Student No.: 202246543
Module: MRes Research Project (700060_A22_T3A)

An Analysis of Highway Electrical Workers' Attitudes Towards the Risk of Underground Utility Strikes

MRes (Research) Occupational Health, Safety and Environmental Management (in partnership with NEBOSH)

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Word Count: 26,192

July 2024

1. Abstract

Despite improvements in the UK construction industry's safety record, workplace fatalities remain widespread. Highway electrical workers are particularly vulnerable to the dangers of underground utility strikes.

This mixed-methods study investigates these workers' perceptions of risk, exploring how factors like regulatory understanding, training, organizational culture, and personal experiences shape their attitudes towards safety. Quantitative survey data will assess the prevalence of attitudes and safety practices, while in-depth interviews will explore the underlying reasons and motivations.

The research will examine the relationship between worker attitudes and their compliance with safety procedures, considering the potential influence of leadership, incentives, training and worker's age. The goal is to provide evidence-based recommendations for enhancing safety measures and reducing underground utility strike incidents within the highway electrical sector.

2. Acknowledgements

I would like to express my gratitude to my supervisor, Steve Pace, for his invaluable guidance, insightful feedback, and support throughout this research journey. His expertise and encouragement were instrumental in shaping this thesis.

My sincere thanks go to my colleagues at Electrical Testing Ltd for their understanding and flexibility, allowing me the necessary time to pursue this academic endeavour. I am grateful for their support.

I extend my appreciation to the companies within the highway electrical sector who generously opened their doors and enabled me to engage with their staff. Their participation and insights were essential to this research.

Finally, my heartfelt thanks to my family and my wife, Mariea. Your support throughout the 'one more year' stretches was invaluable. I could not have accomplished this without you.

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4. Abbreviations

CAT - Cable Avoidance Tool (inferred from common usage in the industry)

CGA - Common Ground Alliance

CIOB - Chartered Institute of Building

CSV - Comma-Separated Values

DIRT - Damage Information Reporting Tool

ENA - Energy Networks Association

ETL - Electrical Testing Ltd

GDPR - General Data Protection Regulation

GIS - Geographic Information System

GPS - Global Positioning System

GPR - Ground-Penetrating Radar

HEA - Highway Electrical Association

HERS - Highway Electrical Registration Scheme

HROs - High-Reliability Organisations

NLTK - Natural Language Toolkit

NUAR - National Underground Assets Register

PBP - Proficiency-Based Progression

SPSS - Statistical Package for the Social Sciences

STAMP - Systems-Theoretic Accident Model and Processes

UK - United Kingdom

UKRIO - UK Research Integrity Office

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7. Introduction

Underground utility strikes represent a significant risk to highway electrical workers.

These incidents can result in injuries, fatalities, and substantial infrastructure damage, with the UK Government estimating there are 60,000 strikes per annum (Gov.uk, 2021). Understanding worker attitudes towards this hazard is essential for developing effective safety interventions, as attitudes directly influence safe work practices (Metje et al., 2015; Patel et al., 2012).

While other research studies have covered broader safety issues within the construction industry (ENA, 2020; Sherratt, 2012; Lingard, 2013; Sherratt and Dainty, 2017; HSE, 2022), there's a need for deeper insights into the specific attitudes of highway electrical workers. These individuals face distinct hazards when excavating around existing utilities, unlike general construction where careful avoidance is often standard practice. This study aims to fill this research gap.

This work will take place in supervised workplaces at different sites in the UK that are recognised within the Highway Electrical Registration Scheme (HERS). Information on settings (e.g., organisation, management structure, employee profile), including the position of the safety function within the organisation, will serve to contextualise the study.

This research therefore hypothesises that highway electrical workers' safety attitudes are influenced by complex factors, including organisational culture, leadership styles, training effectiveness, and individual experiences.

A mixed-methods approach will be used, combining an online survey, interviews, and non-participant observations to gain an understanding of worker perceptions. Data analysis will involve thematic coding, frequency distributions, and cross-tabulations. The study will consider the potential impact of the National Underground Asset Register (NUAR) on safety practices (Geospatial Commission, 2024).

This research has the potential to provide evidence-based recommendations for improving safety protocols and minimising the risk of underground utility strikes within the highway electrical sector.

8. Research Aim & Objectives

8.1. Aim

To investigate how training, organisational culture, and worker experience influence highway electrical workers' risk perceptions of underground utility strikes in the UK.

8.2. Objectives

This study seeks to understand the factors that shape highway electrical workers' perceptions of risk regarding underground utility strikes in the UK's construction sector.

1. Conduct a literature review to synthesize existing knowledge on risk perception in the construction industry (relating to underground utility strikes) identifying gaps and areas for further research.
2. Analyse how current mandated & company specific training programs shape highway electrical workers' attitudes towards the risks of utility strikes.
3. Explore the relationship between organisational culture (including leadership and safety communication) and highway electrical workers' adherence to safety practices.
4. Compare risk perceptions of underground utility strikes among highway electrical workers with different levels of experience.
5. Develop recommendations to improve safety practices and reduce underground utility strikes based on research findings.

9. Literature Review

9.1. Introduction

The research explores the challenge presented by accidental strikes on the UK's underground utility network, which extends over 4 million kilometres. Every year, around 60,000 strikes occur, posing serious safety risks and costing the economy about £2.4 billion. This situation underscores the urgency of examining how we approach underground utilities to prevent these incidents. This studies goal is to investigate the root causes of the high frequency of these strikes, looking into how safety practices, worker attitudes, and technology are involved.

The urgency of the research is highlighted by other sources like the National Underground Assets Register (NUAR) and the Energy Networks Association (ENA). Their findings show the scale of the problem but also make a strong case for finding better ways to manage the risks associated with underground utilities.

This study aims to look at the issue, incorporating findings from key research like those by Metje et al. (2015), Patel et al. (2012), and Donaghy (2009). These studies help us understand the human elements, company culture, and larger systemic problems that lead to utility strikes. They emphasise the importance of proper safety training, communication, and the role of technology in preventing these incidents.

The literature review is structured to guide the reader through a logical progression of themes, starting with an overview of the statistical evidence, followed by an analysis of human factors and organisational culture. It then examines the effectiveness of technological solutions and safety measures before culminating in a synthesis of research directions. This approach aims to identify gaps in the existing literature, informed by theoretical and conceptual frameworks that draw on human factors, organisational culture, and risk perception theory.

9.2. The Significance of Underground Utility Strikes

The UK's vast underground utility network, spanning over 4 million kilometres, presents a considerable risk if not properly managed (Geospatial Commission, 2023). The National Underground Assets Register (NUAR) estimates approximately 60,000 accidental strikes occur annually, costing the UK economy around £2.4 billion (Geospatial Commission, 2024). These statistics highlight the problem's scale and the urgent need for improved mitigation strategies.

The Energy Networks Association (ENA, 2020) reports alarming statistics that underscore the severity of this issue. Their findings reveal that nearly a third of construction workers neglect to check for underground electricity cables before beginning work. Such lapses have led to 354 life-altering injuries within the last five years, with tradespeople involved in four out of five reported incidents.

The ENA data also shows a 46% increase in cable strikes since the 2021 national lockdown. This is concerning, especially as 93% of construction workers believe they follow safe practices, yet nearly a third admit to not always checking for cables. Common reasons cited for this include a belief that the responsibility lies elsewhere (15%) or that they won't be digging deep enough (24%) (ENA, 2020: 2). This disconnect between perceived and actual safe practices warrants further investigation.

These statistics are particularly relevant to the highway electrical industry, where nearly half (47%) of reported incidents occur on public highways, construction sites, and industrial areas (ENA, 2020: 2). This highlights the heightened risk faced by workers in this sector.

The data reveals not only risky behaviours but also systemic issues contributing to these incidents. These findings compel us to examine the attitudes and practices that lead to such dangerous outcomes, justifying the need for this research study.

Beyond the human and operational costs, the economic impact of underground utility strikes is substantial. Gov.uk (2021) provides detailed cost estimates for different types of strikes (electric, gas, telecoms), including both direct and indirect expenses. Their findings underscore the significant financial burden borne by the industry and society. Approximately 30% of strikes could potentially be prevented through improved data management and accessibility, highlighting an area for improvement.

The economic implications, alongside the safety risks, emphasise the need for better safety measures and risk management. This study seeks to understand the attitudes and practices contributing to underground utility strikes.

9.3. Human Factors and Organisational Culture

One of the important works in the field of underground utility strikes is the research conducted by Metje et al. (2015), which delves into the causes, impacts, and costs of strikes on buried utility assets. This study serves as a foundation for framing the current research on highway electrical workers' attitudes towards the risk of underground utility strikes.

While Metje et al. (2015) provide valuable insights, particularly highlighting the prevalence of human error and non-compliance with safety protocols, the study’s methodology warrants a closer examination. The reliance on retrospective data and self-reported incidents raises questions about the potential for recall bias and the accuracy of the reported data. Moreover, the study's cross-sectional design limits the ability to infer causality between the identified factors (such as the use of CAT scans) and the occurrence of utility strikes.

Metje et al.'s finding that over 50% of utility strikes involving hand tools occurred despite the prior detection of utilities using CAT scans suggests significant gaps in the practical application of safety protocols. However, the study does not delve deeply into the reasons for this non-compliance. Future research could benefit from a mixed-methods approach, incorporating qualitative interviews with workers to uncover the behavioural and cognitive factors contributing to such lapses in safety practices.

Furthermore, while the study highlights the need for better training and compliance mechanisms, it stops short of evaluating the effectiveness of specific training programs. This gap presents an opportunity for the current research to assess how different training interventions influence workers' attitudes and adherence to safety protocols, thereby addressing Objective 2 of this study.

Another critical point is the generalisability of Metje et al.'s findings. The study's sample was predominantly composed of workers from large construction firms, which may not reflect the practices and challenges faced by smaller companies or independent contractors. This limitation underscores the importance of ensuring a diverse sample in the present study to capture a broader spectrum of experiences and attitudes within the highway electrical sector.

Another critical finding from Metje et al. (2015) is that rules not followed and errors *“account for over 80%”* of utility strikes (Metje et al., 2015:171). This statistic raises questions about the efficacy of existing safety guidelines and organisational culture in mitigating the risks associated with underground utility strikes. It also serves to frame the current study's objective of examining the role of organisational culture and Health and Safety legislation in shaping workers' attitudes and practices. We will see shortly that complementing Metje et al.'s findings, Patel et al. (2012) explore the perception among utility operatives that cable strikes are an inevitable part of their work. This resignation to risk reflects a broader cultural issue within the industry, where the presence of safety measures does not necessarily translate into safer practices.

One particularly intriguing aspect of Metje et al.'s (2015) research is the identification of peak times for underground utility strikes, notably between 09.00 and 12.00. This temporal pattern raises important questions regarding the underlying factors that contribute to the increased risk during these hours. Despite the critical insights offered by Metje et al., a notable gap remains in understanding why these peak times for strikes occur, especially within the specific context of the UK's highway electrical industry. This gap signifies an interplay of factors such as work scheduling, morning routines, and possibly a shift in workers' attentiveness and decision-making processes at different times of the day.

Exploring this gap could reveal insights and inform targeted interventions to mitigate the risks associated with underground utility strikes.

Patel et al.’s concept of the *"inevitability of cable strikes as a daily occurrence*” is a finding that serves to frame the current research study. According to Patel et al. (2012), almost all utility operatives interviewed had experienced a cable strike, and most could not articulate the reasons behind these incidents. This led to a widespread belief that *"accidents will happen,"* suggesting an ingrained belief that cable strikes are an inevitable part of the work (Patel et al., 2012: 408). This perception of inevitability could be indicative of a systemic issue within the industry, where safety measures may be in place but are not effectively altering the attitudes or behaviours of the workers.

The study by Patel et al. (2012) also emphasises that human error is often considered the final link in a much longer chain of events leading to cable strikes. This perspective suggests that safety management should extend its focus beyond frontline operatives to seek improvements higher up the causal chain (Patel et al., 2012: 410). This aligns with the current study's objectives to explore systemic factors that influence attitudes and compliance with safety practices among highway electrical workers.

Another key finding from Patel et al. (2012) is the fragmented nature of communication between the site and the office. Their study points out that the commercial policy of the company often contradicts the health and safety policy, affecting the safety processes in practice, whereby *“the implementation of onerous procedures, and payment structures that fundamentally contradict safety processes”* (Patel et al., 2012: 410). This finding is particularly relevant to this study's objective of examining the role of organisational culture and communication in shaping workers' attitudes and practices.

Donaghy (2009) offers an examination of the underlying causes of fatal accidents in the construction industry. The study identifies an interplay of factors, such as training inadequacies, information and advice deficiencies, and poor risk perception, as contributing to fatal incidents.

Donaghy's study further underscores the absence of a robust safety culture in the industry, highlighting the lack of adequate training and supervision as significant gaps (Donaghy, 2009: 76). This observation aligns with the focus of the present study, which seeks to investigate how organisational culture and supervisory practices influence workers' attitudes and compliance with safety guidelines and legislation.

The report by Donaghy (2009) explicitly calls for additional research in several areas, including the development of *"robust measures of exposure to risk"* (Donaghy, 2009: 77). This recommendation serves to emphasise the importance of the present study, which aims to provide an understanding of the attitudes and practices contributing to the risks associated with underground utility strikes in the highway electrical industry.

Another item influencing safety in the construction industry, the role of family considerations emerges as a noteworthy point. Donaghy (2009) emphasises the importance of workers considering the impact of unsafe practices on their families. She recommends that workers should take responsibility for their own safety, as far as they are able, with the understanding that their actions have broader implications for their families (Donaghy, 2009: 14).

Both Patel et al. (2012) and Donaghy (2009) converge significantly on the systemic nature of safety issues within the construction industry, underscoring the necessity to delve deeper than the superficial layer of individual worker actions. Patel et al. highlight the inevitability of cable strikes, noting that despite awareness of safety procedures, utility operatives frequently encounter these incidents without a clear understanding of the underlying causes. This phenomenon is not merely about the act of striking a utility but reflects a broader systemic failure where the existing safety measures fail to alter worker attitudes or behaviours. Similarly, Donaghy's examination of fatal accidents in construction points to systemic failures including training inadequacies and a poor safety culture that fail to mitigate risks adequately.

Both studies suggest that human error is not an isolated factor but the culmination of an interplay of systemic deficiencies. Patel et al. argue that safety management needs to extend beyond just the frontline operatives to address higher levels of the causal chain, proposing a re-evaluation of how safety practices are integrated and managed (Patel et al., 2012). This aligns closely with Donaghy's findings, which call for a transformation in training, supervision, and the overall safety culture within the industry (Donaghy, 2009).

Furthermore, the fragmented communication between site operations and management highlighted by Patel et al. resonates with Donaghy's observations on the inadequacies in the flow of safety-related information and advice. Both studies criticise the existing operational and management practices that often prioritise commercial interests over safety, leading to conflicting policies that undermine the safety culture.

These shared insights between the two studies enhance the understanding of how deeply entrenched systemic issues contribute to safety failures. By integrating these perspectives, this research aims to develop an understanding of the systemic factors influencing safety compliance and the role of organisational culture in shaping safety attitudes among highway electrical workers. The alignment of these studies supports the current study's objective to explore these broader systemic factors and their impact on safety in the construction industry, particularly in contexts involving high risks like underground utility work (Patel et al., 2012; Donaghy, 2009).

The "CGA Locator White Paper" (CGA, 2020) alongside the CGA's Damage Information Reporting Tool (DIRT) Report, from the Common Ground Alliance, provides a critique of the underground utility location industry in the U.S., shedding light on challenges that resonate globally. The reports reveal that high notification volumes significantly pressure workers to prioritise productivity over accuracy, potentially compromising the safety and reliability of locates. This critical issue underscores a broader industry dilemma where the demand for rapid responses may inadvertently elevate the risk of utility strikes. Moreover, the emphasis on the role of updated facility maps as a remedy for improving location accuracy, brings into focus the urgent need for advancements in data management and technology within the sector (CGA, 2020:7).

These insights not only offer a reflection on the U.S. context but also serve as a mirror to the UK's highway electrical sector, where similar challenges persist. Through a review of these documents, it becomes evident that there is a universal need for a shift towards integrating more robust safety protocols, enhancing training programmes, and cultivating a safety-conscious organisational culture. This aligns with Objective 2 & 3 of the thesis. The stagnation in damage rates and the staggering economic costs associated with utility strikes, as highlighted by the DIRT Report (CGA, 2023), further bolster the argument for a concerted effort to improve practices and technologies in utility location and management globally.

While the primary focus of this research study is on highway electrical workers, as with the CGA, it is instructive to consider findings from related sectors, such as the construction industry, to provide a broader context. A study by Rauscher et al. (2010) explored the social contexts affecting the safety of young construction workers and yielded two key findings that are relevant to this study.

Rauscher et al. (2010) found that *“Having a family-firm connection was associated with fewer hazard exposures and greater safety practices”* (Rauscher et al., 2010:

A178). This finding could be pertinent to Objective 3 of the current study, which aims to explore the impact of factors such as organisational culture and past experiences on workers' attitudes towards risks. The family-firm connection could serve as a proxy for organisational culture, suggesting that familial ties within the workplace may positively influence safety practices and attitudes towards risk.

The study also indicated that *“Youth who worked on job sites with a larger workgroup (11–50 workers) reported greater hazard exposure but also greater safety practices.”* (Rauscher et al., 2010: A178). This finding aligns with Objective 3 of the current study, which seeks to examine the relationship between workers' attitudes, compliance with safety practices, and communication with other stakeholders. The size of the work group could be a factor affecting both hazard exposure and the effectiveness of safety practices, thereby influencing workers' attitudes and compliance levels.

Sherratt's (2012) research underscores the importance of the social dimension in shaping safety practices on construction sites. This perspective aligns with the current study's focus on understanding how organisational culture influences worker attitudes towards risk. Sherratt's findings suggest that informal interactions, cultural norms, and power dynamics within the workplace can significantly impact how workers perceive and respond to safety hazards. This insight is particularly relevant to the highway electrical sector, where the complex interplay between established practices, safety protocols, and worker interactions could be pivotal in mitigating the risks of underground utility strikes.

One of the most salient factors affecting the frequency and severity of underground utility strikes is the quality of training received by excavator operators and locators. A study by Koschmann et al. (2021) conducted in Melbourne, Australia, emphasised this aspect. The research found that the working conditions, which are often a direct result of the level of training, significantly influence the likelihood of such incidents. This highlights the critical need for training programmes that not only cover the technical aspects but also instil a culture of safety and risk awareness.

The study also touched upon procedural issues, noting that most utility strikes occurred when the utilities were not marked at all and *“A key finding was that inaccurate mapping of underground utilities causes a significant number of strikes”* *(*Koschmann et al., (2021:2300)*.* This procedural lapse raises questions about the effectiveness of existing safety guidelines and Health and Safety legislation. While procedural adherence is crucial, the findings suggest that even the best procedures can fail if the individuals responsible for implementing them are not adequately trained.

Koschmann et al. (2021) exposes a critical truth: training must go beyond technical proficiency to be effective in preventing utility strikes. Their work underscores the need for programmes that cultivate a vigilant, 'safety-first' mindset alongside practical skills. This directly supports Objective 2 of the study, which aims to assess how current training approaches impact both workers' technical abilities and their overall safety attitudes.

9.4. Technological Solutions and Safety Measures

According to Chenxi et al. (2020), utility strikes occur at an alarming frequency, averaging one incident per minute in the United States alone. These incidents are not merely operational disruptions; they have severe consequences, including fatalities, injuries, and substantial financial losses.

The financial ramifications of these incidents are significant, with Chenxi et al. estimating "eight billion dollars in financial losses" in the United States between 1998 and 2017, emphasising that the lack of complete and accurate records of underground utilities contributes to these costly incidents. The financial burden extends beyond immediate repair costs to include legal fees, penalties, and even reputational damage for the companies involved.

Chenxi et al. (2020) also highlight the role of technology in mitigating these risks. Ground-penetrating radar (GPR) is cited as a promising tool for the accurate detection, location, and measurement of underground utilities. The paper argues that high-quality location data of subsurface utilities is a crucial prerequisite for reducing the risk of utility strikes. This technological solution could be a pivotal factor in not only reducing the frequency of these incidents but also in the associated costs.

In the context of mitigating the risks associated with underground utility strikes, the role of training and technology cannot be overstated. Tanoli et al. (2019) propose an integrated approach that combines Ground Penetrating Radar (GPR), RTK GPS, and a machine guidance system to provide real-time visual guidance to equipment operators during excavation. This technological intervention aims to significantly reduce the incidence of utility strikes, emphasising the importance of proper training for operators to effectively utilise these advanced systems.

The study suggests that the adoption of such technologies could be pivotal in shaping workers' attitudes towards risk and safety. This question of worker acceptance of new technologies aligns with Tanoli et al.'s emphasis on proper operator training. This dissertation will investigate how worker attitudes towards these innovations influence their effectiveness, offering insights into maximising the benefits of these solutions.

The research conducted by Gallagher et al. (2020) offers evidence on the effectiveness of Proficiency-Based Progression (PBP) training in mitigating the incidence of utility strikes. The study reported a significant 35% reduction in utility strikes per 10,000 hours worked when compared to data from 2016, and an even more substantial 61% reduction when compared to 2017. This finding accentuates the critical role that specialised training programs can play in enhancing workplace safety, particularly in high-risk environments such as the highway electrical industry.

Furthermore, Gallagher et al. (2020) observed that PBP training led to a 33% reduction in critical errors made by utility workers. This is particularly noteworthy because the training program did not merely assess whether tasks were completed; it also evaluated the quality of performance. This focus on reducing performance errors could be a pivotal aspect in shaping safety guidelines and educational programs aimed at reducing the risks associated with underground utility strikes.

However, it is important to investigate whether such training goes far enough to address systemic issues identified in earlier studies, such as those by Metje et al. (2015), Patel et al. (2012), and others, such as time pressures and organisational culture. This study will investigate this tension between individual skill-building and tackling deeper root causes of unsafe practices.

The integration of uncertainty-aware geospatial systems into the management of underground utilities could represent an advancement in mitigating risks associated with utility strikes, a critical concern within the UK's highway electrical sector. These systems, by leveraging Ground Penetrating Radar (GPR), Global Positioning System (GPS), and Geographic Information System (GIS), not only enhance the accuracy of utility mapping but crucially introduce a novel approach to visualising the uncertainties around utility locations (Shuai, L. et al., 2015). This technological innovation directly supports the study's aim of conducting an analysis of safety issues stemming from underground utility strikes by addressing Objective 3, which seeks to investigate the influence of safety protocols and educational initiatives on workers' risk perceptions.

By providing detailed 3D visualisations of the probabilistic uncertainty bands around mapped utilities, these systems offer a tangible tool for improving the effectiveness of safety training programmes, thereby potentially transforming the safety culture within organisations. Moreover, the ability to accurately visualise and understand the uncertainties associated with underground utilities could significantly impact workers' perceptions of risk, making this technology an essential consideration for Objective 2 which focuses on the effects of safety training on overall safety culture.

As the research progressed, it became apparent that further exploration of the impact of leadership on individual risk perception (see Results and Discussion section) would be needed for a complete discussion of the data. The relationship between worker perceptions of supervisor commitment to safety and their personal experiences with utility strikes emerged as a significant theme during this study's data analysis. To fully explore this dynamic, a further examination of the literature was conducted. This led to the inclusion of Lingard et al.'s (2012) research on the influence of supervisor safety commitment on safety climate. This conceptual framework proved valuable in understanding how scepticism towards supervisors can shape workers' safety-related attitudes and potentially impact their adherence to safety protocols.

9.5. Theoretical Perspectives and the Iterative Nature of Research

Within the landscape of systemic safety analysis, the works of Leveson (2011), Reason (1997), Perrow (1984), and Weick & Sutcliffe (2007) present a confluence of perspectives that, while adjacent to the specific context of utility strikes in the highway electrical sector, provide foundational concepts inherently applicable to the thesis topic. Leveson's *Engineering a Safer World: Systems Thinking Applied to Safety* introduces the Systems-Theoretic Accident Model and Processes (STAMP), urging a shift from component reliability to systemic interactions as the crux of safety management (Leveson, 2011). This notion finds resonance with Reason's *Managing the Risks of Organisational Accidents*, where the Swiss Cheese Model illustrates how systemic vulnerabilities align to precipitate accidents (Reason, 1997). Both models underscore the complexity of systems and the multifaceted nature of safety.

Perrow's *Normal Accidents: Living with High-Risk Technologies* further enriches this discourse by asserting that high-risk systems are inherently predisposed to "normal accidents" due to their intricate and tightly coupled nature (Perrow, 1984). This concept is crucial in understanding the inevitability of certain failures in the context of utility excavation, as highlighted by Patel et al. (2012), identifying the importance of systemic awareness and resilience.

Weick and Sutcliffe’s exploration of High-Reliability Organisations (HROs) offers practical insights into achieving reliability in complex operational environments through mindfulness and continuous adaptation (Weick & Sutcliffe, 2007). This approach is pertinent to enhancing safety protocols and reducing the incidence of utility strikes by fostering an organisational culture that prioritises safety and adaptability.

Initially, the research process was perceived as linear. Inspired by textbook diagrams, it was envisioned to follow a straightforward progression: theory would neatly shape the conceptual framework, the literature review would pinpoint the knowledge gap, and so on. A flowchart was confidently sketched, depicting a clear path from one stage to the next, labelled as Figure 1.

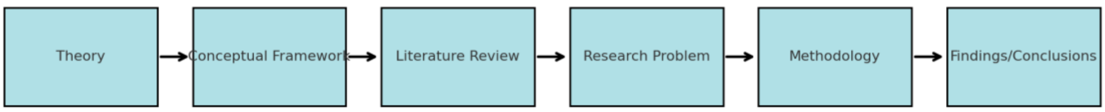
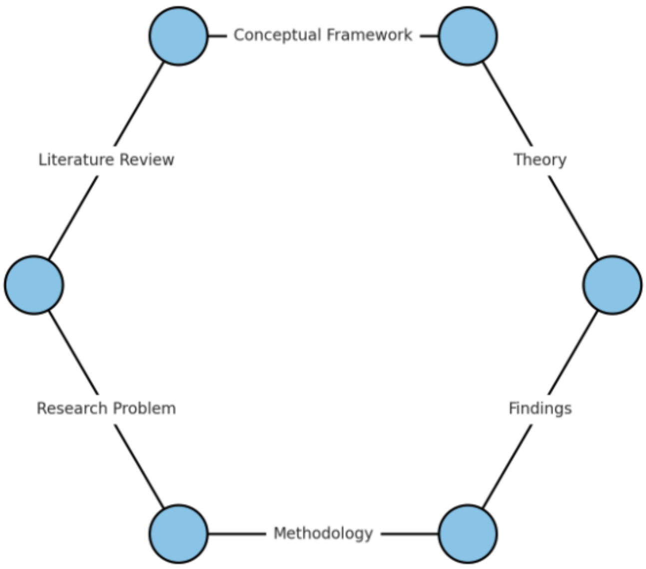


Figure 1 Linear Process

However, as the study progressed, the boundaries blurred. Early survey results raised theoretical questions that had not been anticipated, forcing the conceptual framework to be revisited and the focus adjusted. With each analysis cycle, the understanding of the framework seemed to spiral outward, simultaneously building upon and reshaping the initial assumptions.

Figure 2 Iterative Process



Where the initial model resembled a rigid blueprint, the reality proved to be more akin to overlapping spheres of thought, where 'methodology' informed 'literature review', which in turn illuminated new theoretical implications. The linear model failed to capture the iterative and often unexpected nature of research. Each discovery held the potential to send the study back to refine a previous stage – a constant cycle of questioning, refining, and building knowledge, as illustrated in Figure 2.

9.6. Theoretical and Conceptual Frameworks

Informed by the literature review, this study employs three pivotal theoretical frameworks—Human Factors Theory, Organisational Culture Theory, and Risk Perception Theory—as its intellectual foundation. Each framework provides a unique lens through which to examine the research problem and directly informs the research questions and objectives as follows:

9.6.1. Human Factors Theory

This theory focuses on how individual characteristics, such as training and experience, impact safety behaviours. It directly informs Research Objective 2, which aims to analyse how current mandated and company-specific training programs shape highway electrical workers' attitudes towards the risks of utility strikes. Questions in the survey related to training effectiveness and personal safety practices are designed to explore these aspects.

9.6.2. Organisational Culture Theory

This framework examines the influence of organisational norms, leadership styles, and communication on safety practices. It is central to Research Objective 3, which explores the relationship between organisational culture (including leadership and safety communication) and highway electrical workers' adherence to safety practices. The survey and interview questions addressing organisational support, communication effectiveness, and leadership engagement are informed by this theory.

9.6.3. Risk Perception Theory

This theory helps understand how workers perceive and respond to risks based on their experiences and information. It underpins Research Objective 4, which compares risk perceptions of underground utility strikes among workers with different levels of experience. Survey questions about personal experiences with utility strikes and perceived adequacy of safety measures are based on this framework.

By integrating these theoretical frameworks, the study ensures a comprehensive approach to examining the multifaceted issue of underground utility strikes. The frameworks guide the formulation of the questionnaire items and data analysis techniques, ensuring that each research question is addressed through a relevant theoretical lens.

As McCombes (2022) and Ravitch and Riggan (2017) articulate, a theoretical framework serves as a conceptual structure that provides a set of assumptions, concepts, and relationships shaping the study's design and methods. Kumar (2019) addresses the paradox of needing a framework to guide a literature review while also requiring literature to form a framework. His solution, echoed by Vinz (2022), is to develop a loose framework that can be refined as the literature is appraised.

This study also incorporates a conceptual framework, which builds on the chosen theoretical frameworks to directly map out the research problem and guide the investigative process (Kumar, 2019; Regioniel, 2015). This aligns with the perspectives of Oliver (2012) and Gavin (2016), who emphasise that the conceptual framework must be grounded in theory to provide context for interpreting findings. Ultimately, both the theoretical and conceptual frameworks shape this research, from the literature reviewed to the data analysis techniques employed.

The theoretical frameworks in this study are rooted in established theories and will guide the formulation of questionnaire items and data analysis techniques. For instance, Human Factors Theory will focus on training, experience, and behavioural aspects, while Organisational Culture Theory will probe the alignment between commercial policies and health and safety guidelines. Risk Perception Theory will examine workers' attitudes towards taking precautions before digging.

Drawing upon the insights of Machi and McEvoy (2012), Bell and Waters (2018), and Verma and Beard (1981), the theoretical and conceptual frameworks extend beyond a mere inventory of literature. They actively question assumptions, evaluate existing findings, and construct a theoretical structure that elucidates the relationships between various facts.

9.7. Synthesis and Research Directions

This literature review underscores the value of employing Human Factors, Organisational Culture, and Risk Perception theories to analyse utility strikes. These frameworks explain the interplay between worker attitudes, training effectiveness, and the overall safety culture within workplaces.

9.7.1. Synthesis of Key Findings

The literature consistently highlights the significant role of training in shaping safety behaviours. For example, studies by Metje et al. (2015) and Patel et al. (2012) demonstrate that effective, hands-on training directly correlates with reduced incidents of utility strikes. However, there is a notable gap in understanding the specific impact of experiential learning and real-world practice in this context.

Organisational culture also emerges as a critical factor, with strong leadership and clear communication being essential for fostering a safety-first mindset. Donaghy (2009) and Sherratt (2012) emphasise that when management prioritises safety over productivity, compliance with safety protocols improves significantly. This finding is supported by qualitative feedback from workers who value leadership commitment and transparent communication.

Risk perception is intricately linked to both training and organisational culture. Workers' attitudes towards safety measures are often shaped by their personal experiences and the perceived support from their supervisors. Research indicates that younger, less experienced workers tend to underestimate risks compared to their more seasoned counterparts, highlighting the need for tailored training programs that address these perceptual differences.

9.7.2. Identified Research Gaps

Despite these insights, there is limited research specifically focused on highway electrical workers. Existing studies often generalise findings across the construction sector without accounting for the unique challenges faced by these workers. Furthermore, the impact of emerging technologies, such as augmented reality for training, remains underexplored.

9.7.3. Research Directions

To address these gaps, this research proposes the development of a conceptual framework tailored to the highway electrical sector. This framework will facilitate a comparative analysis of how human factors, organisational culture, and risk perception influence worker behaviour across different companies and job sites. Specific research directions include:

- Experiential Learning and Training Effectiveness: Investigate how practical, hands-on training programs can be optimised to enhance safety behaviours among highway electrical workers. This includes the use of simulation technologies and real-world scenario-based training.
- Leadership and Communication: Explore the role of leadership styles and communication strategies in promoting a safety-centric organisational culture. This involves assessing the effectiveness of various communication channels and feedback mechanisms.
- Technological Innovations: Evaluate the potential of new technologies, such as augmented reality and advanced detection tools, in improving safety training and reducing utility strikes. This includes pilot studies to assess usability and impact on safety outcomes.

By integrating these research directions into a coherent framework, the study aims to provide actionable insights and targeted recommendations.

10. Methodology

10.1. Introduction

This chapter outlines the methodology used to address the research objectives. Given the complexity of safety issues in the UK's highway electrical sector, particularly regarding underground utility strikes, a mixed-methods approach was deemed most appropriate. This approach, which combines quantitative and qualitative data, facilitates a comprehensive exploration of highway electrical workers' perceptions of safety risks and adherence to regulations and practices (Creswell & Plano Clark, 2011).

Ethical considerations, particularly the safeguarding of participant data and anonymity, were prioritised. Stringent quality assurance protocols ensured the study's credibility and reliability. Recognising variations in individual risk perceptions (Slovic, 1987), the study focused on primary data collection through a mixed-methods survey, structured interviews, and observational studies. This was supplemented by a critical literature review to contextualise findings and address potential gaps in understanding safety culture within the sector.

Primary data collection began with an online mixed-methods survey targeting a diverse cross-section of highway electrical workers. Survey questions aimed to collect quantitative data on safety practices, experiences, and risk perceptions, alongside factors within organisational culture shaping adherence to safety procedures (Shorten & Smith, 2017). Open-ended questions allowed for unfiltered reflections, enhancing the richness of the data (Bhat, 2023).

Based on survey responses, a subset of participants was selected for individual interviews to provide deeper insights into their experiences and beliefs, complementing the surveys and interviews with on-site observations.

10.1.1. Reaching Participants

Various methods for reaching the target population were considered:

- **Email:** Email offers quick and inexpensive outreach to a potentially large audience. However, response rates can be low, and there's a risk of emails being marked as spam.
- **Physical Mail:** Though potentially more formal, physical mailings are typically more costly and time-consuming. They may also suffer from low response rates.
- **Online Platforms (e.g., industry forums, social media):** These platforms offer targeted access to the population but may raise concerns about representativeness and the ability to verify participants' employment status.

After careful consideration, email was selected as the primary method for reaching participants. This decision balanced efficiency and cost-effectiveness with the potential to access a sufficient sample size of highway electrical workers.

10.1.2. Survey Type Considerations

Several survey types were considered for this research:

- **Cross-Sectional Surveys:** These provide a snapshot of attitudes or behaviours at a single point in time. They are efficient for gathering data from a large sample but cannot track changes over time.

- **Longitudinal Surveys:** These involve repeated surveys of the same population over an extended period, allowing for the analysis of trends and changes. However, they can be expensive and time-consuming and may suffer from participant attrition.
- **Exploratory Surveys:** These are primarily used for preliminary investigations of under-researched topics, often focusing on qualitative data. They help generate hypotheses but may lack the generalisability of larger-scale studies.

For this study, a cross-sectional online survey was deemed the most appropriate. This choice was driven by the need to gather insights into the current attitudes of highway electrical workers within a defined time frame. The mixed-methods approach, incorporating both quantitative and qualitative elements, allowed for the collection of both numerical data on worker perceptions and open-ended responses for a deeper understanding of their experiences and concerns.

10.1.3. Mixed-Methods Approach

This mixed-methods approach aligns with the realist tradition, valuing diverse data collection methods for a rounded understanding of the research problem. Examining issues like safety attitudes necessitates consideration of both subjective experiences and objective behaviours.

Despite critiques from some methodological purists (Reichardt & Rallis, 1994), a growing academic consensus recognises the value of mixed-methods research, particularly within social science contexts. Scholars like Creswell & Plano Clark (2011) emphasise this approach's ability to provide a more complete understanding through the integration of diverse data types. After the online survey reached saturation, supplemental face-to-face interviews deepened the qualitative exploration of emerging themes. While time-consuming, these interviews added valuable insights and complemented the broader survey data.

10.1.4. Questionnaire Design

The design of the questionnaire was a critical aspect of the research process, given its role as a primary tool for data collection. The questionnaire was created to elicit responses that would provide both breadth and depth of understanding regarding highway electrical workers' attitudes towards the risk of underground utility strikes.

Breadth was achieved through an array of questions that covered various aspects of the workers' experiences and perceptions. Questions about demographic data such as age group and years of experience in the industry helped categorise responses to see differences or trends across different worker segments. This allows the research to cover a wide range of factors and perspectives, from newer workers to those with extensive experience.

Depth was obtained through targeted questions that probed deeper into the workers' personal experiences and opinions. For example, questions such as:

- 'If you, or someone you work with, has ever had a utility strike, could you provide a brief account of what happened and how it impacted you and your perception of the risk associated with underground utility strikes?'

- 'Can you describe a specific situation where you, or a coworker, unintentionally struck a utility during construction? What were the events leading up to the incident and what do you think could have been done differently to prevent it?'

These questions invite narratives that provide insights into the context, emotional responses, and the complexities surrounding each incident of a utility strike. They offer a depth of understanding by capturing detailed anecdotal evidence that can illustrate broader trends or highlight discrepancies between perceived and actual safety practices.

To further enhance the questionnaire's effectiveness, a mix of closed-ended and open-ended questions was used. Closed-ended questions, such as those asking participants to select from provided options or to rank their confidence on a scale, facilitate the statistical analysis of data, making it easier to identify trends and general patterns. Open-ended questions, on the other hand, allow respondents to express their thoughts freely, contributing richer, qualitative data that can be used to explore nuances not captured by quantitative measures.

Additionally, the inclusion of situational and hypothetical questions helps gauge the workers' practical understanding and application of safety protocols under different circumstances. Questions about the effectiveness of recognition and awards, or the adequacy of safety measures and training, provide insight into motivational and behavioural factors that influence safety practices.

Finally, by including questions that address both personal experiences and observations of colleagues' experiences, the questionnaire gathers a spectrum of data on the collective and individual awareness and behaviours regarding utility strikes.

10.1.5. Question Formulation

The questionnaire comprised a mix of open-ended and closed-ended questions. To maintain clarity and minimise bias, specific attention was paid to the formulation of each question:

- **Clarity and Simplicity:** Questions were worded in plain, easily understandable language, appropriate for participants from various educational backgrounds. Technical jargon or complicated phrasing was avoided.
- **Avoiding Ambiguity:** Questions were designed to have a single, clear interpretation. This reduced the risk of misinterpretation by participants and facilitated accurate data analysis.
- **Eliminating Bias:** Leading questions or those implying a "preferred" answer were avoided. Moreover, double-barrelled questions (those asking about multiple issues simultaneously) were eliminated to ensure focused, reliable responses.
- **Diverse Participants:** The questionnaire's phrasing considered the potential for participants from diverse cultural or linguistic backgrounds. Words or phrases that might be confusing or carry different connotations in other cultures were identified and revised for clarity.

10.1.6. Question Types

- **Closed-Ended Questions:** Likert scales, sliders, and multiple-choice formats were used to collect quantifiable data on attitudes and behaviours. This allowed for statistical analysis and identification of trends.
- **Open-Ended Questions:** Questions designed to capture participants' own words and experiences were included. These offer deeper, qualitative insights and help uncover variations in attitudes and motivations.

10.1.7. Questionnaire Structure

The questionnaire's flow was strategically designed to optimise engagement and response quality:

- **Easing In:** Initial questions were broad and non-sensitive, facilitating a comfortable entry into the survey.
- **Sensitive Questions:** More complicated or potentially sensitive enquiries were placed mid-questionnaire.
- **Informed Consent:** In accordance with the University of Hull's ethics guidelines, a clear informed consent form preceded the questionnaire. This outlined the study's purpose, data usage, and participant rights (University of Hull, 2023).

10.1.8. Refinement Process

- **Pilot Testing:** A pilot study with a small group of colleagues helped identify any unclear or potentially biased questions. Their feedback was incorporated into revisions for the final version.
- **Literature-informed Design:** The questionnaire's design drew heavily from established principles in the academic literature on survey research. Seminal works like Dillman et al. (2007) informed the methodological approach, with an emphasis on reliability and validity.

10.1.9. Sampling Design and Sample Size

This study set out with an ambition to utilise the Highway Electrical Association (HEA) network to disseminate the questionnaire broadly across a potential population of approximately 4,000 highway workers. However, when collaboration with the HEA proved unfeasible, the researcher pivoted to a dual strategy of convenience and judgemental sampling (Kumar, 2019) to procure data.

This approach encompassed reaching out to pre-existing contacts within four key organisations within the highway electrical sector. These organisations were chosen based on a judgemental sampling method, informed by the researcher's assessment that the workforce within these entities would be representative of the wider community's attitudes towards underground utility strikes. The contacts in these organisations were well-positioned to distribute the questionnaire effectively, thus, they were selected to participate in the study.

For the organisation where the researcher served as Chief Engineer, Electrical Testing Ltd, an internal messaging system was utilised to distribute the questionnaire, leveraging convenience sampling to facilitate ease of access to potential respondents. These combined efforts aimed to secure a sample that, while smaller than the HEA’s membership, was expected to yield relevant data on the research topic.

In designing the research, the parameters for sample size were initially calculated with a view to achieving a 95% confidence level with a 5% margin of error, as advised by the Raosoft Sample Size Calculator (Raosoft, 2004) for a population size of 300. This was deemed to provide a sample size that would allow for a comprehensive and statistically robust analysis, ensuring that the findings would be reflective of the population with a high degree of precision.

The researcher was prepared to accept a lower level of confidence, or a higher margin of error should the sample size be reduced due to practical constraints. Such flexibility was incorporated into the research design to ensure that, despite potential limitations in the sampling process, the study could proceed with a valid analysis of the data. This acceptance of modified statistical parameters was an integral part of the study's design, allowing for the derivation of valuable insights while maintaining the integrity of the research within the bounds of the data collected.

The methodology, thus, acknowledges the balance between the ideal conditions for sample size and the pragmatic adjustments that may be necessitated by the response rate. It asserts that while aiming for the highest standards of statistical confidence, the research is designed to adapt to the realities of data collection, ensuring that the conclusions drawn are both legitimate and reflective of the available data.

10.2. Structured Interviews

The survey gathered broad quantifiable data on practices and perceptions. To uncover the reasons behind these trends, structured interviews were employed. These interviews allowed for exploring personal narratives, lived experiences, and attitudes that would be unattainable through survey responses alone.

A subset of participants was invited for structured interviews with the aim of delving deeper into workers' experiences and perspectives. Due to limited responses and practical constraints, an adaptation was required from the original plan of proportionate stratified sampling (Lynn, 2019). Consequently, the study adopted a purposeful sampling approach, recognising that a smaller sample size would necessitate prioritising exploratory insights over statistical representativeness. Although a larger interview cohort would have been preferable, this approach is consistent with the use of qualitative methods aimed at achieving a profound understanding of a topic, rather than producing broadly generalisable data.

10.3. From Survey Findings to In-Depth Exploration

Survey data analysis revealed potential variations in safety attitudes and practices, hinting at the influence of factors such as age, experience, and job role. To understand the reasons behind these trends, the study prioritised diversity in interviewee selection. Participants were chosen to represent a range of ages, levels of experience within the highway electrical sector, and distinct job responsibilities.

Additionally, the survey responses themselves informed this selection. Specifically, individuals were targeted whose answers diverged from the most common patterns, offering opportunities to explore alternative perspectives and the potential reasoning behind them.

Geographical location was also a logistical consideration, ensuring that in-depth interviews could be conducted efficiently. This aligns with the adaptive nature of qualitative research (Budiu, 2021). Although a larger interview sample would have been ideal, the unavailability of one interviewee underscored the sometimes unpredictable nature of this method. Even with this limitation, the selected participants provided valuable insights into individual worker experiences.

10.4. Data Saturation

Data saturation is defined as the point at which additional data does not contribute further insights related to the research question (Guest, Bunce, & Johnson, 2006).

The data collection for this study commenced on 27th September 2023, marking the beginning of an active and engaged response period. Initially, surveys were issued around this start date, with a notable peak in responses observed on the very same day, 27th September 2023. This early surge in data collection provided a foundational understanding of the workers' attitudes. However, to enhance the depth and breadth of the responses, surveys were issued again on 17th November 2023 and at the beginning of December 2023. The influx of responses following this push indicated continued interest and engagement among the participants.

Despite these renewed efforts, a clear plateau in the influx of new data was observed shortly thereafter, indicating that subsequent responses were offering diminishing returns in terms of novel insights. This plateau, evident in the graph (Figure 3), is recognised as an indicator of data saturation, as outlined in Saunders et al.'s (2018) discussion on saturation in qualitative research.

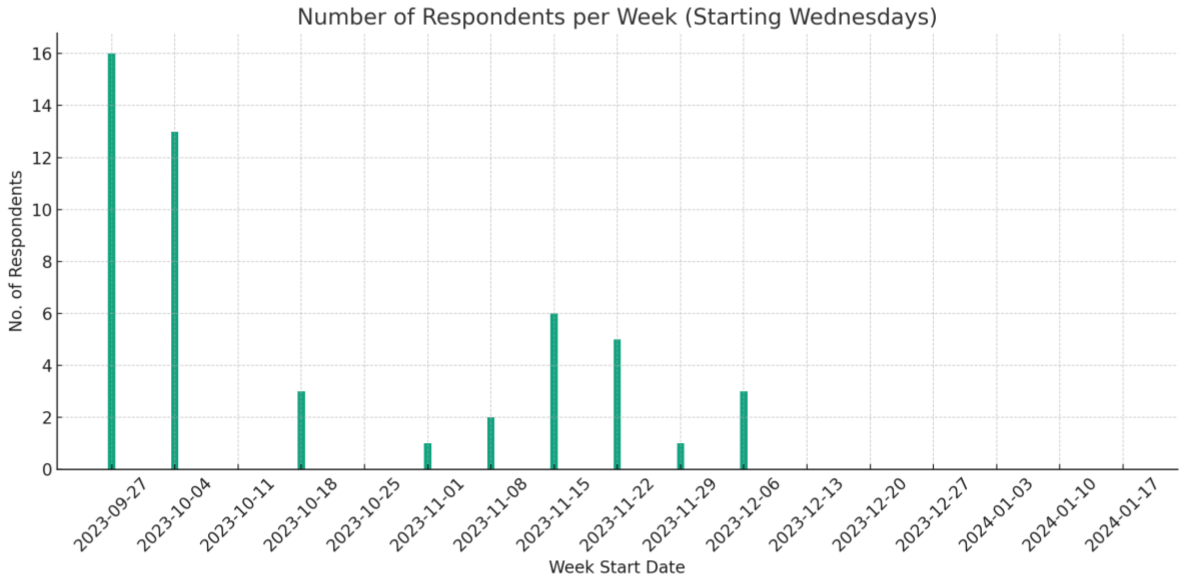


Figure 3 Number of respondents per week

Furthermore, by the end of data collection on 17th January 2024, there was an increasing recurrence of similar themes and perspectives in the responses. This redundancy, as noted by Fusch and Ness (2015), was not indicative of a lack of data richness but rather signalled that the dataset sufficiently addressed the research aims. To determine data saturation, following criteria was employed:

Thematic Redundancy: the emergence of new themes was monitored during the coding process. Once new data no longer introduced additional themes or sub-themes, the data was considered to be saturated.

Codebook Stability: The stability of the codebook was another indicator. After several rounds of coding and refinement, the addition of new data ceased to alter the structure of the codebook, suggesting that all relevant themes had been captured.

Participant Variation: Data was collected from participants across various roles and levels of experience within the highway electrical sector. Saturation was assessed not only within individual subgroups but also across the entire dataset, ensuring comprehensive coverage of the diverse perspectives.

Additionally, the concept of saturation must be contextualised within the constraints of the research, including time and resources (Morse, 2015). The decision to declare saturation was influenced by the practical assessment of the research scope and the depth of data already acquired.

Therefore, data saturation in this study was determined through a combination of emerging data redundancy and the practical constraints faced. This approach aligns with O'Reilly and Parker’s (2013) recommendations for a balanced consideration of data depth and research pragmatics in declaring data saturation.

10.5. Data Processing and Analysis

This study employed a mixed-methods approach, combining quantitative data collected through a questionnaire with open and closed-ended questions, and qualitative data gathered through in-depth interviews. To ensure the integrity of the qualitative data, responses transferred from online systems to data analysis tools such as CSV files were meticulously reviewed and checked against the original submissions to identify any potential discrepancies or errors. Quantitative data underwent a rigorous cleaning process, including outlier management and missing value imputation, with detailed techniques provided in Appendix 16.5.

The qualitative data was preserved in its original format, including any spelling or grammatical errors (SPAG errors) made by the participants. This approach was chosen to ensure the most authentic representation of the respondents' voices and perspectives. By maintaining the original phrasing, the analysis could capture the full range of participant experiences and expressions, without the risk of introducing bias through grammatical corrections.

For data organisation, tools such as SurveyMonkey and Excel were initially used. Further data manipulations and visualisations were conducted using Python libraries including Pandas, Matplotlib, and Scikit-learn. SPSS was utilised for statistical testing.

Qualitative data was extensively analysed using the Natural Language Toolkit (NLTK) in Python. This powerful tool facilitated text mining and helped maintain consistency in coding across diverse data sets. NLTK was instrumental in identifying and coding thematic elements within the text, such as terms related to 'safety attitudes'. These themes were then correlated with quantitative data from the surveys, specifically looking at the frequency of safety training, using SPSS. This cross-referencing allowed for a triangulation of findings, enhancing the reliability of the conclusions drawn. By integrating qualitative insights with quantitative data, the study was able to explore and validate potential relationships, providing a deeper understanding of the dynamics at play in safety practices and attitudes.

10.5.1. Data Analysis - Statistical Techniques

10.5.1.1. Qualitative Methods - Content Analysis

The study utilised content analysis to probe the qualitative feedback from highway electrical workers, focusing on their insights and experiences concerning safety protocols and the hazards posed by underground utility strikes. This technique proved instrumental in dissecting the lived experiences shared by the participants, illuminating recurring themes, sentiments, and specific terminologies mentioned in their responses.

The process began with the disaggregation of responses into distinct analytical units. The subsequent iterative coding process aimed to distil these units into a coherent framework reflecting the data's primary themes. This phase heavily depended on the researchers' interpretive lens to classify and decode the responses, potentially colouring the analysis with their preconceptions. Such subjectivity underscores the critical need for reflexivity in the coding process, where researchers must constantly question and validate their interpretative choices against the data.

Moreover, the structured nature of content analysis, for all its merits in organising and clarifying the qualitative data, might have constrained the breadth of exploration into the participants' perspectives. By fitting responses into pre-established categories, there is a risk of curtailing the spontaneity and richness of the data, potentially side-lining emerging themes that do not neatly align with the initial coding schema. This procedural rigidity could limit the research's capacity to fully embrace the workers' experiences and insights.

Additionally, the thesis includes findings from focused on-site observation of a street lighting column installation crew. This observational data provided a valuable 'reality check', allowing for comparison between the self-reported practices from the survey and actual behaviours witnessed in the field. The potential impact of the Hawthorne Effect – a phenomenon where participants may modify their behaviour when aware of being observed (Weber, 2002) – was considered to minimise misinterpretation of results arising from reactivity.

Figure 4 On-site observation

By incorporating both survey data and observations, this study employed a multi-method approach to content analysis. This triangulation of findings offered a deeper understanding of the factors influencing safety practices in highway electrical work.

10.5.2. Qualitative Methods - Thematic Analysis

Alongside content analysis, the study employed thematic analysis to examine the qualitative responses provided by the highway electrical workers. This approach allowed the researcher to identify recurring patterns or themes within the data, revealing common concerns, experiences, and perspectives. Thematic analysis involved an iterative process of coding the text, grouping codes based on shared meaning, and refining themes to accurately represent the essence of the participants' insights.

In qualitative research, the interpretation of data inherently involves a degree of subjectivity, as the researcher's perspectives and preconceptions could influence analytical outcomes. Recognising this potential for bias, the researcher implemented a reflexive approach throughout the data analysis process. This reflexive process involved continual self-assessment and critical examination of the researcher's own biases, assumptions, and the influence of their background and experiences on the interpretation of the data.

To enhance the reliability and credibility of the analysis, the researcher actively engaged in several strategies aimed at minimising these subjective influences. Firstly, the researcher sought peer debriefing sessions, where colleagues reviewed the coding and thematic development processes. These sessions provided external perspectives, challenging the researcher's interpretations, and ensuring the coding was not unduly influenced by personal viewpoints. The feedback from these sessions was crucial in refining the themes and ensuring they accurately reflected the data rather than the researcher's preconceptions.

Furthermore, the researcher employed a technique known as 'triangulation' to cross-verify the findings. This involved comparing and contrasting emerging themes with existing literature and integrating different data sources and analytical methods. The researcher aimed to build an argument extending beyond personal interpretations, and this triangulation solidified the themes as truly grounded in the data.

An instance of triangulation in the research involved the use of multiple data sources to assess safety practices. Data from observational notes gathered during site visits and survey responses were compared to evaluate consistency in the application of safety protocols. For example, safety reports often declared strict adherence to protocols, which was substantiated during a site visit. The observed team was following safety measures, showing caution around shallow services and cables encased in concrete—issues highlighted as significant in survey responses.

This congruence between different sources confirmed the reliability of the self-reported data and provided an understanding of the effectiveness of safety practices. Triangulation thus reinforced the validity of the findings and deepened the insight into the practical implementation of safety measures on site.

These reflexive and methodological consistencies ensured that the themes identified were rooted in the participants' responses, offering a transparent analysis.

10.5.2.1. Frequency Tables

In the methodology employed for analysing the survey data, frequency tables played a crucial role. These tables provided a foundational understanding of the distribution of responses across categorical variables. By categorising and counting the responses, frequency tables allowed for a clear and concise visual representation of the data, which is particularly useful for initial data exploration and identifying basic patterns.

For example, responses to questions on the demographic characteristics of participants, such as age groups and years of experience in the industry, were organised into frequency tables to provide an overview of the sample's composition. Similarly, frequency tables categorised the incidence of utility strikes experienced by workers, thus quantifying their exposure to this particular risk.

In terms of Likert-scale questions, which assess attitudes towards safety practices, training effectiveness, and risk perception, frequency tables summarised the distribution of responses. This offered an initial quantitative assessment of the prevailing attitudes and allowed for the identification of consensus or divergence within the workforce. The frequency of certain responses guided the need for further qualitative inquiry, where patterns emerged that required deeper exploration.

The use of frequency tables structured the raw survey data into an interpretable form, which facilitated the subsequent application of more advanced statistical analyses. These tables served as a preliminary step, providing a snapshot of the data and highlighting areas that warranted more detailed investigation.

To ensure clarity and rigour in the analysis, a Codebook was developed and included in Appendix 14.3. This Codebook detailed the variables, coding categories, and corresponding codes, thereby providing a transparent framework for the analysis process. It served as a key reference for interpreting the data and ensured that the frequency tables were understood in the context of the study's broader analytical framework.

10.5.2.2. Descriptive Statistics

In this study, alongside content analysis, descriptive statistics were employed to provide an initial snapshot of the qualitative data. This approach quantified how often certain terms and themes, uncovered through content analysis, appeared, thereby injecting a quantitative dimension into the analysis of predominantly qualitative feedback. By doing so, descriptive statistics aimed to spotlight key topics and themes within the participant discussions, acting as a conduit between the qualitative findings and a more structured, numerical understanding of the data's overarching patterns.

While this method provided a useful means to quantify and thereby highlight prevalent themes within the data, it also introduced a level of simplification that could potentially obscure the depth inherent in qualitative responses. By focusing on the frequency of specific terms or themes, there is a risk of valuing quantity over the quality of insights, potentially side-lining less frequent but equally significant narratives that could offer valuable perspectives on the research questions.

This critique underscores the importance of balancing numerical overviews with engagement with the qualitative content to ensure a holistic analysis. The integration of descriptive statistics with thorough qualitative interpretation allows for a more comprehensive understanding of the data, recognising the importance of both dominant and marginal voices in constructing a view of the study's findings.

10.5.3. Quantitative Techniques

10.5.3.1. Central Tendencies (Specifically, the Mode)

In this study, the researcher opted to use the mode as the primary method for initially analysing the survey data. This decision was carefully considered given the nature of the responses collected, which were predominantly categorical, relating to safety measures and experiences with utility strikes. The mode, which identifies the most frequently occurring answer, was particularly suitable for understanding the prevailing opinions and experiences of the workers.

The researcher selected the mode over the mean or median for good reasons. The mean could have been easily skewed by a few outlying responses – for example, if one or two workers reported extremely high or low numbers of utility strikes. Similarly, the median, which identifies the middle value of all responses, might not have truly reflected the common experiences or sentiments of the workers because it does not indicate the frequency of occurrence of that middle response.

Choosing the mode allowed the researcher to circumvent the issues that outliers might introduce and to focus on what the majority of workers reported. This was crucial for achieving the study's objective of pinpointing prevalent attitudes and trends in the safety culture among these workers. Essentially, the mode provided a straightforward and clear depiction of the collective experiences of the workers, without the risk of being misled by extreme or atypical responses.

Furthermore, this choice underscores the importance of selecting the appropriate statistical tool for the specific dataset and research objectives. In this case, understanding the predominant safety concerns and practices among highway electrical workers was paramount, and the mode offered a lens that brought these elements into sharp focus, avoiding unnecessary complication or distortion.

10.5.3.2. Spearman Rank Test

In selecting the most suitable statistical methods for this thesis, the Chi-square test was initially considered, as it is well-suited for data that falls into clear, separate categories (nominal data). However, a closer examination of the survey responses, particularly those on the Likert scale, revealed that the data was ordinal, meaning the responses were ranked in order, not just categorically different. The Chi-square test does not account for this ranking—it treats all responses as if they're merely different, without a higher or lower relation (Bevans, 2023). This limitation would have overlooked the subtle but important differences in the intensity of workers' feelings about various safety measures and attitudes.

Recognising this limitation, the research turned to the Spearman Rank Test. This choice was pivotal because the Spearman Rank Test is specifically designed to work with ordinal data, such as the rankings in a Likert scale. It assesses how two sets of rankings correlate, which was perfect for understanding the relationship between different safety attitudes and behaviours among workers. Unlike the Chi-square method, the Spearman Rank Test does not assume that the data follows a normal distribution, making it more suitable for the type of survey data in this study.

By choosing the Spearman Rank Test over the Chi-square method, the research was better aligned with the actual structure of the data collected. This choice was crucial for ensuring that the study's conclusions were as accurate and relevant as possible, allowing the study to explore how different factors related to safety were interconnected, based on the actual rankings of importance, or concern that workers provided in their responses. This approach significantly strengthened the study's findings, providing a solid base of evidence for understanding how attitudes towards safety and actual safety practices influence each other in the field of highway electrical work.

10.5.3.3. Bootstrap (Bootstrap Resampling)

To augment the strength of the Spearman Rank Test outcomes, the study employed bootstrap resampling, executing 1000 iterations. This method helped approximate the sampling distribution for the Spearman correlation coefficients, aiming to clarify their consistency and significance. Through bootstrap resampling, the study sought to establish confidence intervals for these coefficients, thereby aiming to bolster the trustworthiness of the statistical evaluations undertaken.

While bootstrap resampling is noted for its capacity to enhance inference about the stability of correlation coefficients, its efficacy depends on the assumption that the resampled data adequately represents the original dataset's distribution. The choice of 1000 iterations, although commonly practiced, requires scrutiny; the adequacy of this number in capturing the true sampling distribution may vary based on the data's complexity and the underlying relationships being analysed.

Furthermore, the reliance on bootstrap resampling to construct confidence intervals and assert the analysis's credibility assumes a level of uniformity and predictability in the resampled distributions that may not always be present. This methodological choice, while adding a layer of sophistication to the analysis, also introduces the challenge of interpreting the bootstrap results in the context of the study's specific data characteristics. It necessitates careful consideration of whether the bootstrap approach, with its inherent assumptions and limitations, truly enhances the understanding of the Spearman Rank Test results or if it potentially complicates the interpretation with additional layers of statistical abstraction.

It was considered that while bootstrap resampling serves as a valuable tool for reinforcing the statistical analysis, its application within the study also invites better consideration of its implications for the reliability and interpretability of the Spearman Rank Test findings, and so it was retained.

10.5.3.4. One-Sample T-Test

In the research, for questions that asked participants to rate their responses on a scale, the one-sample t-test was employed. This statistical method was chosen because it excels at determining if the average response from survey participants differs significantly from what might be expected generally. Essentially, it assesses whether the workers' opinions or feelings on certain safety issues significantly deviate from a 'normal' or neutral baseline.

The one-sample t-test relies heavily on the assumption that you can compare the survey responses to a hypothetical average response. This assumption is significant because it presupposes a clear understanding of what a 'neutral' response would look like for these workers. However, what is considered neutral can vary widely depending on who you ask and the context of their work.

Additionally, this method emphasises the mean (average) as the principal metric for understanding the data. While averages can be informative, they do not always convey the full story, especially if the responses are diverse or if there are a few very high or very low scores that could skew the results. This means the study might overlook how different workers perceive safety risks or how varied their confidence levels might be in preventing accidents.

Thus, while the one-sample t-test provides a means to statistically assess how much the workers' views differ from an assumed average, it is crucial to acknowledge that this approach has its limitations. It makes significant assumptions about what 'normal' looks like and focuses mainly on average scores, which might not capture the entire spectrum of safety attitudes among highway electrical workers.

10.5.4. Statistical Analysis Techniques Summary

An array of statistical techniques was applied to analyse survey responses from highway electrical workers regarding their perspectives on safety and underground utility strikes. This methodology section includes a table (Table 1) summarising the statistical methods utilised for each question in the survey, showcasing the approach to data analysis.

The study leveraged both qualitative and quantitative analytical strategies. For categorical responses, Descriptive Statistics, particularly the use of the mode, helped identify prevalent trends and attitudes among the workforce. Content Analysis was employed for open-ended responses, enabling a deeper dive into the workers' experiences and viewpoints by identifying common themes.

To explore relationships within the data, the Spearman Rank Test and Bootstrap resampling were applied broadly. The Spearman Rank Test was particularly suitable for analysing ordinal data from Likert-scale questions, offering insights into correlations without assuming a normal distribution. Bootstrap resampling supported this by assessing the Spearman correlation coefficients' reliability through repeated sampling, thus ensuring robustness in the correlation findings.

For questions requiring a scale-based response, the One-Sample T-Test compared mean scores against a theoretical population mean. This approach quantitatively assessed the workers' confidence and perceptions related to specific safety practices.

Table 1 below provides a concise overview of the statistical methods applied to each survey question, reflecting the study's approach to understanding the dynamics at play in the field of highway electrical work safety.

Table 1: Statistical Methods

Question Number	Applied Statistical Method
1	Descriptive Statistics (Mode)
2	Descriptive Statistics (Mode)
3	Descriptive Statistics (Mode)
4	Descriptive Statistics (Mode)
5	Descriptive Statistics (Mode)
6	Descriptive Statistics (Mode)
7	Descriptive Statistics (Mode)
8	Descriptive Statistics (Mode)
9	Descriptive Statistics (Mode)
10	Descriptive Statistics (Mode)
11	Descriptive Statistics (Mode)
12	Descriptive Statistics (Mode)
13	Descriptive Statistics (Mode)
14	Content Analysis
15	Content Analysis
16	One-Sample T-Test
17	One-Sample T-Test
18	Qualitative Data Analysis
19	Qualitative Data Analysis
20	Qualitative Data Analysis
21	Qualitative Data Analysis
22	Qualitative Data Analysis

11. Results and Discussion

11.1. Introduction to Results

This study initially aimed to survey 300 respondents to achieve a 95% confidence level with a 5% margin of error. However, due to data collection constraints, the final sample size was reduced to 56 respondents. This necessitated adjusting the confidence level to 90% and the margin of error to 10%, providing a realistic framework for analysis.

While these revised statistical parameters offer slightly less certainty than the original projections, they still allow for meaningful analysis of the data. Acknowledging the implications of the smaller sample size and broader confidence intervals ensures a balanced interpretation of the findings.

This research explores safety issues associated with underground utility strikes among highway electrical workers in the UK. The focus is on workers' knowledge of, and adherence to, safety protocols, the effectiveness of training programs, and the influence of organisational culture on safety compliance. Other factors considered include communication, leadership styles, incentives, recognition, and the influence of age on safety attitudes and practices.

11.2. Quantitative Analysis: Descriptive Statistics

11.2.1. Measures of Central Tendency

The mode (the most frequently occurring response) was the primary measure of central tendency used to analyse data from highway electrical industry professionals regarding underground utility strike risks. It is particularly appropriate for categorical data, where averages (means) and midpoints (medians) are less informative.

Data collected from the survey provided clarity on the backgrounds, experiences, and safety perceptions of our worker sample. Descriptive statistics for the data are presented in Table 1. These cover Mode responses and focus on central tendency. For scale questions, particularly Questions 16 and 17, where the mode calculation is not applicable, the range of responses received is highlighted.

Table 2: Descriptive statistics for the data summary

No.	Question	Mode Response	Codes	Most Common Response
1	What is your age group?	1	1, 2, 3, 4, 5, 6	45-54
2	What is your gender?	1	1, 2	Male
3	How many years have you worked in the highway electrical industry?	2	1, 2, 3, 4	10 years and above
4	Have you ever had an underground utility strike at your work?	1	1, 2	Yes
5	How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?	1	1, 2, 3, 4	0-3
6	Do you feel that the safety measures currently in place are sufficient to prevent utility strikes?	1	1, 2	Yes
7	How often do you receive safety training related to underground utility strikes?	1	1, 2, 3, 4, 5, 6,7,8,9,10,11,12	Annually
8	How often do you check for underground cables before beginning work?	1	1, 2, 3, 4	Always
9	During what time of day do most utility strikes occur?	2	1, 2, 3, 4, 5, 6	Don't know

10	How effective are recognition and awards in motivating you to follow safety practices?	4	1, 2, 3, 4, 5	Neither likely nor unlikely
11	How effective do you think any training you have received is in preventing utility strikes?	3	1, 2, 3, 4, 5	Very effective
12	How interested do you think your supervisor is in your safety?	1	1, 2, 3, 4, 5	Extremely interested
13	How important do you think the accuracy of stat plans is when preventing utility strikes?	1	1, 2, 3	Extremely important
14	Descriptive, multiple-response data; no coding required.			
15	Descriptive, multiple-response data; no coding required.			
16	On a scale of 1-10, does working with a familiar team reduce utility strike risk?	N/A	1-10 Scale	1
17	On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike?	N/A	1-10 Scale	8

11.2.2. Key Insights from Descriptive Statistics

1. The age groups of the respondents primarily fall within the "45-54" range, suggesting that the majority are at a stage in their careers where they have accumulated significant experience. This group's prevalence indicates that they likely have a strong influence on safety culture in the industry. This finding aligns with previous research indicating that mid-career professionals often play key roles in shaping workplace norms and practices.

2. In terms of gender, most survey participants are male, reflecting the current gender makeup of the industry. Female respondents, though fewer in number, offer insights into safety practices and workplace dynamics. Future research should explore gender-specific safety concerns and promote diversity initiatives to ensure an inclusive safety culture.

3. Most survey participants have been in the industry for "10 years and above," indicating an understanding of the work and its associated risks. This experience is crucial for evaluating the effectiveness of safety measures and provides a foundation for mentoring less experienced workers.

4. & 5. The occurrence of utility strikes is a common experience for many workers, with most respondents having encountered such incidents at least once. This frequent occurrence underscores the critical need for continuous improvement in safety measures. This finding aligns with previous studies suggesting that while safety measures exist, their practical implementation often falls short.

6. Regarding the sufficiency of current safety measures, the general sentiment is positive, with the majority expressing confidence in the protocols in place. However, some workers disagree, suggesting areas where improvements might be needed.

7. & 8. The frequency of safety training varies, but "Annually" is the most common response, indicating a commitment to regular safety education. The practice of checking for underground cables before starting work is widespread among the workers, reinforcing a strong commitment to preventative safety actions.

9. Respondents were largely uncertain about the specific times of day when utility strikes occur, indicating a lack of clear patterns. This uncertainty suggests a need for better tracking and analysis of incident data to identify any time-related trends. Understanding these patterns could inform the scheduling of high-risk activities and enhance targeted safety interventions during periods of increased risk.

10. Respondents expressed mixed feelings about the effectiveness of recognition and awards in motivating safe behaviour, indicating that these incentives have varied impacts across the workforce. This finding suggests that while recognition programs can be part of a broader safety strategy, they should be complemented with motivators such as personal responsibility and a strong safety culture.

11. Training to prevent utility strikes is generally seen as "Very effective", highlighting the value of training programs. Nonetheless, a minority of workers who see room for improvement suggests that training could be better tailored to workers' needs.

12. Respondents generally perceive their supervisors as highly interested in their safety, which is a positive indicator for fostering a strong safety culture within the industry. This perception is crucial as supervisory commitment to safety can significantly influence workers' attitudes and behaviours.

13. The accuracy of statutory plans is overwhelmingly seen as crucial in preventing utility strikes, emphasising the need for accurate and reliable planning for safe operations.

16. The influence of working with family or friends on safety practices varies, with the most common response indicating it has "No Influence At All". This suggests personal relationships do not significantly change how safely workers behave on-site.

17. Finally, the confidence among workers in their ability to prevent utility strikes is relatively high, with the majority feeling quite confident in their abilities, which bodes well for safety on the job.

Note: Questions 14 and 15 yielded descriptive, multiple-response data without a dominant "mode" response; these are excluded from this section.

11.3. Frequency Tables

Frequency tables were essential during the initial data analysis of highway electrical workers' attitudes towards underground utility strike risks. These tables provided a clear understanding of how categorical variables were distributed within the dataset.

By organising responses into countable categories, frequency tables offered a concise and informative presentation of key data characteristics.

Frequency tables also summarised responses to Likert-scale questions about safety practices and training effectiveness. Tabulating these responses offered a quick overview of prevailing attitudes within the workforce, pinpointing areas of strong agreement or significant differences in opinion.

Overall, frequency tables were crucial in transforming raw survey data into a structured and interpretable format, facilitating a more efficient analysis and understanding of the collected data.

11.3.1. Codebook

For a detailed understanding of the data analysis, refer to the Codebook in Appendix 14.3. This Codebook provides descriptions of variables, coding categories, and corresponding codes. It serves as a reference for interpreting the quantitative data presented in the Frequency Tables section, ensuring clarity and consistency in the analysis process.

1. **What is your age group?**

This table reflects the diverse age range of the respondents, indicating a broad representation of experiences in the industry.

	N	%
45-54	22	39.3%
35-44	13	23.2%
25-34	11	19.6%
55-64	7	12.5%
18-24	2	3.6%
<18	1	1.8%

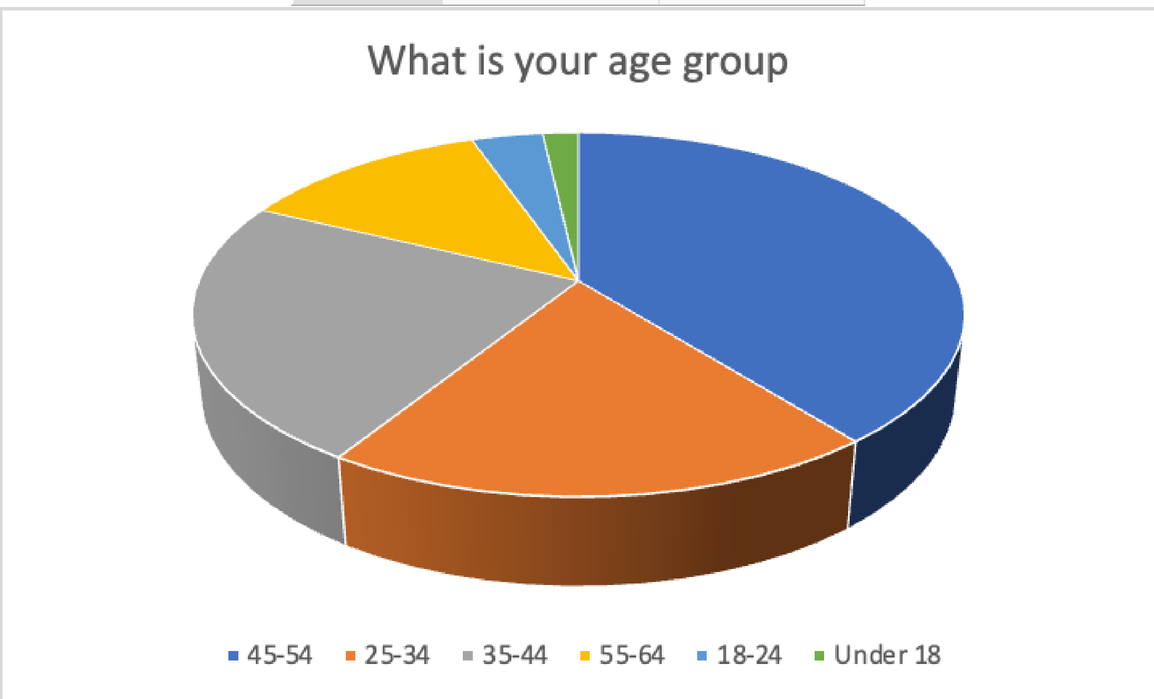


Figure 5 Age Group

2. What is your gender?

The gender distribution in this survey can provide insights into the gender dynamics within the highway electrical industry.

	N	%
Male	54	96.4%
Female	2	3.6%

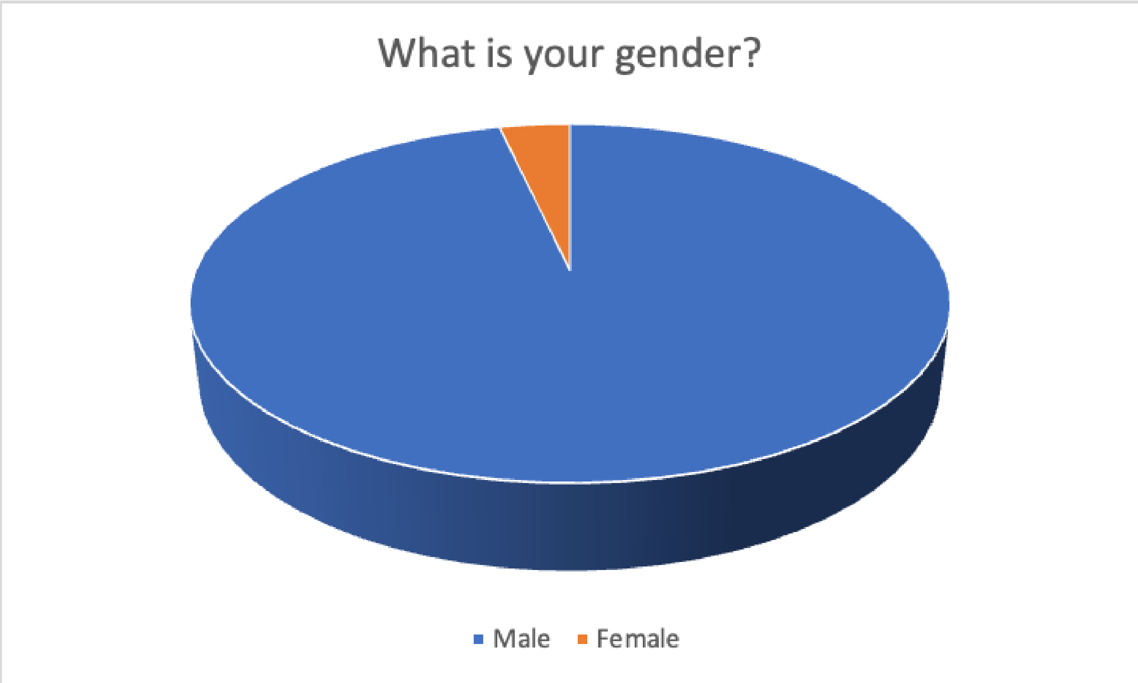


Figure 6 Gender

3. How many years have you worked in the highway electrical industry?

This table helps understand the depth of industry experience among the respondents.

	N	%
>10	38	67.9%
5-9	8	14.3%
0-1	5	8.9%
2-4	5	8.9%

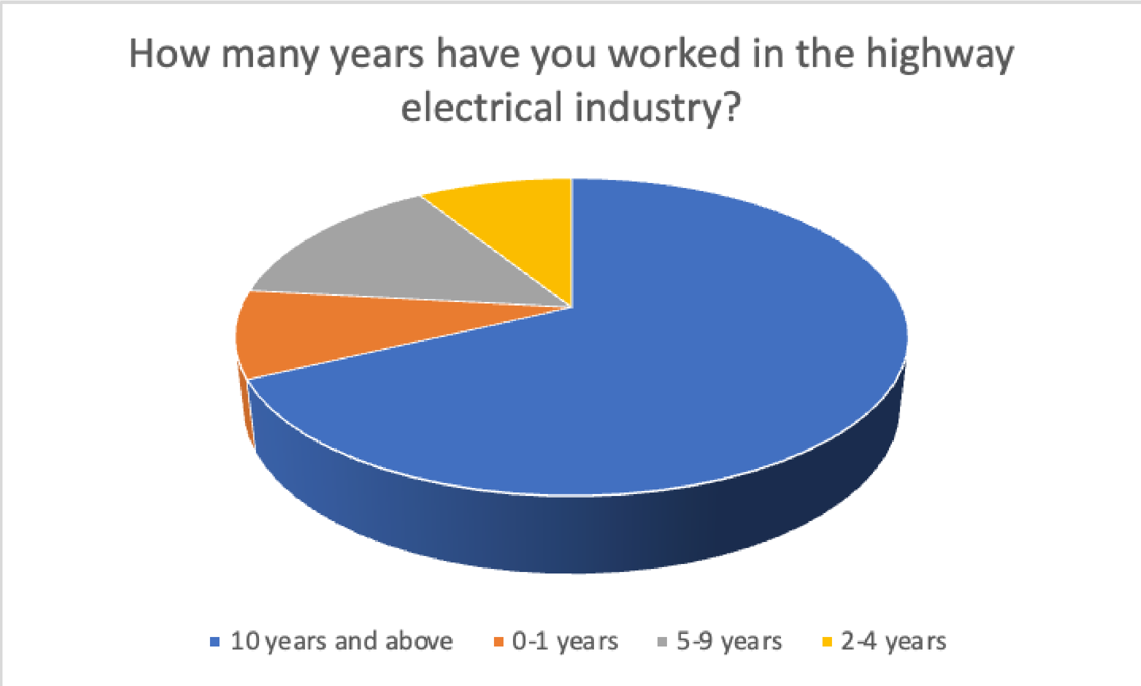


Figure 7 How many years worked in highway electrical industry?

4. Have you ever had an underground utility strike at your work?

Responses to this question reveal the prevalence of utility strikes in the workers' experience.

	N	%
Yes	39	69.6%
No	17	30.4%

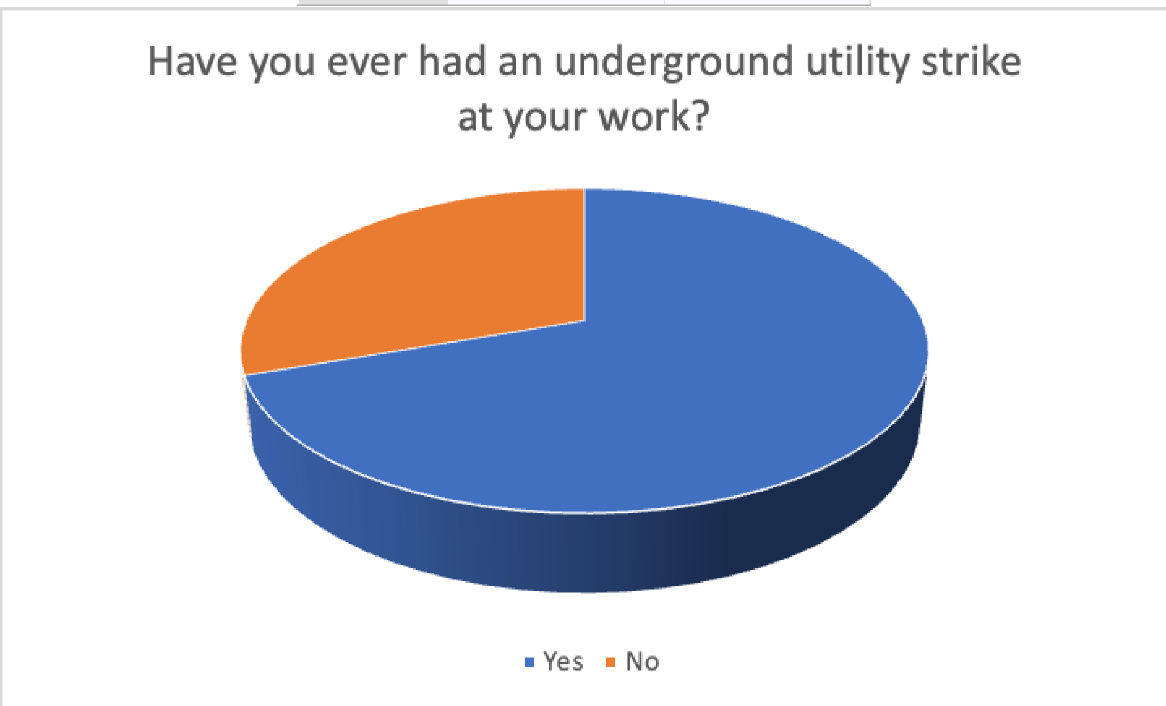


Figure 8 Have you ever had an underground utility strike at your work?

5. **How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?**

This information highlights the frequency of encounters with underground utility strikes, reflecting on risk exposure.

	N	%
0-3	24	42.9%
>10	17	30.4%
4-6	10	17.9%
7-10	5	8.9%

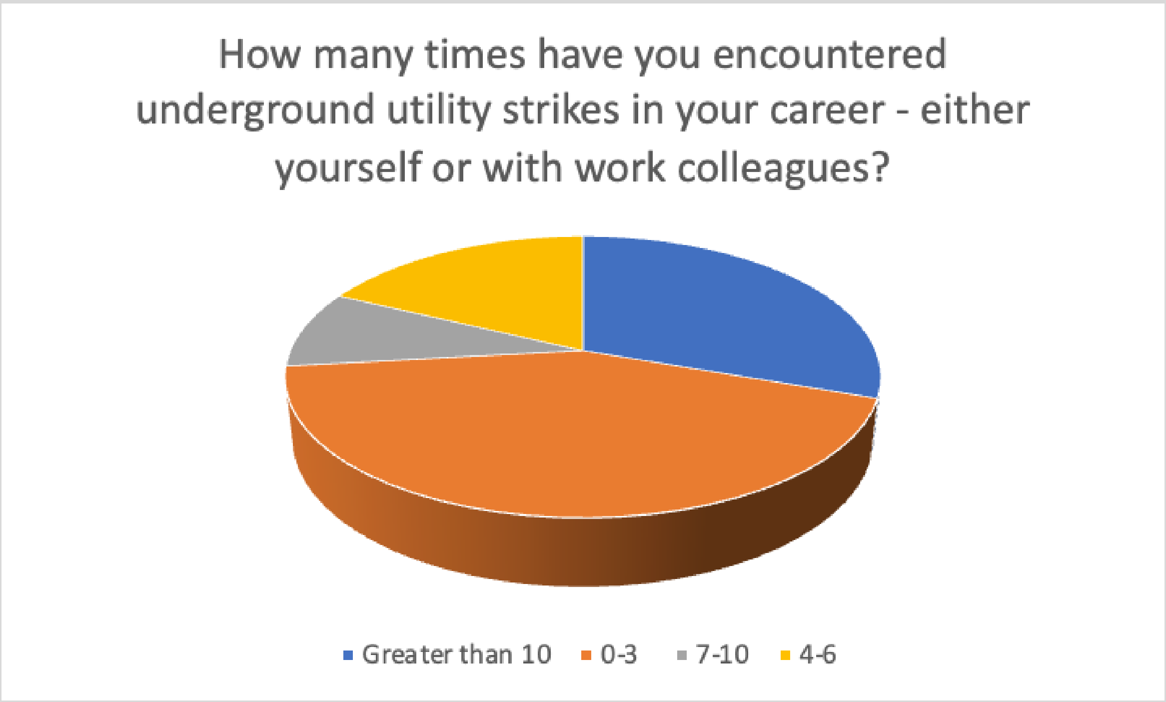


Figure 9 How many times have you encountered underground utility strikes?

6. **Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?**

Assessment of current safety measures' adequacy from the workers' perspective is critical for evaluating risk management strategies.

	N	%
Yes	39	69.6%
No	17	30.4%

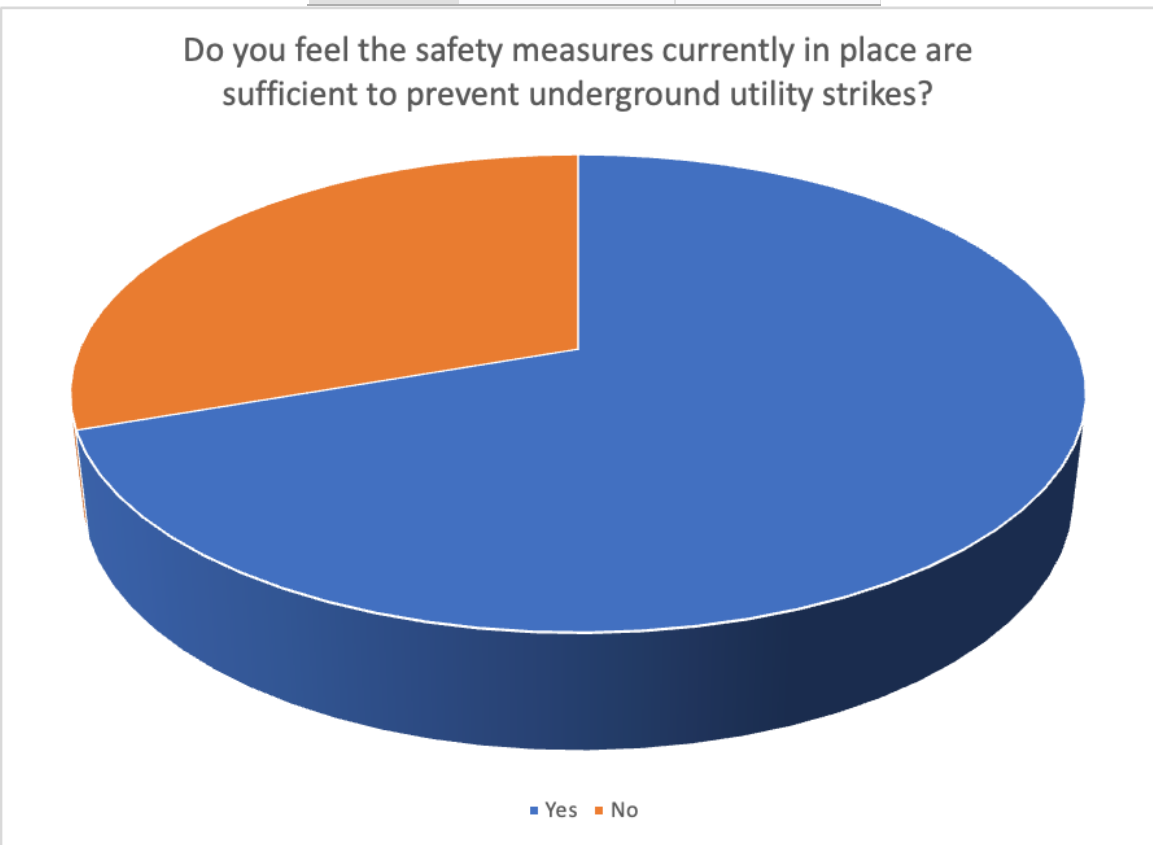


Figure 10 Do you feel that the safety measures currently in place are sufficient?

7. How often do you receive safety training related to underground utility strikes?

This table shows the unique responses to the survey question: 'How often do you receive safety training related to underground utility strikes?'.

How often do you receive safety training related to underground utility strikes?	Frequency
Annually	28
Quarterly	9
Never	5
Monthly	4
3 years	1
5 years	1
Any time we do cat and genny training	1
Discussed in training on a regular basis (weekly)	1
I have received regular Toolbox talks on the subject, in combination with self study	1
I’ve only been working for Etl for a year in which I received training so not sure how often the refresher training is	1
Once in a while	1
Refreshed when service strikes happen on different contracts	1
Regular toolbox talks and updates and personally I am part the safe dig working group	1
When the expiry date is near its end, normally every third year	1

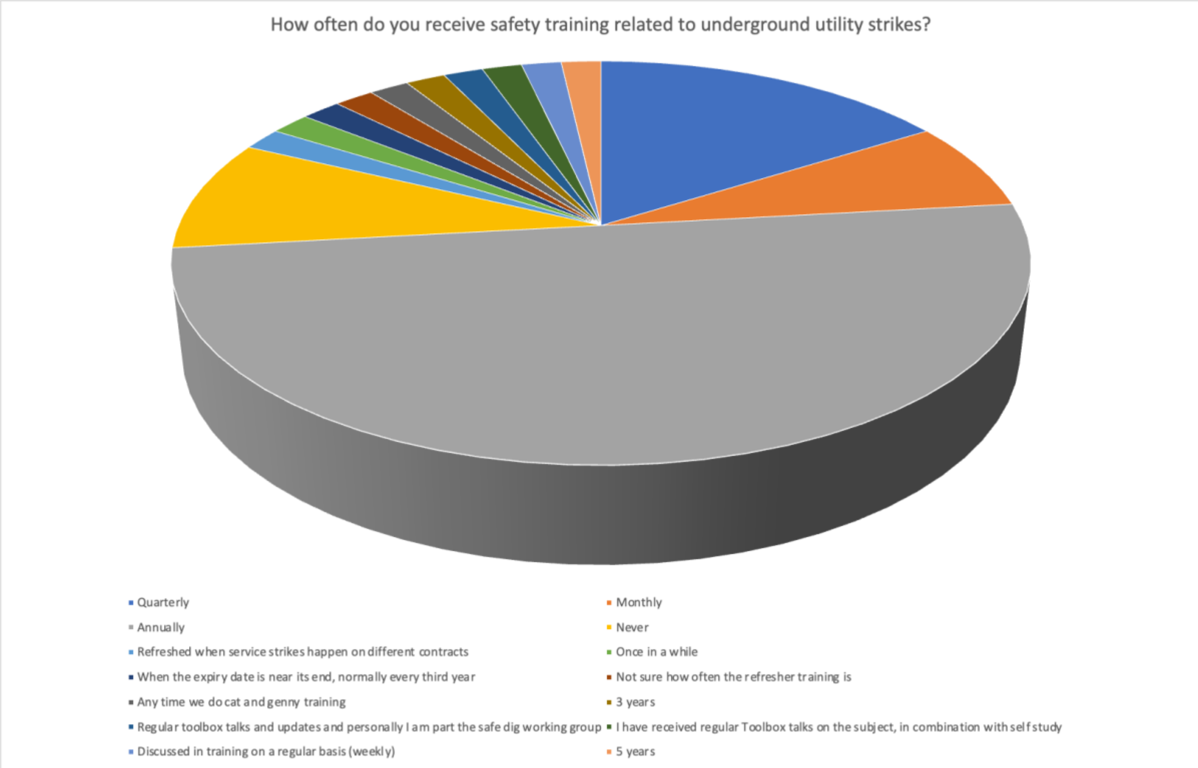


Figure 11 How often do you receive safety training?

8. How often do you check for underground cables before beginning work?

This table shows the unique responses for the survey question: 'How often do you check for underground cables before beginning work? (Select one)'.

	N	%
Always	47	83.9%
Never	5	8.9%
Usually	2	3.6%
Rarely	2	3.6%

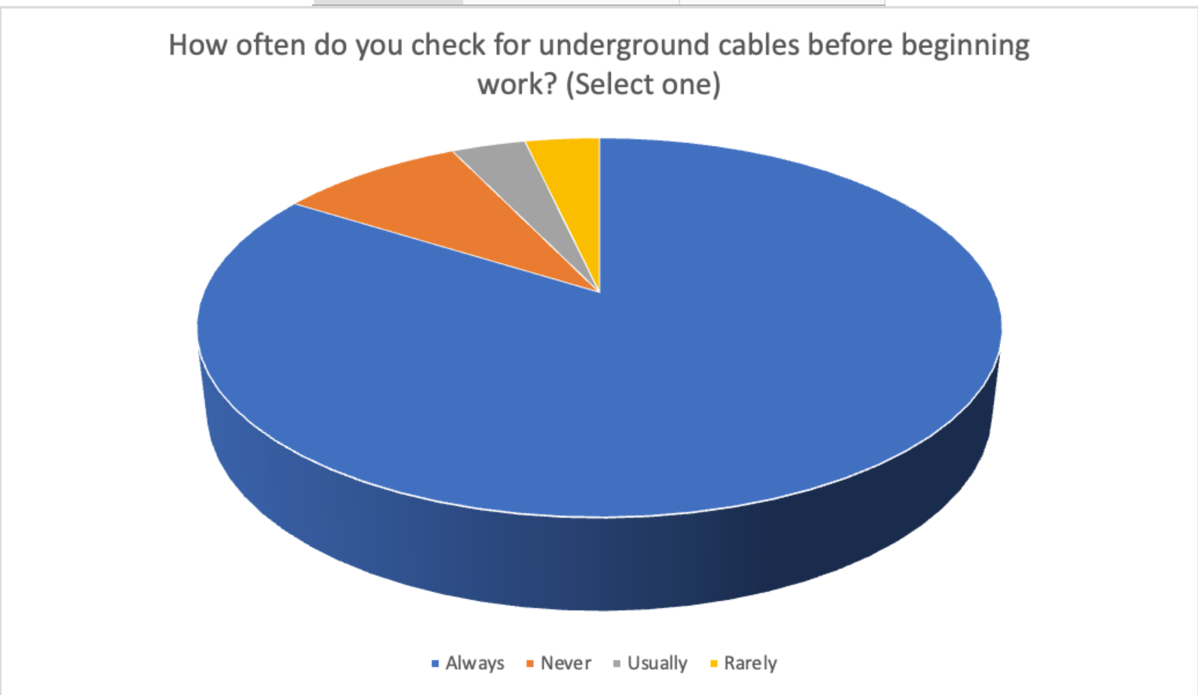


Figure 12 How often do you check for underground cables?

9. During what time of day do most utility strikes occur in your experience?

This table shows the unique responses for the survey question: 'During what time of day do most utility strikes occur in your experience?'.

	N	%
Don’t know	21	37.5%
Afternoon (12:00 - 17:00)	16	28.6%
Mid-morning (9:00 - 12:00)	11	19.6%
Night (20:00 - 6:00)	4	7.1%
Early morning (6:00 - 9:00)	3	5.4%
Evening (17:00 - 20:00)	1	1.8%

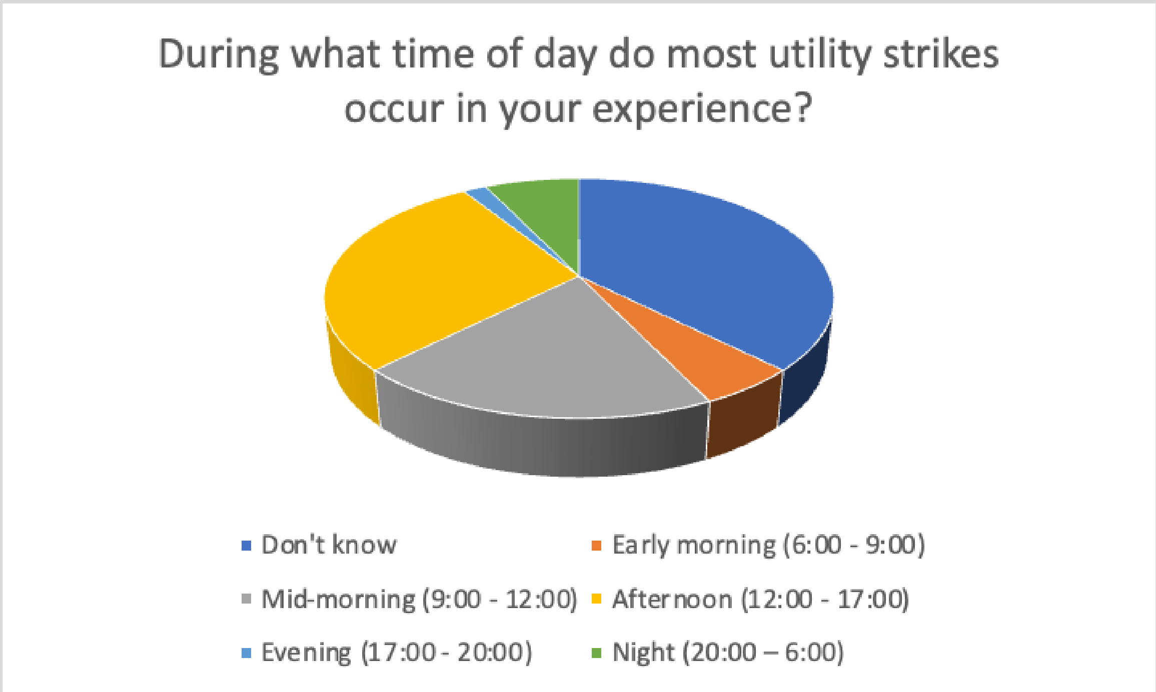


Figure 13 During what time of day do most utility strikes occur in your experience?

10. How effective are recognition and awards in motivating you to adhere to safety protocols?

This table shows the unique responses for the survey question: 'How effective are recognition and awards in motivating you to adhere to safety protocols? '.

	N	%
Neither likely nor unlikely	21	37.5%
Likely	15	26.8%
Very likely	9	16.1%
Very unlikely	8	14.3%
Unlikely	3	5.4%

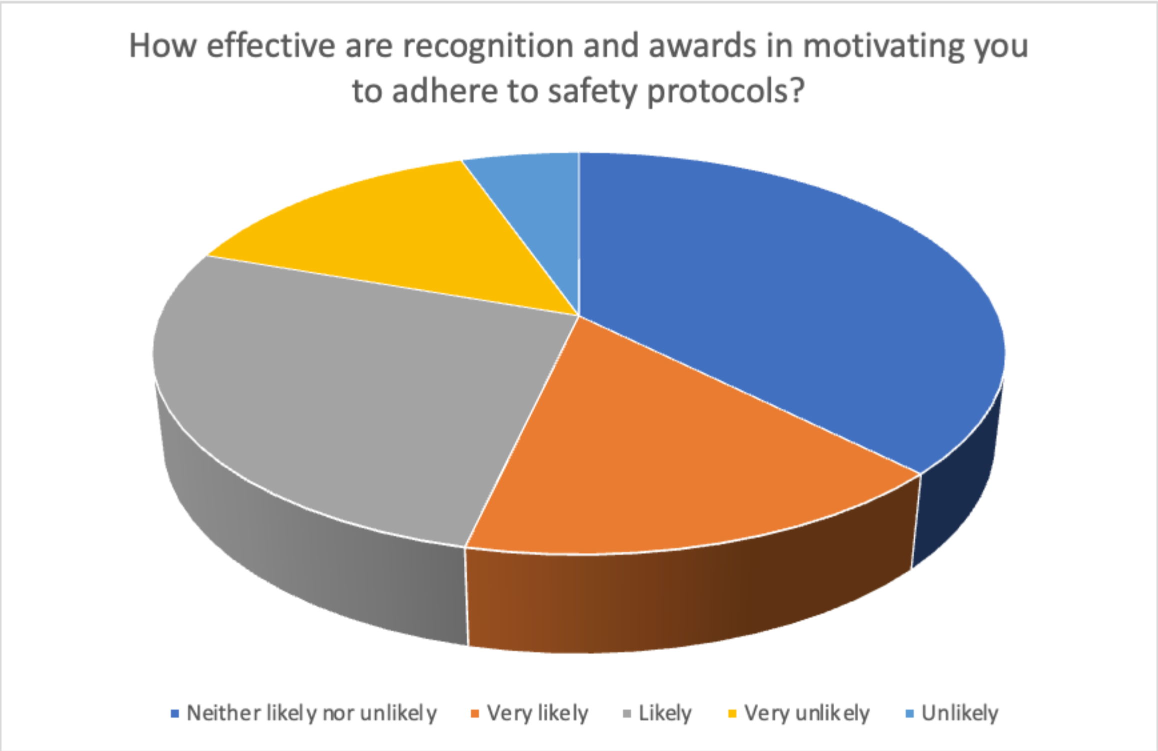


Figure 14 How effective are recognition and awards in motivating you to adhere to safety protocols?

11. How effective do you think any training you have had to prevent utility strikes has been?

Evaluates the perceived effectiveness of training programs in mitigating the risk of utility strikes.

	N	%
Very effective	27	48.2%
Extremely effective	16	28.6%
Somewhat effective	9	16.1%
Not at all effective	3	5.4%
Not so effective	1	1.8%

Figure 15 How effective is training?

12. How interested do you think your supervisor is over your safety?

Insights into how workers perceive their supervisors' commitment to safety can influence workplace safety culture.

	N	%
Extremely interested	28	50.0%
Very interested	21	37.5%
Not at all interested	3	5.4%
Somewhat interested	3	5.4%
Not so interested	1	1.8%

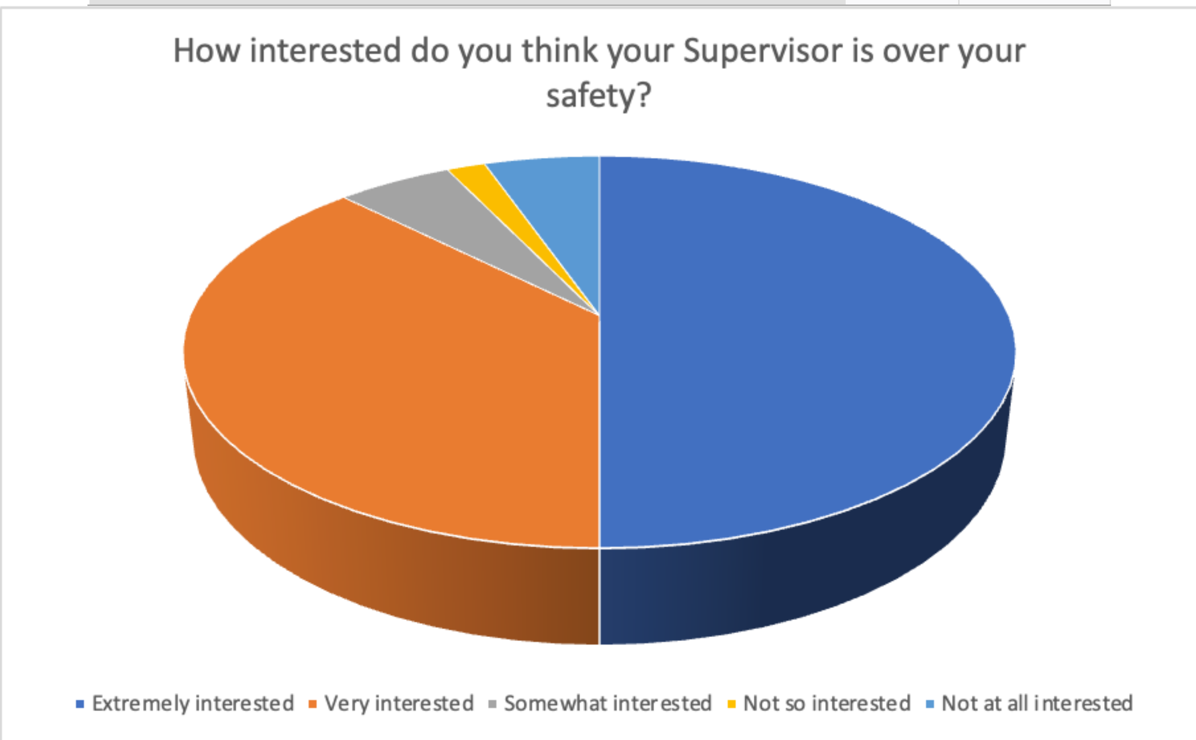


Figure 16 How interested do you think your supervisor is?

13. How important do you think the accuracy of stat plans is when preventing utility strikes?

Understanding the perceived importance of stat plan accuracy can guide improvements in safety protocols.

	N	%
Extremely important	37	66.1%
Very important	13	23.2%
Somewhat important	6	10.7%

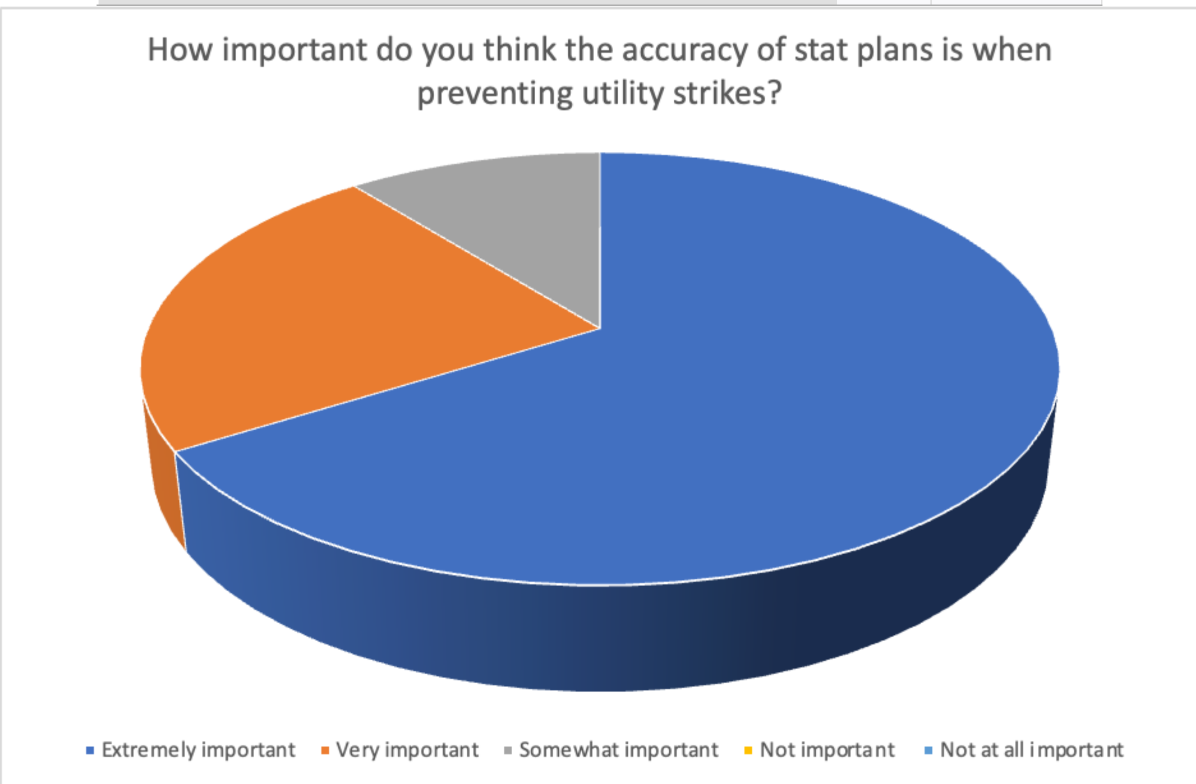


Figure 17 How important is the accuracy of stat plans?

Q14. Frequency Distribution of 'Tools'

To understand the tools commonly used by highway electrical workers and their potential association with the risk of underground utility strikes, a frequency analysis was conducted on the data collected. This analysis aimed to identify which tools are most frequently employed in the field and to explore any possible links between tool usage and utility strike incidents.

Responses from workers detailing the tools they used in their day-to-day operations were initially grouped together in the dataset under the column titled 'Concatenated_Column_Tools'. To accurately determine the prevalence of each tool, these concatenated strings were disaggregated, ensuring that every mention of a tool was counted, regardless of whether it was cited individually or in conjunction with other tools. This method allowed for a tabulation of the frequency of each tool's mention, providing clear insights into the most and least utilised tools in the industry.

The disaggregation process involved splitting the strings on the delimiter that separated different tools within the responses. Subsequently, the data was flattened such that each tool, now isolated from its original string, was treated as an individual entry. This resulted in a frequency table that encapsulated the occurrences of each tool across all responses.

The frequency table revealed that certain tools were mentioned with high recurrence, indicating their ubiquity in the industry's practices. The 'Hydraulic Breaker', 'Spade', and 'Mini Digger/Excavator' were the most frequently cited, each being mentioned over 20 times. Lesser cited tools included the 'Pickaxe', 'Cut off saw (Stihl)', and

'Road saw'. The presence of these tools in the responses highlights the spectrum of equipment that workers are exposed to, potentially reflecting the varying levels of risk associated with different tasks.

Analysing this frequency table provides valuable insights into potential focal points for enhancing safety measures. Understanding which tools are most prevalent in the industry allows for the tailoring of safety protocols to mitigate the risks associated with their use. Moreover, the frequency of these tools' mentions could serve as an indicator of their involvement in incidents of utility strikes, warranting further investigation into their usage and the contexts in which they are employed.

Table 3: Frequency of tools used in strikes

Tool	**Frequency**
Mini Digger / Excavator	25
Spade	24
Hydraulic Breaker	22
Shovel	15
Pickaxe	11
Cut off saw (Stihl)	9
Road saw	4
Long grafter	1
Grafter	1
Long grafter for column hole digging	1
Shovel holers	1
Tongs	1
Insulated graft and bar	1
Chisel and point bar	1

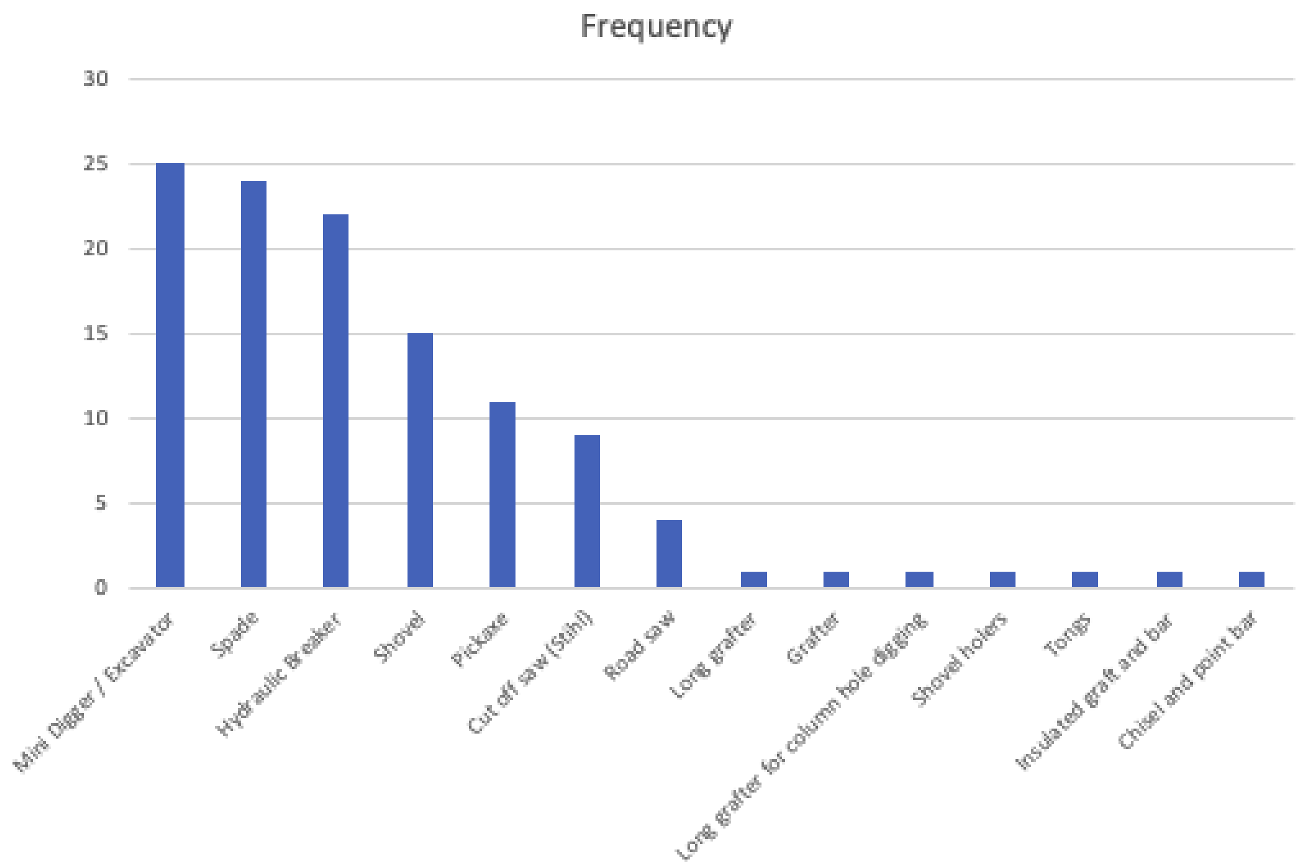


Figure 18 Frequency of tools used in strikes.

Q15. Frequency Distribution of 'Reasons for Underground Utility Strikes'

The raw data highlighted a diverse array of factors contributing to underground utility strikes as identified by highway electrical workers. To streamline the analysis, similar and interrelated reasons were amalgamated, enabling a clearer synthesis of the core issues. This consolidation was based on thematic similarities and underlying issues that each set of reasons pointed towards. For instance, factors reflecting worker competencies, such as training and experience, were merged into a single category. Similarly, different expressions of time-related pressures were combined to reflect the overarching impact of haste on safety.

The consolidation process involved evaluating each reason and determining its fundamental attribute. This allowed for the creation of a frequency table that not only reduced redundancy but also provided a more potent depiction of the prevalent issues. Each combined category was then recounted to reflect the total mentions across the dataset, thus yielding an updated frequency of occurrences.

The analysis of frequency data revealed that the predominant factor leading to underground utility strikes was 'Inaccurate Maps or Information/Incorrect Utility Depths,' accounting for a significant portion of incidents. It was followed closely by 'Time Pressure/Rushing,' reflecting the impact of hastened operations on safety. In contrast, issues such as 'Lack of Training/Experience' were reported less frequently, yet they remain critical considerations for preventative measures.

'Operational or Personnel Issues' and 'Inadequate Preparation/Equipment' were also identified, albeit to a lesser extent, highlighting the need for improved on-site practices and equipment readiness.

Reason	**Frequency**
Inaccurate Maps or Information/Incorrect Utility Depths	30
Time Pressure/Rushing	27
Operational or Personnel Issues	13
Inadequate Preparation/Equipment	5
Other (reasons not clearly fitting into a category)	5
Lack of Training/Experience	3

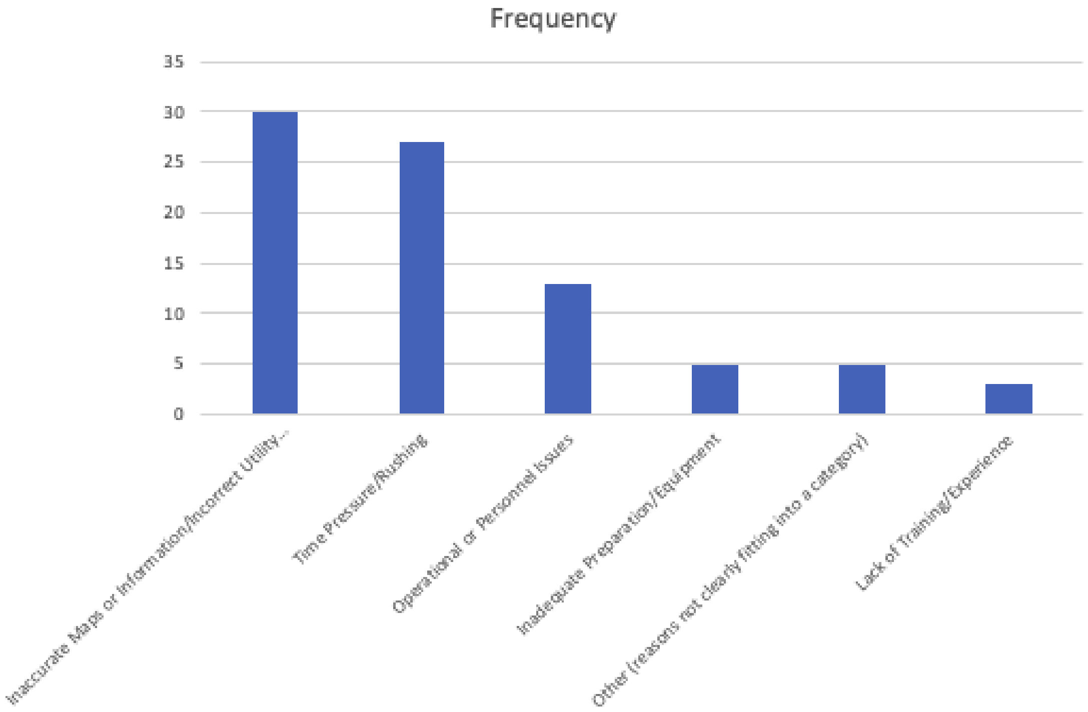


Figure 19 Reasons for utility strike.

16. On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')

Understanding the perceived importance of working with a family member or friend.

	N	%
0	7	12.5%
1	14	25.0%
2	2	3.6%
5	10	17.9%
6	2	3.6%
7	6	10.7%
8	6	10.7%
10	9	16.1%

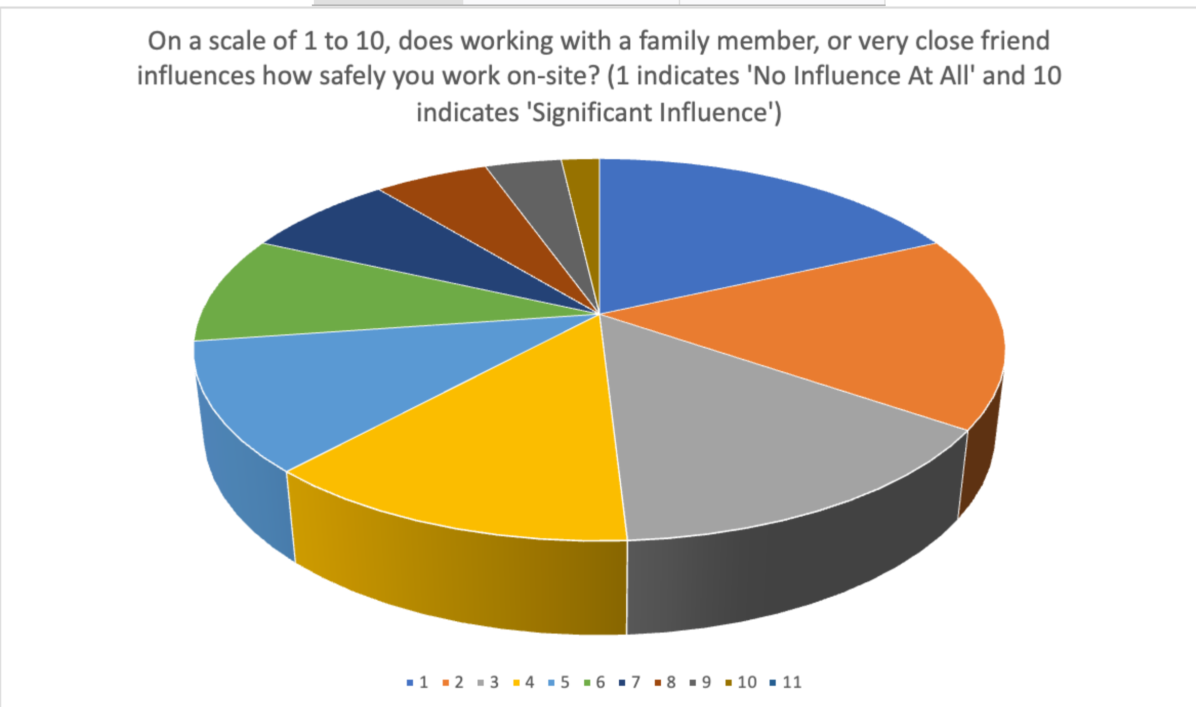


Figure 20 Does working with a family member change attitude?

17. On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike? (1 indicates being not confident at all, 10 indicates being very confident)

Understanding the perceived importance of the ability to prevent a utility strike.

On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike? (1 indicates being not confident at all, 10 indicates being very confident)	Frequency
0	1
1	0
2	0
3	0
4	0
5	2
6	2
7	7
8	16
9	14
10	13

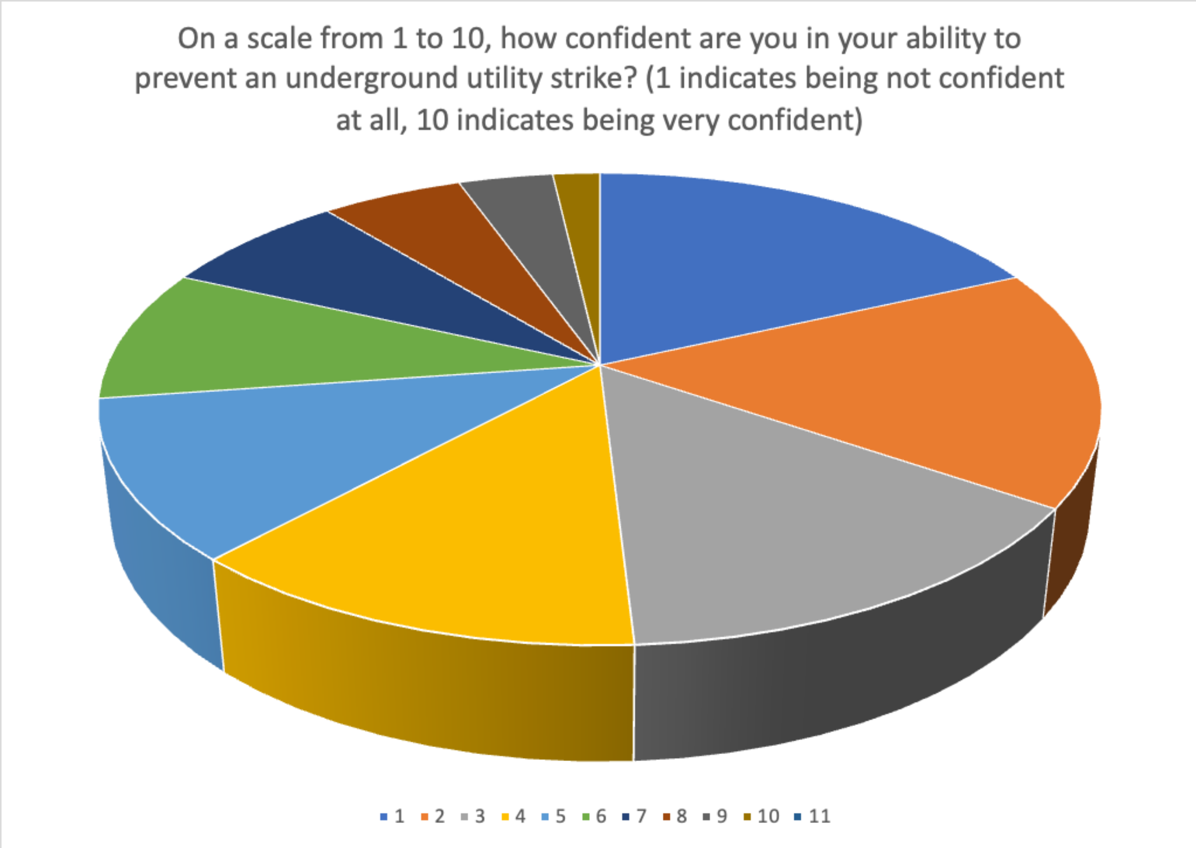


Figure 21 Confidence to avoid utility strike?

11.3.2. Frequency Table Summary

Frequency tables play a role in guiding the analytical process by providing an initial overview of response distributions across variables. This preliminary assessment informs the subsequent selection of appropriate statistical techniques. These tables offer insights into patterns and trends derived directly from the survey responses of highway electrical professionals. While these observations may not yield definitive conclusions, they illuminate areas warranting deeper investigation.

To illustrate, consider the age-related variations in reported utility strikes (Table 4). The observed differences in strike prevalence, with the highest percentage in the 45-54 age group, suggest a potential relationship between age and safety incidents.

Building upon this initial finding, further analysis seeks to uncover the underlying factors contributing to this observed trend. This approach ensures a data-driven and focused exploration of the most significant patterns emerging from the frequency distributions.

Table 4: Percentage strike by age

Age Group	Total	Utility Strike	Percentage with Strike
18-24	2	2	100%
25-34	11	5	45.45%
35-44	13	9	69.23%
45-54	22	19	86.36%
55-64	7	4	57.14%
65 and over	0	0	N/A
Under 18	0	0	N/A

11.4. Thematic Analysis of Worker Responses

This study examined qualitative responses from highway electrical workers to understand their perceptions and experiences concerning safety and the risks associated with underground utility strikes. The analysis was instrumental in documenting authentic narratives from participants, directly contributing to the research objectives.

To better understand the factors contributing to utility strikes, and how safety practices can be enhanced, a thematic analysis of worker experiences was conducted. A frequency table was initially generated from qualitative data (figure 6u), identifying key thematic terms. These terms served to guide the analysis, revealing several interconnected themes that impact safety practices and risk perception within the industry. Here's an exploration of these key themes, illustrated by worker accounts.

11.4.1. Experiences of Utility Strikes

Participants reported specific instances, such as, "*Went through a cable wrapped in concrete, had to wait for WPD, caused a delay and cost to job*." These incidents often led to increased caution and a re-evaluation of safety practices. Another worker recounted, "*Cable incased in concrete with nowhere to cut back outside have to get the Cable out somehow*," which reflects the unexpected challenges encountered during excavations.

11.4.2. Training and Competence

The need for enhanced training was emphasised with suggestions like, "*More training, more time to practice using equipment, an overall better understanding of underground services.*" Workers indicated that while formal training is provided, it often does not fully prepare them for the realities of fieldwork, as evidenced by the comment, "*None training all good cat and genny course complete strikes happen mostly when cables are shallow or in concrete*."

11.4.3. Reliability of Stat Plans and Equipment

The inaccuracy of statutory plans was a recurrent theme. One respondent noted, "*Quality of stat plans where completely wrong, services not being listed, cat and jennys are old and not good could do with upgrading*," underscoring the need for reliable documentation and equipment.

11.4.4. Workplace Culture and Safety Practices

The influence of workplace relationships on safety practices was noted, with mixed responses. Some said, "*No shouldn't matter who you working with friend family or not practice should be the same*," while others acknowledged a heightened sense of responsibility, "*Makes you curious and a higher attention to detail as you would not want to hurt them*."

11.4.5. Suggestions for Safety Improvements

Ideas for improvements included better hands-on training and updated practices to prevent utility strikes. A participant suggested, "*Vac ex*," indicating a preference for vacuum excavation as a safer alternative. The necessity for ongoing education was highlighted: "*Training is to a good standard*," yet there was a consensus that training must evolve to stay effective.

These accounts illustrate the challenges faced by workers along with the complexities of maintaining safety on a job site driven by productivity pressures.

11.4.6. On-site Observations

The on-site observation provided valuable insights into the work practices of the street lighting column installation team. Upon arrival, the crew had already established their work area and were initiating the process of marking underground utilities with a Cat & Genny cable locator. This initial action aligns with the safety protocols outlined in the online survey responses.

During the observation, a member of the crew (who was a questionnaire respondent), voluntarily presented his statutory plans (stat plans) and explained how these plans informed their work. He specifically pointed out the location of a marked electricity main cable on the plans and expressed confidence in its accuracy based on the Cat & Genny readings. This demonstrates a proactive approach to safety, exceeding the minimum requirement of simply using a cable locator.

Figure 22 Operative utilities marking

When prompted about potential challenges encountered during installations, the operative identified two common issues: shallowly buried utilities and service cables encased in concrete. These observations resonate with findings from the online survey, where similar concerns were raised by many respondents.

The on-site observation provided a valuable opportunity to witness safety protocols being implemented in a real-world setting. Additionally, the crew's voluntary actions, such as presenting the stat plans and discussing potential hazards, suggest a safety culture that goes beyond simply following the minimum guidelines.

11.4.7. Specific: Questions 18-22

Question 18: Analysis of Utility Strikes and Worker Caution

Survey responses indicated an increase in worker caution following utility strikes. Direct quotes from participants highlighted experiences of utility strikes, such as cables encased in concrete causing incidents. Workers reported a frequent reliance on pre-digging checks with tools like CAT & GENNY, despite expressing doubts about the reliability of utility maps and plans. Reports included instances of rushing due to management pressure and noted inconsistencies in training and awareness levels among workers. The dependency on technology for safety and issues with construction materials and practices were also documented.

Question 19: Accounts of Unintentional Utility Strikes

Participants described specific incidents of unintentional utility strikes, with one detailed account involving an 11 kV cable strike during excavation. Themes emerged around rushing and lack of caution, inadequate utility mapping, training and competency gaps, reliance on technology, poor reinstatement and construction practices, the need for accurate plans, and adherence to depth guidelines.

Question 20: Insights on Safety Training Programs

Feedback on safety training programs suggested a need for more practical, hands-on training and education on the use of Cable Avoidance Tools (CAT & GENNY). Suggestions included frequent refresher sessions, mentorship from experienced personnel, education on the reality of shallow burials, and video documentation of the excavation process.

Question 21: Influence of Family and Friends on Safety Practices

Most workers reported no change in safety practices when working with family or friends, emphasising consistency in practice. However, some acknowledged a heightened sense of attention and caution, highlighting the importance of knowledge transfer and mentorship. Personal narratives also underscored the impact of accidents involving close ones on commitment to safety protocols.

Question 22: Challenges in Locating Underground Utilities

Challenges identified include concerns over concrete encasements, the rush to complete projects leading to shallow service installation, doubts about the accuracy and completeness of statutory plans, and the presence of unlisted or inaccurately documented services. Additional challenges included time constraints, educational deficiencies, and poor equipment conditions.

11.5. Statistical Quantitative Analysis

11.5.1. Introduction

This section presents the statistical analysis of data gathered from the online survey ('_CSV_FINAL Concatenated Data_Highway Electrical Workers View on Underground Strike Risks231218.csv'). To understand the attitudes of highway electrical workers towards the risk of underground utility strikes, Spearman's Rank Correlation Test was employed for analysing Likert-scale questions (1-15). This approach aligns with the ordinal nature of Likert-scale data, where categories possess order but may not have equal spacing. Spearman's Correlation assessed the strength and direction of associations between ranked variables without assuming linearity or normal distribution (Hinkle et al., 2003; RGS, 2014). Chi-square tests were deemed less suitable as they treat ordinal Likert data as nominal, potentially overlooking underlying sequential patterns (SHU, 2014). Utilising Spearman's Correlation ensured an accurate interpretation of the relationships among variables.

For questions 16 and 17, a one-sample t-test was used to accommodate the different data types collected. Additionally, bootstrap resampling (1000 rotations) was employed to establish confidence intervals and assess the strength of Spearman Correlation coefficients (Efron & Tibshirani, 1993).

In this section, observed correlations were categorised based on their statistical significance and strength. A statistically significant correlation was defined as one where the p-value was less than 0.05, providing strong evidence against the null hypothesis of no association (Cohen, 1988).

Correlation coefficients ranged from -1 to +1, with values closer to the extremes representing stronger associations. Significant negative correlations were classified as those with coefficients less than -0.4, moderate negative correlations as those between -0.3 and -0.39, and significant positive correlations as those with coefficients greater than +0.3. While these thresholds are widely adopted, it's important to note that interpretations of correlation strength can vary slightly depending on the specific field and research context. Some disciplines may employ slightly different boundaries (Hinkle et al., 2003; RGS, 2014).

The following section focuses on statistically significant Spearman Rank Correlation relationships with reported p-values below 0.05, which are grouped as "GREEN" Correlations:

11.5.2. GREEN Correlations

Experience of Underground Utility Strikes and Frequency of Encounters:

A significant negative correlation (-.437, p=0.001) was observed between having experienced an underground utility strike and the frequency of such encounters. The bootstrap analysis, showing a bias of 0.004 and a standard error of 0.111, with a 95% confidence interval ranging from -0.621 to -0.186, confirms the robustness of this correlation.

Experience of Strikes and Supervisor's Interest in Worker Safety:

A moderate negative correlation (-.339, p=0.011) was found between experiencing a utility strike and the perceived interest of supervisors in worker safety. The bootstrap analysis supports this finding, with a bias of -0.005 and a standard error of 0.114, and a confidence interval between -0.555 and -0.084.

Years in Industry and Importance of Stat Plans Accuracy:

A moderate negative correlation (-.337, p=0.011) was identified between the number of years worked in the industry and the perceived importance of the accuracy of statutory plans in preventing strikes. Bootstrap analysis, with a bias of -0.004 and a standard error of 0.093, further cements this finding, with the confidence interval ranging from -0.507 to -0.150.

Perceived Sufficiency of Safety Measures and Effectiveness of Training:

A moderate positive correlation (.302, p=0.024) was found between workers' beliefs in the sufficiency of current safety measures and their views on the effectiveness of training. Bootstrap analysis revealed a minimal bias of -0.001 and a standard error of 0.115, with the confidence interval between 0.052 and 0.503.

Frequency of Checking for Cables and Confidence to Avoid Strikes:

A significant negative correlation (-.354, p=0.007) was observed between the frequency of checking for underground cables and confidence in avoiding strikes. The bootstrap analysis, with a bias of -0.001 and a standard error of 0.114, and a confidence interval ranging from -0.562 to -0.121, reinforces the reliability of this correlation.

Continuing with the analysis of further relationships identified in the survey, the correlations classified as **‘GREEN/AMBER’** provide additional insights, but all have reported results with p-values marginally above the commonly accepted threshold of 0.05, and/or correlation coefficients just below the moderate strength cut-off of ±0.3 (RGS, 2014). This suggests that while the identified relationships are indeed present, they are subtle and not strongly pronounced. As such, these findings should be interpreted with caution, recognising that they approach but do not surpass conventional levels of statistical significance and effect size.

11.5.3. GREEN/AMBER Correlations

Age and Experience of Underground Utility Strikes:

A modest positive correlation (0.296, p=0.027) was noted between the age group of the respondents and the incidence of experiencing an underground utility strike at work. The bootstrap analysis lends support to this correlation, with a minimal bias of -0.005 and a standard error of 0.129, alongside a 95% confidence interval ranging from 0.035 to 0.535.

Industry Tenure and Training Effectiveness:

A slight negative correlation (-0.285, p=0.033) was found between the number of years workers have been in the highway electrical industry and their perception of the effectiveness of training to prevent utility strikes. The bootstrap analysis, with a bias of 0.004 and a standard error of 0.149, shows a 95% confidence interval from -0.551 to 0.039.

Safety Checks and Influence of Working with Familiar Individuals:

There was a weak positive correlation (0.241, p=0.073) between the frequency of checking for underground cables before beginning work and the influence of working with a family member or very close friend on-site safety. Despite the bootstrap analysis showing a bias of -0.005 and a standard error of 0.104, the 95% confidence interval (0.028 to 0.432).

Training Effectiveness and Confidence to Avoid Strikes:

Lastly, there was a weak negative correlation (-0.248, p=0.066) between the perceived effectiveness of training and confidence in avoiding utility strikes. The bootstrap analysis reveals a bias of 0.000 and a standard error of 0.139, with the 95% confidence interval spanning from -0.491 to 0.058.

The analysis of the 'GREEN' and 'GREEN/AMBER' correlations, supported by the bootstrap analysis, sheds light on the attitudes and perceptions of highway electrical workers regarding safety practices and the risks of underground utility strikes.

A different approach was taken for questions 16 and 17, where a one-sample t-test was conducted to compare the mean scores provided by respondents against a hypothesized population mean. This test was specifically chosen for its suitability in situations where a single sample mean is tested against a known or hypothesized population mean.

For question 16, "On a scale of 1 to 10, does working with a family member, or very close friend influence how safely you work on-site?", and question 17, "On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike?", the one-sample t-test was employed to discern whether the central tendency of responses significantly deviated from a neutral point on the scale.

The results from SPSS showed that for question 16 (Figure 21), the mean was 4.6, indicating that respondents did not have a significantly favourable or unfavourable view on the impact of working with a family member on their attitude to safety, $t(55) = 0.89$, $p = 0.465$.

Correlation	**Category**	**Coefficient**	**Strength**	**p-value**	**Significance**
Experience/Frequency of Strikes	GREEN	--0.437	Moderate	0.001	Significant
Cable Checks/Confidence	GREEN	--0.354	Moderate	0.007	Significant
Experience/Supervisor Interest	GREEN	--0.339	Moderate	0.011	Marginally Significant
Years/Importance of Plans	GREEN	--0.337	Moderate	0.011	Marginally Significant
Safety Measures/Training Effectiveness	GREEN	+0.302	Moderate	0.024	Marginally Significant
Age/Experience of Strikes	GREEN/AMBER	+0.296	Weak	0.027	Marginally Significant
Industry Tenure/Training Effectiveness	GREEN/AMBER	--0.285	Weak	0.033	Marginally Significant
Training Effectiveness/Confidence	GREEN/AMBER	--0.248	Weak	0.066	Not Significant
Safety Checks/Working with Familiars	GREEN/AMBER	+0.241	Weak	0.073	Not Significant

Table 5: Summary of statistical significance

One-Sample Test

	Test Value = 4.6				
			Significance		
	t	df	One-Sided p	Two-Sided p	Mean Difference
On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')	.089	55	.465	.929	.043

One-Sample Test

	Test Value = 4.6	
	95% Confidence Interval of the Difference	
	Lower	Upper
On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')	-.92	1.01

Figure 23 Q16 One Sample T-Test

For Question 17, using SPSS and the data from the survey, the Mean for Q20 was 8.2 and the People who were surveyed had neither significantly favourable nor unfavourable views on the confidence they had in their ability to prevent a utility strike, t(55) = 0.61, p = 0.476 (Figure 22).

One-Sample Test

	Test Value = 8.2				
			Significance		
	t	df	One-Sided p	Two-Sided p	Mean Difference
On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike? (1 indicates being not confident at all, 10 indicates being very confident)	.061	55	.476	.952	.014

One-Sample Test

	Test Value = 8.2	
	95% Confidence Interval of the Difference	
	Lower	Upper
On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike? (1 indicates being not confident at all, 10 indicates being very confident)	-.46	.48

Figure 24 Q17 One Sample T-Test

11.6. Discussion

This section of the thesis presents an opportunity to amalgamate findings from the empirical research conducted on the attitudes and experiences of highway electrical workers towards the risk of underground utility strikes, with a particular focus on the integration of quantitative and qualitative data obtained from the online survey. This survey, administered through SurveyMonkey and distributed to HERS registered staff across five companies in the highway electrical sector, yielded 56 responses from an estimated 300 staff members. This response rate of approximately 19% is considered reasonable for industry-specific research, although it falls short of more robust participation rates often desired in academic studies (Nulty, D, 2008; PeoplePulse, 2024).

This chapter will juxtapose the study's findings against existing literature, highlighting both concordances and divergences. Notably, several themes emerged underscoring a tension between safety and productivity and revealing gaps in training that contribute to unsafe practices. The responses from participants offered insights into the complexities of risk management in the field, particularly the impact of personal experiences and management practices on safety attitudes.

The balance between productivity demands and safety protocols within the highway electrical industry encapsulates a prevalent challenge, illustrated by workers' experiences. One worker's account demonstrates how time constraints can lead to utilities being laid too shallow, epitomising a broader industry dilemma where the urgency to meet deadlines potentially compromises safety standards. This scenario is not isolated but reflects a systemic issue within the construction and related sectors, resonating with Donaghy (2009), who argued for a paradigm shift towards valuing safety on par with productivity. The necessity for such a shift is further emphasised when considering challenges like the quality of statutory plans and the condition of excavation equipment, which compound the safety-productivity conflict.

The need for a systemic shift, including a cultural re-evaluation of work practices to embed safety as a foundational value, is critical. "*Trying to expose Lv cables that have concrete poured on top of cables*," as one participant observed, highlights the infrastructural and procedural hurdles that demand attention. This observation echoes the sentiments of Metje et al. (2015), who found inaccurate utility information to be a major cause of utility strikes, underscoring the importance of accurate and reliable statutory plans in enhancing safety measures.

Moreover, the study reveals a notable gap between the safety training provided and its practical application in job situations. This disparity is particularly significant for tools such as hydraulic breakers, which are reported as commonly involved in utility strikes but are not adequately covered in general industry training. A worker's plea for "*More training, more time to practice using equipment, an overall better understanding of underground services*" underscores the gap between existing training content and the practical risks associated with using these tools. This concern aligns with Koschmann et al. (2021), who emphasised the critical need for training programs tailored to the specific hazards of the equipment used in the field.

The tendency for productivity pressures to lead to the circumvention of learned safety protocols underscores a critical insight: training, while essential, may not be fully effective without the reinforcement of a supportive workplace culture. This study's findings resonate with Patel et al. (2012), who highlighted the industry's acceptance of cable strikes as an inevitable risk, suggesting that a shift in cultural attitudes towards safety is paramount.

Leadership's role in mitigating this safety-productivity conflict is pivotal. This study illustrates that when leaders are actively engaged in safety, workers exhibit greater caution and a more conscientious approach to risk management. This is exemplified by the impact of leadership on the use of equipment, such as hydraulic breakers and mini diggers, in preventing utility strikes. Leadership that actively promotes safety can transform workplace safety culture, as observed in this study, which aligns with Rauscher et al. (2010), who noted the positive influence of social contexts, including leadership practices, on safety outcomes.

Another key finding from the survey that warrants attention is the uncertainty among workers about the specific times during the day when utility strikes are most likely to occur. This uncertainty contrasts with the detailed temporal patterns identified in the Literature Review, such as the peak times for utility strikes noted by Metje et al. (2015). Understanding the timing of these incidents is crucial for developing targeted interventions and risk mitigation strategies. For instance, if utility strikes are more common during certain hours, this could inform the scheduling of high-risk work or the allocation of supervisory staff. The lack of clarity observed in the survey responses suggests a need for better data collection and analysis within the industry, which could lead to more informed decision-making and potentially reduce the frequency of utility strikes. This discrepancy between the workers' perceptions and the documented evidence in the literature highlights an area for improvement in both industry practice and future research.

Building on these insights, which set the stage for a discussion of the attitudes and experiences of highway electrical workers towards safety and productivity conflicts, we progress to a detailed exploration of survey Questions 18 through 22. These questions delve into the realities faced by workers, uncovering the tangible impacts of utility strikes on safety perceptions and practices. Through this analysis, the study aims to bridge the gap between theoretical considerations and the lived experiences of workers.

As highlighted in Section 10, the following qualitative data, was preserved in its original format, including any spelling or grammatical errors (SPAG errors) made by the participants.

Reflecting on survey question 18, *"If you, or someone you work with has ever had a utility strike, could you provide a brief account of what happened and how it impacted you and your perception of the risk associated with underground utility strikes (made me more or less cautious etc)?",* the responses unveil an examination of the aftermath of utility strikes on workers' safety perceptions and behaviours. The feedback illustrates a significant shift towards increased caution, fundamentally altering workers' approaches to risk management in their operational environments.

The first-hand accounts, such as the one highlighting the encasement of cables in concrete leading to utility strikes, not only underscore the tangible impacts of these incidents but also align with the discourse presented in the Literature Review. Specifically, the discussion mirrors the concern raised by Metje et al. (2015) regarding the accuracy of utility information and the crucial role of adequate training, as identified by Koschmann et al. (2021). These secondary sources resonate with the workers' experiences, particularly emphasising the disparity between the safety training provided and its practical application, further substantiated by the reliance on tools like CAT & GENNY amidst doubts about the reliability of utility maps and plans.

Moreover, the expressed need for "*More training, more time to practice using equipment, an overall better understanding of underground services*" echoes the literature's call for a systemic shift towards integrating safety as a foundational value within work practices. This parallel extends to the observed influence of management practices on risk-taking behaviours, highlighting the critical need for leadership that prioritises safety, aligning with Donaghy's (2009) advocacy for a shift towards valuing safety on par with productivity.

Responding to Question 19, *"Can you describe a specific situation where you, or a co-worker, unintentionally struck a utility during construction? What were the events leading up to the incident and what do you think could have been done differently to prevent it?",* participants offered narratives that reveal the circumstances leading to utility strikes. One particular account vividly illustrates the scenario: *"my mate was digging with a jack hammer breaking the surface of tarmac in clevedon near business centre with we hit 11 Kw cable we had cat a genny area and pick up a signal so we moved away from it and started to dig down ,all of a sudden a massive flash and bang it bolw my mates helmet off and he black dust over his face and* *clothes the jack hammer had a v in the spade. i dont no we had stats and we cat a genny area .the cable shouldn"t have been so close to surface,the safest option would have been to hand dig."* This incident underscores the need for additional safety measures, such as hand digging near detected utilities, to prevent such dangerous outcomes.

This experience, among others, brings to light the pressing issues within the construction sector related to safety and risk management. The urgency often associated with construction tasks leads to a propensity to prioritise speed over caution, mirroring concerns raised in the Literature Review about the tension between productivity demands and safety protocols, as discussed by Metje et al. (2015). Such a rush, even in the presence of sophisticated detection technology, can result in overlooking essential safety checks, illustrating the limitations of relying solely on technological solutions for utility detection.

Furthermore, the narratives highlight a significant gap between the training provided to workers and the practical skills required in the field, a concern that is emphasised by the quantitative finding from Question 14 of the survey. The data indicates that hydraulic breakers, (referred to as jackhammer in the quotation above), are frequently involved in utility strikes, yet there is a conspicuous absence of recognised training for the use of this tool within the frameworks of HEA Training (HEA, 2023), City & Guilds, and EUSR awarding organisations. This gap underscores the necessity for training programs to address not only the technical aspects of utility detection and excavation practices but also to foster a deep understanding of the risks involved.

Koschmann et al. (2021) stresses the importance of training programs tailored to the specific hazards of the equipment used in the field. The reliance on technology, such as CAT & GENNY, is invaluable for utility detection, but it is not infallible. The survey accounts reveal that while these tools are critical, they should function in tandem with, rather than as a replacement for, manual verification methods to ensure a more universal approach to safety. This dual strategy is crucial, particularly when considering the limitations of current training which does not cover the use of hydraulic breakers - a tool that is not only ubiquitous on construction sites but also implicated in a number of utility strike incidents.

The recounted incidents also draw attention to systemic issues within construction practices, including inadequate utility mapping and the poor reinstatement of cables, which exacerbate the risk of strikes. These observations align with the economic and human impact discussions presented by Gov.uk (2021), emphasising the need for improved accuracy in utility plans and adherence to depth guidelines to mitigate these risks effectively.

Addressing Question 20, "*What changes or improvements would you suggest to the current safety training programs, to better prepare workers to avoid utility strikes?",* the participants provided feedback that points towards enhancements needed in safety training protocols. One participant poignantly noted the misalignment between common assumptions and the harsh realities of construction work:
"*We need to discuss more and prepare people for the reality that services are often buried much shallower than the NJUG guidance suggests. It's a common*

misconception that electricity is buried at 450mm, but with service cables, this is not always the case."

This sentiment captures a key theme that resonates throughout the study's responses, emphasising the need for safety training programs to reflect the actual conditions workers encounter. There's a call for more practical, hands-on training that moves beyond theoretical knowledge to encompass the realities of the field, echoing the emphasis on experiential learning highlighted in the works of Koschmann et al. (2021).

In line with the literature, the study's respondents also advocated for frequent refresher training sessions, which would enable workers to retain crucial safety knowledge and stay abreast of the latest protocols. Moreover, the benefits of mentorship were underscored, with calls for guidance from experienced personnel to ensure less experienced workers develop the competencies needed for safe excavation work, a recommendation that aligns with the findings of Donaghy (2009), emphasising the importance of adequate supervision and training.

Addressing shallow burials was another critical point raised, challenging the industry's entrenched misconceptions about the depth of utility services, and highlighting the need for education on the variability of service burial depths. The suggestion for video documentation of excavation processes further speaks to innovative approaches to safety, allowing for a visual reinforcement of safety procedures and offering a real-time record that could be used for both training and verification purposes.

Collectively, these insights from workers articulate a clear directive for revising safety training programs. They underscore the importance of evolving these programs to be more aligned with the on-the-ground realities of construction work, focusing on practical training, continuous learning, and the effective use of technology - all aimed at fostering a culture of safety that prioritises the prevention of utility strikes. This aligns with the literature that calls for a holistic approach to safety management, encompassing technological, procedural, and educational strategies to mitigate the risks associated with underground utility strikes.

When considering the influence of personal relationships on safety practices within the context of utility strikes, Question 21 posed: "*If you have ever worked with a family member, or very close friend, has this affected your safety practices, particularly in relation to avoiding utility strikes - and if so why?"*

This enquiry brought to light varied perspectives from the workforce, with most participants maintaining that their adherence to safety protocols was unaffected by the presence of family or friends on site. As one worker firmly put it, *"No, shouldn't matter who you're working with, friend, family, or not; practice should be the same."*

Yet, for some workers, the proximity of loved ones on the job site did indeed intensify their focus and diligence. *"makes you curious and a higher attention to detail as you would not want to hurt them,"* shared one respondent, highlighting the natural inclination to protect those close to us. This sentiment resonates with the themes discussed in the Literature Review, particularly the findings of Rauscher et al. (2010), which suggest that social contexts, including familial relationships, can significantly influence safety practices.

The study's findings also looked at the role of mentorship and the transfer of knowledge within close-knit workgroups. The sharing of safety knowledge and experiences, as one participant noted, *"Yes, passing knowledge down to close friends and also co-workers on-site,"* is a crucial aspect of cultivating a safety-first environment. This aligns with Donaghy’s (2009) emphasis on the need for healthy safety cultures within the industry, where mentorship and shared responsibility for safety are paramount.

Moreover, the emotional narratives of workers who have experienced accidents involving close colleagues or relatives underscore the profound psychological impact such incidents can have on a worker’s dedication to safety protocols. This finding dovetails with the observations of Patel et al. (2012) regarding the *‘inevitability’* of cable strikes, suggesting that personal experiences, especially those involving family or friends, can deeply affect workers' attitudes towards risk and the observance of safety measures.

Question 22 posed to the survey respondents was, *"In your experience, what challenges have you faced in trying to locate and avoid underground utilities during excavation or construction work?"*

This enquiry yielded insights into the array of obstacles encountered in the field. Participants detailed several challenges, with one highlighting the difficulty of dealing with encased utilities: *"Trying to expose LV cables that have concrete poured on top of cables."* This issue speaks to the broader problem of identifying and managing buried services, which often diverge from standard expectations.

Workers pointed out the frequent urgency in project timelines leading to compromised installation quality, with one participant noting, *"Contractors rushing and putting service too shallow and to a poor standard."* This rush is in line with the Literature Review's findings by Metje et al. (2015), who noted the human errors contributing to utility strikes, compounded by pressures to expedite work.

Statutory plans' reliability or lack thereof was a recurring concern among respondents. This echoes the findings from Gov.uk (2021), which emphasised the need for better data management to prevent utility strikes. *"Quality of stat plans where completely wrong, services not being listed, cat and jennys are old and not good, could do with upgrading,"* shared a participant, revealing frustration with the tools and information available.

In line with concerns raised by Donaghy (2009), the challenge of unlisted or inaccurately documented services was identified, with the added difficulty of inexperienced operatives working under time constraints. *"You always find young people trying to dig holes the fastest and make their team quicker,"* a respondent observed, acknowledging the risk posed by inexperienced workers.

These challenges - ranging from time pressures and educational gaps to equipment deficiencies and the accuracy of utility mapping - underscore the need for improvements across the sector. They reinforce the importance of addressing the issues highlighted by the Literature Review, particularly the call by Patel et al. (2012) for a shift in cultural attitudes towards safety and the adoption of more safety measures.

This study's findings underscore the urgent need for enhancements in utility mapping accuracy, training programs, and safety culture development to mitigate the risks associated with excavation and construction work.

11.6.1. Interviews: Validation and Deeper Insights

Interviews with participants provided a valuable complement to the quantitative survey data. In most cases, interview responses largely aligned with the attitudes and beliefs expressed in the survey. This alignment strengthens the validity of the findings, suggesting consistency in workers' perceptions of safety and risk within the sector.

However, even within this general alignment, interviews offered a more detailed perspective on specific aspects of risk management. One interviewee, for instance, expressed concerns about shallow service installations and the role of individual attitudes during the interview, while his survey responses were more focused on technical aspects of safety. This indicates that interviews can uncover subtle yet important insights that may not be readily apparent in quantitative data.

The overall value of the interviews lies in their ability to add richness and depth to the understanding of worker perceptions, going beyond the limitations of structured survey responses. This combination of methods – triangulation – enhances the internal validity of the study, ensuring that the findings reflect the realities of safety and risk management in the highway electrical sector.

11.6.2. Integration of Findings

Having drawn a picture of the daily challenges faced by highway electrical workers through their personal accounts, the discussion now shifted focus to the empirical data. In this section, statistical findings from the survey were interwoven with the experiences and stories shared by the workers. This approach served as a bridge, linking quantitative data with human narratives to present a clear, evidence-based understanding of the industry's safety culture. The goal was to weave these elements together, grounding theoretical discussions in the lived realities of workers. This ensured that recommendations for improving safety standards were both practical and impactful. Such an approach helped solidify the conclusions drawn from the research, facilitating their translation into actionable steps for the field.

11.6.2.1. Underground Utility Strikes and Frequency of Encounters

In examining the relationship between experiencing underground utility strikes and the frequency of such events, a significant negative correlation emerged from the quantitative data analysis. This pattern suggests that workers who have had a utility strike are likely to encounter similar incidents again. It points to an inherent risk within certain work environments or practices, leading to a higher probability of repeated utility strikes.

The qualitative feedback from workers offers additional context to this data, illustrating a narrative that aligns with the Human Factors Theory. This theory suggests that personal experiences and the learning that follows shape an individual's perception of risk and behaviour. Workers' narratives describe an increased awareness and caution following utility strikes, yet this does not always correspond to a decrease in the occurrence of such incidents. This discrepancy highlights a potential gap between individual behavioural changes and workplace issues that continue to pose risks.

This intersection of quantitative data and qualitative insights brings to light a broader issue that resonates with themes from the Literature Review. The works of Metje et al. (2015) and Patel et al. (2012) discuss the prevalence of utility strikes due to human error and non-compliance with rules, despite 'zero harm' initiatives within organisations.

The study's findings here reflect this discourse, suggesting that while workers may individually learn from incidents, there is a need for organisational and systemic change to reduce the frequency of utility strikes effectively.

Additionally, the qualitative responses indicate a growing mistrust among experienced workers toward statutory plans, a point which echoes the concerns raised in the Literature Review. Gov.uk (2021) and ENA (2020) stress the importance of accurate utility information and effective data management. Workers' scepticism towards statutory plans due to repeated discrepancies between these plans and actual site conditions calls for a re-evaluation of these safety tools' reliability. This distrust, as highlighted in the Literature Review, can lead to a disregard for safety protocols, potentially increasing the risk of utility strikes.

The insights from this study, woven together with the established discourse in the Literature Review, highlight critical areas for development within industry practices. A revamp of safety measures and a renewed confidence in the accuracy of statutory plans are pressing necessities. What's apparent here is the need for a shift that transcends individual behavioural changes and tackles the systemic shortcomings that lead to repeated utility strikes. Aligning with theoretical insights, these practical findings from the field stress the importance of a unified approach. This means not only raising awareness among workers but also re-evaluating and reinforcing the very systems and tools designed to safeguard them. Such a strategy ensures a balance between acknowledging the workers' experiences and addressing the structural challenges that continue to pose risks on the ground.

11.6.2.2. Experience of Strikes and Supervisor's Interest in Worker Safety

The relationship between workers' experiences of utility strikes and their perceptions of supervisors' commitment to safety in the highway electrical sector reveals a contradictory dynamic. The study found a moderate negative correlation suggesting that workers who have encountered utility strikes may express greater scepticism regarding the prioritisation of safety by their supervisors. This scepticism underscores a perceived disconnect between supervisor actions and the promotion of a safety culture.

Interviews with industry professionals further explain this tension. Interviewee (DW) recounting of a near-miss with an underground cable illustrates the lasting impact such experiences can have on individuals, potentially leading to heightened caution. However, this wariness can translate into a sense of cynicism when workers believe that management does not consistently uphold safety standards.

This perception aligns with Lingard et al.'s (2012) emphasis on the critical role of supervisor attitudes in shaping a strong safety climate. Workers who have experienced strikes may doubt a supervisor's sincerity if they perceive that production pressures sometimes override safety concerns. This disconnect can diminish trust, fostering a sense that safety is a theoretical ideal rather than a daily mandate actively safeguarded by those in leadership roles.

Conversely, interviewee (AS) perspective presents a more optimistic view, reflecting years of positive evolution in safety practices and leadership roles. AS's narrative indicates a sector undergoing significant improvements in safety culture, backed by effective training, technological advancements, and a stronger overall commitment to safety. This perspective suggests that consistent actions demonstrating safety as a non-negotiable priority can help rebuild lost trust among experienced workers.

These contrasting experiences underscore the importance of leadership in shaping the daily realities of safety within the workplace. When supervisory leadership effectively reflects safety as a core value, it fosters a culture where utility strikes are perceived as anomalies – preventable through vigilance rather than taken as inherent to the work itself.

Integrating these insights into our discussion, it becomes evident that the highway electrical sector is at a crossroads. On one hand, there is a clear need for leaders to actively demonstrate their commitment to safety, going beyond mere rhetoric to ensure safety is a central pillar of workplace culture. On the other hand, the positive developments highlighted by AS indicate a pathway towards reconciling the gap between safety policies and their practical implementation.

11.6.2.3. Years in Industry and Importance of Stat Plans Accuracy

The analysis exploring the link between how long highway electrical workers have been in the industry and how much they trust the accuracy of statutory plans (-.337, p=0.011) brings out an interesting insight. It seems that as workers gain more experience, they start to value the reliability of these plans less. This shift towards relying more on their own experience over official safety guidelines hints at a growing scepticism towards these formal procedures among more seasoned workers.

Looking at the feedback from those in the field, a pattern of distrust towards statutory plans becomes evident. Comments like, *"The stat plans are not to be trusted as they can often be wrong...,"* reflect a common view among experienced workers that their practical knowledge is more reliable than what's presented in these plans. Such a stance, further echoed by another worker’s assertion that *“stat plans are never that accurate and can’t be trusted,”* points to a deeper issue.

Workers repeatedly coming across incorrect plans have led them to expect inaccuracies as the norm, based on their past experiences.

This phenomenon, where seasoned workers anticipate errors in statutory plans due to their frequent encounters with inaccuracies, aligns with discussions in the Literature Review, particularly referencing the importance of accurate information in preventing utility strikes as emphasised by Metje et al. (2015) and the ENA (2020).

Moreover, the critique about statutory plans being overly complex and not user-friendly, as one worker described UKPN's plans as *"the most complicated to read,"* highlights a practical barrier. This feedback suggests that the usability and effectiveness of statutory plans decrease with the worker's experience, contributing to a reliance on personal judgement over formal guidelines.

By marrying these qualitative observations with the quantitative data, a complex picture emerges. Experienced workers' tendency to downplay the importance of statutory plans, driven by their habitual encounters with inaccuracies, is illuminated under the lens of Human Factors Theory. This theory suggests that personal experiences heavily influence professional behaviours and risk assessments.

Considering the safety and economic impacts of utility strikes discussed in the Literature Review, such as those highlighted by Gov.uk (2021), this study emphasises the urgent need to reconcile workers' real-world experiences with the formal safety measures in place.

Ensuring the accuracy, reliability, and accessibility of statutory plans is crucial in fostering a balanced safety culture within the industry, where both experience and formal guidelines are valued equally.

11.6.2.4. Perceived Sufficiency of Safety Measures and Effectiveness of Training

The study of how highway electrical workers perceive the adequacy of safety measures and the quality of training unveils a strong positive correlation, indicating a direct link between the confidence workers have in safety protocols and their evaluation of training's effectiveness. This correlation, evidenced by a Spearman Rank correlation coefficient of .302 ($p=0.024$), is enriched by the qualitative feedback from those on the ground.

Feedback from the workforce often praises the positive nature of existing training while simultaneously valuing hands-on experience. As one participant aptly put it, *"I think that all the possible training out there is above and beyond what is needed. The only thing better than the training is an operative's experience."* This observation not only affirms the quality of current training initiatives but also the irreplaceable value of real-world experience in enhancing safety competencies.

Yet, the survey responses also reflect a spectrum of views on the efficacy of safety training, with some highlighting areas for enhancement. For example, comments such as, *"More frequent training and better cats with more time on job,"* suggest a need for more practical training sessions and improved resources like Cable Avoidance Tools (CAT).

This call for more immersive, on-site training experiences underscores the essential role of practical application in safety education, resonating with findings from Metje et al. (2015) and ENA (2020) that emphasise the critical need for accurate and accessible information to mitigate risks effectively.

One response specifically addresses the industry's understanding of competency: *"The thing what always struck my mind the most is the training side of the industry and word 'competent'. We sometimes receive trainings such as 'Locate underground services' (Cat and Genny) or 'Safe digging practise' as an example, but some of us then never really have a chance to use Cat and Genny or put theoretical/1 day of training knowledge into practise."* Which is an insight that highlights a gap between theoretical training and its practical application, echoing the Literature Review's emphasis on the necessity for training that bridges this divide, as discussed in Gov.uk (2021).

The integration of quantitative data with qualitative insights paints a picture of the training landscape within the highway electrical industry. While current programs are valued, there is a call for training that better mirrors the on-the-ground realities faced by workers, aligning with the practical demands of their roles. This study underscores the need for a balanced approach to safety training, one that harmonises theoretical knowledge with essential hands-on experience, as suggested by the broader discussions in the Literature Review.

Furthermore, the survey data revealed an intriguing contradiction. Out of 56 respondents, 39 reported experiencing underground utility strikes, with 28 encountering four or more strikes. Yet, of those 39 respondents, 31 rated the effectiveness of their safety training as "Extremely Effective" or "Very Effective." This apparent disconnect between frequent strike occurrences and positive training appraisals prompts closer examination through psychological and organisational lenses.

Cognitive dissonance theory (Festinger, 1957) provides a potential explanation. Workers may be inclined to reconcile the mismatch between training and frequent strikes by reaffirming the training's perceived effectiveness. Such a response could alleviate internal dissonance and preserve confidence in the safety system.

Additionally, optimism bias (Weinstein, 1980) might lead workers to underestimate their personal vulnerability. They might believe that they are exceptions–equipped with the skills provided through training–while overlooking broader systemic factors that increase strike probability.

The influence of organisational culture also deserves consideration. A work environment that implicitly or explicitly prioritises productivity over safety adherence might foster the normalisation of deviance (Vaughan, 1996). Repeated exposure to risk potentially desensitises workers. Within this context, training might primarily be viewed to mitigate severe outcomes rather than a tool for outright strike prevention.

These psychological dynamics suggest an interplay between workers' experiences of utility strikes, their perceptions of safety training effectiveness, and the underlying cognitive processes that reconcile these aspects. Engaging with these psychological constructs could provide a better understanding of the efficacy of safety training programs and strategies to enhance risk perception and management in the highway electrical sector. This area, ripe for further investigation, warrants attention in future studies focusing on the development of safety interventions that not only address the practical gaps in training but also consider the psychological factors influencing workers' perceptions and behaviours towards safety practices.

11.6.2.5. Frequency of Checking for Cables and Confidence to Avoid Strikes

The study's exploration into the correlation between the frequency of checking for underground cables and workers' confidence in avoiding utility strikes unveils a paradox that invites critical examination. The statistical analysis, indicating a negative correlation (-.354, $p=0.007$), suggests that workers who diligently check for cables before excavation report lower confidence in their ability to avoid strikes. This is seemingly counterintuitive.

Evaluating this finding, several factors come to the fore. Firstly, the consistent checking for underground utilities, while a hallmark of safety-conscious behaviour, may inadvertently heighten workers' awareness of the multitude of risks present, leading to a more cautious outlook. This vigilance, though beneficial in preventing accidents, could also foster a sense of uncertainty or doubt about the effectiveness of these precautionary measures, as evidenced by the workers' narratives. One worker's reflection that “*Service cable not marked on drawing. Pot ends not identifiable. Ukpn not at correct depths*”, illustrates an encounter with a previously undetected cable, and encapsulates this heightened state of caution, underscoring the inherent unpredictability of underground environments despite the use of detection tools like CAT & GENNY.

This observation aligns with the insights from the Literature Review, where studies such as those by Metje et al. (2015) and the reports by ENA (2020) underscore the unpredictable nature of underground utilities. These resources suggest that even with rigorous checks, the possibility of encountering unmarked or inaccurately documented utilities remains a significant challenge, which could explain the reduced confidence among diligent workers.

Furthermore, the qualitative feedback reveals an acceptance among workers of the inevitability of strikes, irrespective of the precautions taken. This resignation to the potential for accidents, despite adherence to safety protocols, reflects a realistic appraisal of the limits of current practices and technology in eliminating the risk of utility strikes. It also highlights a gap in the safety training and the effectiveness of detection tools, where workers are trained and equipped to mitigate risks but still acknowledge the limitations of these measures.

Additionally, the critical evaluation must consider the psychological impact of experiencing or witnessing utility strikes on workers' confidence levels. Those who frequently engage in precautionary checks might do so out of a heightened sense of risk, possibly stemming from past incidents. This experience, rather than reassuring workers of their safety measures' effectiveness, might instead serve to remind them of the ever-present danger of utility strikes, thus lowering their confidence in completely avoiding such incidents.

In essence, this paradoxical finding challenges the assumption that increased safety measures directly correlate with greater confidence in risk avoidance. Instead, it suggests that a deeper understanding of the risks, amplified by frequent checks and personal experiences of strikes, contributes to a perhaps less confident outlook on the ability to avoid utility strikes entirely. This insight calls for a re-evaluation of current safety protocols and training programs, advocating for approaches that not only emphasise the technical aspects of risk avoidance but also address the psychological impacts of risk awareness on worker confidence.

11.6.2.6. Examining Age and Utility Strike Frequency

The survey data reveals a troubling trend: utility strikes are experienced at high rates across most age groups. While the 18-24 group had a 100% strike rate (which warrants caution due to the small sample size), the 45-54 bracket also exhibited a concerningly high percentage of strikes. This challenges the assumption that greater experience automatically translates to reduced risk.

To specifically address the question of younger vs. older workers, further analysis is needed. While raw percentages suggest younger groups may have it worse, statistical tests (e.g., Chi-Square) could determine if these differences are statistically significant after accounting for the unequal sample sizes in each age category. Regardless of the precise outcome, these results raise important questions about whether age-specific training or interventions could mitigate risks for both younger and more experienced workers.

11.6.2.7. Resonance with the Literature and Broader Context

These results underscore the systemic challenges highlighted by the CGA Locator White Paper (2020) and DIRT Report (2023). The emphasis on a potential trade-off between rapid response times and locate accuracy echoes the concerns raised within the UK highway electrical sector regarding potential pressures compromising safety protocols. Furthermore, the need for better data management and technological advancements aligns with Objective 3 of this thesis. Both the CGA documents and this study highlight that achieving improved safety outcomes will likely require a multi-faceted approach that tackles procedural limitations as well as cultivating a strong safety culture.

The findings regarding higher strike prevalence among older workers also invite a cross-sector comparison with Rauscher et al.'s (2010) study on young construction workers. Their observation that larger workgroups reported both greater hazard exposure AND greater safety practices aligns with Objective 4 of the current study. This dynamic, where both risks and safety measures seem elevated, could be relevant to the highway electrical context. Perhaps factors like team size and composition influence workers' safety behaviours.

11.6.3. Methodological Reflections and Future Directions

This study's combination of survey data and interviews offered valuable insights into worker attitudes and experiences regarding utility strikes. However, the emphasis on Likert-scale items, while providing quantifiable trends, may have constrained the exploration of reasoning behind safety practices and the social dynamics influencing workplace behaviours. It was found that Likert scales, with their limited response options, can sometimes mask the individual motivations that the open-ended interview questions and qualitative analysis can reveal.

While the interviews provided valuable qualitative depth, the study could benefit from a follow-up with a larger interview cohort or the inclusion of focus groups. This expanded qualitative approach would prioritise open-ended exploration, potentially illuminating the lived experiences, challenges, and decision-making processes of workers more comprehensively.

Additionally, future research should consider incorporating longitudinal studies to track changes in worker attitudes and safety practices over time. This would provide insights into the long-term effectiveness of safety interventions and training programs. Moreover, integrating more advanced statistical techniques, such as structural equation modelling (SEM) Wikipedia, (2024), could help in understanding the relationships between training effectiveness, organisational culture, and safety outcomes.

11.6.4. Discussion Summary

In examining the perspectives and experiences of highway electrical workers concerning the risk of underground utility strikes, the study uncovered a narrative that combines quantitative findings with the personal stories shared by the workers. The statistical analysis lays bare trends that align closely with the descriptive feedback from those on the front lines, offering an insight into the challenges and safety perceptions encountered daily.

A recurring theme is the continued risk of utility strikes among workers who have faced such incidents in the past. This observation from the data analysis is brought to life by the workers' own accounts, which detail an enduring state of alertness and an increased sense of caution, even in the face of technological assurances. One worker's experience of anticipating cable encounters, despite the use of detection tools, underscores the profound effect of past incidents on their approach to risk.

This substantiates the perception of inevitability surrounding cable strikes in the highway electrical sector, echoing Patel et al. (2012). It highlights a systemic issue, where despite adherence to safety measures, workers frequently encounter utility strikes, reinforcing the belief that such incidents are an inevitable aspect of their work. This belief suggests that current safety protocols may not be fully effective in altering worker attitudes or behaviours. Furthermore, the gap between the safety training provided and its application in practical settings is evident, underscoring the need for a shift towards integrating safety as a foundational value, supported by leadership commitment. This analysis confirms the literature's findings on the perception of inevitability in cable strikes.

Discussions on the relationship between the occurrence of utility strikes and workers' views on their supervisors' commitment to safety reveal insightful dynamics within the industry. Many workers share stories highlighting a discrepancy between the urgency to meet project deadlines and the implementation of safety measures, suggesting a need for greater alignment between managerial expectations and safety priorities.

Moreover, the analysis points to a noticeable shift in how experienced workers perceive formal safety protocols, such as adherence to statutory plans. Experienced workers in the field often report a reliance on personal judgment over official guidelines, suggesting an understanding of risk management gained through years of experience. However, this reliance on personal experience raises questions about potential complacency towards formal safety measures.

The effectiveness of training and its impact on safety measures is another intersection where quantitative data and qualitative narratives meet. While the overall confidence in the current training framework is acknowledged, there is a clear call from workers for training that is not only comprehensive but also directly applicable to the realities of their work environment.

This study echoes Donaghy (2009) by examining how close relationships affect safety behaviours among highway electrical workers. It highlights the importance of leadership and promoting a safety-first culture, alongside understanding individual experiences and the collective workplace ethos. By combining empirical data with workers' stories, this discussion emphasises the need for a safety culture that values procedural adherence and recognises the impact of family connections on motivating safer work practices. Integrating these family considerations into safety training and leadership could be key to improving safety in the industry.

The study also delves into the paradoxical relationship between the regularity of checking for underground cables and the confidence in avoiding strikes. Despite diligent checks, the acceptance of the occasional inevitability of strikes amongst workers highlights a realistic appraisal of the limitations of current safety practices.

These insights about specific aspects of safety procedures pave the way for the broader conclusions outlined below.

12. Conclusions

12.1. Introduction

This study explored the widespread issue of underground utility strikes in the UK's highway electrical sector, aiming to deepen understanding and enhance safety practices.

The research employed a mixed-methods approach, combining quantitative and qualitative analyses to gather insights. Surveys and interviews were conducted to gauge the effects of safety training, attitudes towards risks, and the influence of factors like organisational culture and leadership on safety perceptions.

The methodology, designed for data collection, involved selecting participants across various roles within the industry, ensuring a broad spectrum of perspectives. This approach facilitated an examination of the interplay between safety training, worker attitudes, and industry practices, aiming to identify actionable strategies for reducing utility strikes.

12.2. Review of Research Problem

The research problem identified throughout the study was the ongoing challenge of underground utility strikes within the highway electrical sector. This issue was examined through the lens of highway electrical workers' attitudes and experiences, revealing the balance between safety protocols, training effectiveness, and the practical realities of fieldwork.

The study underscored the need for systemic improvements in safety training, more accurate utility mapping, and a culture shift towards prioritising safety equally with productivity.

12.3. Review of Research Goals

The research aimed to conduct an analysis of safety issues arising from underground utility strikes within the UK's highway electrical sector, focusing on the factors influencing electrical workers' perceptions of risk. These factors included their understanding of safety protocols, the effectiveness of training programs, and the impact of company culture.

The goal was to generate insights and recommendations to enhance safety practices and reduce the incidence of accidents associated with underground utility strikes.

To assess whether this study met its objectives and, by extension, its overarching aim of an examination of each objective, will be undertaken sequentially. Before this evaluation, it is important to reflect on the research methodology, which played a pivotal role in shaping the research goals.

12.4. Review of the Method

The research methodology adopted in this thesis aimed to provide a framework for investigating the attitudes of highway electrical workers towards the risks of underground utility strikes. This mixed-methods approach, combining quantitative and qualitative analyses, proved to be a successful strategy.

12.4.1. Strengths of the Mixed-Method Approach

The quantitative component, supported by Spearman Rank Correlation Tests, Bootstrap Resampling and One-Sample T-Tests, served its purpose well. These statistical tools were instrumental in identifying patterns and correlations within the dataset collected through the online survey. They helped to establish trends in worker attitudes and risk perception across various demographics and experience levels.

However, the true strength of the adopted methodology lies in its integration of qualitative data. Content analysis of open-ended survey responses and the on-site observation provided valuable insights that extended beyond the confirmatory nature of statistical tests. These qualitative aspects uncovered the underlying reasons and motivations behind worker attitudes, revealing the "why" behind the "what" identified through quantitative analysis.

For example, quantitative analysis might reveal a correlation between years of experience and risk perception. However, qualitative data through content analysis could explain why more experienced workers might feel less confident about identifying underground utilities. This deeper understanding of worker perspectives wouldn't have been possible solely through statistical analysis.

By combining both quantitative and qualitative methods, this research achieved an understanding of highway electrical workers' attitudes towards utility strike risks. The quantitative analysis provided evidence of trends and correlations, while the qualitative aspects illuminated the underlying reasons and motivations shaping these attitudes. This triangulation of findings strengthens the overall conclusions drawn from the research.

Despite efforts to maintain the quality and integrity of the research process through methodical design, ethical considerations, and a systematic approach to data analysis, it is essential to acknowledge the inherent limitations of the study. Primarily, the development and execution of this research were undertaken by a single researcher, which presents both strengths and limitations. On one hand, this allowed for a consistent vision and approach throughout the research process. On the other hand, the decisions made at various stages of the research—from the design to the interpretation of data—reflect the perspectives and judgments of an individual.

This individual-centric approach inherently limits the research, as it confines the analysis to the interpretations and methodological decisions of one researcher. It is conceivable that other researchers, bringing their perspectives might have arrived at different interpretations of the data or even questioned the suitability of the chosen methodological structure. The subjective nature of qualitative analysis underscores this point, as it relies heavily on the researcher's ability to interpret and make sense of the data within the context of existing literature and theoretical frameworks.

It is also important to consider the possibility of alternative analytical interpretations and methodological structures that other researchers might propose. Such alternatives could potentially offer different insights or highlight aspects not captured by this study. The acknowledgement of these limitations is not to diminish the value of the research conducted but to situate its findings within a broader context of scholarly inquiry.

12.5. Review of Aim

This research aimed to look into the factors that shape highway electrical workers' risk perceptions of underground utility strikes in the UK, with a particular emphasis on the influence of training, organisational culture, and worker experience. The study sought to generate evidence-based strategies to enhance safety practices within this sector. A thorough analysis of the findings demonstrates that the research has successfully fulfilled its stated aim.

The investigation examined the impact of safety training, organisational culture, leadership styles, and the diverse experiences of workers on their attitudes towards utility strike risks. The results revealed the importance of practical training that specifically addresses tools like hydraulic breakers, which were frequently associated with strikes. Additionally, a strong safety culture and proactive leadership were found to promote a positive safety climate within companies and adherence to safety measures. The data highlighted that both intrinsic motivation and external recognition play a role in shaping safety consciousness among workers.

Crucially, the research identified the interplay between age, experience, and the likelihood of encountering underground utility strikes. While younger workers may benefit from age-specific training to bridge knowledge gaps, the study emphasised the importance of continuous learning for all workers, regardless of tenure.

The researcher believes this research has been successful in generating well-substantiated insights that align with the aims and support the development of actionable recommendations, and these findings will be put to industry to drive improvements in safety practices within the highway electrical sector.

12.6. Review of the Objectives

Objective 1, *Conduct a literature review to synthesize existing knowledge on risk perception in the construction industry (relating to underground utility strikes) identifying gaps and areas for further research.*

This study began with a literature review to understand existing research on risk perception in the construction industry and to pinpoint areas where further investigation is needed. Several key themes emerged from this review, which aligned with the findings of this thesis. These themes include the economic and safety costs of utility strikes, the importance of accurate data, and the critical role of safety training.

Crucially, the review also revealed a significant gap in the research: there's a lack of in-depth understanding about the specific attitudes of highway electrical workers towards safety and the risks they face. This study directly addresses this gap by offering an exploration of workers' perspectives, adding depth to the existing knowledge base.

Furthermore, the literature review underscored the urgency of research focused on preventing underground utility strikes. It identified a need to better understand the human factors, organizational culture, and broader systemic barriers that contribute to these incidents. This study takes a step towards addressing this need by investigating these factors.

Conclusion

Objective 1 has been successfully met. The literature review provided a theoretical foundation for this research and guided the methodology. By comparing this study's findings with existing literature, it's clear that this work contributes valuable new insights, helping address a gap in our understanding of how to prevent utility strikes in the highway electrical sector.

Objective 2, *Analyse how current mandated & company specific training programs shape highway electrical workers' attitudes towards the risks of utility strikes.*

This study aimed to analyse how current training programmes shape highway electrical workers' attitudes towards the risk of utility strikes. Findings strongly indicate that training plays a crucial role in shaping overall safety culture.

Survey data shows a clear positive correlation between workers' perceptions of training effectiveness and their confidence in existing safety measures. This highlights the importance of delivering high-quality, relevant training that aligns with the realities of the job site. Workers who receive such training are more likely to embrace safety protocols and believe in their effectiveness.

Qualitative feedback powerfully reinforces this finding. Workers advocate for practical, hands-on training that directly prepares them for the specific challenges they encounter. However, a notable disconnect continues to exist between the theoretical aspects of training and the practical application of safety knowledge on the job. To address this gap and create more immersive training experiences, incorporating the following elements would be beneficial:

Prioritise Hands-On Learning: Include simulations or site-specific scenarios that directly prepare workers for the challenges they will encounter.

Provide Equipment-Specific Training: Focus on the safe use of tools frequently involved in utility strikes, such as hydraulic breakers.

Conclusion

Objective 2 has been successfully met. This study offers clear evidence that effective training is essential for fostering a safety-conscious workforce and minimising the risk of utility strikes. While progress has been made, the persistent gap between theory and practice underscores the need for ongoing innovation in training programs within the highway electrical sector.

Objective 3, *Explore the relationship between organisational culture (including leadership and safety communication) and highway electrical workers' adherence to safety practices.*

This study explored the relationship between organisational culture (with a focus on leadership and safety communication) and how it shapes highway electrical workers' adherence to safety practices, particularly in the context of underground utility strikes. Findings reveal both positive trends and areas where improvements are needed.

Leadership has a profound impact. Workers are significantly more likely to follow safety protocols when they believe leaders are genuinely committed to their wellbeing. However, challenges remain in ensuring consistent safety behaviours across the workforce. The persistent tension between meeting productivity goals and upholding safety standards presents a significant barrier. Addressing this tension requires a systemic shift where:

Leaders Model Safety: Leaders at all levels must visibly demonstrate their commitment to safety, even when productivity pressures are high.

Communication is Two-Way: Effective safety communication must encourage worker feedback and address concerns raised from the field.

Conclusion

Objective 3 has been successfully met. This study offers insights into how organisational culture can both support and hinder worker safety in the highway electrical sector. The findings underscore the importance of strong leadership and open communication channels to create a robust safety culture. However, the research also points to the need for a broader transformation within the industry, where safety is consistently prioritised.

Objective 4, *Compare risk perceptions of underground utility strikes among highway electrical workers with different levels of experience.*

This study sought to compare how highway electrical workers with different experience levels perceive the risk of underground utility strikes. Findings reveal how experience significantly shapes workers' attitudes in several ways.

First, while all workers recognise the risks, experienced workers often express scepticism towards formal safety protocols like statutory plans. This scepticism likely stems from a reliance on practical knowledge gained through past encounters, highlighting a disconnect between lived experiences and formal guidelines. Addressing this disconnect is a key challenge for the industry, requiring safety protocols to better reflect and resonate with the realities faced by workers.

Additionally, the study found that even after extensive training, workers at all experience levels frequently encounter utility strikes. This reinforces a sense of inevitability that may undermine safety efforts and points to a limitation of training on its own. This highlights the need for a more proactive, deeply embedded safety culture within the sector – one driven by strong leadership.

Leadership plays a vital role. When workers believe leaders genuinely value safety, they are more likely to prioritise it themselves. Close personal relationships were also found to influence safety behaviours, though further research is needed to explore this dynamic.

Conclusion

This objective has been successfully met. The study illuminates the complexities of how workers' perceptions of risk vary based on experience. Several key challenges emerge:

- Statutory Plan Reliability: Ensuring these tools accurately reflect on-site conditions is essential for building worker trust.
- Hands-On Training: Training must directly mirror the challenges workers face to be truly effective.
- Fostering a Safety-Centric Culture: While training is vital, leaders must consistently model safety behaviours to create lasting change.
- Understanding Worker Psychology: Addressing the sense of inevitability around strikes and exploring the role of personal relationships in promoting safety awareness are areas for future research.

Objective 5, *Develop recommendations to improve safety practices and reduce underground utility strikes based on research findings.*

This thesis has successfully achieved its final objective: developing actionable recommendations to improve safety practices and reduce underground utility strikes within the highway electrical sector. These recommendations offer a strategy, combining the need for further research with practical interventions for the industry.

The recommendations are grounded in the study's findings, addressing the interplay of psychological factors, training needs, and systemic issues. Several key themes emerge:

- Focus on Worker Well-Being: Research into the psychological impact of strikes and age-specific training modules prioritises the needs of the workforce.
- Data-Driven Prevention: A proposed database for incident tracking will allow for evidence-based improvements.
- Innovation: Scenario-based training, technology upgrades, and a cross-sector task force demonstrate a commitment to proactive safety solutions.
- Sustainability: The cost-benefit analysis underscores the importance of finding solutions that are both effective and financially feasible for the industry.

This approach to safety improvement holds the potential to transform practices within the highway electrical sector. By implementing these recommendations, the industry can create a stronger safety culture, ultimately protecting both workers and critical infrastructure.

12.7. Contribution to Knowledge

This research has contributed to the existing body of knowledge surrounding safety practices in the highway electrical sector, specifically concerning underground utility strikes. By focusing on the attitudes and experiences of highway electrical workers, the study has provided new insights into risk perception that were not fully explored in previous research. Key contributions include:

- Practical Training: Highlighting the role of practical, hands-on training that addresses specific tools like hydraulic breakers.
- Organisational Culture: Demonstrating how organisational culture and leadership influence safety attitudes and practices.
- Age and Experience: Providing insights into how age and experience impact the likelihood of encountering utility strikes, informing tailored training and risk mitigation strategies.

These findings have the potential to directly enhance safety within the industry. The study's recommendations will be shared with the Highway Electrical Association (HEA) to inform potential alterations to industry-wide training programs, ensuring they align with the identified needs. By bridging the gap between research and practice, this study contributes to improvements in the safety of highway electrical workers, reducing the risks associated with underground utility strikes.

12.8. Limitations of the Study

Although this research provides important insights into safe work attitudes of highway electrical workers, readers should be mindful of some of the limitations of this research themselves, for a balanced interpretation. First, the sample composition, though representative of the existing workforce for highway electrical workers (for instance, the industry is still predominantly comprised of older men, and this was the same in this sample), limits generalisability to a more diverse workforce in the future. Recruitment strategies deliberately targeting individuals across a broader spectrum of age and gender could provide an additional layer of usefulness and wider applicability of this work. Second, relying mostly on Likert-scale questions also limited what kind of answers could be provided on the survey, and what data analysis options were available overall. An increase in open-ended questions, in combination with qualitative analysis in addition to statistical measures, could lend itself to a richer sense of data analysis and shape what is known about worker perceptions more subtly.

A full-time job and a part-time degree did not afford me the time to cultivate a larger sample or do more interviews. The results would have been strengthened with a sizable sample and greater depth of interview time. While 56/300 is a modest but acceptable response rate, more interviews might have made the findings better still, and the researcher and his senior position might have introduced some response bias into the study. That is, participants might have felt moved to tailor their comments to what they perceived as industry expectations. Researchers may unintentionally introduce bias when they try too hard to appear neutral, especially in a less controlled setting outside the laboratory. In a project of this kind, which might be seen by some participants as a researcher from outside the community, efforts to identify and manage potential response bias are well worth the effort.

Concurrent with the study’s examination of attitudinal safety factors, the researcher was engaged in full-time employment and the pursuit of a master’s degree. This division of focus potentially constrained the depth of analysis undertaken, as well as the ability to thoroughly investigate emergent themes.

13. Recommendations

13.1. Introduction

The preceding chapters have outlined the challenges highway electrical workers grapple with when it comes to underground utility strikes, offering a detailed examination of the attitudes, experiences, and contributing factors. This Recommendations section aims to translate the study's findings into actionable steps that can enhance safety practices and minimise the risk of these potentially disruptive and dangerous incidents. The recommendations are divided into two categories: Firstly, areas for further academic research to deepen our understanding of the problem and illuminate solutions, and secondly, targeted interventions for the industry to implement and cultivate a more robust safety culture within the sector.

13.2. Recommendations for Further Academic Research

Three recommendations are made here, aimed at further expanding the conclusions found in this study.

1. **Psychological Impact of Utility Strikes:**

Design studies to investigate the long-term psychological and emotional effects of utility strikes on both individual workers and the overall safety culture within the highway electrical sector. Investigate cognitive dissonance (Festinger, 1957), optimism bias (Weinstein, 1980), and the normalisation of deviance (Vaughan, 1996) to understand their influence on safety attitudes and behaviours of highway electrical workers.

2. **Impact of Time Pressure:**

Research should quantify the correlation between project deadlines and the frequency of utility strikes. This involves data collection on project timelines, deadlines, and incident reports. Understanding this correlation will help in designing strategies to mitigate risks associated with time pressures, such as better planning, realistic scheduling, and stress management training for workers.

3. **Investigation of Temporal Patterns in Utility Strikes:**

Future research should examine temporal patterns in underground utility strikes to determine if specific times of day are associated with higher incidences. This includes factors such as worker fatigue, shift changes, lighting conditions, and deadline pressures. Identifying these patterns will inform targeted interventions to reduce risks during high-incidence times, enhancing both worker safety and operational efficiency.

13.3. Industry Recommendations for Interventions

There are five recommendations, within three headings.

13.3.1. Transform Safety Training

4. **Implement Scenario Based Training Prioritising Real-World Challenges:**

Develop training models that centre on realistic scenarios replicating the specific challenges highway electrical workers face, particularly shallow services, utilities embedded in concrete, and other complex installation situations. Develop detailed training scenarios that closely mirror on-the-job hazards.

Prioritise hands-on training activities that simulate the physical challenges of working safely around these hazards. Provide facilities and resources that allow workers to develop the skills and judgment needed for excavation, exposing of services, and safe work practices.

If budget and resources allow, integrate augmented or virtual reality technologies to aid with the following:

- Visualising underground service locations to enhance planning and risk assessment.
- Providing diverse CAT scanning practice for complicated scenarios to ensure accurate interpretation.

5. **Tool-specific training:**

To enhance safety measures for hydraulic breakers, it is essential to introduce specialised training modules that focus on operational techniques, risk identification, and safety protocols specific to this equipment. The training should include practical exercises that simulate on-site conditions, maintenance best practices to ensure tool integrity and expert-led sessions for knowledge exchange. These targeted modules aim to fill the current gap in mandatory industry training, equipping workers with the necessary skills to safely operate hydraulic breakers in proximity to underground utilities.

6. **Experience-related Training:**

Implement a two-tiered safety training approach. For inexperienced workers, provide intensive hands-on training modules that simulate real-world scenarios, bridging the gap between theoretical learning and practical application. For experienced workers, restructure training to combat complacency through advanced problem-solving workshops that challenge their existing knowledge and introduce innovative safety practices. This ensures training is relevant and engaging for all workers, reinforcing lifelong learning.

13.3.2. Statutory Plan Accuracy and Accessibility

7. **Establish a Cross-Sector Task Force:**

Form an interdisciplinary task force including frontline workers, highway electrical contractors, utility providers, and regulatory authorities. This task force should enhance statutory plans to ensure they are up-to-date, accurate, and user-friendly. It will serve as a collaborative platform for regular review and optimisation of statutory plan quality, integrating field experiences and technological advancements.
Advocate for integrating statutory plan improvements with the National Underground Asset Register (NUAR) initiative, contributing to national efforts to safeguard workers and infrastructure.

13.3.3. Invest in Technology and Innovation

8. **Data-Driven Prevention:**

Establish a central database to track incidents and near-misses involving underground utilities. Record detailed information such as location, utility depth, tools used, and incident circumstances. Analysing this data will identify trends and weaknesses, allowing for evidence-based prevention strategies. Use these insights to develop targeted safety interventions and continuously improve safety protocols.

As noted, these 5 recommendations for interventions are made with the intention of developing and improving existing safety management systems of UK highway electrical contractors.

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16. Appendix

16.1. Coding Data – Python code to create a codebook from data

One-hot encoding for categorical data.
Numerical encoding for ordinal data.
Multi-label binarization for multi-select categorical data, such as the tools involved in utility strikes.

```
from sklearn.preprocessing import OneHotEncoder, MultiLabelBinarizer
# Helper function to clean and split concatenated columns into lists
def clean_and_split(df, column_name):
    # Drop the header row in the data which has 'Response' as entries
    df = df[df[column_name] != 'Response']
    # Split the concatenated strings into lists
    df[column_name] = df[column_name].str.split('|').apply(lambda x: [item.strip() for item in x]
if isinstance(x, list) else [])
    return df

# Clean and split the concatenated columns for tools and reasons
data = clean_and_split(data, 'Concatenated_Column_Tools')
data = clean_and_split(data, 'Concatenated_Column_Reasons')

# One-hot encode categorical variables
categorical_columns = ['What is your age group?', 'What is your gender?',
                       'How many years have you worked in the highway electrical industry?',
                       'Have you ever had an underground utility strike at your work?',
                       'Do you feel that the safety measures currently in place are sufficient to
prevent underground utility strikes?',
                       'How often do you receive safety training related to underground utility
strikes?',
                       'How often do you check for underground cables before beginning work?
(Select one)',
                       'During what time of day do most utility strikes occur in your experience?',
                       'How effective are recognition and awards in motivating you to adhere to
safety protocols? ',
                       'How effective do you think any training you have had to prevent utility strikes
has been?',
                       'How interested do you think your Supervisor is over your safety?',
                       'How important do you think the accuracy of stat plans is when preventing
utility strikes?']

one_hot_encoder = OneHotEncoder(sparse=False)
encoded_categorical_data =
one_hot_encoder.fit_transform(data[categorical_columns].astype(str))
encoded_categorical_df = pd.DataFrame(encoded_categorical_data,
columns=one_hot_encoder.get_feature_names(categorical_columns))

# Merge the one-hot encoded columns back with the original data
processed_data = data.join(encoded_categorical_df).drop(categorical_columns, axis=1)

# Numerically encode ordinal variables
ordinal_mappings = {
```

```
    '0-3': 1,
    '4-6': 2,
    '7-10': 3,
    '10+': 4
}
processed_data['How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?'] = processed_data[
    'How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?'].map(ordinal_mappings)

# Multi-label binarize the concatenated columns for tools and reasons
mlb_tools = MultiLabelBinarizer()
mlb_reasons = MultiLabelBinarizer()

tools_binarized = mlb_tools.fit_transform(data['Concatenated_Column_Tools'])
reasons_binarized = mlb_reasons.fit_transform(data['Concatenated_Column_Reasons'])

tools_binarized_df = pd.DataFrame(tools_binarized, columns=mlb_tools.classes_)
reasons_binarized_df = pd.DataFrame(reasons_binarized, columns=mlb_reasons.classes_)

# Merge the binarized columns back with the processed data
processed_data =
processed_data.join(tools_binarized_df).join(reasons_binarized_df).drop(['Concatenated_Column_Tools', 'Concatenated_Column_Reasons'], axis=1)

# Save the processed data to a new Excel file
output_file_path = '/mnt/data/Coded_Highway_Electrical_Workers_Data.xlsx'
processed_data.to_excel(output_file_path, index=False)

output_file_path
```

Codebook creation

```
# Create a codebook dictionary with explanations for the coding scheme
codebook_dict = {
    'Variable': [],
    'Category': [],
    'Code': [],
    'Definition': []
}

# The data provided contains the first row as 'Response', which we will skip
# Populate the codebook dictionary with codes based on the unique values in each column
for column in data_for_coding.columns[1:]:  # Skip the first column which is an ID column
    # Skip the concatenated columns for now
    if column.startswith('Concatenated'):
        continue

    # Get unique values excluding 'Response'
    unique_values = data_for_coding[column][1:].unique()

    # Depending on the type of the data, we assign codes differently
    if column == 'What is your age group?':
        # This is an ordinal variable
```

```
        age_groups = ['Under 18', '18-24', '25-34', '35-44', '45-54', '55-64', '65 and over']
        for i, value in enumerate(age_groups):
            codebook_dict['Variable'].append(column)
            codebook_dict['Category'].append(value)
            codebook_dict['Code'].append(i+1)
            codebook_dict['Definition'].append(f"Respondents aged {value}")
    elif column == 'What is your gender?':
        # This is a categorical variable with known categories
        genders = {'Male': 1, 'Female': 2, 'Prefer not to say': 3, 'Other': 4}
        for value, code in genders.items():
            codebook_dict['Variable'].append(column)
            codebook_dict['Category'].append(value)
            codebook_dict['Code'].append(code)
            codebook_dict['Definition'].append(f"Respondents who identify as {value}")
    else:
        # For all other columns, treat as categorical
        for code, value in enumerate(unique_values, start=1):
            codebook_dict['Variable'].append(column)
            codebook_dict['Category'].append(value)
            codebook_dict['Code'].append(code)
            codebook_dict['Definition'].append(f"Response indicating {value}")

# Create a DataFrame from the codebook dictionary
codebook_df = pd.DataFrame(codebook_dict)

# Save the codebook DataFrame to an Excel file
codebook_file_path = '/mnt/data/Codebook_Highway_Electrical_Workers_Data.xlsx'
codebook_df.to_excel(codebook_file_path, index=False)

codebook_file_path
```

16.2. Concatenate ‘Tools’ & ‘Reason’ data

```
import pandas as pd
from scipy.stats import chi2_contingency

# Load the data from the Excel spreadsheet
data = pd.read_excel('Concatonnated_Highway_Electrical_Workers_v3.xlsx')

# Get the list of column headings to test
columns_to_test = [
    'What is your age group?',
    'What is your gender?',
    'How many years have you worked in the highway electrical industry?',
    'Have you ever had an underground utility strike at your work?',
    'How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?',
    'Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?',
    'How often do you receive safety training related to underground utility strikes?',
    'How often do you check for underground cables before beginning work? (Select one)',
    'During what time of day do most utility strikes occur in your experience?',
```

```
    'How effective are recognition and awards in motivating you to adhere to safety protocols?',
    'How effective do you think any training you have had to prevent utility strikes has been?',
    'How interested do you think your Supervisor is over your safety?',
    'How important do you think the accuracy of stat plans is when preventing utility strikes?',
    'On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates \'No Influence At All\' and 10 indicates \'Significant Influence\')',
    'On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike? (1 indicates being not confident at all, 10 indicates being very confident)',
    'Concatenated_Column_Tools',
    'Concatenated_Column_Reasons'
]

# Perform tests for all combinations of columns
for i in range(len(columns_to_test)):
    for j in range(i+1, len(columns_to_test)):
        column1 = columns_to_test[i]
        column2 = columns_to_test[j]

        # Create a contingency table for the two columns
        observed_table = pd.crosstab(data[column1], data[column2])
```

16.3. Codebook

Table 6 Codebook

Question	Variable Name	Description	Data Type	Possible Values	Codes
1	What is your age group?	What is your age group?	Categorical	45-54, 35-44, 25-34, 55-64, 18-24, Under 18	1, 2, 3, 4, 5, 6
2	What is your gender?	What is your gender?	Categorical	Male, Female	1, 2
3	How many years have you worked in the highway electrical industry?	How many years have you worked in the highway electrical industry?	Categorical	2-4 years, 10 years and above, 5-9 years, 0-1 years	1, 2, 3, 4
4	Have you ever had an underground utility strike at your work?	Have you ever had an underground utility strike at your work?	Categorical	Yes, No	1, 2
5	How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?	How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?	Categorical	0-3, Greater than 10, 7-10, 4-6	1, 2, 3, 4
6	Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?	Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?	Categorical	Yes, No	1, 2
7	How often do you receive safety training related to underground utility strikes?	How often do you receive safety training related to underground utility strikes?	Categorical	Annually, Quarterly, Monthly, Never, Once in a while, Refreshed when service strikes happen, When expiry date is near (every 3 years), Not sure (for new employees, etc.), Regular toolbox talks/updates, Self-study, Discussed in training (weekly), Every 5 years, Other (specify if possible)	1, 2, 3, 4, 5, 6,7,8,9,10,11,12,13,14
8	How often do you check for underground cables before beginning work? (Select one)	How often do you check for underground cables before beginning work? (Select one)	Categorical	Always, Never, Rarely, Usually	1,2,3,4
9	During what time of day do most utility strikes occur in your experience?	During what time of day do most utility strikes occur in your experience?	Categorical	Early morning (6:00 - 9:00), Don't know, Afternoon (12:00 - 17:00), Night (20:00 - 6:00), Mid-morning (9:00 - 12:00), Evening (17:00 - 20:00)	1, 2, 3, 4, 5, 6
10	How effective are recognition and awards in motivating you to adhere to safety protocols?	How effective are recognition and awards in motivating you to adhere to safety protocols?	Categorical	Very likely, Very unlikely, Likely, Neither likely nor unlikely, Unlikely	1, 2, 3, 4, 5
11	How effective do you think any training you have had	How effective do you think any training you have had to prevent utility strikes has been?	Categorical	Extremely effective, Somewhat effective, Very effective, Not so effective, Not at all effective	1, 2, 3, 4, 5

	to prevent utility strikes has been?				
12	How interested do you think your Supervisor is over your safety?	How interested do you think your Supervisor is over your safety?	Categorical	Extremely interested, Very interested, Not at all interested, Not so interested, Somewhat interested	1, 2, 3, 4, 5
13	How important do you think the accuracy of stat plans is when preventing utility strikes?	How important do you think the accuracy of stat plans is when preventing utility strikes?	Categorical	Extremely important, Very important, Somewhat important	1, 2, 3
14	Which tool(s) are most commonly involved in utility strikes in your experience? (Select all that apply)	Descriptive, multiple-response data; no coding required.	Categorical	N/A	N/A
15	Can you identify any factors that you believe contribute to the occurrence of utility strikes in your experience? (Select all that apply)	Descriptive, multiple-response data; no coding required.	Categorical	N/A	N/A
16	On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')	Descriptive, multiple-response data; no coding required.	1-10 Scale	1-10	N/A
17	On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike? (1 indicates being not confident at all, 10 indicates being very confident)	Descriptive, multiple-response data; no coding required.	1-10 Scale	1-10	N/A

16.4. Coded data

Table 7 Coded data

What is your age group?	What is your gender?	How many years have you worked in the highway electrical industry?	Have you ever had an underground utility strike at your work?	How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?	Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?	How often do you check for underground cables before beginning work? (Select one)
1	1	2	1	1	1	2
1	1	2	2	1	2	2
4	1	2	2	1	1	2
3	1	3	1	2	2	1
4	1	2	2	1	2	1
3	1	1	2	1	2	1
1	1	2	1	3	2	1
2	1	2	2	1	1	1
2	1	2	1	2	2	1
1	1	2	1	2	2	1
1	1	2	1	1	1	1
1	1	3	1	1	1	1
5	1	1	1	1	2	3
3	1	3	2	4	1	1
2	1	2	1	4	2	1
3	1	2	1	4	1	1
2	2	2	2	1	1	1
1	1	2	1	2	1	1
3	1	1	2	1	1	1
1	1	2	1	2	2	2
3	1	3	1	1	1	4
4	1	2	1	1	1	1
4	1	2	1	4	1	2
2	1	2	1	2	1	1
1	1	2	1	3	1	1

2	1	2	1	1	1	1
4	1	2	1	4	1	1
1	1	2	1	4	2	1
3	1	3	1	1	1	3
1	1	2	1	2	2	1
2	1	2	2	2	1	1
1	1	3	1	4	1	4
1	1	2	1	2	1	1
2	1	2	1	3	1	1
1	1	2	1	2	2	1
3	1	4	2	1	1	1
1	1	2	2	2	1	1
4	1	2	1	2	2	1
4	1	2	2	2	1	1
2	1	3	1	4	2	1
1	1	2	1	1	1	1
2	1	3	1	4	1	1
3	1	2	1	2	1	1
1	1	1	1	1	1	1
2	1	2	1	2	1	1
3	1	4	2	1	1	1
2	2	4	2	1	1	1
1	1	2	1	3	1	1
1	1	2	1	4	1	1
2	1	2	1	2	2	1
6	1	4	2	1	1	1
1	1	2	1	2	2	1
1	1	2	2	1	1	1
1	1	2	1	3	1	1
3	1	4	2	1	1	1
5	1	1	1	1	1	1

During what time of day do most utility strikes occur in your experience?	How effective are recognition and awards in motivating you to adhere to safety protocols?	How effective do you think any training you have had to prevent utility strikes has been?	How interested do you think your Supervisor is over your safety?	How important do you think the accuracy of stat plans is when preventing utility strikes?	On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')	On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike? (1 indicates being not confident at all, 10 indicates being very confident)
2	3	5	5	2	8	10
3	4	5	1	3	7	7
2	4	2	1	2	1	7
3	4	2	2	1	1	7
3	4	5	1	1	10	8
2	4	4	3	1	7	6
5	3	3	1	1	5	9
2	4	1	1	2	0	10
2	2	2	2	1	1	9
2	2	2	2	1	8	7
2	3	3	2	1	0	5
2	4	1	2	1	5	5
3	3	2	3	3	5	9
6	4	3	1	1	5	7
2	4	2	1	1	8	9
5	4	1	1	2	1	9
5	4	1	1	2	10	8
5	2	3	1	2	1	8
2	3	3	2	1	8	8
2	2	3	2	1	8	10
4	3	1	2	1	7	0
5	4	3	2	2	5	9
3	1	3	2	1	7	10
5	1	3	2	1	0	9
3	1	2	2	1	2	8
3	3	3	2	2	1	9

2	4	3	2	2	8	10
5	3	3	2	3	7	10
2	2	2	4	1	6	9
3	5	3	1	1	1	9
4	3	3	1	1	0	8
4	2	1	1	1	10	10
2	4	1	1	1	0	10
1	3	3	1	2	1	5
3	4	3	1	1	0	10
2	3	1	1	1	7	10
3	1	3	1	1	5	7
4	5	3	2	3	1	9
3	5	3	2	1	5	10
5	4	2	2	1	0	8
5	4	3	2	3	10	8
3	1	3	5	1	6	8
5	3	1	5	2	10	8
1	1	1	1	1	10	8
3	2	3	1	2	5	10
2	1	1	1	1	5	6
2	4	1	1	1	1	8
2	4	3	1	1	10	9
1	4	1	1	1	10	8
5	2	3	1	1	5	8
2	1	1	1	1	1	10
2	3	3	1	3	1	8
2	4	3	1	1	1	9
3	1	1	2	1	2	8
3	3	3	2	1	10	7
3	3	1	3	2	1	9

16.5. Methodology for Data Cleaning and Preparation

Quantitative Data Management

The design of the online survey meant it prevented null entries for quantitative questions. This ensured complete datasets for these variables. Therefore, there was an absence of missing data within the quantitative sections of the survey. This approach meant that the data cleaning process was straightforward and there were no handwritten transcripts etc that needed cleansing. This allowed for a focus on quality and consistency checks rather than addressing missing values, which saved time in the later analysis.

Qualitative Data Handling

For qualitative responses, the survey questions allowed respondents to provide free-text answers. Several participants chose not to provide a response and so these were marked with a dash (-) to signify the absence of data, rather than an empty field that could be mistaken for a data error.

The survey also included checkbox responses for questions related to 'tools' and 'reasons for cable strikes', allowing respondents to select multiple answers. To enhance the analysis, these multiple responses were concatenated into single fields for both "tools" and "reasons". This process was instrumental in simplifying the subsequent analysis, with the specific Python scripts used for concatenation detailed in Appendix 2.

Data Coding and Integration for Analysis

The cleaned and prepared data underwent coding to enable analysis using Statistical Package for the Social Sciences (SPSS). This coding process, executed via a Python script (outlined in Appendix 1), transformed qualitative responses and concatenated fields into a format suitable for statistical analysis.

To ensure data integrity and compatibility with SPSS, survey data was exported directly into a CSV file. This step was crucial for preserving data formatting, especially for variables such as leading zeros, which can be inadvertently modified by spreadsheet software like Excel. The direct export to CSV format helped in maintaining the accuracy and consistency of the data set.

16.6. Frequency Tables

What is your age group?

	N	%
1	22	39.3%
2	13	23.2%
3	11	19.6%
4	7	12.5%
5	2	3.6%
6	1	1.8%

What is your gender?

	N	%
1	54	96.4%
2	2	3.6%

How many years have you worked in the highway electrical industry?

	N	%
1	5	8.9%
2	38	67.9%
3	8	14.3%
4	5	8.9%

Have you ever had an underground utility strike at your work?

	N	%

1	39	69.6%
2	17	30.4%

How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?

	N	%
1	24	42.9%
2	17	30.4%
3	5	8.9%
4	10	17.9%

Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?

	N	%
1	39	69.6%
2	17	30.4%

How often do you check for underground cables before beginning work? (Select one)

	N	%
1	47	83.9%

2	5	8.9%
3	2	3.6%
4	2	3.6%

During what time of day do most utility strikes occur in your experience?

	N	%
1	3	5.4%
2	21	37.5%
3	16	28.6%
4	4	7.1%
5	11	19.6%
6	1	1.8%

How effective are recognition and awards in motivating you to adhere to safety protocols?

	N	%
1	9	16.1%
2	8	14.3%
3	15	26.8%
4	21	37.5%
5	3	5.4%

How effective do you think any training you have had to prevent utility strikes has been?

	N	%
1	16	28.6%
2	9	16.1%
3	27	48.2%
4	1	1.8%
5	3	5.4%

How interested do you think your Supervisor is over your safety?

	N	%
1	28	50.0%
2	21	37.5%
3	3	5.4%
4	1	1.8%
5	3	5.4%

How important do you think the accuracy of stat plans is when preventing utility strikes?

	N	%
1	37	66.1%
2	13	23.2%
3	6	10.7%

Confidence to avoid strike

	N	%

1	6	10.7%
2	23	41.1%
3	27	48.2%

On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')

	N	%
0	7	12.5%
1	14	25.0%
2	2	3.6%
5	10	17.9%
6	2	3.6%
7	6	10.7%
8	6	10.7%
10	9	16.1%

16.7. Most Common Words

Python script was used to extract common words, not including ‘stop words’ from the Quantitative questions, 18 to 22.

```
# Correctly importing Counter from collections and redefining necessary components for analysis
from collections import Counter

# Redefining the function with all necessary imports and definitions included
def find_common_words_final(file_path):
    # Define English stop words within the function
    stop_words = set([
        "i", "me", "my", "myself", "we", "our", "ours", "ourselves", "you", "your", "yours",
```

```
        "yourself", "yourselves", "he", "him", "his", "himself", "she", "her", "hers",
        "herself", "it", "its", "itself", "they", "them", "their", "theirs", "themselves",
        "what", "which", "who", "whom", "this", "that", "these", "those", "am", "is", "are",
        "was", "were", "be", "been", "being", "have", "has", "had", "having", "do", "does",
        "did", "doing", "a", "an", "the", "and", "but", "if", "or", "because", "as", "until",
        "while", "of", "at", "by", "for", "with", "about", "against", "between", "into",
        "through", "during", "before", "after", "above", "below", "to", "from", "up", "down",
        "in", "out", "on", "off", "over", "under", "again", "further", "then", "once", "here",
        "there", "when", "where", "why", "how", "all", "any", "both", "each", "few", "more",
        "most", "other", "some", "such", "no", "nor", "not", "only", "own", "same", "so",
        "than", "too", "very", "s", "t", "can", "will", "just", "don", "should", "now", "d",
        "ll", "m", "o", "re", "ve", "y", "ain", "aren", "couldn", "didn", "doesn", "hadn",
        "hasn", "haven", "isn", "ma", "mightn", "mustn", "needn", "shan", "shouldn",
"wasn",
        "weren", "won", "wouldn"
    ])

        # Read the document with ISO-8859-1 encoding
    with open(file_path, 'r', encoding='iso-8859-1') as file:
        text = file.read().lower()  # Convert text to lowercase for consistency

        # Tokenise the text and filter out stop words and non-alphabetic tokens
    words = re.findall(r'\b[a-z]+\b', text)

        # Extract words using regular expression
    filtered_words = [word for word in words if word not in stop_words]

        # Count the frequency of each word
    word_counts = Counter(filtered_words)

        # Find the 10 most common words
    common_words = word_counts.most_common(10)

    return common_words

        # Execute the corrected and final analysis function
common_words_final = find_common_words_final(file_path)
common_words_final
```

Table 8 Most common words from survey

Common Word	No. of Occurrences
Cable/Cables	98
Digging/Dig	48
Cat	39
Training	34
Plans	31
Service	27
Genny	22
Work	22
Concrete	21
Genny	21

16.8. Survey Questionnaire

Note: Question numbers do not correspond with the studies' codebook and coded data, questions 1, 2 and 3 were not subject to analysis.

ELECTRICAL TESTING

Highway Electrical Workers' View on Underground Strike Risks

Informed Consent

Conducted by Simon Hobbs, University of Hull and Electrical Testing Ltd.

Dear Participant,

We are conducting an important study focused on the attitudes of highway electrical workers towards the risk of underground utility strikes in the UK construction industry. Your unique perspectives are invaluable for this research, which aims to inform improvements in health and safety measures.

Before you proceed, please read and consent to the following statements:

- **Understanding of the Study: I confirm that I have read the "Participant Information Sheet" that explains the study in detail.**
- **Opportunity for Questions: I have had the opportunity to consider the information and have been given contact details of the researcher to ask questions and discuss the study. Any questions or concerns I have about the study have been answered satisfactorily.**
- **Voluntary Participation: I understand that my participation is voluntary, and I am free to withdraw at any time during the study without giving any reason.**
- **Withdrawal Period: I understand that my data will be anonymised immediately after the completion of the questionnaire or the follow-up interview, whichever I choose to participate in. Once the data is anonymised, it will not be possible to withdraw my data from the study. I am free to withdraw my participation at any point before the anonymisation process is completed.**
- **Data Retention and Sharing: I understand that the data will not be made openly available to the public or shared with any third parties, including fellow researchers. This is to protect the confidentiality and privacy of the participants involved in the study. There is no intention to use the data on completion of the MRes project. It will be securely stored in the designated cloud storage provided by Hull University via Teams files or SharePoint for a duration of 5 years following the conclusion of the study. After this period, the data will be destroyed in accordance with the University of Hull's guidelines.**
- **Data Security: I understand that any personal data will be stored securely in line with GDPR requirements. Any personal data will be destroyed at the end of the project. Transcripts will be anonymised.**
- **Further Participation: I understand that I can voluntarily provide my name and contact information if I agree to the research team contacting me to participate in the study further.**

By selecting "AGREE" below, you offer your informed consent, meaning you understand the research, what's asked of you, and agree to your data being used as outlined.

Thank you for considering participating in this crucial study.

1. I agree to participant in this research project

- [ ] Agree
- [ ] Disagree

2. **Entering your name is optional**

First name ______

Last name ______

3. **Entering your email address is optional**

Email address ______

* 4. What is your age group?

* 5. What is your gender?

- ◯ Female
- ◯ Male
- ◯ Other (specify)

* 6. How many years have you worked in the highway electrical industry?

* 7. Have you ever had an underground utility strike at your work?

- ◯ Yes
- ◯ No

* 8. How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?

- ◯ 0-3
- ◯ 4-6
- ◯ 7-10
- ◯ Greater than 10

* 9. Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?

- Yes
- No

* 10. How often do you receive safety training related to underground utility strikes?

- Monthly
- Quarterly
- Annually
- Never
- Other (please specify)

* 11. How often do you check for underground cables before beginning work? (Select one)

- Always
- Usually
- Sometimes
- Rarely
- Never

* 12. During what time of day do most utility strikes occur in your experience?

- Early morning (6:00 - 9:00)
- Mid-morning (9:00 - 12:00)
- Afternoon (12:00 - 17:00)
- Evening (17:00 - 20:00)
- Night (20:00 - 6:00)
- Don't know

* 13. How effective are recognition and awards in motivating you to adhere to safety protocols?

- Very likely
- Likely
- Neither likely nor unlikely
- Unlikely
- Very unlikely

* 14. How effective do you think any training you have had to prevent utility strikes has been?

- Extremely effective
- Very effective
- Somewhat effective
- Not so effective
- Not at all effective

* 15. How interested do you think your Supervisor is over your safety?

- ◯ Extremely interested
- ◯ Very interested
- ◯ Somewhat interested
- ◯ Not so interested
- ◯ Not at all interested

* 16. How important do you think the accuracy of stat plans is when preventing utility strikes?

- ◯ Extremely important
- ◯ Very important
- ◯ Somewhat important
- ◯ Not important
- ◯ Not at all important

* 17. Which tool(s) are most commonly involved in utility strikes in your experience? **(Select all that apply)**

- ☐ Shovel
- ☐ Spade
- ☐ Cut off saw (Stihl)
- ☐ Hydraulic Breaker
- ☐ Mini Digger / Excavator
- ☐ Road saw
- ☐ Pickaxe
- ☐ Other (please specify)

* 18. Can you identify any factors that you believe contribute to the occurrence of utility strikes in your experience? **(Select all that apply)**

- ☐ Lack of training
- ☐ Time pressure
- ☐ Inadequate tools or equipment
- ☐ Miscommunication
- ☐ Inaccurate maps or information
- ☐ Other (please specify)

* 19. On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site?

(1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')

0 10

* 20. On a scale from 1 to 10, how confident are you in your ability to prevent an underground utility strike?

(1 indicates being not confident at all, 10 indicates being very confident)

0 10

Alright, we're shifting gears a bit here in the survey.

We're moving from the tick-box and number-rating questions to ones that need a bit more of your thoughts and words.

These open-ended questions can give us some really valuable insights, but we get it, they might take a bit more time.

If you're up for it, please do your best to answer them. But, if they're making this survey too long and you're thinking about packing it in, feel free to skip them and hit the DONE button at the bottom.

Your time's valuable and we appreciate any input you can give us.

21. If you, or someone you work with has ever had a utility strike, could you provide a brief account of what happened and how it impacted you and your perception of the risk associated with underground utility strikes (made me more or less cautious etc)?

22. Can you describe a specific situation where you, or a coworker, unintentionally struck a utility during construction? What were the events leading up to the incident and what do you think could have been done differently to prevent it?

23. What changes or improvements would you suggest to the current safety training programs, to better prepare workers to avoid utility strikes?

24. If you have ever worked with a family member, or very close friend, has this affected your safety practices, particularly in relation to avoiding utility strikes - and if so why?

25. In your experience, what challenges have you faced in trying to locate and avoid underground utilities during excavation or construction work - could be people you work with, quality of stat plans, condition of equipment... or anything else?

16.9. Full Spearman Rank Correlation

Table 9 Spearman Rank Correlation

					What is your age group?	What is your gender?	How many years have you worked in the highway electrical industry?	Have you ever had an underground utility strike at your work?	How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?	Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?	How often do you check for underground cables before beginning work? (Select one)	During what time of day do most utility strikes occur in your experience?	How effective are recognition and awards in motivating you to adhere to safety protocols?	How effective do you think any training you have had to prevent utility strikes has been?	How interested do you think your Supervisor is over your safety?	How important do you think the accuracy of stat plans is when preventing utility strikes?	Confidence to avoid strike	On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')
Spearman's rho	What is your age group?	Correlation Coefficient			1.000	0.006	0.089	.296[*]	-0.208	-0.100	0.088	0.111	0.116	-0.094	0.256	0.119	-0.145	-0.015
		Sig. (2-tailed)				0.964	0.513	0.027	0.124	0.462	0.520	0.417	0.396	0.492	0.057	0.383	0.285	0.915
		N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
		Bootstrap[c]	Bias		0.000	.001[d]	-0.001	-0.005	0.003	-0.006	-0.001	-0.002	-0.005	-0.004	-0.003	-0.001	0.000	0.002
			Std. Error		0.000	.043[d]	0.152	0.129	0.136	0.134	0.161	0.124	0.143	0.139	0.134	0.149	0.137	0.131
			95% Confidence Interval	Lower	1.000	-.087[d]	-0.197	0.035	-0.471	-0.365	-0.237	-0.150	-0.169	-0.363	-0.021	-0.173	-0.391	-0.273
				Upper	1.000	.093[d]	0.388	0.535	0.077	0.157	0.402	0.350	0.387	0.176	0.515	0.411	0.126	0.243
	What is your gender?	Correlation Coefficient			0.006	1.000	0.155	.291[*]	-0.202	-0.127	-0.084	0.044	0.180	-0.257	-0.184	0.043	0.026	0.057
		Sig. (2-tailed)			0.964		0.255	0.029	0.135	0.351	0.539	0.750	0.185	0.056	0.175	0.754	0.847	0.674
		N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
		Bootstrap[c]	Bias		.001[d]	.000[d]	.008[d]	.009[d]	-.004[d]	-.003[d]	-.001[d]	-.004[d]	.003[d]	-.005[d]	-.003[d]	-.003[d]	.004[d]	-.004[d]
			Std. Error		.043[d]	.000[d]	.154[d]	.087[d]	.058[d]	.039[d]	.028[d]	.160[d]	.055[d]	.073[d]	.055[d]	.130[d]	.120[d]	.162[d]
			95% Confidence Interval	Lower	-.087[d]	1.000[d]	-.084[d]	.168[d]	-.335[d]	-.223[d]	-.151[d]	-.217[d]	.101[d]	-.419[d]	-.312[d]	-.161[d]	-.178[d]	-.203[d]
				Upper	.093[d]	1.000[d]	.425[d]	.481[d]	-.123[d]	-.074[d]	-.042[d]	.315[d]	.303[d]	-.161[d]	-.110[d]	.277[d]	.231[d]	.339[d]
	How many years have you worked in the highway electrical industry?	Correlation Coefficient			0.089	0.155	1.000	0.173	0.042	-0.189	0.063	0.062	-0.062	-.285[*]	-0.112	-.337[*]	0.180	-0.037
		Sig. (2-tailed)			0.513	0.255		0.202	0.760	0.163	0.646	0.651	0.648	0.033	0.413	0.011	0.185	0.787
		N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
		Bootstrap[c]	Bias		-0.001	.008[d]	0.000	0.003	0.000	0.004	0.000	-0.002	0.001	0.004	0.005	-0.004	-0.002	0.004
			Std. Error		0.152	.154[d]	0.000	0.148	0.153	0.115	0.153	0.130	0.136	0.149	0.152	0.093	0.137	0.126
			95% Confidence Interval	Lower	-0.197	-.084[d]	1.000	-0.128	-0.260	-0.402	-0.258	-0.204	-0.332	-0.551	-0.391	-0.507	-0.090	-0.269
				Upper	0.388	.425[d]	1.000	0.454	0.337	0.037	0.353	0.329	0.195	0.039	0.203	-0.150	0.428	0.221

Have you ever had an underground utility strike at your work?	Correlation Coefficient			.296*	.291*	0.173	1.000	-.437**	-0.183	-0.092	-0.119	0.182	0.061	-.339*	-0.150	-0.031	0.028
	Sig. (2-tailed)			0.027	0.029	0.202		0.001	0.178	0.499	0.381	0.181	0.656	0.011	0.271	0.823	0.837
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		-0.005	.009[d]	0.003	0.000	0.004	0.001	0.006	-0.003	-0.003	-0.001	-0.005	0.002	-0.001	-0.005
		Std. Error		0.129	.087[d]	0.148	0.000	0.111	0.119	0.118	0.131	0.131	0.142	0.114	0.119	0.146	0.136
		95% Confidence Interval	Lower	0.035	.168[d]	-0.128	1.000	-0.621	-0.388	-0.289	-0.371	-0.071	-0.222	-0.555	-0.363	-0.318	-0.236
			Upper	0.535	.481[d]	0.454	1.000	-0.186	0.070	0.169	0.132	0.432	0.330	-0.084	0.098	0.259	0.288
How many times have you encountered underground utility strikes in your career - either yourself or with work colleagues?	Correlation Coefficient			-0.208	-0.202	0.042	-.437**	1.000	0.156	-0.143	0.247	-0.069	0.043	-0.100	-0.128	0.176	-0.006
	Sig. (2-tailed)			0.124	0.135	0.760	0.001		0.252	0.294	0.066	0.615	0.753	0.462	0.346	0.194	0.966
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		0.003	-.004[d]	0.000	0.004	0.000	0.007	-0.001	-0.001	0.005	0.003	0.005	-0.004	-0.002	0.005
		Std. Error		0.136	.058[d]	0.153	0.111	0.000	0.127	0.144	0.144	0.132	0.145	0.136	0.134	0.129	0.137
		95% Confidence Interval	Lower	-0.471	-.335[d]	-0.260	-0.621	1.000	-0.085	-0.398	-0.039	-0.331	-0.243	-0.350	-0.402	-0.093	-0.256
			Upper	0.077	-.123[d]	0.337	-0.186	1.000	0.398	0.153	0.526	0.191	0.335	0.184	0.123	0.420	0.262
Do you feel that the safety measures currently in place are sufficient to prevent underground utility strikes?	Correlation Coefficient			-0.100	-0.127	-0.189	-0.183	0.156	1.000	0.019	0.093	0.202	.302*	0.017	0.032	-0.230	-0.043
	Sig. (2-tailed)			0.462	0.351	0.163	0.178	0.252		0.891	0.496	0.136	0.024	0.900	0.817	0.088	0.755
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		-0.006	-.003[d]	0.004	0.001	0.007	0.000	-0.004	0.002	0.000	-0.001	-0.009	-0.004	0.008	-0.001
		Std. Error		0.134	.039[d]	0.115	0.119	0.127	0.000	0.136	0.127	0.123	0.115	0.130	0.153	0.134	0.133
		95% Confidence Interval	Lower	-0.365	-.223[d]	-0.402	-0.388	-0.085	1.000	-0.229	-0.157	-0.055	0.052	-0.232	-0.288	-0.479	-0.282
			Upper	0.157	-.074[d]	0.037	0.070	0.398	1.000	0.276	0.345	0.442	0.503	0.265	0.320	0.052	0.230

How often do you check for underground cables before beginning work? (Select one)	Correlation Coefficient			0.088	-0.084	0.063	-0.092	-0.143	0.019	1.000	-0.039	-0.163	0.003	0.210	0.105	-.354**	0.241
	Sig. (2-tailed)			0.520	0.539	0.646	0.499	0.294	0.891		0.774	0.229	0.982	0.120	0.441	0.007	0.073
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		-0.001	-.001[d]	0.000	0.006	-0.001	-0.004	0.000	0.000	0.001	0.000	-0.005	-0.001	-0.001	-0.005
		Std. Error		0.161	.028[d]	0.153	0.118	0.144	0.136	0.000	0.111	0.110	0.149	0.143	0.146	0.114	0.104
		95% Confidence Interval	Lower	-0.237	-.151[d]	-0.258	-0.289	-0.398	-0.229	1.000	-0.250	-0.380	-0.283	-0.074	-0.183	-0.562	0.028
			Upper	0.402	-.042[d]	0.353	0.169	0.153	0.276	1.000	0.176	0.058	0.316	0.486	0.398	-0.121	0.432
During what time of day do most utility strikes occur in your experience?	Correlation Coefficient			0.111	0.044	0.062	-0.119	0.247	0.093	-0.039	1.000	0.040	0.157	0.092	0.224	-0.026	-0.056
	Sig. (2-tailed)			0.417	0.750	0.651	0.381	0.066	0.496	0.774		0.770	0.247	0.500	0.097	0.848	0.682
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		-0.002	-.004[d]	-0.002	-0.003	-0.001	0.002	0.000	0.000	-0.002	0.004	0.009	-0.008	0.004	-0.002
		Std. Error		0.124	.160[d]	0.130	0.131	0.144	0.127	0.111	0.000	0.128	0.129	0.130	0.135	0.128	0.140
		95% Confidence Interval	Lower	-0.150	-.217[d]	-0.204	-0.371	-0.039	-0.157	-0.250	1.000	-0.222	-0.103	-0.160	-0.067	-0.268	-0.343
			Upper	0.350	.315[d]	0.329	0.132	0.526	0.345	0.176	1.000	0.279	0.414	0.363	0.465	0.253	0.233
How effective are recognition and awards in motivating you to adhere to safety protocols?	Correlation Coefficient			0.116	0.180	-0.062	0.182	-0.069	0.202	-0.163	0.040	1.000	0.117	-0.159	0.217	-0.108	-0.071
	Sig. (2-tailed)			0.396	0.185	0.648	0.181	0.615	0.136	0.229	0.770		0.392	0.241	0.109	0.427	0.604
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		-0.005	.003[d]	0.001	-0.003	0.005	0.000	0.001	-0.002	0.000	-0.003	-0.002	-0.005	0.000	-0.002
		Std. Error		0.143	.055[d]	0.136	0.131	0.132	0.123	0.110	0.128	0.000	0.134	0.121	0.120	0.135	0.128
		95% Confidence Interval	Lower	-0.169	.101[d]	-0.332	-0.071	-0.331	-0.055	-0.380	-0.222	1.000	-0.154	-0.391	-0.033	-0.369	-0.326
			Upper	0.387	.303[d]	0.195	0.432	0.191	0.442	0.058	0.279	1.000	0.366	0.089	0.427	0.160	0.180
How effective do you think any training you have had to prevent utility strikes has been?	Correlation Coefficient			-0.094	-0.257	-.285*	0.061	0.043	.302*	0.003	0.157	0.117	1.000	0.101	0.146	-0.248	0.056
	Sig. (2-tailed)			0.492	0.056	0.033	0.656	0.753	0.024	0.982	0.247	0.392		0.458	0.283	0.066	0.683
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		-0.004	-.005[d]	0.004	-0.001	0.003	-0.001	0.000	0.004	-0.003	0.000	-0.006	0.001	0.000	0.001
		Std. Error		0.139	.073[d]	0.149	0.142	0.145	0.115	0.149	0.129	0.134	0.000	0.143	0.131	0.139	0.146
		95% Confidence Interval	Lower	-0.363	-.419[d]	-0.551	-0.222	-0.243	0.052	-0.283	-0.103	-0.154	1.000	-0.184	-0.109	-0.491	-0.214
			Upper	0.176	-.161[d]	0.039	0.330	0.335	0.503	0.316	0.414	0.366	1.000	0.361	0.408	0.058	0.347
How interested do you think your Supervisor is over your safety?	Correlation Coefficient			0.256	-0.184	-0.112	-.339*	-0.100	0.017	0.210	0.092	-0.159	0.101	1.000	0.101	-0.258	0.147
	Sig. (2-tailed)			0.057	0.175	0.413	0.011	0.462	0.900	0.120	0.500	0.241	0.458		0.458	0.055	0.281
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		-0.003	-.003[d]	0.005	-0.005	0.005	-0.009	-0.005	0.009	-0.002	-0.006	0.000	0.002	0.009	-0.002
		Std. Error		0.134	.055[d]	0.152	0.114	0.136	0.130	0.143	0.130	0.121	0.143	0.000	0.131	0.140	0.129
		95% Confidence Interval	Lower	-0.021	-.312[d]	-0.391	-0.555	-0.350	-0.232	-0.074	-0.160	-0.391	-0.184	1.000	-0.162	-0.516	-0.127
			Upper	0.515	-.110[d]	0.203	-0.084	0.184	0.265	0.486	0.363	0.089	0.361	1.000	0.359	0.027	0.396
How important do you think the accuracy of stat plans is when preventing utility strikes?	Correlation Coefficient			0.119	0.043	-.337*	-0.150	-0.128	0.032	0.105	0.224	0.217	0.146	0.101	1.000	-0.156	-0.017
	Sig. (2-tailed)			0.383	0.754	0.011	0.271	0.346	0.817	0.441	0.097	0.109	0.283	0.458		0.251	0.902
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		-0.001	-.003[d]	-0.004	0.002	-0.004	-0.004	-0.001	-0.008	-0.005	0.001	0.002	0.000	-0.003	-0.002
		Std. Error		0.149	.130[d]	0.093	0.119	0.134	0.153	0.146	0.135	0.120	0.131	0.131	0.000	0.136	0.130
		95% Confidence Interval	Lower	-0.173	-.161[d]	-0.507	-0.363	-0.402	-0.288	-0.183	-0.067	-0.033	-0.109	-0.162	1.000	-0.431	-0.275
			Upper	0.411	.277[d]	-0.150	0.098	0.123	0.320	0.398	0.465	0.427	0.408	0.359	1.000	0.101	0.235
Confidence to avoid strike	Correlation Coefficient			-0.145	0.026	0.180	-0.031	0.176	-0.230	-.354**	-0.026	-0.108	-0.248	-0.258	-0.156	1.000	-0.103
	Sig. (2-tailed)			0.285	0.847	0.185	0.823	0.194	0.088	0.007	0.848	0.427	0.066	0.055	0.251		0.449
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		0.000	.004[d]	-0.002	-0.001	-0.002	0.008	-0.001	0.004	0.000	0.000	0.009	-0.003	0.000	-0.001
		Std. Error		0.137	.120[d]	0.137	0.146	0.129	0.134	0.114	0.128	0.135	0.139	0.140	0.136	0.000	0.143
		95% Confidence Interval	Lower	-0.391	-.178[d]	-0.090	-0.318	-0.093	-0.479	-0.562	-0.268	-0.369	-0.491	-0.516	-0.431	1.000	-0.391
			Upper	0.126	.231[d]	0.428	0.259	0.420	0.052	-0.121	0.253	0.160	0.058	0.027	0.101	1.000	0.181
On a scale of 1 to 10, does working with a family member, or very close friend influences how safely you work on-site? (1 indicates 'No Influence At All' and 10 indicates 'Significant Influence')	Correlation Coefficient			-0.015	0.057	-0.037	0.028	-0.006	-0.043	0.241	-0.056	-0.071	0.056	0.147	-0.017	-0.103	1.000
	Sig. (2-tailed)			0.915	0.674	0.787	0.837	0.966	0.755	0.073	0.682	0.604	0.683	0.281	0.902	0.449	
	N			56	56	56	56	56	56	56	56	56	56	56	56	56	56
	Bootstrap[c]	Bias		0.002	-.004[d]	0.004	-0.005	0.005	-0.001	-0.005	-0.002	-0.002	0.001	-0.002	-0.002	-0.001	0.000
		Std. Error		0.131	.162[d]	0.126	0.136	0.137	0.133	0.104	0.140	0.128	0.146	0.129	0.130	0.143	0.000
		95% Confidence Interval	Lower	-0.273	-.203[d]	-0.269	-0.236	-0.256	-0.282	0.028	-0.343	-0.326	-0.214	-0.127	-0.275	-0.391	1.000
			Upper	0.243	.339[d]	0.221	0.288	0.262	0.230	0.432	0.233	0.180	0.347	0.396	0.235	0.181	1.000

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

d. Based on 855 samples

Bootstrap Specifications

Sampling Method	Simple
Number of Samples	1000
Confidence Interval Level	95.0%
Confidence Interval Type	Percentile

16.10. Interview Transcripts

Interview 1

Interviewee (AS)
Interviewer (SAH)

SAH: I'm here with AS, and we have about 5-10 minutes for this interview, based on the feedback from your survey. It's confidential, and all recordings will be deleted post-transcription as per my ethical proposal. Let's begin. Can you tell me your name and briefly describe your history in highway electrical, please?

AS: Certainly. My name is AS, and I've been in the industry since 1991, marking my 33rd year. I started as a labourer, thanks to my father, who worked as a motor mechanic for the business, and my brother was also involved. I initially trained as a PE teacher before joining this industry. Over the years, I progressed to become a supervisor in 2003 and later a manager. I've worked on various projects, including the Barnet and Enfield PFI and for companies like Skanska and Kier, focusing on connections and LV connections. Eventually, I transitioned to training within the industry, leveraging my teaching interest and experience.

SAH: Which company did you start with?

AS: I started with David Websters, spending around eleven years on the tools before moving into a supervisory role in 2006. I aimed to become a manager within five years and achieved it in three and a half.

SAH: Moving on to utility strikes, can you share your experience with them? What frequency did they occur at, and how did it impact your approach to jobs?

AS: Initially, the availability of stat drawings and tools like Cat and Gennys was limited, so we relied more on visual risk assessments. Strikes did happen, which taught us to excavate with caution. Over time, as cat and Jenny became more common and statutory drawings were introduced, safety improved significantly.

SAH: Do you think utility strikes are more a result of system failures or individual behaviours, or a mix of both?

AS: From my experience, particularly with national vocational qualifications and site visits, it seems more related to individual behaviours. Despite knowing the location of underground services, distractions or personal issues can lead to a lapse in concentration, resulting in strikes.

SAH: What have your experiences with statutory plans been in terms of their accuracy?

AS: Statutory plans have generally been quite accurate in my experience, about eight times out of ten. Training on how to interpret these drawings has significantly improved over the years.

SAH: How did you perceive your supervisor's concern for safety, particularly in the event of a cable strike?

AS: In the 90s, supervisors may not have had specific training for their role, but they took incidents seriously and provided the necessary support. Over time, as training improved, this concern for safety became more ingrained in both supervisory and management levels.

SAH: What is your confidence level in avoiding cable strikes now?

AS: I would say my confidence in avoiding cable strikes is 100%.

SAH: Reflecting on your safety training, particularly with cat and Jenny, how well do you think it prepares individuals for real-world scenarios? Are there any gaps?

AS: The training and its application in the field have been highly effective. The use of up-to-date equipment, adherence to statutory plans, and proper excavation techniques are evident on sites. I haven't noticed any significant gaps in training over the past seven years.

SAH: Excellent. We've covered everything in about 13 minutes. Before we conclude, is there anything else you'd like to discuss?

AS: No, that's everything. Thank you for your time.

SAH: Thank you as well, Adrian. Your insights have been invaluable.

Interview 2

Interviewee (DW)
Interviewer (SAH)

SAH: We're looking into how safe highway electrical workers feel, especially when it comes to underground utility strikes. Your feedback from the survey was really helpful. I'd like to know more. So this chat's going to take 10 to 15 minutes, but I'm not tied into a time so if it goes longer, that's fine. I'm going to record it to help with my note-taking, but don't worry, it'll be kept private and I will be deleting it afterwards.

DW: No problem.

SAH: So we'll get started. The first sort of question I'd like to ask you is really simple. Can you state your name for the recording and tell me a bit about your history in highway electrical?

DW: Okay, my name is DW. I've been in the highway electrical industry for probably the last 12 years or so now. Started my career off with McCann's when they were doing the Olympic Park, the car park street lighting. So that was my first sort of entrance into the highway side of things. Then I moved over to Balfour Beatty when they were doing the Cambridgeshire public funding investment. Followed that through with them, went on to Northamptonshire PFI, then went to Milton Keynes, Ringways to finish off before stepping away.

SAH: So how many years is that?

DW: It's probably over a 12-year period of actually being out on the tools. So pretty well experienced. I'd like to think I've got a good understanding.

SAH: Good stuff. Alright, so the first sort of meaty question I'd just like to ask you, just following on from the survey. Can you describe your experience with underground utility strikes? And if you've had one, how it impacted your approach to safety on the job?

DW: Okay, so I've not come across, I have not been unfortunate enough to come in contact with an underground utility or service. But I was in the vicinity when a colleague did actually go through an electrical cable with quite a big bang. Luckily enough everyone was, you know, it didn't require any hospital treatment, but the surrounding on there. That was a shallow service, which is what the issue was. And the guy actually went through with a floor saw. We knew that the cable was there, the depth was the one, because it was shallow. It was just sitting below the actual tarmac.

SAH: Yeah, so you'd identified it, but you just didn't know how deep it was. And it should be at 450 or something.

DW: And we were only breaking the surface of the tarmac itself away, which ended up obviously happening.

SAH: Did that have any impact on how you approach jobs in the future?

DW: Definitely, definitely. It was one of those issues that we all know that there could be shallow services. And we, you know, we try to do our best. But when you, until you actually see how shallow some of these services can be, it's surprising you that just breaking the surface of a standard tarmac patch or a concrete slab, that they could literally be, you know, touching the bottom of that, really makes you think every time that, you know, you are opening the ground that this could be to happen. So for me personally, every time I used floor saws or sillsaws to open it up, it was three or four sort of journeys across the actual cut that I was going to make before I actually broke through to the depth to start lifting things out. So massively, just because, yeah.

SAH: So you were, yeah, so you were feeling quite conscious that there could be something there.

DW: Yeah, definitely. Yeah, definitely. Always in the back of your mind, you know, from witnessing that beforehand, probably a little bit lax of the importance of shallow services.

SAH: Okay. And how far into your 12 years were you when you had witnessed that, do you think?

DW: So this was quite early on.

SAH: Okay.

DW: Yeah. So this is when I was still on the McCann's contract, I would say in the Olympic car parking. So been an electrician in the electrical industry before coming into highways. So very aware of the dangers of electricity themselves and the other things that come along there. But yeah, so it was a good eye-opener that, you know, being outside where previous electrical knowledge was in a box, I'm in a factory, I'm in a house and you expect to be cables buried behind walls and ceilings, not so much out when you're out there on the highways and down footpaths and things like that. It kind of changes the dynamics of where you're looking for these cables and where they could be. So, yeah.

SAH: Good. All right. That's great. So, moving on to the next thing. In your opinion, what are the main factors contributing to utility strikes, and how do individual actions compare to maybe systems? So taking that in two parts, really, or maybe the first part?

DW: The main factors, I believe, are just the awareness of the actual dangers that services can cause. It's very much, you go through the training, you go through using cable avoidance tools and the journeys to highlight these things. But it's just the cable; it's just a pipe. There's no real understanding of what kind of damage that can do if you come in contact with it. So there's a bit of a, sometimes a blasé attitude, like, yeah, there's a cable down there, just be careful.

SAH: And from your experience with inaccuracies in statutory plans, how does that influence your trust in the documents?

DW: Well, I've always viewed statutory plans as guidance only. There have been occasions where it says there's a particular LV cable on one side of the road, and it can't be located. We find out it's actually on the opposite side of the road. So I think sometimes, some of the statutory plans I've seen have not reflected the new changes. But once again, it's always been just guidance for me. I've never ever relied on them completely.

SAH: Can you share your perception of your supervisors' commitment to safety and the safety culture in the organisations you've worked with?

DW: The strike I witnessed was chaotic. Unfortunately, it seemed like because there was a zero tolerance for service strikes, that fed down into the supervisors and management, making them very nervous and scared about uncovering ground. It felt like the fear of getting into trouble outweighed their safety concerns.

SAH: Reflecting on the safety training you've had over the years, how well do you think it prepares you for real-world scenarios on the job?

DW: The issue, especially in highways, is that every single area you work in is completely different. The training that I've had with cable avoidance tools is a very small snippet of what you encounter in the real world. It's difficult because the training doesn't always apply to the actual job scenarios you face.

SAH: Lastly, how does the practice of checking for underground cables influence your confidence in preventing a strike?

DW: Every time I was to break ground, I would be doing the initial survey. However, I would love to say I'm a hundred percent confident, but I'm not. There are always variables and things that you do which can have an effect on something else.

SAH: Good. That's great. Danny, thank you very much for your time and your insight into these questions. I really appreciate it.

DW: No problem.

Interview 3

Interviewee (RS)
Interviewer (SAH)

SAH: Okay, so thanks for joining me. We're going to look into how safe highway electrical workers feel when it comes to underground utility strikes. Your feedback from our survey was really helpful, and I want to know more. So, this chat is going to take 10 to 15 minutes tops. If it goes longer, it takes as long as it takes or as short as it takes. As I said, I'm going to record it if that's okay, just to help with my notes, but it's going to be kept private. I'll then delete it afterwards. And the first question, can you tell me your name and can you tell me a bit about your history working in street lighting?

RS: RS, I've been here for four years this year, I think. I love the job, and I'm a jointers mate, and I do what I'm told. I make sure the site's set up, all the barriers.

SAH: Do you do any of the civils, digging out, or is that all done by others?

RS: No, I do all the digging.

SAH: So, yeah, all the marking up with the cat and jenny and everything like that?

RS: Yeah, all the marking up, cat and jenny.

SAH: So, your experience with excavation and digging and doing all of that is quite extensive then?

RS: Yeah.

SAH: So, how many jobs a week do you do?

RS: We try to get about 10 jobs, but we also do evening work. So, we do quite a bit.

SAH: Yeah, so you've got pretty four years of doing 10 jobs a day, a week, every week. All right, so next thing is, can you describe your experience with any underground utility strikes that you've had, if you've had any, and how it impacted your approach afterwards?

RS: A gas one. Okay. I had a gas one. So, I was digging down, cut it, there was nothing, but it was only about 200 mil below the surface. At surface.

SAH: So, it was shallow?

RS: Yeah, gas main going into a house.

SAH: Okay.

RS: And all of a sudden, I could smell gas. I said, stop. I looked down, scraped some earth away, yellow gas main was there. So, we called the gas company. Yeah. And we just barricaded it off, made sure no one stood around smoking. Yeah. And no one went near it, and then they came out and repaired it. And they said that it's not our fault because it was shallow. It shouldn't have been that shallow.

SAH: Okay. Did that have any impact on how you worked in the future? Did it make you more safe, less safe, or?

RS: Yeah, it makes me more cautious, knowing that that was shallow, what other services are going to be shallow next time. Okay. So, always take your time, always check around me, look for whichever way the gases or services go into a house outside. Okay. And any scarring on the path. So, always cautious. I'm looking over here because I've got my notes, you see. So, my memory's terrible. Yeah. So, I mean, so leading on to that, what do you think are the biggest factors that contribute to utility strikes? Is it systems? Is it people? Is it behaviour? Is it shallow services? Is it plans? What is it, or is it lots of things? What are your feelings on it? It's shallow services, but it's also if your head's not in the game.

SAH: Okay. So, what do you mean by that?

RS: Basically, I mean, if you've got one of those bad attitudes where if it happens, it happens, that's the wrong attitude to have. Okay. Yeah. Because it shouldn't happen. Yeah. But sometimes you can't help it if it's shallow. Yeah. So, it's a mixture of...

SAH: So, without putting words in your mouth, if you've come at it with the wrong attitude, so the service is in the right place, and it's at the right depth, would it be less of a system? Would it be less the supervisor's fault and more the guy on site's fault if it's an attitude thing, or?

RS: No. It'd be the... because it'd be the guy on site's fault. Yeah. Because it's their attitude. Okay. So, when they get out there, if... I mean, when they come in here, if they've got a good attitude, then as far as the officer's concerned, they're fine.

SAH: So, not naming names, and it might have been somewhere else, but people that you've come across that have not got a good attitude to safety, any of your thoughts on why that might be, or any ideas on how you could change it? Have you seen people's attitudes change from bad to good, or?

RS: Yeah, it's... I mean, it could be mental health. Okay. They could, I think, be having problems at home.

SAH: Have you got anyone in mind that you've worked with that was... you don't have to name them, that had a terrible attitude?

RS: Yeah, they had strikes, and their attitude didn't really change. It's still the same. It was like, this is just how it is? Yeah.

SAH: Okay. So, would you think there wasn't really anything anyone could have done to have changed it?

RS: No. No, sometimes they're beyond help.

SAH: Right, okay. Okay, yeah, that's fine. I've got some specific questions now, just on your experience. So, what's your relationship with stat plans? How do you use them? The accuracy of them? How much attention you give to them?

RS: I always check the stat. I mean, being in building before, as a carpenter, looking at drawings on building sites and all that, I always look into detail. And if I see a line on a plan, and I think, what's that? I always look at the bottom, and then it explains what the line is, and what the drawing shows.

SAH: Okay. And how much trust do you have in your stat plans?

RS: Always check the date. And depending on if it's a couple of years old, they can always change. And sometimes, you don't get the up-to-date copy.

SAH: So nothing's perfect, but in this area, how accurate do you find your plans? Pretty good?

RS: Yeah, they've been pretty good. Pretty good? Yeah.

SAH: Okay. So, presumably, if you think they're pretty good, you spend a bit of time looking at them?

RS: Yeah.

SAH: Again, it's really specific to you. Everyone's different. How do you feel your supervisor's attitude to safety is, with regards to things?

RS: No, definitely on the ball. A hundred percent.

SAH: And if you did have a cable strike, what would your feeling be about your supervisor's attitude towards that?

RS: They deal with it, and it's safe. They explain the situation, then it goes through the right channels.

SAH: Training. What sort of training have you had? How have you found the training? Have you got any thoughts on how it could be better or worse?

RS: I love training. It's all a different sort of thing, and I just love adding things to my experience. Yeah.

SAH: Okay. And the training that you've had, how would you rate it? Good? Really good?

RS: Oh, really good. Really good? Yeah.

SAH: And it's relevant to the job that you're doing?

RS: A hundred percent.

SAH: So like the Cat and Genny training, stuff that you're taught in the classroom, do you find that useful for site?

RS: Yeah. Yeah? Yeah.

SAH: Does it reflect what happens on site? You find the training that you get?

RS: Yeah.

SAH: So you go in the classroom or you go for a day's training using the Cat and Jenny, most scenarios are covered. You feel comfortable to then take that to sight?

RS: Yeah. Definitely. Yeah.

SAH: Last question then, Richard, is what's... So you're pretty comfortable with your training, you're comfortable with your attitude towards things and your stat plans, et cetera. So you're a man that's going to site and doing the job the right way. What's your confidence level on being able to avoid hitting a utility?

RS: You can never always avoid anything because you don't know the depth, you don't know if those stats are up to date. But I take my time and I'm confident that I won't hit nothing.

SAH: A hundred percent of the time?

RS: Yeah

SAH: That’s great, excellent, thank you very much and I shall end it there.

16.11. Highway Electrical Registration & Training Specification

Table 10 Highway Electrical Job Competencies

NHSS8/HERS Competency & Occupations Matrix – All Sectors – Combined Part One – Common Areas

Competency Element Number	Competency Element Description	Competency Element included in NVQ Certification (Y / N)	Trainee	Installation Operative	Installation Operative (Crane)	Lead Inst. Operative	Routine Mtce Operative	Mtce Op – Fault Repair	Mtce & Inst. Operative	Painting Operative	Night-time Monitor	Structural Tester	Highways Electrician / Service Operative	Tunnel Operative	Supervisor	Approved Person	Approved Person – Manager
Found01	Basic Health & Safety (incl. ECS HE H&S assessment) + M.T.		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Found 01/1	Work in Confined Spaces + M.T.		X														
Found02	Lorry mounted crane – Slinger / Signaller + M.T.		X														
Found03	Lorry mounted crane – Operator + M.T.		X		M												
Found04	Power Tools including hand tools + M.T. (PowerTools)		X	M	M	M	2	M	M	M			M				
Found05/1	Mobile Elevating Work Platform + M.T.		X					3	3	M							
Found05/2	Use of steps and ladders + M.T.		X														
Found05/3	Erection of Scaffold Towers + M.T.		X														
Found05/4	Accessing fixed structures at height (other than MEWPS, steps, ladders and scaffold towers) + M.T.		X														
Found06	Temporary Traffic Management + M.T.		X		1		1	1	1	1		1	1		1		
Found07	Working in the vicinity of DNO/IDNO Equipment + M.T.		X		M			M	M	M			M		3	6	6
Inst01	Excavate, backfill & reinstate + M.T.		X		M				1								
Inst05	Install underground cables		X														
Inst06	Terminate and joint cables		X							X	X	X				X	
Inst07	Avoiding danger from underground services + M.T.		X		M	M			1	X	X						
Main04/1	Emergency Inspection Procedures		X														
Main07	Underground Cable test and repair		X							X	X	X					
4A	Electrical safety in Non-energised testing		X							X	X	X					
6A	Maintenance of Poles, Lanterns & Brackets (Equipment spec)		X				10										
6E	Maintenance of supply tails & earthing		X														
Test01 (4C)	Initial Electrical Inspection and Testing – initial + M.T.		X	X	X	X	X	X	X	X	X	X	M	X		X	
Test02 (6I)	Periodic Electrical Inspection and Testing + M.T.		X	X	X	X	X	X	X	X	X	X	M	X		X	
Test07	Inspection and Testing for the Addition or Alteration to an Installation + M.T.		X														
Sup01	Supervise teams on site		X							X	X	X			M		
Sup02	Set teams to work & supervise Quality, Safety & Productivity		X							X	X	X					
8/Sup05	CDM Awareness + M.T.		X														M
Inst02	Erect, remove and realign columns and other street furniture		X		M				M								
Inst03	Install electrical equipment and wiring only		X														
Inst04	Install high mast lighting		X														
Main01	Painting of structures + M.T.		X							M							
Main02	Routine General Maintenance		X				M	M	M								
Main03	Remove and replace components		X					M	M								
Main04/2	Emergency Work		X														
Main05	Operate raising and lowering columns		X														
Main06	Maintaining high mast lighting		X														
Rep01	Identify and replace faulty components		X					M	M								
Rep02	Diagnose fault on equipment and replace faulty component		X	X			X	X	X	X	X	X				X	X
Rep03	Locate faults on underground cables		X	X			X	X	X	X	X	X					
Insp01	Visual Inspection Optical Structural & Electrical		X					M	M				M				
Insp02	Night-time monitoring		X								M						
Test03	Periodic structural testing		X									M					
Test04	Photometric performance testing		X														

HERS Highway Electrical Registration Scheme

Site Assessment Form

Found 04 | Power Tools incl. Hand Tools

(Underpinning knowledge – Training Spec.: Module 204, 204.1)

Name of Person Being Observed:	

Site Address:	**Equipment:**	**Activity:**

	Observed Tasks: *(To cover all work equipment likely to be used by the employee)*	**Date Observed On Site as Competent:**
1.	Electrical hand tools satisfactorily used, maintained and sorted	
2.	Digging tools, satisfactorily used, maintained and stored (if applicable)	
3.	Cable jointing & terminating tools satisfactorily used, maintained and stored (if applicable)	
4.	Disc power saw satisfactorily used, maintained and stored (if applicable)	
5.	Disc power saw dust suppression satisfactorily used, maintained and stored (if applicable)	
6.	Road breaker satisfactorily used, maintained and stored (if applicable)	
7.	Trenching machine satisfactorily used, maintained and stored (if applicable)	
8.	Powered auger satisfactorily used, maintained and stored (if applicable)	
9.	Mini digger satisfactorily used, maintained and stored (if applicable)	
10.	Electrically powered hand tools satisfactorily used, maintained and stored (if applicable)	
11.	All relevant PPE in satisfactory condition, correctly used and stored	
12.	Fire extinguisher available for hot work processes (if applicable)	

Observation Comments (if none, write None):

Comments from Person Being Observed (if none, write None):

Has an action plan been produced identifying additional training needs/competency assessments? Yes ☐ No ☐

NVQ Assessor Name (if used to carry out site assessment above)			
Qualified Supervisor Name:		**QS No:**	
Signature:		**Date:**	

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Qualifications & Training Evidence Form
Found 04 | Power Tools incl. Hand Tools
(Underpinning knowledge – Training Spec.: Module 204, 204.1)

Qualifications and Training Evidence (*See note below):		Date Achieved:	Witnessed as seen original:
1.	NRSWA or 204.1 Hand Power Tools (add named type/group here):		Please Select...
			Please Select...
			Please Select...
			Please Select...
			Please Select...
			Please Select...
			Please Select...
			Please Select...
			Please Select...

Authorising Officers Comments (if none, write None):

AUTHORISING OFFICER:				
Outcome: Assessed as:	Competent:		Not yet competent:	

Authorising Officer Name:		AO Number:	
Signature:		Date:	

*Note:

1. All Training must be in strict accordance with the Highway Electrical Training Specification and must be delivered by Highway Electrical Skills Academy (HESA) Approved Trainers other than the named accepted alternative provision. The Training Specification and details on the Requirements for Approved Trainers are available as downloads from the HERS web-site - https://thehea.org.uk/hers-hesa/approved-trainers/
2. Add details of additional education & training evidence relevant to the occupation & tasks carried out, if any
3. An occupationally competent and qualified NVQ assessor may be used by organisations employing less than 5 people to carry out this site assessment in addition to a QS

Site Assessment / Quals and Training Forms Issue 3 – Dec 2021

Figure 25 Site Assessment for Power Tools

Section 2 Specialist Course Modules - Public Lighting & Illuminated Signs

Certificated Specialist Courses: - Public Lighting - Installation Techniques

Certification	Course Ref No	Title	Pre-requisite Underpinning knowledge	Mandatory Pre-requisite certificated training (note alternative provision may apply)	Page	Course Rec. Hrs	Learning Hours	Maximum Learner Number
Available individually & combined	211	Lorry mounted crane – Slinger / Signaller	All 100's; 201, 207		78	7	6	10
	212	Lorry mounted crane – Operator	All 100's; 201, 207		79	7	6	10
Certification for all the courses in this table in total and individually	501	Erect Columns and Brackets	All 100's; 201, 202, 203, 204, 207, 208, 209, 210, 211, 212; 302		80	3	3	10
	502	Remove columns and brackets	All 100's; 201, 202, 203, 204, 207, 208, 209, 210, 211, 212, 214; 302.1		81	2	2	10
	503	Re-align columns and brackets	All 100's; 201, 202, 203, 204, 207, 208, 209, 210, 211, 212; 302.1		82	1	1	10
	504	Install feeder pillars	All 100's; 201, 202, 203, 204, 207, 208, 209, 210;		83	1	1	10
Certification for all the courses in this table in total and individually	505	Install Base lit bollard base	All 100's; 201, 202, 203, 204, 207, 208, 209, 210;		84	4	3.75	10
	508	Installation of base-lit bollard	All 100's; 201, 203, 204, 207, 208, 209, 210, 214; All 402,		85	4	3.75	10
Certification for all the courses in this table in total and individually	506	Installation of lantern and bracket	All 100's; 201, 203, 204, 205.1, 206.2/3, 207, 208, 209, 210, 214; 302.1; 402,		86	3	3	10
	507	Installation of wiring and control gear	All 100's; 201, 203, 204, 207, 208, 209, 210, 214; All 402,		87	4	3.75	10
Available individually	509	Install underground cables	All 100's; 201, 203, 204, 207, 208, 209, 210, 214; 302.1		88	7	6	10
Certification for all the	510	Terminate and connect U/G cable into cut out	All 100's; 201, 203, 204, 207, 208, 209, 210, 214; All 402, , 404		89	3	3	10

Figure 26 HERS Training Matrix for Power Tools

Note 1: 204.1 (Hydraulic Breaker) is not a mandated training course for any training that involves the erection and installation of highway electrical equipment (204 is general non-powered hand tools training).

Note 2: 204.1 - Hand Powered Tools - *Petrol Driven/Cordless Cut-Off Saws and Abrasive Wheels* is the only 204.1 HESA Training course with training material provided (no hydraulic breaker training material).

16.12. Further Psychological Investigations

1. Cognitive Dissonance

What it is: The psychological discomfort or tension we feel when our beliefs, attitudes, and actions don't align. We're motivated to reduce this discomfort, often by changing our behaviour, justifying our actions, or seeking information that supports our choices.

Example: A smoker knows smoking is harmful but continues to do so, experiencing dissonance. They might reduce this dissonance by downplaying the risks ("My grandmother smoked and lived to 90") or focusing on the pleasure of smoking.

2. Optimism Bias

What it is: The tendency to overestimate the likelihood of positive events happening to us and underestimate the likelihood of negative ones. This leads to unrealistic expectations and potentially risky decision-making.

Example: Someone who believes they're exceptionally good at driving might be more likely to speed or take risks they shouldn't.

3. Normalisation of Deviance

What it is: A gradual process where actions or situations that were once considered unacceptable or dangerous become routine over time. This can create a dangerous culture where safety risks are overlooked or minimised.

Example: A workplace where minor safety violations are commonplace might eventually tolerate more serious breaches, leading to accidents.

16.13. Frequency of Key Terms

Table 5 provides a frequency analysis of key terms extracted from the qualitative responses of the survey participants. This table illustrates the common themes and concerns that emerged during the thematic analysis of worker responses. By quantifying the frequency of each term, the table not only highlights the most pressing issues, as perceived by the workers, but also underscores the recurrent themes that need addressing within the industry.

The terms listed in Table 5, such as "Strike," "Safety Practices," and "Training & Education," were identified as significantly influential in shaping the workers' perceptions and attitudes towards safety and risk management related to underground utility strikes. The frequency of these terms provides a quantitative measure of the importance of these issues to the workers and serves as an indicator of areas that might benefit from enhanced focus in policy and practice improvements.

For instance, the high frequency of the terms "Safety Practices" and "Training & Education" suggest a strong call from the workforce for better and more practical safety training, aligning with the qualitative insights that call for improvements in safety protocols and training methods.

Table 11: Frequency of key terms

Term	Frequency	Associated Words
Strike	34	Utility strikes, cable strikes, accident incidents
Work Process	31	Excavating, trenching, digging practices, cable laying
Safety Practices	29	HSG47, safe digging, PPE, caution, safety videos
Training & Education	27	Cat and Genny course, safety training, on-site training
Risk Assessment	25	Hazard identification, risk analysis, safety checks
Equipment/Tools	21	CAT & Genny, jack hammer, insulated tools, breaker, cable avoidance
Experience/Competence	20	Expertise, proficiency, skill level, knowledgeable

Planning	19	Stat plans, site surveys, project design, utility mapping
Infrastructure	16	Utilities, cables, services, electrical networks
Project Management	15	Supervision, job planning, project coordination
Communication	14	Briefings, toolbox talks, site communication, reports
Compliance	13	Regulations adherence, industry standards, legal requirements
Teamwork	12	Collaboration, communication, co-workers, joint efforts
Emergency Response	8	Accident handling, first aid, emergency procedures
Family/Friends	6	Working with relatives, shared safety responsibility