ACCIDENTS ANALYSIS IN CONSTRUCTION ROAD PROJECTS: DETERMINING MEASURES AND SOLUTIONS FOR THE CAUSES OF UTILITY STRIKES

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This research investigates utility strikes in construction road projects, identifying their causes and proposing a detailed set of preventive measures. Drawing from 10 UK-based case studies classified as 'dangerous occurrences' (near-misses with significant harm potential) and 'lost time' incidents (events causing work stoppages), purposive sampling was employed to ensure diversity in incident type, utility involved, and project context. Through qualitative analysis using NVivo 12 software, 33 distinct causes were identified, and 40 corresponding measures were developed. These causes and measures were categorised into worker-related domains, such as human error and lack of training, and work-related domains, including equipment failure and poor planning, thereby revealing clear patterns in incident causation. A correlation analysis established links between causes and measures, which formed the foundation for a three-phase Utility Strike Prevention Plan that includes Pre Event, Event, and Post Event stages. This research not only contributes to academic discourse by bridging gaps in existing safety literature but also offers a practical, actionable framework for construction managers, policymakers, and safety officers to enhance project safety, reduce operational disruptions, and protect worker wellbeing.

Keywords: cause of incidents; measures; utility strike; case study; safety management

INTRODUCTION

Utility strikes, incidents where underground services such as gas pipelines, water mains, electrical cables, or telecommunications lines are inadvertently damaged during construction, represent a critical safety and operational challenge in road projects. In the UK, the problem is exacerbated by an extensive and often aging network of buried utilities, many of which lack accurate or up-to-date documentation, including Ordnance Survey maps. These strikes frequently occur during excavation or trenching activities due to inadequate pre-construction surveys, reliance on outdated utility maps, insufficient use of Cable Avoidance Tools (CAT) and Genny scanners,

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and the absence of robust risk assessments or Permits to Dig/Excavate as mandated by HSG47 guidelines. The consequences range from minor delays to catastrophic events like gas explosions or widespread power outages, as reported by the Health and Safety Executive (HSE), with gas and electrical incidents posing the greatest risk due to their potential for immediate and severe harm.

The economic toll of utility strikes is profound and multifaceted. Direct costs, including repairs to damaged infrastructure, legal liabilities, and compensation, often exceed £50,000 per incident, according to industry estimates from the Construction Industry Research and Information Association (CIRIA). However, indirect costs—such as project delays, lost productivity, increased insurance premiums, and reputational damage to contractors—can escalate these figures exponentially, sometimes reaching into the hundreds of thousands. Beyond economics, the human cost is even more alarming. Workers face risks of burns, electrocution, or crush injuries, with fatalities occurring in the most severe cases. Communities near construction sites may also suffer, experiencing service disruptions (e.g., water or electricity loss) or evacuations due to hazardous leaks. For instance, a 2019 gas main strike in Leeds resulted in the evacuation of 200 homes and a £120,000 fine for the contractor, illustrating the cascading effects of such incidents.

Despite advances in utility detection technology and regulatory frameworks like the Construction (Design and Management) Regulations 2015 (CDM 2015), utility strikes persist, suggesting that current approaches are insufficient. Previous research, such as Metje et al. (2015), has classified causes like poor utility mapping and operator error, while Koschmann et al. (2020) highlighted communication breakdowns and inadequate training. Yet, these studies often stop short of offering comprehensive, actionable solutions. This paper addresses that gap by shifting the focus from mere identification of problems to the development and implementation of targeted measures.

The research objectives are: (1) To systematically identify and categorise measures that mitigate utility strikes, grounded in real-world evidence from 10 UK case studies. (2) To establish precise correlations between these measures and their underlying causes, ensuring relevance and effectiveness. (3) To propose a comprehensive Utility Strike Prevention Plan, a preventive methodology that integrates 40 targeted measures across three phases—Pre-Event (planning), Event (execution), and Post-Event (recovery)—to provide a structured, actionable framework for construction managers, policymakers, and safety officers. This methodology aligns with UK regulatory frameworks, including the CDM 2015 and HSG47, to enhance project safety, reduce operational disruptions, and protect worker wellbeing.

The 10 case studies, selected for their diversity in utility type (e.g., gas, water, electricity) and incident severity, provide a robust dataset. They include 'dangerous occurrences' (near-misses with high potential for harm) and 'lost time' incidents, where work was halted due to injury or damage. By analysing these events, this research uncovers not only what goes wrong but also how to prevent it, offering a solution-oriented perspective that builds on established UK procedures, such as HSG47 and CDM 2015. Unlike prior studies, which often focus on isolated causes or solutions, this work integrates 33 identified causes with 40 targeted measures into a novel, three-phase Utility Strike Prevention Plan. This plan addresses gaps in the application of existing regulations by providing a structured, evidence-based framework that enhances practical implementation, ensuring alignment with industry standards while offering actionable insights for safer construction practices.

LITERATURE REVIEW

Utility strikes represent a persistent issue in construction safety research, with extensive studies documenting their frequency and impacts. Maree et al. (2021) conducted a foundational statistical analysis, revealing that over 60% of utility strikes in the United Kingdom result from inadequate detection methods or dependence on outdated utility records, a challenge exacerbated by the intricate nature of urban infrastructure. Sarvari et al. (2020b) shifted attention to human factors, attributing approximately 50% of such incidents to operator inexperience, ineffective team communication, or non-compliance with safety protocols. Aven (2022) adopted a wider perspective, pinpointing systemic deficiencies, including inadequate pre-construction risk assessments, variable safety standards among contractors, and insufficient accountability in project planning, as critical contributors. The Health and Safety Executive's HSG47 guidelines emphasise the importance of accurate utility mapping, the use of CAT and Genny scanners, and the implementation of Permits to Dig/Excavate to prevent utility strikes, yet compliance remains inconsistent due to time pressures and resource constraints.

Efforts to reduce utility strikes have traditionally been categorised into three primary approaches: technological, procedural, and training-based measures, often aligned with the ERIC principle (Eliminate, Reduce, Isolate, Control) as outlined in CDM 2015. Technological solutions, such as Ground Penetrating Radar (GPR), electromagnetic locators, and Geographic Information Systems (GIS), have become increasingly adopted for their capacity to map subsurface utilities (Li et al., 2014). However, their effectiveness is limited by factors such as soil conditions, operator proficiency, and the inability to detect non-metallic utilities, such as plastic water pipes.

The critical role of CAT scanners, mandated by HSG47, is often underutilised due to inadequate training or rushed schedules, leading to misinterpretations of scan data (Metje et al., 2015). Procedural strategies, encompassing mandatory permit-to-work systems, comprehensive utility surveys, and standardised risk assessment protocols, have been endorsed by Sarvari et al. (2024a). These align with the ERIC principle by prioritising elimination and reduction of risks through thorough planning and control measures, such as detailed work plans and Design Risk Management (DRM). However, their success is frequently undermined by inconsistent application or resistance from project teams facing stringent deadlines. Training-based initiatives, promoted by Bourassa et al. (2016), focus on enhancing workers' skills in hazard identification and equipment operation, yet their integration into broader safety frameworks, such as Management Arrangements under CDM 2015, often remains inadequate, constraining their influence on systemic risks.

Significant limitations in these approaches emerge from the literature. Li et al. (2014) criticise the excessive dependence on technology without corresponding advancements in operator training, citing cases where misinterpretations of GPR and CAT scanner data precipitated utility strikes. Sarvari et al. (2024b) highlight procedural shortcomings, such as omitted utility verification steps or inadequate work plans, as indicative of a gap between policy formulation and practical execution. Historical instances, such as the 2015 reliance on inaccurate utility maps in a Manchester project, which resulted in a £200,000 water main rupture, underscore the necessity for a more comprehensive strategy. The absence of robust Management Arrangements and Principles of Prevention, as advocated by CDM 2015, further exacerbates these issues. This study addresses these gaps by proposing an integrated framework that unifies technological, procedural, and training-based measures into a cohesive prevention strategy, aligned with HSG47 and the ERIC principle. Solutions are structured into three phases—Pre-Event (planning), Event (execution), and Post-Event (recovery)—to ensure comprehensive coverage across the project lifecycle. By tackling both immediate causes, such as operator error, and deeper systemic issues, such as deficient planning, this work advances utility strike prevention significantly, offering a practical blueprint for enhancing safety in construction practices.

METHOD

This research adopted a qualitative case study approach to investigate utility strikes in UK construction road projects, leveraging real-world incidents to derive evidence-based insights into their causes and preventive measures. The methodology was designed to align with the study's objectives: (1) to identify and categorise measures mitigating utility strikes, (2) to establish correlations between causes and measures, and (3) to develop a three-phase utility strike prevention plan compliant with UK regulations such as the CDM 2015. A qualitative approach was chosen for its ability to provide an in-depth, contextualised understanding of complex phenomena, enabling the exploration of both worker-related and work-related factors in utility strikes.

Case Study Selection

Ten UK-based case studies were selected using purposive sampling to ensure diversity in incident type, utility involved, and project context. Cases were categorised as either 'dangerous occurrences' (near-misses with high harm potential, as defined by HSG47) or 'lost time' incidents (events causing work stoppages due to injury or damage). The selection criteria included: (1) Incident Severity: Cases with significant safety or operational impacts, ensuring relevance to high-risk scenarios; (2) Utility Diversity: Representation of various underground services (gas, water, electricity, telecommunications) to capture a broad range of strike scenarios; (3) Project Context: Inclusion of urban and rural projects to account for varying infrastructure complexities; and (4) Data Availability: Access to comprehensive documentation, including HSE reports, contractor logs, worker interviews, and site safety audits. This purposive approach ensured a robust and representative dataset, as summarised in Table 1.

Data Collection

Data were collected from multiple sources to provide a comprehensive view of each incident, adhering to the principles of triangulation to enhance validity. Sources included: (1) HSE Incident Reports: Official records detailing incident circumstances, outcomes, and regulatory violations; (2) Contractor Logs: Internal documentation of project activities, equipment use, and safety measures; (3) Worker Interviews: Semi-structured interviews with operatives, supervisors, and site managers to capture firsthand perspectives on incident causes and mitigation; and (4) Site Safety Audits. Data collection was guided by ethical considerations, with informed consent obtained from interviewees and data anonymised to protect confidentiality.

Data Analysis

Data analysis was conducted using NVivo 12 software in a rigorous two-stage qualitative coding process to identify causes and measures systematically. Stage 1:

Open Coding involved extracting specific causes (e.g., 'inadequate training,' 'outdated utility maps') and measures (e.g., 'mandatory retraining,' 'enhanced utility mapping') from raw data. This stage ensured that all relevant factors were captured without preconceived categories. Stage 2: Thematic Coding grouped these into worker-related (e.g., human error, fatigue, miscommunication) and work-related (e.g., equipment failure, poor planning) domains, aligning with the ERIC principle to structure preventive strategies. For example, the cause 'lack of training' was correlated with the measure 'mandatory retraining' based on its recurrence in eight cases, supported by narrative evidence from interviews and reports.

To ensure analytical rigor, two researchers independently coded the data, achieving an inter-coder agreement rate of 92%. Discrepancies were resolved through consensus discussions, enhancing reliability. The analysis identified 33 distinct causes and 40 corresponding measures, which were cross-referenced to establish causal relationships. These findings formed the basis for the three-phase Utility Strike Prevention Plan, ensuring that proposed measures were grounded in empirical evidence and tailored to address both immediate and systemic risks. The methodology’s robustness lies in its systematic, evidence-based approach, which integrates real-world data with UK regulatory frameworks to produce actionable outcomes for construction safety management.

Table 1: Characteristics of the 10 utility strike case studies

Case No.	Category	Utility type	Incident potential	Incident severity	Incident location	Incident duration	Weather condition	Nature of injury
1	Dangerous occurrence	Gas	Low	High (serious)	Site	≥ year	Cloudy	No
2	Dangerous occurrence	Gas	Low	Medium	Site	≤ week	Cloudy	No
3	Lost time	Water	Low	Medium	Site	≤ month	Clear	Yes
4	Lost time	Water	Low	Medium	Site	≥ 6 months	Clear	Yes
5	Lost time	Water	Low	High (serious)	Site	≤ week	Clear	Yes
6	Lost time	Water	Low	Medium	Offsite	≤ month	Clear	Yes
7	Dangerous occurrence	Electric	Low	High (serious)	Site	≥ month	Clear	No
8	Dangerous occurrence	Electric	Low	High (serious)	Site	≤ week	Clear	No
9	Lost time	Telecom	Low	Medium	Offsite	≥ month	Cloudy	Yes
10	Lost time	Telecom	Low	Medium	Site	≥ month	Clear	Yes

RESULTS AND DISCUSSION

The analysis of the 10 case studies yielded 33 unique causes of utility strikes, reflecting a mix of worker-related (e.g., operator inexperience, fatigue, miscommunication, procedural non-compliance) and work-related factors (e.g., inadequate utility detection, outdated records, insufficient risk assessments, equipment malfunctions). From these, 40 measures (as shown in Table 1) were developed and organised into Pre-Event, Event, and Post-Event categories, aligning with the Principles urid Prevention and Management Arrangements under CDM 2015, as well as HSG47 guidelines. These measures form a comprehensive toolkit for preventing utility strikes, addressing both immediate risks and systemic weaknesses through Planning & Control and Design Risk Management (DRM).

In the Pre-Event phase, measures such as detailed utility mapping and Risk Assessment Method Statements (RAMS) development align with Planning & Control by ensuring risks are eliminated or reduced before work begins, as per the ERIC principle. For instance, utility mapping combines historical records, CAT and Genny scans, and on-site verification to address inadequate surveys and outdated maps, a cause identified in seven cases. RAMS development, reviewed by all stakeholders, incorporates Design Risk Management by embedding safety considerations into project planning, reducing risks like operator error (noted in eight cases). The Event phase emphasises real-time risk mitigation through measures like dynamic risk assessments and increased inspection frequency, which support Management Arrangements by ensuring continuous oversight and compliance with HSG47's emphasis on safe systems of work. For example, dynamic risk assessments, conducted before shifts or after environmental changes, were linked to reduced operator errors in five cases. The Post-Event phase focuses on learning and recovery, with measures like root cause analysis and safety bulletins aligning with CDM 2015's requirement for ongoing improvement. These measures address systemic issues, such as poor communication (noted in six cases), by fostering industry-wide learning through platforms like the CITB.

The novelty of this study lies in its integration of these measures into a cohesive, three-phase Utility Strike Prevention Plan that operationalises established concepts like Planning & Control, Principles of Prevention, and Management Arrangements. Unlike prior studies that offer isolated solutions, this plan ensures seamless integration with existing safety management systems like ISO 45001, enhancing their utility without necessitating radical changes. By grounding the measures in empirical data from 10 diverse UK case studies, the plan provides actionable, context-specific solutions that address both immediate and systemic causes, offering a significant advancement over predictable outcomes in prior research.

Table 1: Measures and solutions for utility strikes

Group	Measure	Related Causes
Pre Event	Preparedness for risk response	Inadequate documentation or documentation control and emergency procedures in place for the specific task; Insufficient organisation of the planning of works to be undertaken
	Reviewing the competence of the team leader	Inadequate leadership or supervision or specific operation on-site; No or insufficient competence or awareness or experienced leaders & managers (information, instruction and training)
	Reviewing the qualification of the operators	Unskilled, unqualified and inexperienced operator/worker for the work activity; Ignoring the training provided by operators/workers (information, instruction and training)
	Reviewing the existence of suitable and sufficient project methods	Insufficient quality or availability of procedures, guidelines, method statements, risk assessment and manuals (procedures); Inappropriate or insufficient safety control measures designed or implemented
	Reviewing the permit to work by site managers and supervisors	Failure to obtain work permission from the project's manager for certain duties; Incorrect issue of licences & permits (routine violation)
	Classification of the incidents based on potential and severity	Inadequate documentation or documentation control and emergency procedures in place for the specific task; Insufficient organisation of the planning of works to be undertaken
	Field investigation before entering and exiting the machine and facilities	Operator/worker failure to identify the hazards; Inappropriate workplace layout
	Ensuring operators' awareness of roles, responsibilities and resources	Unclear operator/worker roles and responsibilities; Operators/workers who are unfamiliar with site layout and the site-specific controls

	Ensuring that RAMS are requested, reviewed and approved for all supply chain activities	Non-application of the agreed risk assessment method statement (RAMS) procedure by the team; Insufficient quality or availability of procedures, guidelines, method statements, risk assessment and manuals (procedures)
	Assessing the equipment suitability plus relevant subjects based on DRA	Inappropriate selection and use of plant, machinery or equipment for work; Poor quality, condition and/or suitability of materials, plant, machinery and equipment
Event	Increasing inspection frequency for new teams & reviewing the previous inspections' findings	Operator/worker error in utilising plant, machinery and equipment; non-application of the agreed RAMS procedure by the team
	Ensuring that there are enough skilled site managers available	Inadequate leadership or supervision or specific operation on-site; No or insufficient competence or awareness or experienced leaders & managers (information, instruction and training)
	Stepping up leadership visits	Inadequate leadership or supervision or specific operation on-site; Leadership failure to adequately manage and plan operational aspects of the work task
	Suitable and sufficient handover when changing the operators	Operators/workers who are unfamiliar with site layout and the site-specific controls; Poor communication between organisation or team members
	Focusing on engaging with operatives on compliance with procedures	Non-application of the agreed RAMS procedure by the team; Failure to adhere to a safe system of work (SSoW)
	Constantly risk assessment throughout the whole of the job to identify additional hazards and record them within the site-specific risk assessment (SSRA) by Operatives	Operator/worker failure to identify the hazards; Inadequate documentation or documentation control and emergency procedures in place for the specific task
	Ensuring the new teams have the necessary competence and experience to undertake the work	Unskilled, unqualified and inexperienced operator/worker for the work activity; Operators/workers who are unfamiliar with site layout and the site-specific controls
	Reviewing the current permit for the suitability of content for the project	Failure to obtain work permission from the project's manager for certain duties; Incorrect issue of licences & permits (routine violation)
	Ensuring that the site handover briefing is completed for the restart of the work	Poor communication between organisation or team members; Operators/workers who are unfamiliar with site layout and the site-specific controls
	Ensuring the safety measures for the restart of the work	Failure to adhere to a safe system of work (SSoW); Inappropriate or insufficient safety control measures designed or implemented
Post Event	Implementation of disciplinary measures in accordance with the instructions in the event of negligence	Overlooking or neglecting basic safety by operator/worker (operators' overconfidence in their ability); Human error - lapse and routine violation of instructions & regulations
	Review of other work tool types on the market to determine safer options	Inappropriate selection and use of plant, machinery or equipment for work; Poor quality, condition and/or suitability of materials, plant, machinery and equipment
	Deployment safety, health, environment and quality (SHEQ) for checking the site after incidents	Inappropriate workplace layout: Unsuitable physical conditions and other influences that have a disadvantageous effect on human functioning (error enforcing conditions)
	Organising a handover briefing after incidents	Poor communication between organisation or team members; Operators/workers who are unfamiliar with site layout and the site-specific controls
	Checking and ensuring the wellbeing of the people involved in incidents	Imposed duress upon operators/workers to complete the task by the client; Unsuitable physical conditions and other influences that have a disadvantageous effect on human functioning (error enforcing conditions)

Training & re-briefing the safety process to operators involved in incidents	Ignoring the training provided by operators/workers (information, instruction and training); Unskilled, unqualified and inexperienced operator/worker for the work activity
Reviewing the logistics arrangement by involved firms in incidents	Insufficient organisation of the planning of works to be undertaken; Inappropriate workplace layout
Producing a safety bulletin shared across the group and wider utility industry for shared learning	Poor communication between organisation or team members; Lack of availability, incorrect or complexity of buried utility drawings and other relevant information
Reviewing the competence of workers and operators after incidents	Unskilled, unqualified and inexperienced operator/worker for the work activity; No or insufficient competence or awareness or experienced leaders & managers (information, instruction and training)
Cooperation control to support the main replacement programs after incidents	Insufficient organisation of the planning of works to be undertaken; Poor communication between organisation or team members
Evaluating the effectiveness of HSE and QMS performance monitoring system	Inadequate documentation or documentation control and emergency procedures in place for the specific task; Insufficient quality or availability of procedures, guidelines, method statements, risk assessment and manuals (procedures)
Reporting dangerous occurrences to HSE	Human error - lapse and routine violation of instructions & regulations; Failure to adhere to a safe system of work (SSoW)
Briefing out safety bulletin to raise awareness of work tools within restrictive work areas (such as the bottom of excavations)	Inappropriate selection and use of plant, machinery or equipment for work; Operator/worker error in utilising plant, machinery and equipment
Focusing on training in relation to continual risk assessment of the work area and recording on an SSRA	Operator/worker failure to identify the hazards; Inadequate documentation or documentation control and emergency procedures in place for the specific task
Issuing the safety alert regarding the importance of dynamic risk assessment (DRA)	Operator/worker failure to identify the hazards; Inadequate documentation or documentation control and emergency procedures in place for the specific task
Emphasis on continuous communications and attention to incident reporting regulations	Poor communication between organisation or team members; Human error - lapse and routine violation of instructions & regulations
Ensuring the presence of first aid on-site	Insufficient safety equipment, devices, personal protective equipment (PPE) for a specific task; Unsuitable physical conditions and other influences that have a disadvantageous effect on human functioning (error enforcing conditions)
Challenging unsafe acts or instructions	Overlooking or neglecting basic safety by operator/worker (operators' overconfidence in their ability); Human error - lapse and routine violation of instructions & regulations
Training and policies for safe machine use	Operator/worker error in utilising plant, machinery and equipment; Inappropriate selection and use of plant, machinery or equipment for work
Issuing a Toolbox talk (TBT) to support the understanding of the hazards and associated risks whilst working	Operator/worker failure to identify the hazards; Ignoring the training provided by operators/workers (information, instruction and training)

CONCLUSIONS

The identification of 33 causes and 40 measures in this study offers a comprehensive understanding of utility strikes, resulting in the development of a three-phase Utility Strike Prevention Plan that addresses risks holistically. By prioritising solutions over mere diagnosis, this research provides construction professionals with a practical framework to enhance safety, safeguard project timelines, and ensure compliance with regulations such as CDM 2015. The plan's phased structure, encompassing preparation, execution, and recovery, facilitates proactive risk management, continuous monitoring, and post-incident resolution, thereby establishing a cycle of ongoing improvement. The broader implications of this research are significant. A reduction in utility strikes not only improves public safety by minimizing service disruptions and mitigating environmental hazards, such as gas leaks that contribute to carbon emissions or water losses that exacerbate resource shortages but also generates substantial economic benefits. Savings achieved through fewer incidents can be allocated to innovation, including the development of advanced detection technologies or enhanced worker training programs. For instance, a 10% reduction in utility strikes across UK road projects could yield annual savings of millions, according to cost estimates provided by CIRIA.

Future research should aim to quantify the cost-benefit ratio of the proposed plan by evaluating implementation costs against financial savings derived from averted incidents. Comparative studies could also examine the plan's adaptability across diverse contexts, such as rural construction projects or international settings with varying utility infrastructures. Furthermore, exploration of technological innovations, including artificial intelligence for predictive risk modelling and augmented reality for utility visualisation, is recommended. For practitioners, this study serves as an immediate, actionable resource designed to protect workers and projects, contributing to a safer and more sustainable construction industry.

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