerbate risks [42].

Statistical evidence underscores the severity of these incidents. In the United States, equipment-related caught-in/between accidents account for 59% of such incidents, with trench cave-ins comprising 33% and material shifts causing 8% [43]. Specific causes include machinery errors (25.45%), vehicle errors (5.45%), loading and unloading mistakes (5.45%), and building structure collapses (5.45%) [8].

Regional variations exist. In Malaysia, for instance, between 2010 and 2019, serious injuries or fatalities resulted from workers being caught between working platforms and structures (46%), construction machinery or equipment (42%), and trench cave-ins (12%).

Behavioral analysis reveals that approximately 69.5% of fatalities stem from unsafe worker actions, including [22]:

- Working near running machinery (21.2%).

- Unintended tool or machine activation (14%).
- Adopting unsafe postures (13.3%).
- Operational errors (6.1%).
- Failing to properly secure equipment (5.2%).

Preventative strategies are crucial [28]. Recommended measures include implementing rollover protective structures, mandating seat belts for heavy equipment operators, establishing lock-out/tagout procedures, creating restricted access zones around machinery, and assigning spotters near equipment and trucks.

3.7. Trade Workers Involved

The types of trade workers involved in caught-in/between accidents vary significantly across different studies, with some studies omitting specific details about the workers involved. Machine operators were frequently mentioned in several reports, alongside heavy equipment operators (including backhoe and truck operators) and construction laborers. Additionally, specific analyses highlighted heavy truck drivers, construction operators, construction machinery fitters, operators, and mechanics, as well as plumbers and pipefitters. Studies focusing on vehicles indicated the participation of dump truck operators, maintenance workers, helpers, and other vehicle drivers. Crane and tower crane operators, heavy machinery operators, and various general construction workers were also documented in incidents involving caught-in/between accidents. Certain projects specifically noted Handypersons and crane operators. In Malaysia, analyses revealed that construction laborers were most commonly involved, followed by machine operators, bricklayers, scaffolders, carpentry workers, non-construction workers or civilians, and others such as painters, drillers for installing explosives, tillers, welders, and iron benders.

Among the 56 fatalities analyzed, 12.5% were dump truck operators, 37.5% were construction laborers (including spotters, flaggers, and other workers on foot), 41.1% were workers maintaining dump trucks, and 15.15% were other workers (including other vehicle drivers and passengers and workers and passengers on dump trucks) [20]. Heavy equipment operators and construction laborers collectively accounted for 63% of all fatalities related to heavy equipment and trucks, with backhoes and trucks being responsible for half of these fatalities [17].

Crafts associated with the use and operation of large machinery, such as crane maintenance, equipment mechanics, equipment operators, and plumbers/pipe fitters, are particularly susceptible to accidents where workers are struck by or caught in equipment [10]. Structural collapse incidents were significant for plumbers/pipefitters, while incidents involving being caught in machinery were notable for construction machinery fitters, operators, and mechanics [19]. Ensuring the safety of heavy equipment operators is crucial, especially in excavation operations [17]. The highest risk of caught-in/between accidents was observed among welders and flame cutters, heavy truck drivers, construction operators, plumbers and pipefitters, and construction machinery fitters, operators, and mechanics [19].

Construction laborers were found to be the primary trade workers affected by caught-in/between accidents, primarily due to trench cave-ins, followed by machine operators who failed to adhere to safe operating procedures and masons who were affected by structural collapses (see Table 5). According to Im et al. [19], heavy truck drivers, construction operators, construction machinery fitters, operators and mechanics, and plumbers and pipefitters were among the most affected trade workers in Korea due to caught-in/between accidents. Crafts linked to heavy equipment operations are consistently involved in caught-in/between accidents [44]. It is imperative that these identified trade workers receive adequate safety training to prevent or reduce caught-in/between accidents on construction sites.

Table 5. Trade workers suffered from caught-in/between accidents in Malaysia (2010–2019).

Trade Work Name	Frequency	Percentage (%)
Construction laborers	16	29.63
Machine operators	11	20.37
Bricklayers	8	14.82
Scaffolders	3	5.56
Carpentry workers	2	3.70
Non-construction worker or civilian	2	3.70
Other (painters, drillers for installing explosives, tillers, welders, and iron benders)	5	9.26
Total	54	100

3.8. Construction Activities Associated with Caught-In/Between Accidents

Caught-in/between accidents occur during various construction activities, many of which involve heavy machinery, unstable structures, or complex operations. Excavation and deep foundation work are frequently cited as high-risk activities due to the inherent instability of trenches and the potential for soil collapses. Similarly, tasks such as demolition, earthmoving, drilling, perforation, and lifting materials involve significant hazards, particularly when operating heavy machinery or handling construction equipment.

In specific cases, heavy equipment operations, including crane maintenance and lifting of construction materials, are highlighted as contributing factors. Truss work in building construction projects and general construction processes also pose notable risks. Manual handling and walking around construction sites, particularly in activities involving concrete mixers, are additional sources of potential injury.

While some studies provided detailed insights into specific activities, others generalized their findings without specifying essential construction tasks associated with caught-in/between incidents. For example, one study noted that 19.3% of such fatalities could be prevented through better management and worker judgment, but it did not identify the underlying activities. The lack of specificity in certain cases underscores the need for more precise reporting on activity-related risks to improve safety interventions.

The construction activities where caught-in/between accidents occurred were meticulously identified, coded, and analyzed, as detailed in Table 6 from the Malaysian construction accidents database (DOSH). Management's focus should be on the trade workers engaged in these activities, ensuring they receive comprehensive safety training to prevent or mitigate caught-in/between accidents on construction sites. It is crucial to enforce rigorous supervision and monitoring across all activities. Skilled workers should be specifically hired or assigned to handle these tasks, with management ensuring the availability of adequate PPE, tools, machinery, equipment, and necessary supplies. Adequate lighting for night shifts and continuous checks to monitor worker behaviors and prevent unsafe acts are essential. Implementing primary safety measures such as safety nets, warning signs, and regular housekeeping, along with secondary measures like protective helmets, clothing, and boots, should be prioritized as necessary safeguards. The identified activities often result from a combination of management practices, unsafe site conditions, and workers' behaviors that require ongoing attention and mitigation strategies.

Table 6. Construction activities during which caught-in/between accidents occurred.

Construction Activities	Frequency	Percentage (%)
Hoisting or lifting of construction materials/objects using tower or mobile crane or forklift	19	35.19
Carpentry works (formwork installation and dismantling)	6	11.11
Concrete works	6	11.11
Earthworks	5	9.26
Housekeeping	4	7.41
Brickworks	4	7.41
Scaffolding erection or dismantling	3	5.56
Ground pipe installation	2	3.70
Excavation/trench excavation	2	3.70
Site clearance	2	3.70
Stone crushing	1	1.85
Total	54	100

3.9. Physical and Psychological Effects on Workers

Workers involved in caught-in/between accidents often sustain severe injuries such as fractures, amputations, crush injuries, and internal organ damage [45]. These injuries can result in permanent disabilities, affecting mobility, dexterity, and overall physical function. Some injuries may lead to chronic pain, nerve damage, or musculoskeletal disorders that persist long after the accident.

Additionally, workers may experience post-traumatic stress disorder (PTSD) or anxiety disorders due to the traumatic nature of the accident [46]. Coping with severe injuries, disability, or the fear of returning to work can lead to depression and psychological distress. These psychological effects can significantly diminish quality of life, impacting personal relationships, social interactions, and overall well-being.

3.10. Economic Impact on Companies and the Construction Industry

Companies face immediate expenses for medical treatment, hospitalization, surgeries, and rehabilitation for injured workers. Additionally, financial compensation, including wage replacement benefits and disability payments, increases company expenses [47]. Legal costs for defending against lawsuits, settlements, or fines from regulatory authorities also add significantly to the financial burden.

Accidents disrupt workflow, causing downtime, project delays, and reduced productivity until replacement workers are trained or hired [48]. Recruitment and training of new employees, along with retraining existing staff, further strain company resources. Moreover, increased insurance premiums following accidents and claims can severely impact company finances.

Public perception of safety practices and workplace conditions can significantly affect a company's reputation and brand image [49]. Clients and partners may reconsider contracts or business relationships with companies known for poor safety records. Non-compliance with safety regulations can lead to fines, penalties, or restrictions on future contracts or project bids, further affecting the company's prospects [50].

High accident rates can result in increased insurance premiums across the construction industry, reducing profitability for all stakeholders [51]. The cumulative economic impact of accidents raises the costs of construction projects and infrastructure development, influencing overall industry growth and competitiveness. Addressing the physical and psychological effects on workers and mitigating the economic impact on companies requires proactive safety measures, robust training programs, strict adherence to safety protocols, and a commitment to fostering a culture of safety within the construction industry.

3.11. Knowledge Gap

Most of the studies reviewed in this systematic analysis did not include an explanation of worker compensation schemes for caught-in/between accidents. Future research directions should focus on exploring the current practices and adequacy of worker compensation schemes across various regions and regulatory frameworks, as recommended by previous studies [52]. Additionally, researchers should conduct an analysis of the types and severity of injuries sustained in caught-in/between accidents, along with their impact on worker health and productivity, a factor largely overlooked in the existing literature [22]. Evaluating the economic and productivity impacts of caught-in/between accidents on construction workers should also be prioritized, involving an assessment of the number of working days lost per incident and per worker [53].

Furthermore, there is a need to investigate the correlation between workers' years of experience, age demographics, and their susceptibility to caught-in/between accidents, a crucial aspect that has not been thoroughly examined in most studies [16]. Identifying and evaluating the effectiveness of training programs designed to mitigate caught-in/between accidents, taking into consideration variations in skill levels and job roles, is essential for enhancing workplace safety measures [54,55]. Moreover, examining participation rates and gender-specific risks associated with caught-in/between accidents among the construction workforce can provide valuable insights into disparities and targeted intervention strategies [56]. Finally, scholars should analyze how the nature and scale of construction projects influence the frequency and severity of caught-in/between accidents, including differences observed between residential, commercial, and industrial projects [57]. Addressing these research gaps will contribute to developing more effective policies and practices aimed at reducing the occurrence and impact of caught-in/between accidents in the construction industry.

3.12. Practical Implications

Our analysis of caught-in/between accidents in the construction sector reveals compelling evidence for the necessity of enhanced safety protocols. The data particularly emphasize the hazards associated with heavy equipment operations, including excavation, deep foundation work, and crane and truck operations. These findings suggest that employers must implement more stringent safety measures, with particular emphasis on equipment maintenance protocols, proper deployment of safety mechanisms, and strict adherence to lockout/tagout procedures during both operation and maintenance activities.

The research identifies human factors, specifically worker misjudgment and non-compliant safety behaviors, as persistent contributors to caught-in/between incidents. This observation underscores the imperative for enhanced safety training initiatives designed to elevate risk awareness and decision-making capabilities during high-risk operations. Such programs should emphasize proper PPE utilization, correct material handling protocols, and systematic adherence to safety procedures, particularly in contexts involving manual manipulation, lifting operations, and navigation through active construction environments.

Our findings further indicate that spatial constraints and unstable working environments, particularly in trenching and deep excavation operations, significantly amplify the risk of caught-in/between incidents. This suggests the need for more sophisticated site planning approaches and robust hazard mitigation strategies, including appropriate implementation of shoring, shielding, and sloping techniques for excavation stability. The research supports the implementation of clearly defined work zones and stringent access control measures to minimize exposure to hazardous conditions.

Certain construction activities, including demolition, truss work, and earthmoving operations, emerge as requiring specialized safety protocols. The evidence suggests that enhanced structural bracing methodologies should be developed to prevent structural failures, while crane operations and lifting procedures should be governed by comprehensive lift plans and precise load calculations. Regular safety audits during these high-risk activities emerge as a crucial component of risk mitigation strategies.

The findings indicate a pressing need for enhanced collaboration between regulatory bodies and industry stakeholders to establish and enforce more rigorous safety standards, particularly in sectors demonstrating elevated risk profiles. Our analysis suggests that the implementation of mandatory inspection regimes, sophisticated reporting mechanisms, and robust accountability frameworks could significantly improve regulatory compliance. Moreover, the research identifies smaller enterprises as particularly vulnerable to safety oversights, suggesting the potential benefit of targeted support mechanisms, including subsidies or enhanced access to safety resources.

4. Conclusions

This systematic review comprehensively examined caught-in/between accidents in the construction industry, uncovering critical insights into their underlying causes, injury patterns, and research limitations. The analysis revealed significant accident triggers, including machinery and equipment errors, vehicle incidents, loading and unloading mishaps, and building structure collapses. Heavy equipment rollovers, trench cave-ins, and material shifts emerged as particularly prevalent hazards, underscoring the inherent risks in construction work involving complex machinery and excavation processes.

The injury spectrum ranged from minor to fatal, yet existing research demonstrated substantial gaps in understanding long-term impacts on worker health and productivity. Economic consequences were profound, with considerable working days lost, though few studies quantified these losses comprehensively. An underexplored dimension was the correlation between workers' experience, age, and accident susceptibility, suggesting vulnerability among both inexperienced and older workers.

Training emerged as a critical intervention point. Inadequate safety protocols and insufficient training significantly contributed to accident rates, while gender-specific risks remained poorly documented. This review also highlighted a notable absence of detailed comparative analyses examining how construction project characteristics influence accident frequency and severity.

Recommendations for mitigating caught-in/between accidents centered on multifaceted strategies: implementing stricter safety regulations, developing robust training programs, advancing safety technologies, cultivating a comprehensive safety culture, and establishing comprehensive support systems for injured workers.

Acknowledging the dynamic nature of safety research, this review emphasized the importance of adaptive methodological approaches. Future systematic reviews should prioritize frequent literature searches, establish continuous monitoring mechanisms, and embrace living review methodologies to ensure that insights remain current and relevant.

The study's limitations—including geographical constraints and potential publication biases—underscore the need for more inclusive, comprehensive research. By addressing these gaps and maintaining a proactive, iterative approach to safety investigation, researchers and industry stakeholders can work collaboratively to minimize caught-in/between accidents and fundamentally improve workplace safety standards in the construction industry.

Our systematic literature review, while yielding valuable insights, encountered several methodological constraints that warrant consideration. The geographical limitations of our dataset and potential publication biases suggest the need for more expansive and methodologically robust research initiatives. These identified limitations underscore the importance of developing more sophisticated investigative approaches to workplace safety—approaches that facilitate meaningful collaboration between researchers and industry practitioners in their shared goal of reducing caught-in/between incidents and elevating construction industry safety standards.

The trajectory of future research in this domain should prioritize granular analysis of causative factors, with particular attention to trade-specific risk profiles and activity-associated hazards. Such investigations should also incorporate rigorous evaluation of existing safety protocols' effectiveness. The emerging technological landscape presents compelling opportunities for advancing workplace safety practices. Specifically, the integration of machine learning algorithms for predictive risk assessment and the deployment of wearable safety monitoring systems offers promising avenues for enhancing safety outcomes in the construction sector.

These methodological considerations and future research directions reflect our commitment to advancing the empirical foundation necessary for meaningful improvements in construction workplace safety. By acknowledging current limitations while identifying promising areas for future investigation, we contribute to the ongoing dialog surrounding construction safety enhancement and risk mitigation strategies.

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