

**Mandatory collision avoidance systems: Lived experiences of South African  
mineworkers**

11220075

A research project submitted to the Gordon Institute of Business Science,  
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degree of Master of Business Administration.

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## **Abstract**

The study explored the intersection between regulatory enforcement, technology acceptance, and safety behaviour in the South African mining industry, following the mandatory adoption of Collision Avoidance Systems (CAS) on Trackless Mobile Machinery (TMM). Although these regulations aim to prevent collisions, persistent incidents raised questions about whether mineworkers genuinely accept CAS or merely comply with it.

Mineworkers' experiences were explored in terms of how they perceive, trust, and respond to CAS under mandatory conditions, and how these experiences affect their effective use and compliance behaviours. A qualitative approach was employed, conducting semi-structured interviews with twelve participants from various mining operations, including operators, artisans, and a safety officer. The data was analysed thematically to identify emergent themes of perceptions, trust, and behavioural responses.

The findings revealed that mineworkers recognised CAS as beneficial to their safety. However, acceptance of the system was broadly symbolic and driven by compliance pressure and operational demands. Technical limitations, CAS performance and inconsistent enforcement were found to foster conditional trust and workarounds. The study concludes that mandatory enforcement achieves compliance but not genuine acceptance. Legitimacy, trust, and user perception are all critical for effective technology adoption modelling of safety systems in high-risk, regulated environments.

## **Keywords**

*Mandatory Adoption, Technology Acceptance, Symbolic Compliance, CAS*

### **Plagiarism Declaration**

*I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.*

11220075, 3 November 2025

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## Abbreviations

|                |                                                    |
|----------------|----------------------------------------------------|
| <b>CAS</b>     | Collision Avoidance System                         |
| <b>DMRE</b>    | Department of Mineral Resources and Energy         |
| <b>EMESRT</b>  | Earth Moving Equipment Safety Round Table          |
| <b>GDP</b>     | Gross Domestic Product                             |
| <b>ISO</b>     | International Organization for Standardization     |
| <b>LoA</b>     | Levels of Automation                               |
| <b>LoC</b>     | Levels of Control                                  |
| <b>MHSA</b>    | Mine Health and Safety Act                         |
| <b>MINCOSA</b> | Minerals Councils South Africa                     |
| <b>MOSH</b>    | Mining Industry Occupational Safety and Health     |
| <b>SAE</b>     | Society of Automotive Engineers                    |
| <b>TAM</b>     | Technology Adoption Model                          |
| <b>TMM</b>     | Trackless Mobile Machinery                         |
| <b>TPB</b>     | Theory of Planned Behaviour                        |
| <b>UTAUT</b>   | Unified Theory of Acceptance and Use of Technology |

## **1 Chapter 1: Introduction to the Research Problem**

### **1.1 Research Problem**

Mining remains one of the largest sectors in South Africa's economy, employing over 480,000 people and contributing R204.8 billion to the GDP in the third quarter of 2024 (Pienaar, 2024; Trading Economics, 2025). Although significant to the economy, the mining industry remains one of the riskiest sectors for Trackless Mobile Machinery (TMM) safety. Between 2021 to 2023, TMM-related incidents accounted for the highest number of incidents resulting in section 54s in the South African mining industry (Department of Mineral Resources and Energy, 2022b, p.66, 2024, p.62), which are notices of non-compliance issued by the Department of Mineral Resources and Energy (DMRE). These notices halt operations until compliance with the Mine Health and Safety Act, 1996 (Act No. 29 of 1996), is restored. The high number of TMM Section 54s not only causes operational disruptions but also indicates ongoing safety concerns regarding TMMs in the industry.

To enhance the safety of mineworkers exposed to TMMs in South African mines, the Department of Mineral Resources and Energy (DMRE) introduced regulations 8.10.1 and 8.10.2 within the Mine Health and Safety Act (MHSA). These regulations require the deployment of a system to slow down the TMM and ultimately halt it if no other intervention is made to eliminate the risk of a collision. The regulations were promulgated in 2015, with mines in South Africa required to be compliant by 21 December 2022 (Department of Mineral Resources and Energy, 2015; Department of Mineral Resources and Energy, 2022a).

As a result of the regulations above, Collision Avoidance Systems (CAS) emerged as a critical safety technology to comply with the law and improve the safety of TMMs in the mining industry. These systems are designed to operate across three increasing levels of control intervention, namely levels seven (7) to nine (9) (Earth Moving Equipment Safety Round Table, n.d.). Whereby, Level 7 is operator awareness, Level 8 is advisory controls, and Level 9 is the automatic retarding or stopping of the machine without human intervention.

Mines across South Africa are currently at different stages of implementation, with the system's learning and adaptation ongoing. However, the enforcement of regulations for the technology across mines, amid TMM safety concerns, raises the

question of whether mineworkers are merely complying with the law or actually using the technology effectively and intentionally.

## 1.2 Context of Study

TMM Fatalities across the mining industry persist despite mandatory CAS enforcement (Likhi, 2024). Additionally, almost a third of incidents across mines worldwide are reported to be due to TMMs (van Aswegen et al., 2024), indicating a global industry concern about TMM safety and the technology's effectiveness in South African mines, regardless of the law in place.

The introduction of CAS Level 9 controls is intended to minimise the need for human intervention in situations where a collision risk exists. Therefore, the intent is to increase the safety of TMMs by reducing the risk of human decision-making errors through automated functions (Horowitz & Kahn, 2024; Leonida, 2023). However, CAS, like any other safety system, requires human behavioural interaction or the correct use to be fully effective (Ismail et al., 2021a; Swanson et al., 2019). This includes, but is not limited to, using personnel ID tags to ensure pedestrians are detected in relevant areas, in accordance with the regulation. Fatal incidents, such as those reported below by the Minerals Council, still occur in South African mines after the regulation's enforcement, indicating either ineffective system implementation or poor human usage.

The following quotation refers to a special towing task, during which mineworkers typically bypass the system so that the towing TMM can operate without nuisance alarms. Such an override reflects operational pressures and the challenges of balancing the system's sensitivity with functionality in unique cases, where alarms might cause frustrations and ultimately undermine trust (Hrica et al., 2022; Simonson et al., 2022).

*“The now deceased Trackless Foreman was fatally injured when he was caught between a Trackless Mobile Machinery Mining dump truck and the sidewall whilst in the process of recovering the same dump truck to the workshop.” – (January 2024, supplied Minerals Council Reports)*

Despite the presence of CAS Level 9 in the following incident, the Personnel ID was not detected. It is known that operators sometimes override such systems (Burgess-

Limerick, 2020). In practice, this could also involve removing a personnel ID tag, which would cause the machine to stop detecting the person if the system was not faulty. These behaviours could undermine the effectiveness of CAS in the mining sector.

*“The now deceased Continuous Miner (CM) Operator was fatally injured when he got pinched between the CM and the rib-side whilst relocating the CM. The CM remote was still in his hand and the second remote had to be used to move the CM and free him. He was declared deceased on the scene.” – (August 2022, supplied Minerals Council Reports)*

The above cases illustrate that even with CAS, aspects such as system limitations and behavioural non-compliance can render the technology ineffective. Therefore, there is a requirement to investigate how mineworkers perceive the system and what influences their behaviour towards it, especially in cases which may ultimately lead to ineffective use, regardless of the law in place.

In addition to the potential behavioural issues, higher levels of automation or automated function in vehicles, such as shared control features of CAS Level 9 on TMMs, are known to affect the use of automated systems (Swanson et al., 2019). Personal over-trust in automated systems can compromise situational awareness, especially under pressure (Demeulenaere, 2020; W. C. Chang et al., 2023). Situational awareness describes an operator’s ability to perceive elements in the environment, comprehend them and then anticipate a future state in order to make an informed decision (Munir et al., 2022). It is therefore important to understand how such automation influences operator trust and effective use in the context of CAS, given that CAS still requires a level of human input.

CAS systems, overall, rely on human interaction, to reiterate. Decision-making still lies with the operator to respond to and act on warnings (Schnebelen et al., 2020), and the operator’s response may not always be as ideal as an automated intervention (Hancke, 2020). Although the system is required to take over as a last resort to eliminate any imminent risk, the onus is on the operator to ensure the risk is not catastrophic, as the system is similar to the driver-assistance level of automation (Society of Automotive Engineers International, 2021). Furthermore, an operator still needs to proactively manage the risks in scenarios whereby CAS will not automatically intervene, by navigating the alarms effectively (Schnebelen et al.,

2020; Swanson et al., 2019). Therefore, situational awareness is advantageous for effective use (Liang et al., 2021; Munir et al., 2022).

Besides the risks associated with human-operated machinery, fail-safe features such as the inability to self-correct, susceptibility to signal interference, and software glitches that may cause errors in obstacle detection, raise serious concerns about the reliability of automated systems (Burgess-Limerick, 2020). The trust in automated systems depends on their reliability and accuracy (Lee & See, 2004). With the current maturity of CAS still questionable across industries and the reliability potentially compromised as a result (Hrica et al., 2022), operator trust may be at risk with CAS implementation in mining, this in turn can affect effective use (Kenesei et al., 2025). Although automation is essential and is known to reduce risks (Shariff et al., 2021), the effective use by operators and reliability of such systems are both essential to ensure that no mineworker is left behind when it comes to matters of TMM safety in the mines.

The mineworker maintains a critical role around TMM safety when using CAS, wherein their individual behaviour around TMMs, as discussed, may be influenced by various factors such as how they perceive and trust the technology (Kenesei et al., 2025; Parasuraman & Riley, 1997). Models such as the theory of planned behaviour (TPB) (Ajzen, 1991), Technology Acceptance Model (TAM) (Davis, 1989) and Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) provide a theoretical foundation to study technology adoption and acceptance in organisations. These models have factored how various constructs, including reliability and perception, affect use intent and ultimately use behaviour of technology.

However, technology acceptance and adoption models mostly apply to voluntary cases, whereas the adoption of CAS has been primarily due to the mandatory requirements of Regulation 8.10 of the MHSA on TMMs in South African mines. While this is enforced legally at the national level, the argument posed by this research is, this does not guarantee actual acceptance across operators. Acceptance is affected by various factors as discussed. For instance, at different levels of authority, different dynamics shape compliance behaviour (Rashid et al., 2022; Tyler, 1997). When enforcement shifts from managerial authority, which is at the organisational level, to legal authority which is at a national level, the more distant the relational ties (Tyler,

1997; Wong, 2024). Tyler (1997) also shows that distant relational ties exert low influence on acceptance, even though obedience may be high. Therefore, the adoption and acceptance of CAS in South African mines, given the mandatory requirement, may be affected by the level of authority with which CAS is enforced.

Adoption, which can be considered obedience to regulation in the context of CAS (Tyler, 1997), is not necessarily acceptance in terms of technology adoption models. Adoption is functionally defined as use behaviour (Venkatesh et al., 2003). In contrast, acceptance is driven by perceived beliefs about the system, which influence the intention to use it (Davis, 1989). Adoption can emerge without belief (Venkatesh et al., 2003), which can present risks of ineffective use behaviour if the intent to use the technology is harmful.

Acceptance is primarily based on two belief-based perceptions, perceived usefulness (PU) and perceived ease of use (PEOU) (Davis, 1989). These perceptions may form basis to nuanced elements of how mineworkers interact with CAS in SA. The elements as discussed, are presented by aspects not limited to, usability, reliability, and trust to keep them safe. The primary use of the system according to the Mine Health and Safety Act is generally for safety, therefore its PU can be considered primarily for safety purposes, and the PEOU would be an aspect of the systems usability or technical functionality. PEOU and PU both affect trust (Oesterreich et al., 2024) and the overall technology's acceptance (Kenesei et al., 2025; Marikeyan et al., 2023). If acceptance is formed under the umbrella of the latter, how has the mandated requirement of CAS, with the knowledge of Tyler's (1997) legitimacy theory, affected the technology's overall acceptance in mining? Furthermore, considering the frustrations that mineworkers could face with reliability of the system and potential trust issues to keep them safe, if the system is not reliable, how has this affected the effective mandatory use of the system?

The extended TAM 2 had attempted to capture how legitimacy in the form of involuntariness as a construct, affects acceptance. This however, has not been deeply explored in the context of mandated adoption beyond the organisational level (Brown et al., 2002; Lino et al., 2022). TAM, TAM 2 and UTAUT are also limited in terms of behavioural elements that may result due to trust or legitimacy issues such as, resistance or compliance to a technology due to legal enforcement. Furthermore, mineworkers' acceptance of CAS technology in high-risk regulated environments,

such as mining is yet to be explored (Heidenreich & Talke, 2020). Their perception based on how they interact and experience the system, would provide insights into how the legitimacy brought forth by the mandatory requirement of CAS intersects the actual use behaviour, which translates to the extent of acceptance.

In emphasis, South Africa is the only country amongst large mining countries such as the United States (US) and Australia, to legislate the implementation of CAS Level 9 systems across all TMMs of significant risk, and not only on underground coal machinery (Hoebbel et al., 2024; Rowland, 2025; Swanson et al., 2019), offers a unique opportunity to explore how legitimacy at the national level influences adoption and affects genuine acceptance. There is limited qualitative research on South African mineworkers' perceptions of CAS technology overall. Bellanca et al. (2019) conducted such a study in the US, but research is still dominated by technical evaluations of the technology in SA. Considering the recent promulgation of Regulation 8.10 in 2022 (Mantashe, 2022), this study is timeously justified. The objective of the study is to examine how mineworkers accept technology, with a focus on the mandatory use of CAS in South African mines. It aims to understand how factors such as use, reliability, and trust influence miners' resistance or compliance with the technology.

### **1.3 Purpose Statement**

Mining is a high-risk environment that employs strict regulatory frameworks in South Africa to ensure personnel safety. Furthermore, CAS is a safety device enforced by the DMRE through regulations in the MHSA and not a sole function of technology maturity. The intended use of the system is to safeguard mineworkers against TMM collisions, which have persisted in the years before the regulation. Therefore, the compulsory adoption of CAS in mines is currently in effect to mitigate these incidents. According to recent reports, mineworkers are still being injured as a result of TMM interactions.

The purpose of this study is to gain insights on mineworkers' experiences interacting with the system following mandatory implementation of CAS across South African mines. These experiences, in the form of how mineworkers interact, perceive and trust the system, aim to highlight insights into mandated technology adoption and its acceptance in South African mines. This will further explain how these perceptions

affects safety regarding TMMs. Given the high number of incidents presented by TMMs in mining, this research is urgently required in order to contribute to safety improvement efforts for TMM-related incidents, by providing insights that may facilitate effective implementation and acceptance of mandated technology in South African mining. These cases illustrate mandated adoption without acceptance, motivating the need for research into how perception and trust shape behavioural use.

#### **1.4 Business Contribution**

The business need for this study stems from the operational and financial impact of TMM-related incidents in mines. In 2022 and 2023, the DMRE issued and identified 633 and 529 section 54s in these respective years (Department of Mineral Resources and Energy, 2022b, 2024), albeit declining, the rate at which the DMRE has halted operations overall on safety concerns is approximately 13 notices per day. Safety presents not only risks of injuries, but also how it is unsustainable to operate under unsafe conditions. The latter also reduces financial outcomes in organisations (Kineber et al., 2023; Thonon et al., 2023). Despite regulatory enforcement, which leads to significant production losses when unreliable or found non-compliant, these systems require mines to make a considerable investment for installations. Their inefficiency threatens the return on investment, especially for smaller operations that are also subject to the regulation. This has been a growing concern with over-regulation risking sustainability and contributing to the informalisation of mining activities in other countries (Veiga & Marshall, 2019). Informal mining has plagued the South African mining industry to date (Bester, 2023; Bester & Groenewald, 2021). Therefore, ineffective implementation risks business sustainability.

Compliance with the MHSA regulations also safeguards the mine's licence-to-operate. This ensures that the mines avoid implications that may result in monetary fines or even closure (Mine Health and Safety, Act No. 29 of 1996). Understanding the mineworker's acceptance of the technology can improve training practices, change management processes, and consider design inputs regarding actual effective use of CAS in mining, which may further improve both safety and productivity when effectively accepted.

## **1.5 Academic Contribution**

The study uses a qualitative approach to extend the application of technology acceptance models to CAS in South African mining and expand on the under-developed research of mandated safety technology adoption in high-risk areas. This is achieved by evaluating how mineworkers perceive, interact and trust CAS under statutory authority to comply, highlighting how this affects acceptance of the technology. In mining, adoption is enforced, but trust determines whether mineworkers accept the system or merely comply. The study aims to explore mineworkers' experiences, on how they interact, perceive, and trust the system, to highlight insights into mandated technology adoption and acceptance in South African mines.

These findings seek to offer new insights that inform the expansion of knowledge in the existing acceptance and adoption models, particularly the UTAUT model to incorporate statutory enforcement and safety systems as a factor of adoption and how it affects acceptance. Furthermore, understanding the mineworker's acceptance can determine use behaviour of CAS in mines, that is, human factors that affect acceptance. This provides insights for the effective implementation of technology under regulatory enforcement, thus improving overall change management and effectiveness of safety technology.

## 2 Chapter 2: Literature Review

### 2.1 Introduction

The conceptual framework provided in Figure 2-1 below illustrates the structure of the following literature review under the three points, that is, (1) regulatory context of CAS and legitimacy influence on compliance and resistance behaviour, (2) how technology acceptance models such as TAM, TPB and UTAUT shape and distinguish adoption and acceptance, and how it is formed based on perceptions and trust, and (3) how safety systems and operational pressures affect behavioural outcomes in high risk environments such as mining with the consideration that CAS is a technology. The latter comprises three sections of the literature review that collectively examine how this affects compliance and resistance behaviours influencing genuine acceptance of CAS.

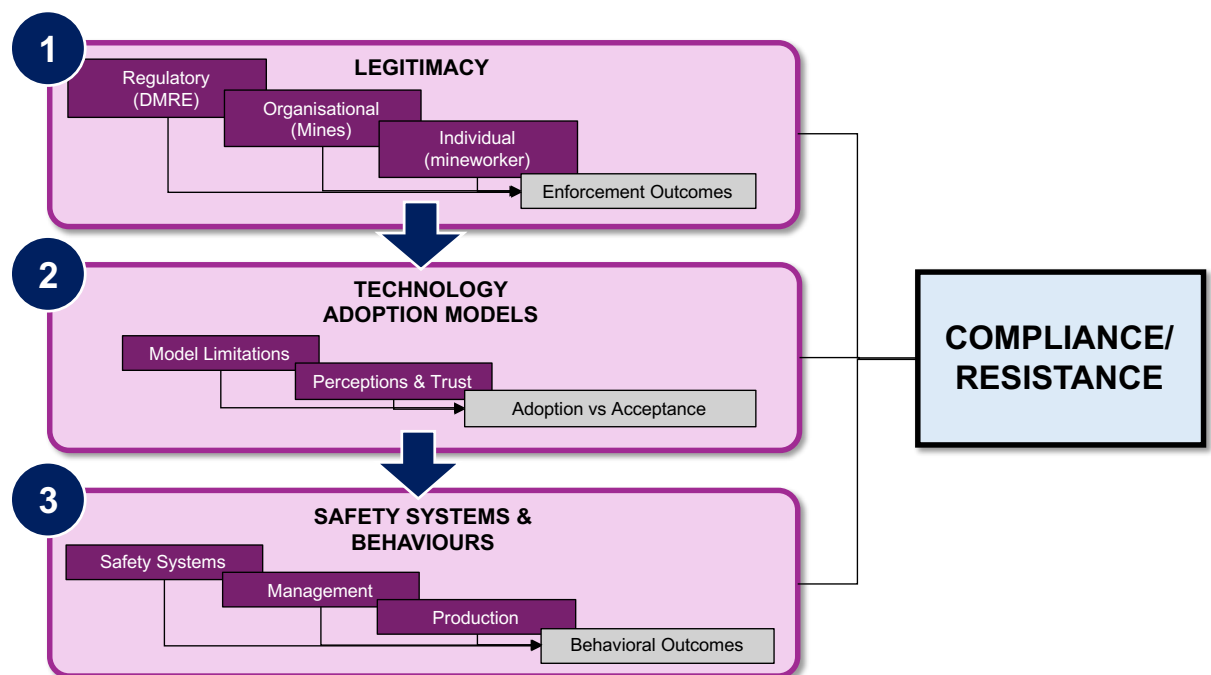


**Figure 2-1: Conceptual Framework of Literature Review**

The first section introduces legitimacy theory to provide background on how CAS, which is positioned within the mining sector as a safety system, is affected by technology adoption and acceptance behaviours under mandates. Then, the context is provided by the regulation governing the implementation of CAS in South Africa. Further explanation is provided regarding the system's functionality and its classification within different levels of automation to provide context and clarification on the extent at which human input is required for effective use. This provides a

foundation for interpreting how CAS operates as a partially automated system and how its mandated nature influences use behaviour.

The discussion then focuses on implications of the regulation, whereby the residual incidents that persist post-enforcement are presented to highlight the safety concerns which form basis for the study. This establishes the foundation for investigating the relationship between regulatory compliance, safety systems, and human behaviour in mining as the incidents persist regardless of this enforcement.

The traditional technology adoption and acceptance models are then explored regarding how CAS fits within existing theories. Models such as TAM and its extensions, and UTAUT are discussed to distinguish adoption from acceptance, and, furthermore, acceptance from effective use, in order to highlight the gaps in mandatory high-risk contexts. Safety literature is introduced to bring the research full circle in terms of analysing a technology, that is, a safety system. Exploring this body of knowledge and how it fits into CAS will assist in understanding behavioural outcomes when it comes to safety systems, and whether CAS has risks of being exposed to any weaknesses that safety systems could exhibit in high-risk environments

## **2.2 Legitimacy - Regulatory Context and Theory**

### *LEGITIMACY THEORY IN THE CONTEXT OF REGULATION*

The origins of legitimacy theory stem from the 1920's with Weber's (1968) sociological analysis of authority. Weber's (1968) work aimed to explain the basis on which individuals recognise authority as valid and comply with it. These views of legitimate authority laid the groundwork for later institutional interpretations of legitimacy. While this study focuses on compliance as a key behavioural construct, Legitimacy Theory provides the theoretical foundation to explain the mechanisms through which compliance occurs. Rooted in institutional theory, Legitimacy Theory suggests that organisations and individuals act in ways that align with societal norms and regulatory expectations to maintain legitimacy and access to resources (Dimaggio & Powell, 1983; Dowling & Pfeffer, 1975; Suchman, 1995; Tyler, 1997)

In the mining context, this includes compliance with regulatory mandates such as MHSA Regulation 8.10 to preserve the organisation's licence to operate and

reputation (Dowling & Pfeffer, 1975; Meesters et al., 2021; Tyler, 1997). The adoption of CAS technology in mining supports companies to maintain their legitimacy, as this demonstrates operational safety and reputational standing by following through with government mandates (Suchman, 1995; Tyler, 1997). However, compliance to mandatory requirements by an organisation does not guarantee mineworkers' individual acceptance of the system (Blanc et al., 2022). Mineworkers may obey out of obligation to but lack the belief in the system. This may result in mere compliance and ineffective use, especially under production pressures (Muthelo et al., 2022; Tyler, 1997).

To explain legitimacy, this manifests at three levels as adapted from Tyler (1997), (1) regulatory or national level, which could be described as alignment to legal mandates and enforcement of the law, (2) organisational level, which aligns with the intent to preserve reputation, thus an organisation following through with such mandates and, (3) individual level, which aligns with mineworkers' belief and trust in CAS or the institution's intent. In the context of mandatory adoption of CAS under the MHSA regulations, this is enforced at a national level of authority, with mining organisations forced to comply by the DMRE, and thus investing their resources on the system at the organisational level. Despite regulatory enforcement for organisations to employ CAS and the industry achieving wide adoption, this may not necessarily result in individual acceptance. Mineworkers may comply, but may not believe in or trust the systems effectiveness, which may create a gap between adoption and actual acceptance (Davis, 1989; Venkatesh et al., 2003).

### *REGULATION CONTEXT*

TMM incidents have seen significant attention in mining, with the prevalence of accidents necessitating regulatory interventions from the government (Ismail et al., 2021a). Government regulations, which were found to be an effective mechanism to ensure compliance in high-risk environments (Gao et al., 2020), was the next essential step to reduce risks of TMMs in mining. With that, the government declared regulation 8.10.1 to 8.10.2 in 2015 under the MHSA for the statutory use of retarding and stopping systems on TMMs, for both pedestrian and vehicle detection to combat safety concerns (MHSA, Act No. 29 of 1996).

The regulations state:

*“All [\*TMMs]... must be provided with means to automatically detect the presence of any pedestrian [any other \*TMM] within its vicinity. Upon detecting the presence of a pedestrian, the operator of the TMM and the pedestrian must be warned... where no action is taken to prevent potential collision, further means must be provided to retard the TMM... whereafter the brakes [TMM] are automatically applied without human intervention.” – (MHSA, Act No. 29 of 1996, pp.186-187)*

The phrase, “*application of brakes without human intervention*”, introduces automated functions as a mandatory requirement. This is at the highest control intervention according to the Earth Moving Equipment Safety Round Table’s (EMESRT) levels of control (LoC), which range from Level 1 to 9 (Earth Moving Equipment Safety Round Table, n.d.). These LoCs were developed primarily for the mining industry by EMESRT to describe the risk control level applicable for collision prevention (Earth Moving Equipment Safety Round Table, n.d.). The industry uses the term CAS Level 9 or collision prevention systems (CPS) to collectively describe the collision prevention technologies and systems for TMMs implemented under these regulations (Earth Moving Equipment Safety Round Table, n.d.; International Organization for Standardization, 2022; Leonida, 2025).

In terms of EMESRT LoCs, Levels 1 to 6 describe physical and administrative controls, while Levels 7 to 9 cover the technology interventions (Earth Moving Equipment Safety Round Table, n.d.). The technology intervention LoCs introduce Collision Prevention Systems (CPS), which include not only proximity detection and retardation systems on TMMs but also other functions, such as fatigue monitoring and vehicle stability systems, to collectively mitigate the risk of TMM collisions (Earth Moving Equipment Safety Round Table, n.d.).

The LoCs are not to be confused with the Society of Automotive Engineers (SAE) J3016 Standard levels of automation (LoA) for vehicles (Society of Automotive Engineers International, 2021). To interpret the LoA applicable on CAS Level 9 systems according to the SAE definition of automation, this would be referred to as Level 1 systems (Driver Assistance) (International Organization for Standardization, 2022). This is where the system primarily intervenes with braking and decelerating

functions to assist the driver, while fully operating the vehicle (International Organization for Standardization, 2022; Society of Automotive Engineers International, 2021). A system designed with an operator in the loop (Parasuraman and Riley, 1997)

CASs are primarily designed to mitigate TMM collisions in the mining sector, and ultimately support safety compliance with the stated MHSA regulations. The regulations are an attempt to achieve safety through technology, however, the effectiveness of CAS relies on human behaviour (van de Merwe et al., 2024). CAS is partial automation, so outcomes depend on human oversight, with the machine taking over under risky conditions instead (Horowitz & Kahn, 2024). CAS Level 9 systems only intervene when the TMM is on a collision path to prevent a crash, but cannot be entrusted with optimal operation and navigation features (Earth Moving Equipment Safety Round Table, n.d.; Horowitz & Kahn, 2024). Therefore, this creates the need to evaluate the actual operational impact of the technology’s enforcement in mining and how it is accepted by mineworkers to effect operational safety of TMMs.

*EFFECT OF THE REGULATION*

In 2024, the industry celebrated an 80% reduction in overall fatalities, with the lowest recorded deaths of 43 fatalities (South African Government, 2025), a significant milestone for the mining industry. Following the enforcement of the regulation, the mining industry has also realised a four-fold reduction in TMM related fatalities over the last decade (Likhi, 2024). However, the significant reduction of overall mining incidents can be argued to be caused by the contraction of the mining sector (Jenke et al., 2021; Joughin, 2024).

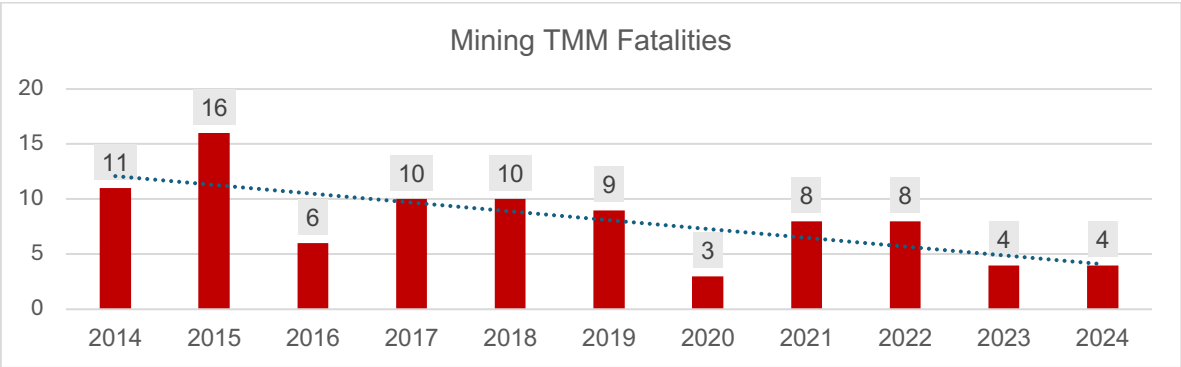


**Figure 2-2: Mining TMM Fatalities (Likhi, 2024)**

Within these lingering incidents, TMM incidents continue to persist, accounting for an average of eight fatalities per year (Figure 2-2). This highlights how technology regulation alone has not eliminated the presumably inherent risks of TMMs in mining, assessing these fatalities post-2015 when the system was mandated.

The overall introduction of automated systems is suggested to reduce human error and lower collision risks without any human intervention (Horowitz & Kahn, 2024; Leonida, 2023), but TMMs remain one of the leading causes of injuries in the South African mining sector regardless of the enforced adoption (Department of Mineral Resources and Energy, 2022b, 2024). This suggests that CAS technology alone has not been able to eliminate collision risks, and achieve the industry's goal of zero harm as intended, this begs the question, why?

The technology is still developing. To date, the South African Bureau of Standards (SABS) has also not yet developed mature standards for the systems apart from the global ISO 21815 series of CAS technical standards, which was only published in 2022. Mine houses in South Africa have been left to rely on the Minerals Council's non-statutory best practices and informal testing guidelines to standardise the process and ensure compliance (Minerals Council South Africa, n.d.). With implementation of safety systems, a lack of clear guidance has been suggested to result in ineffective application (Lumadi & Nyasha, 2024). Furthermore, enforcement without adequate guidance has proven to weaken change management (Harrison et al., 2021). It is recommended for industries such as mining should stress structured policies and communication, which are prerequisites for successful technology adoption (Lumadi & Nyasha, 2024). The latter suggests how CAS adoption in South Africa is actually challenged.

Although the involuntary top-down enforcement of the technology has ensured industry wide adoption, which is observed as compliance, this does not guarantee individual acceptance (Alqahtani & Braun, 2022; Heidenreich & Talke, 2020). Exploring mineworkers' experiences with the technology under mandatory CAS adoption becomes essential to determine if mere regulatory compliance practically translates into safer mining practices when taking into account the adoption challenges. This implies that mineworkers are actually using the technology effectively even under enforced adoption.

*MINING HISTORICAL CONTEXT TO LEGITIMACY SUPPORTING ADAPTATION*

The gap between adoption and acceptance can be derived from South Africa's legislative history. Mining safety regulations have in the past been used to legitimise discrimination and prioritise production under the fallacy of safety (Cobley, 2020; Simons, 1960). From the early 20th century, South African mining regulations in the Mines and Works Act 12 of 1911, used the rhetoric of "safety" to institutionalise racial inequality in the guise of regulatory legitimacy (Maqutu, 2022). The effect of this was met with adoption of regulations that were not otherwise accepted by the disadvantaged mineworkers who didn't have a choice. This led to significant under-reporting, unsafe conditions, and elevated accident rates which was not because of the black mineworkers incompetence, but because the regulations were weaponised to preserve white economic dominance, with little penalties on organisations, rather than to achieve actual safety (Maqutu, 2022; Simons, 1960).

The latter example, may be argued to be an extreme case of racial legitimacy, under a discriminatory government where the disadvantaged mineworkers did not have a choice. However, studies have highlighted how artefacts of this era still exist post-apartheid for the mineworker (Maseko, 2021). Furthermore, the regulatory climate during apartheid continues to influence leadership power dynamics in mining today. For instance, in the dynamics between mine health and safety representatives (HSRs), mineworkers, and the employer regarding safety relations, HSRs are appointed under the MHSA to improve safety concerns of mineworkers, but were found to prioritise the employer's interests over workers, particularly in South Africa (Coulson & Christofides, 2021). Additionally, mineworkers have been observed to suffer the brunt of prioritising production over safety, with psychological safety and security of work found to challenge these priorities (Coulson & Christofides, 2021; Haas & Yorio, 2021).

The argument of such legitimate power presented for this study is that, this may distort the importance of safety systems overall as an optional tool to use when there is no production pressure or fear of management. The evidence is in the known relics of an industry that has been studied to historically prioritise maximising production over the livelihoods of workers, and how it persists to date (Cobley, 2020; Simons, 1960). Furthermore, the dawn of a post-apartheid government has been observed to

have had little effect in improving working conditions in mining, even with the Mining Charter and Basic Conditions of Employment Act in place (Bulled & Singer, 2024; Macmillan, 2017). This may affect the overall mineworkers' beliefs in the organisation's intent for safety, and may be seen only as a ploy to achieve mere compliance.

Albeit that the South African constitution upholds different values on discrimination today (Constitution of the Republic of South Africa, 1996, Preamble), employers are still not trusted by workers in mining (Coulson & Stewart, 2024). This can be further extended to the mining legislature on employing HSRs, and the Mining Charter on mineworkers' conditions (Coulson & Christofides, 2021). They intend to improve worker health and safety accordingly, yet employers undermine this, which can compromise trust in any safety system, especially under production stress, as discussed. CAS overall is a safety regulated system, therefore, it is essential that a study is conducted to understand if it is treated as such.

Mining in South Africa presents a unique social case of regulatory legitimacy worth studying the effect of and on how technology is accepted under such conditions. Regulation 8.10 today mandates the fitment of CAS on all TMMs with significant risk (MHSA, Act No. 29 of 1996). This is aimed at reducing collisions on mobile machinery. Still, the technological requirement of a safety system can fall into the same pattern of mere compliance at the organisational level (Hutchinson et al., 2024), and be adopted as a regulatory legitimacy demonstration rather than truly integrated into the mineworker's safety habits.

Tyler's (1997) model highlights instrumental and relational legitimacy, which can be extended to describe legitimacy based on the belief that CAS improves safety outcomes (instrumental) and legitimacy gained through trust in the fairness and intentions of the DMRE or organisation (relational). These two aspects highlight how mineworkers may use the system to avoid penalty, rather than because they believe in it. Furthermore, technology adoption is more successful when bottom-up engagement and trust-building are present rather than government enforcement (Soares et al., 2021), which may enhance both instrumental and relational legitimacy.

However, hierarchical structures, commonly known as command-and-control structures, can erode trust and safety behaviour in mining. For instance, weaker supervisory engagement is associated with poorer safety climate and lower safety

behaviour in mining (Prinsloo & Hofmeyr, 2022), while work on leadership shows that leadership quality shapes trust or distrust in safety initiatives, whereby empowering leadership instead improves safety outcomes (Abiodun, 2024; Chen et al., 2023).

This makes it critical to explore mineworkers' perceptions under a mandated context to ensure regulation leads to actual acceptance and safe practices, rather than mere compliance aimed at keeping regulators at bay (Hutchinson et al., 2024). Therefore, mandatory adoption of CAS ensures organisational legitimacy through installations, but not individual legitimacy, which is belief-based and the actual driver of effective use.

## **2.3 Technology Acceptance Models – Limitations , Perceptions and Trust**

### **2.3.1 Technology Acceptance Model (TAM)**

Across industrial and organisational settings, human behavioural theories have been used to explain technology acceptance and usage. The Technology Acceptance Model (TAM) was developed by Davis (1989) as an adaptation of Ajzen and Fishbein and Ajzen's (1975) Theory of Reasoned Action (TRA) to identify the psychological factors influencing why individuals accept or reject new technologies. It aimed to identify the primary beliefs that influence user acceptance.

The technology acceptance model (TAM) suggests that, humans' perceptions influence acceptance under two constructs, perceived usefulness (PU) and perceived ease of use (PEOU) (Davis, 1989). PU would measure the degree to which a person believes "CAS can enhance my safety," similarly to instrumental legitimacy (Tyler, 1997), and PEOU would measure the degree to which a person believes "CAS is easy to use," which is more applicable to the reliability and usability aspects of the technology. The last two factors are suggested to influence behavioural intent and use. Behavioural intent indicates the readiness to perform a behaviour, while use refers to actual behaviour performed (Ajzen, 1991).

However, TAM primarily focuses on individual perceptions and does not account for regulatory influence that may drive technology use without acceptance. In the case of CAS, where use is mandatory, the model cannot fully explain operator behaviour, as usage in this case does not necessarily reflect voluntary acceptance or translate to effective use (Venkatesh et al., 2003). The two must therefore be distinguished,

since “use” may refer to mere interaction with the system and not effective operation (Trieu et al., 2022).

The last two factors are suggested to influence behavioural intent and use. Behavioural intent indicates the readiness to perform a behaviour, while use refers to actual behaviour performed (Ajzen, 1991). This does not consider influence broader than the individual’s perception which may drive an individual’s use, such as regulatory or organisational pressure. In terms of CAS, the model would not be able to interpret how mineworkers may use the system because it is mandatory, this also does not necessarily translate to effective use (Venkatesh et al., 2003). Once again, the two should be distinguished, as the current definition describes use as interacting with the system, whether effectively or not (Trieu et al., 2022)

Voluntariness is introduced under social influence as a moderator in an expanded version of TAM2 (Venkatesh & Davis, 2000). In this model, the construct is limited to the individual’s perception of voluntariness, “my use is voluntary” or “not required in my job.” These are both elements of organisational influence. No external influences are catered for in the model, such as for cases that may arise with government or regulatory bodies. Which is a valid concern considering how that has been proven to have a different level of influence for compliance behaviour compared to internal organisational influence (Tyler, 1997).

Furthermore, the voluntariness construct in TAM 2 (Venkatesh & Davis, 2000), does not consider that a system may be installed, where the use is not voluntary but the system is integrated and thus required to complete a task. A case of technology adoption using self-determination theory, has argued that, effective use comes at an individual’s determination to protect one’s health and not legitimate compliance (Hu et al., 2020), which can be motivated by an individual’s risk appetite (Priolo et al., 2025). This further distinguishes how CAS as a safety system adds another layer to the technology’s adoption, a limitation also not addressed in TAM. Brown et al. (2002) further studied voluntariness and defined it along two dimensions, which are system interdependence and the necessity to perform work. The study was over mandatory use in the banking industry, which revealed behavioural differences that would require construct changes in the original TAM2 model to extend to acceptance for safety technologies.

However, there is still a need noted for further research in other sectors, particularly high-risk areas, and for, when use is actually mandated by regulation on a safety technology in order to generalise the studies on voluntariness using TAM (Brown et al., 2002; Lino et al., 2022; Venkatesh & Davis, 2000). Overall, PU of CAS, which can be interpreted as the effectiveness for safety or usefulness of CAS, may be compromised with the distant relational ties of enforcement (Tyler, 1997). This is known to result in environmental mistrust if incidents continue to persist despite the organisation's safety installations (Zhang et al., 2022).

### **2.3.2 Theory of Planned Behaviour (TPB)**

Although TAM and its extensions, such as TAM2, have expanded understanding of technology acceptance through individual perceptions of PU and PEOU, the model is limited as it does not consider external and situational factors that influence behaviour. It does not fully address how social pressure, regulatory control, or perceived autonomy affect use behaviour under mandated adoption. To address these shortcomings, models like the Theory of Planned Behaviour (TPB), developed by Ajzen (1991) as an extension of the TRA (Fishbein & Ajzen, 1975), were created to better explain human behaviour when individuals lack full control over their actions. TPB adds perceived behavioural control and social influence to more accurately account for how personal and external factors influence intention and behaviour.

According to the TPB, human actions are guided by three beliefs which are, (1) behavioural, that is the perceived consequences of behavioural actions, for instance, "will CAS improve safety", (2) normative which is the perceived social pressure, for instance, "someone else requires or expects me to use CAS or finds it valuable" and, (3) control, which is the perceived behavioural control, for instance "am I in control with CAS installed" (Ajzen, 1991).

TPB expands TAM by introducing control and social pressure, external factors that the latter did not have. These are critical to CAS, with level 9 interventions requiring a sense of involuntary give-in of control to the system when it takes over, and regulatory pressure from the organisational and national level to make use of the system. However, the TPB model is not developed to achieve use without behavioural intent (Mehdy et al., 2021). An employee at the mine may use CAS as it is compulsory, but not have the intention to use it, in which the same has been noted for TAM and its extensions (Trieu et al., 2022; Venkatesh et al., 2016). Behavioural

use can still result without strong behavioural intention, mandatory adoption distorts the link from intent to use, which can produce forced or symbolic adoption (Brown et al., 2002; Heidenreich & Talke, 2020; Shareef et al., 2024). On the other hand, mineworkers may voluntarily accept it by virtue of a positive perception towards the regulation or intent of the organisation as discussed. Heidenreich and Talke (2020) describe these two cases as forced and symbolic adoption, respectively, whereby symbolic adoption describes instances whereby the mineworker may formally adopt the technology as required to comply but not effectively use it in practice.

The models fail to capture these nuanced elements of human behaviour that may be influenced by an individual's perceptions or beliefs of CAS or the organisation's intent, which may lead to a form of resistance, whether passive or active. Marikyan et al., (2023) describe this under Cognitive Dissonance Theory, wherein psychological discomfort is experienced by individuals with conflicting beliefs. This may, as a result, motivate a change in behaviour. Additionally, this may lead to a fear of consequences, which is known to compromise autonomy. Guo (2024) explains this through Psychological Reactance Theory how resistance may develop in an attempt to regain this autonomy. This suggests that mineworkers may resist the system if they believe that their autonomy is compromised.

Resistance, however, does not mean not utilising the system. Once CAS is installed, use is, as a result, forced, but effective use with system workarounds can be compromised (Burgess-Limerick, 2020; Muthelo et al., 2022). The model might mask these perceptions towards the system as general involuntariness in hindsight of the latter or identify them as poor influencers of use. There is still a gap in how mandated safety technology affects effective use in traditional technology acceptance models.

### **2.3.3 Unified Theory of Acceptance and Use of Technology**

The UTAUT model was developed by Venkatesh et al. (2003) by consolidating eight technology acceptance theories, which include the previously discussed, TAM, TPB, and TRA. The model aimed to create a comprehensive framework for predicting technology acceptance and use. UTAUT introduces four key determinants for intention and use that is, performance expectancy, effort expectancy, social influence, and facilitating conditions, moderated by gender, age, experience, and voluntariness of use.

The model shows how performance expectancy, effort expectancy, social influence and facilitating conditions indirectly affect behavioural use through behavioural intention, and how facilitating conditions directly influence use behaviour (Venkatesh et al., 2003). This model seems more applicable to study CAS under mandatory requirements. It includes both voluntariness and external factors that may be beyond the individual such as, facilitating conditions influencing the behavioural use variable directly. Furthermore, UTAUT is generalisable as it has been tested across organisations and over longitudinal field data (Venkatesh et al., 2016; Venkatesh & Davis, 2000).

However, similarly to the other technology acceptance models, these were developed under the same voluntary adoption as argued (Ajzen, 1991; Davis, 1989; Venkatesh et al., 2003, 2016; Venkatesh & Davis, 2000). As a result, they fail to demonstrate other emotional and psychological impacts of adoption such as source of trust, fear or influence of compliance introduced by external factors. Shareef et al. (2024) contributed to the discussion by extending UTAUT2 (Venkatesh et al., 2016) for mandated adoption. However, the work does not include automation aspects and human-to-machine interaction factors that shape acceptance on vehicles (TMMs) in high-risk environments.

An inclusion of these aspects in terms of elements that affect effective use rather than mere adoption, would be more relevant in explaining CAS acceptance in South African mines, which is also a complex social environment with under-explored mineworkers' perspectives for enforced technology adoption. Therefore, the following study argues that under regulatory pressure, behavioural use alone as a variable does not define true acceptance or use, and has been found to result in resistance when conflicting beliefs arise (Brown et al., 2002; Heidenreich & Talke, 2020; Lino et al., 2022). Therefore, existing technology acceptance models can be expanded to include the compliance-based use and genuine acceptance

#### **2.3.4 Perceptions and Trust for Technology Acceptance**

To understand human behaviour and how it translates to acceptance of a technology such as CAS, it is essential to expand on the literature about behaviour under automated systems. Although CAS L9 can be regarded under LoA 1, the systems still possess partial automation features, such as the stop, retard, and speed control

of the machine without intervention, and do not even allow the operator to take over unless the system is bypassed.

Studies on partial vehicle automation have shown how automation affects behaviour in predictable ways. Partial automation is associated with increased disengagement (Vasta & Biondi, 2025). It is also argued that familiarity with such systems is what often leads to operator disengagement, where drivers even opt for manual control under high-driving demand situations, preferring automation only when it is deemed safe (Cooper et al., 2023). Other studies have argued that operator skills may decline with increasing automation levels (Endsley, 2024), leading to reduced capabilities of operators to intervene effectively in those skills taken over by the system when required in the context of CAS. Furthermore, anthropomorphic features, that is, human-like features of automation, were linked to higher user adoption, however factors such as facilitating conditions may moderate this effect on the UTAUT model (Tian & Wang, 2022). What can be gathered from this body of evidence is that a level of trust is required for acceptance to occur.

To clarify how this links to this research, trust in automation is defined by Lee and See (2004) as an individual's perception that something or someone will assist in achieving the individual's goals under uncertain and vulnerable circumstances. Foundational work on trust in organisations defines trust as a willingness to be vulnerable based on perceptions of the trustee's ability, benevolence, and integrity (Mayer et al., 1995). This perspective is often used to interpret the source of trust in technical systems. In automation, Parasuraman and Riley (1997) showed that misaligned levels of trust drive ineffective use, building on this, Lee and See (2004) synthesised trust in automation and proposed three determinants known as performance, process, and purpose to guide the design of systems that develop appropriate reliance.

Lee and See's (2004) definition has become foundational and has shaped later models and measures of trust in automation (Hoff & Bashir, 2015; Kohn et al., 2021) and has guided research on the calibration of trust in automation (Manchon et al., 2022). In the context of CAS in mining, this definition of trust synthesises the discussions prior, on what enables or limits technology acceptance.

Trust is developed through consistently reliable automated systems (Lee & See, 2004), which are reinforced to the individual with user experience and performance. This can form the basis of the operators' experiences, translating into their perception of the system. Carter et al. (2024) reinforce this, highlighting that trust develops when users repeatedly observe automated functions operate as expected, which, as a result, influences the individual's willingness to rely on the system. This is also demonstrated in later studies where both over-trust (misuse) and under-trust (disuse) can undermine effective use (Horowitz & Kahn, 2024), highlighting it as a key indicator of effective technology acceptance. This further elaborates on why use behaviour needs to be distinguished from effective use behaviour.

Operating a machine parallel to automated technologies in contrast, is often seen as a nuisance to effective application of automation when alarms lack rationale (Simonson et al., 2022). On the other hand, for this level of automation, an operator is subject to risks of reduced situational awareness with reliance on the assistance (Endsley, 2024; Munir et al., 2022; Mutzenich et al., 2021). Novices also develop mental fatigue earlier in automated systems (Tong et al., 2024), thereby also increasing risks of reduced vigilance. However, this focus of humans as a risk, is techno-centric and reinforces full automation as the ultimate goal. It ignores nuanced social issues, such as misled capabilities resulting in misuse in higher automation levels, which was noted to have low social acceptance (Hopkins & Schwanen, 2021). Therefore, a change in belief is required to drive CAS acceptance beyond mere compliance with the regulation.

Trust is widely defined in automation by Lee and See (2004) as reliance or resistance to an automated system. Several factors can compromise trust in automated systems, such as system performance. CAS with operation can trigger false alarms and unnecessary stoppages (Rammohan et al., 2022), which have been found to lead to frustration and bypassing of the system to continue work effectively (Bellanca et al., 2019). Over and above frustration, frequent trips (or nuisance alarms) have been suggested to lead to alarm fatigue or occupational deafness in the medical field (Gülşen & Arslan, 2025; Xu et al., 2025). As a result, operators could be desensitised from reacting to every alarm, undermining the purpose of the system.

Reliable automated systems in contrast can influence operator adoption. In the context of CAS, if the PU for safety is met, "brakes intervene when they have to," this

can develop operator trust (Rammohan et al., 2022). These factors are not exhaustive, but over and above system reliability, trust in automated systems can be influenced by individual factors such as emotional responses and perceived transparency over organisational systems (Hasija & Esper, 2022; van de Merwe et al., 2024).

Trust can also be influenced by environmental factors as well, such as mine of employment, type of training, and experience (Swanson et al., 2019). These influences are not captured in the UTAUT and UTAUT2 models, which define facilitating conditions primarily as organisational resource support and technical infrastructure (Venkatesh et al., 2003, 2016). In the context of road vehicle safety, inadequate infrastructure, such as poor road designs, has been shown to constrain trust and adoption (Kenesei et al., 2025; Naiseh et al., 2025).

Similarly in the context of mining, the introduction of the Mining Industry Occupational Safety and Health (MOSH) Leading Practice guidelines for traffic management (Minerals Council South Africa, n.d.), which involves the operators' behavioural compliance to road rules, is critical for mitigating TMM collision risks. While not a mandatory practice, these are recommended guidelines that the South African mining industry has adopted to improve conditions that reduce the risk of collisions (Minerals Council South Africa, n.d.) and ensure a holistic approach to collision prevention. These influences CAS design and ultimately may affect perceived performance and facilitating conditions.

The focus in the MOSH is primarily on LoCs 1-6, mainly related to physical controls (site design) and administrative controls for traffic management. Integration of a traffic management strategy to collision prevention was found to be essential in reducing collisions across different applications (Minerals Council South Africa, n.d.; Mooren & Shuey, 2024; Mushtaq et al., 2021; Panchal et al., 2022), while, the over reliance of automated systems, has been argued to pose automation bias risks (Parasuraman & Manzey, 2010; Horowitz & Kahn, 2024). It could be argued that organisations that have not fully adopted may be passively resistant to effective adoption of the system, considering the low-cost alternative of implementing a traffic management strategy instead to reduce the "significant risk," which may be subject to their risk appetite.

An effective collision prevention program, however, includes the adequate implementation of all the LoC from 1 up to 9 for areas of significant risk. MOSH, unfortunately, also relies on human behaviour to implement and maintain aspects such as road conditions, visibility, or maintaining segregation of unidentifiable vehicles (Minerals Council South Africa, n.d.). Despite these being environmental enablers for safe CAS implementation, the high-risk environments notably often fall short on human behaviour-reliant controls (Hunt & Naweed, 2023). Therefore, CAS arguably remains the most effective means for collision prevention in the hierarchy of controls to reduce human behavioural decision making, even though human interaction is still significantly required in the operation of TMMs and in ensuring that the environment it operates within, that is the facilitating conditions, are adequate and maintained.

In addition to the latter on effecting adoption, automation bias can unfortunately develop with excessive trust in the system (Carragher et al., 2024; Horowitz & Kahn, 2024; Parasuraman & Riley, 1997). This can affect the operator's situational awareness, introducing safety risks. Limitations of the systems should therefore be understood to prevent trust-related issues such as automation bias and compromised perceptions of performance and reliability. Horowitz and Kahn (2024) found that automation bias relatively increases with trust in automation when the stakes are high, in individuals with little knowledge of the system.

Therefore, automation bias can result in over reliance of the system in operators who over-trust CAS to take over regardless, therefore compromising safety in high-risk environments. Understanding mineworker perspectives and what influences their behaviour on safety, as Ochoa Pacheco et al. (2022) recommends, may contribute additional factors to technology adoption models such as UTAUT. Furthermore, that can factor in environmental experiences of mineworkers which shape their trust and use of the system.

## **2.4 Behavioural Outcomes and Safety in Mining**

Safety in mining is influenced by multiple factors, with behavioural dimensions often being the most significant (Ismail et al., 2021a). This aligns with Wang et al. (2024), who identified a positive link between unsafe behaviours and exposure to high-risk environments. Leadership influences behaviour significantly, especially when

production goals are placed above safety concerns (Cheng et al., 2020; Ismail et al., 2021b; Chen et al., 2023). Furthermore, leadership is necessary in aligning across work levels to effect safety changes (Le Coze & Dupré, 2022). Grote (2012) highlights how organisations should continuously balance competing goals of efficiency and safety, rather than dominance of one over the other. Conversely, Hollnagel's (2017) Efficiency Thoroughness Trade-Off (ETTO) principle warns that over-focusing on either production or safety can undermine resilience. CAS, therefore, needs to strike a balance between operations and safety functions.

A strong safety culture relies on managed flexibility that encourages adaptation rather than strict adherence (Grote, 2015; Hollnagel, 2017). In regulated environments, such as the mandatory implementation of CAS, this rigidity can create a gap between prescribed systems and actual operations. Literature on Work-as-Imagined (WAI) and Work-as-Done (WAD) concepts describes the gap between operation and systems (Hollnagel, 2014), while others maintain that bridging it through ongoing operational learning and feedback is essential for sustainable safety compliance rather than rigidity (Dekker, 2014). However, safety systems fall short of being managed in this fashion, organisations tend to prioritise audits and compliance rituals than effective safety (Hutchinson et al., 2024; Provan et al., 2020).

Therefore, the social dynamic of leadership influence on production targets alongside safety compliance under mandatory requirements of CAS, may introduce a level of complexity to technology adoption models, where the current voluntariness construct cannot measure social, organisational and technical dynamics. As discussed, these dynamics are driven by leadership styles and culture (Chen et al., 2023; Cheng et al., 2020; Wang et al., 2024), which necessitates qualitative depth to understand the environment fully.

Several technologies including CAS, have been employed across the mining sector to improve overall safety (Hrica et al., 2022; Washburn et al., 2023). Furthermore, recommended actions to mitigate safety concerns arising from TMM incidents often rely on the individual's behaviour (Bellanca et al., 2021) and regardless of these technologies, a level of effort from the mineworker is still required to ensure adequate conditions for CAS operation, as discussed with the MOSH (Minerals Council South Africa, n.d.). This posits that maintaining safety overall is reliant on human behaviour, regardless of the technology.

The system is a LoA 1 Driver Assistance vehicle technology designed to reduce collision risk without human intervention and to limit unsafe behaviour by reducing decision-making errors under stress (Leonida, 2023). However, the nature of human beings in the latter discussions presents evidence that human beings tend to undermine safety systems based on their beliefs and perceptions towards them. Additionally, behavioural adaptation theory suggests that drivers will adjust their behaviour in response to safety technologies, sometimes offsetting intended benefits, and that these adaptations differ by age (Naujoks & Totzke, 2014), highlighting the inherent risk in human behaviour. Technology use is belief influenced (Chang et al., 2022; Ruan et al., 2024), but true acceptance, that is, effective use, relies on subjective factors attributable to the nature of human behaviour towards the technology and their overall personal safety.

## **2.5 Conclusion - Study Approach**

This review discussed how the regulatory context, using legitimacy in mining, regarding safety and human perception, can help identify how it may extend and apply to technology adoption and acceptance. It was discussed that technology acceptance and human factors may strongly shape how mineworkers perceive, interact and experience CAS. Technology limitations regarding studies in this context were discussed to give the reader an idea of the knowledge already available on involuntary technology adoption.

The mining industry in South African operates under strict regulatory confines which have resulted in the legalisation of CAS Level 9 systems on TMMs. This regulatory requirement strives for zero harm across the industry in terms of TMM related incidents, but raises the question, how do mineworkers experience CAS under these mandatory requirements where efforts can be eroded by relational legitimacy. Furthermore, if these experiences have affected their perceptions of CAS, this raises the question whether it has resulted in effective use or mere compliance.

The literature suggested that adoption of CAS is not necessarily achieved by regulation alone. Aspects such as perception and attitude towards the technology have been found to construe traditional models of technology acceptance. Furthermore, these models were developed under voluntary use and demonstrate limitations under mandatory conditions. Evidence from mandatory technology

studies also emphasised that, regulation introduces new dynamics not captured by traditional models.

Trust in automation emerged as an important acceptance factor influencing the effective use of technology. Studies highlighted how this is shaped by the system's reliability, interactive experience and transparency. In the context of CAS, the study positions a new angle on technology adoption, where mineworkers' acceptance in the system may be compromised for reasons not fully measured by traditional models. These are synthesised based on the discussions on, trust in the organisation's legitimate intent, and trust when frustrations may occur under obligations to comply and operational pressures. A qualitative method of study is conducted in order to fully understand if their trust perceptions realise effective use or mere compliance, and is studied through user experience with the system.

Given the complexity in human factors and the limitations of existing models in mandated settings, the need for a qualitative research approach to fully answer the research question was further justified. Of the few studies that attempted to research mineworkers' perceptions of CAS (Bellanca et al., 2019; Swanson et al., 2019), none had been conducted in mandatory CAS settings, and none had addressed the social complexities of laws such as those in South African mining. Although voluntariness in UTAUT seeks to measure this aspect, nuanced elements of unique experiences such as the relationship mineworkers have with safety systems, leadership dynamics and the unique brutal history of mining, shape this study and cannot be consolidated into a single construct.

Furthermore, other influences by external factors, such as the physical environment, which is not a technical or service facilitating condition, are not fully operationalised within technology acceptance models. A qualitative study will provide insight on new constructs of technology adoption, especially for a model such as UTAUT which has already expanded on voluntariness. This method has also been supported by Pickering et al. (2022), where narratives that were created by adopters within an environment, influence attitude to use.

These latter perspectives are aimed at collectively explaining regulatory enforcement at the national level onto organisational level, perceptions and trust at the individual level, and organisational safety culture particularly in high-risk environments. These

are synthesised to describe and establish the gaps in compliance and resistance behaviours towards CAS following the mandatory enforcement of the technology. This would potentially explain whether CAS is genuinely accepted or symbolically complied with and forms the basis of the research questions developed in Chapter 3, whereby research question 1 and 2 address technology acceptance constructs of usefulness and usability, and individual perceptions and trust under (2), respectively, and research question 3 on safety behavioural outcomes under (3). Where (1) is used to address the overarching research question on how acceptance or resistance emerges under mandatory contexts.

The study contributes to the underdeveloped research on mandated safety technology adoption in high-risk areas such as mining, in which mineworkers' experiences, as described by their use and perceptions of the system, shape how safety technology is used. A qualitative, narrative study is employed to conduct the research. The next chapter outlines the research questions from this basis.

### 3 Chapter 3 Research Question

#### 3.1 Purpose of the Research

Building on the literature review in Chapter 2, the following chapter outlines the purpose of the research by formulating the research questions deduced from the literature review in the previous chapter. Given this, the study explores how South African mineworkers experience CAS technology as a safety system installed on TMMs. This is a field in which limited employee experience has been researched regarding mandated technology adoption. As a result, the following research questions are developed to guide an inquisitive approach for the study.

#### 3.2 Research Questions

The research questions are derived from the research problem discussed regarding persistent TMM incidents regardless of legal obligations, and the objective to contribute to the industry's intent on Zero-Harm, through understanding effective use behaviour of safety-mandated technology in the South African mining industry as discussed in Chapter 1. These questions are also intended to guide data collection and analysis for a qualitative methodology approach.

The overarching question the research seeks to answer:

**RQ:** *How do mineworkers perceive and respond to (accept) mandatory CAS in South African mines?*

This was dissected into the following sub-research questions:

**RQ 1:** *What are mineworkers' perceptions of CAS? (in terms of usefulness usability and reliability)*

**RQ 2:** *How have mineworkers experienced CAS? (trust or distrust it in terms of safety)*

**RQ 3:** *How does the mandatory requirement of CAS affect acceptance of the system? (effective use behaviour or misuse behaviour)*

This highlights perception, trust and behaviour as constructs.

Perception is aligned with constructs from models, TAM on perceived usefulness and ease of use (Davis, 1989), and also UTAUT on performance and effort expectancy (Venkatesh et al., 2003). This addresses how operators experience and interpret

CAS as a safety technology. Trust aligns to literature on automation (Lee & See, 2004), such that it provides a critical perspective into issues of reliability, nuisance alarms, and system transparency, which are all factors that relates to issues that erode or build such trust in automation.

Behaviour was deduced by relating technology adoption and legitimacy theory, highlighting how compliance, use behaviour, or resistance could shape actual outcomes under mandatory regulated technology adoption, which is also regulated safety systems and could be treated as such. These questions ensured that the study remained focused on the mineworker's lived experience while contributing to theory by extending acceptance models for mandated, high-risk environments and ultimately contributing to effective CAS implementation and use of TMM safety systems.

## **4 Chapter 4 Research Methodology**

### **4.1 Introduction**

This chapter outlined the research methodology employed to answer the research question posed in [Chapter 3](#), and furthermore to investigate mineworkers' perceptions of CAS in South African mines. The methodology choice was guided by the study objectives of which was to understand the lived experiences of mineworkers, trust, resistance and compliance behaviours of mineworkers following the mandatory enforcement of CAS.

The study is positioned within the interpretivist paradigm, which recognises how meaning is socially constructed and shaped by lived experiences. The methodological choices are then detailed to outline the use of qualitative research, whereby inductive reasoning was used to capture nuanced perceptions that quantitative methods would traditionally overlook. The research design incorporates a narrative inquiry, use of semi-structured interviews, and thematic analysis to contextualise and seek depth from the findings. Furthermore, the population, sampling strategy, data collection procedures, and quality control measures, methodological choice limitations are further studied. This chapter ensures that the study is replicable and, further ensures credibility and rigour in addressing the study objectives.

### **4.2 Research Paradigm**

The study adopted an interpretivist philosophy. Interpretivism is a key paradigm in understanding the meanings mineworkers attach to experiences (Saunders & Lewis, 2018, p.109), particularly to the mandatory use of CAS. The interpretive understanding of human action is critical for understanding subjective meanings that individuals, that is mineworkers in this study, assign to their behaviour (Platt, 1985).

Ontologically, this paradigm assumes multiple realities that are introduced by the diversity of participants' perspectives (Creswell & Poth, 2018, p.54), and epistemologically, it acknowledges that understanding of the subject matter emerges through interactions between the researcher and the participants (Lincoln & Guba, 2000, pp.168-169). This approach, therefore, aligned with the study objectives of understanding how mineworkers perceive, experience, and respond to CAS

following mandatory adoption of CAS. Similarly, in technology adoption studies, this research paradigm has assisted in understanding the 'what', 'how', and 'why' behind nuanced technology integration decisions (Masumbuko & Phiri, 2024) and has highlighted its inclination toward researching the social aspects of technology adoption, particularly within human behavioural studies (Sackstein et al., 2023).

#### **4.3 Methodological Choice And Research Design**

The study employed a mono-method, using only qualitative research. This approach was selected in order to understanding mineworkers' perceptions of CAS and the effective use of the system under regulatory enforcement. The purpose of this was to explore context specific human and industry factors that inhibit adoption or effective implementation of CAS in mining (Hasija & Esper, 2022). Therefore the study maintained a qualitative approach in order to understand nuanced elements such as perceptions and workplace culture not captured by quantitative methods as suggested by Creswell and Poth (2018), for problems that need to be explored (p.84).

#### **4.4 Approach to Theory Development**

An inductive approach was followed, which enabled the research to develop findings directly from the interviews conducted, these interviews served as the primary raw data. This approach entailed expanding the themes and concepts from the raw data into summaries that identified links and patterns aligned to the study objectives (Thomas, 2006), of which the study aimed to generate patterns and relationships related to the mandatory enforcement of CAS in mining, based on mineworkers' experiences collected through the interviews (Thomas, 2006). This approach also intended to deepen understanding of mandatory technology use in mining through mineworkers experiences. These experiences served as narratives offering new perspectives from the themes established, which were then used for characterisation and sense-making in order to address the research questions.

#### **4.5 Research Strategy**

A narrative inquiry research strategy was employed to capture the stories of mineworkers without limiting their perceptions within a survey (Saunders & Lewis, 2018, p.126), which would have limited the broadness of the information collected, and overlooked how they make sense of their own experiences. Adapting this

approach for the study enabled the development of theoretical explanations for technology acceptance in mining from mineworkers' social phenomena with CAS. A review of the DMRE incidents was also conducted in order to justify the research problem, however this served basis to the problem and more importantly familiarisation as insights to the type of risks and environment the mineworkers experience prior to the interviews. This secondary qualitative method complemented the primary interview data by enriching the researcher's understanding of the study setting and helping to justify the research problem (Bowen, 2009).

#### **4.6 Time Horizon, Techniques and Procedure**

A cross-sectional time horizon was employed, the data was collected at a single point in time following implementation of CAS (Rindfleisch et al., 2008). This was relevant given the time allocated for the research to be completed. The time horizon employed was also adequate for the scope of work. Semi-structured interview guide was developed to collect data from mineworkers (Rubin & Rubin, 2005), which entailed three subjects namely on trust of the technology, perceptions for their own lived experiences with the system, and compliance behaviour to understand use. For quality management purposes of the information acquired through the interviews, triangulation was employed over a safety officer and supervisors. To analyse the data collected, a thematic analysis was used to assess the themes that emerged from the interviews (Braun & Clarke, 2006; Saldaña, 2021).

#### **4.7 Proposed Research Methodology and Design**

##### **4.7.1 Population**

The sampled population consisted of mineworkers from anywhere in South African underground and surface operations. The mineworkers were required to have used CAS level 9 systems in their experience. The population sampled was particularly individual mineworkers who had experience operating a TMM installed with the system. These are the mineworkers in which the system is intended to protect, they also interact most with the system.

To locate the mineworkers, the mining industry has regulated appointments made under MHSA, whereby the engineers are responsible for the implementation and functionality of the system, and the operators are licensed to operate a particular TMM under regulation 8.10.23.1 (MHSA, Act No. 29 of 1996). These appointed

personnel were targeted as the primary interviewees as they had been licensed to operate TMMs by the engineer, of whom ensures the regulation is upheld to.

The safety officers and management also play a critical role of influence and managing the safety of operators respectively, as established by Cheng et al. (2020), therefore a safety officer and supervisors who were accounted for within the sampled population was used for data triangulation purposes based on the themes that had emerged in the interviews. This was to ensure the information collected was not biased and had undergone a rigorous quality management process (Morgan, 2024).

#### **4.7.2 Unit of Analysis**

The study analysed the perceptions of individual mineworkers, particularly those who had experience operating TMMs installed with CAS in South African mines. Focusing on individuals is consistent with an interpretivist design that seeks lived meanings from experiences (Creswell & Poth, 2018, p.60). In deciding on the unit of analysis, guidance was based on the specific phenomenon of interest that is the experiences of mineworkers in terms of their perceptions (Yin, 2018; Miles, Huberman & Saldaña, 2014). A criterion-based purposeful sample of operators and maintainers, collectively mineworkers who have actually worked with CAS, ensured data collection richness (Patton, 2015, p.401).

#### **4.7.3 Sampling Method and Size**

Purposive sampling was employed as it considered only mineworker (Adeoye-Olatunde & Olenik, 2021). This sampling method enabled the study of the population that exist within this context only, which was South African mines with CAS level 9 installations on TMMs in South Africa. Furthermore, to depict the perspectives of mineworkers, non-probability sampling presented validity for this population.

Guest et al. (2006) recommends 12 interviews for non-probability purposive sampling in qualitative research, with saturation often reached within the first nine (9) to seventeen (17) interviews (Guest et al., 2006; Hennink & Kaiser, 2022). Saturation was determined according to the recommended process by Guest et al. (2020) by evaluating where the themes began to converge.

The first four interviews served as the initial base themes, whereby the next two interviews were analysed for new emerging themes. When no new themes had emerged in proportion to the initial themes, saturation was considered when the new

themes contributed less than 5% of new information as the process recommended. Additional interviews were conducted in order to triangulate the themes generated in the interviews and to validate the information collected. Saturation was reached after 6 participants, however the primary interviews were cut-off after 11 interviews as shown in Figure 4-1. An additional participant was considered, a safety officer, in order to validate information from the primary interviews as indicated for triangulation.

The code discovery followed a diminishing-returns curve composed of 88 unique codes. By Interview 4, 93% of the codes had been identified, and by Interview 6, 100% of the codes were achieved. No new codes emerged from for the next five consecutive interviews conducted, therefore indicating saturation (see Figure 4-1). The sampled individuals and additional interview for triangulation purposes were interviewed telephonically and through a web-based meeting. Details of mining sites where CAS has been installed was established through personal networks in mining and through engineering forums, whereby access to other mineworkers was through further referrals post-interviews.

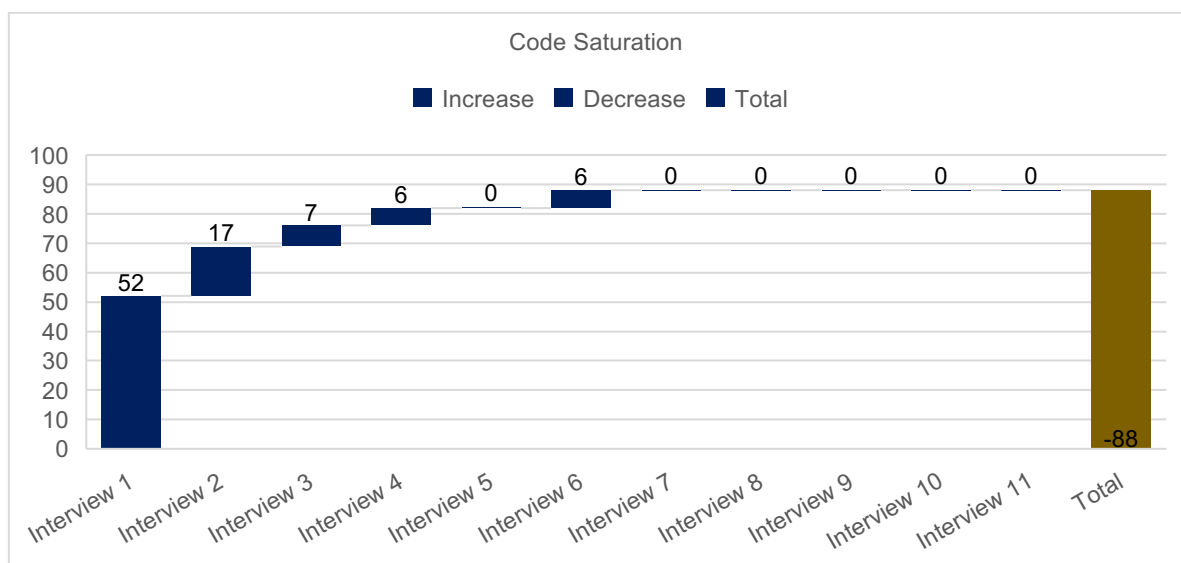


**Figure 4-1: Code Saturation Curve by the author**

#### 4.7.4 Measurement Instrument

The narrative inquiry strategy employed necessitated the use of semi-structured interviews as an instrument to collect mineworkers experiences (Adeoye-Olatunde & Olenik, 2021; Saunders & Lewis, 2018, p.126). This enabled the study to widen the constructs that were otherwise limited to close-ended Likert scale questions.

The semi-structured interview guide in Appendix A was used. This was developed based on the interview protocols by Jacob and Furgerson (2012). Furthermore, this took guidance from similar studies that have outlined questions on perceptions and experiences of users on technology acceptance and adoption models (Hasija & Esper, 2022) and was further guided by the literature review. The questions addressed the objectives of the study, which were to understand mineworkers' experiences under the enforcement of CAS technology in South African mines (Adeoye-Olatunde & Olenik, 2021). The questions were delivered such that they are open-ended, and allowed for further probing to develop further context beyond the design guide (Rubin & Rubin, 2005).

The interviews were executed to follow the design structured as follows:

The mineworker's role and experience in the industry, including background information: This was an opportunity to make the interviewee comfortable by allowing them to provide background information about themselves. Taking note to start with easy questions then probing in the difficult questions about regulation and compliance towards the end of the interview (Jacob & Furgerson, 2012)

The next questions were intended to initiate conversation on the mineworkers' perceptions on CAS by adapting technology acceptance questions into the interview. These questions related the effect of perceptions of on use behaviour.

- (1) How the mineworker's experiences and perceptions have been using CAS, or what their thoughts are of the system was find out their perceptions.
- (2) How easy have they found the system to use or difficult it is to use and what has been challenging about it.
- (3) How they feel about the effectiveness in preventing incidents, if they trust the system will intervene in an emergency and how much of control of their safety, they believe they have when the system intervenes. This has incorporated indicated research on trust and technology acceptance.
- (4) What the mineworkers know and think about the regulation, and role of the managers with regards to the implementation of the system.
- (5) What recommendations do they have for improvement of the system and if there's anything else that they would like to share considering that they were comfortable to open-up on reflections.

#### **4.7.5 Data Gathering Process**

Semi-structured interviews were conducted through two channels, telephonic and through Microsoft Teams. Recordings were made through embedded Microsoft systems for the web-based interviews. The telephonic calls were recorded using the researchers mobile device with a transcription application built in. The two means were able to record and transcribe internally over the interview. The data was then stored on a university supplied cloud-based drive with the back up on an alternative account and a hardware storage device. This information will be retained for a minimum of ten years as required by the University.

#### **4.7.6 Ethics**

The identities of the participants were not presented in the final data in order to protect the privacy and confidentiality of the participants. Although verbal consent was provided prior to the interview, this was also established through a digital form request, whereby further demographic information was collected from the participants in order to cross-check the information supplied from the interviews conducted. Consent was verbally requested and recorded before starting the interviews, however an additional survey as provided in Appendix B was sent after the interviews in order to establish digital evidence of the consent, and collect demographic information to understand the diversity of the interviewed participants and locate the analysis.

#### **4.7.7 Analysis Approach**

Interviews as mentioned were recorded, this was for evidence and record keeping purposes that the research was actually conducted, and primarily for data collection through transcription. These transcripts were analysed verbatim for any errors, and to identify confidential articles to be removed that the interviewees had mentioned. The transcription was then analysed for themes using analytical processes in line with narrative inquiry strategy. Braun and Clarke (2006) recommends a six-phase guide for the analysis, this was employed as follows. The process is depicted in Figure 4-2, whereby the final code to theme map is provided in Appendix C.

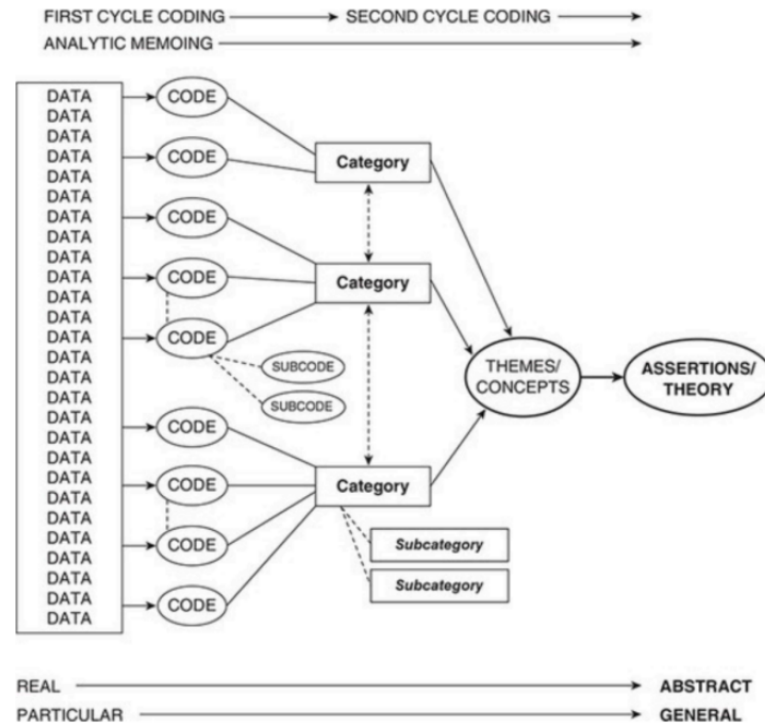


**Figure 4-2: Code to Assertion Process Described by Saldaña (2021)**

In *phase 1*, a rigorous study of the interviews was conducted in order to gain familiarity with the information. An opportunity to study to this material and establish emerging ideas to answer the research question was provided while proofreading the transcription.

In *phase 2*, initial codes were generated from the first set of interviews as indicated to observe saturation, using the first four interviews. These were organised into categories that resemble the codes (open coding). To identify codes in this data, Saldaña (2021) presents mechanics of coding for the selected qualitative research, of which multiple mechanics were employed to identify codes throughout this process. For instance, descriptive coding was used to describe the themes, in-vivo coding was used on certain participants, whereby quotes were taken as code like “*not my decision*”, emotion coding for “*frustration*”, process coding for acts like bypassing and concept coding for situational awareness was employed too.

In *phase 3*, the themes were established from the categories, since the approach is inductive and therefore data driven, the themes emerged from the categorised data. This was taken as an iterative process to establish sub-

themes and main themes, which ultimately established the overarching themes.

A step following the latter mentioned was the final revision of the themes in *phase 4*, where some themes were discarded. A thematic map was developed from the validated themes to synthesize the result of the process.

In phase 5, the themes were defined based on what the data captured, without only paraphrasing but analysing the themes for what they represented. These themes were titled with an appropriate name that ensembled the data collected.

Lastly, in phase 6, a report was produced from the themes that answered the research questions posed. This was presented in an analytical narrative of how mineworkers experiences and perceptions affect the effective implementation of CAS under statutory enforcement.

#### **4.7.8 Quality Controls**

To maintain reliability, the research process and findings was externally reviewed. To validate the research, (1) credibility was ensured through member checks by peers as an alternative to participants. The questions were sent to industry experts prior to conducting the interviews, in order to confirm the relevance and applicability to frontline employees in the face of CAS. This was also to avoid conflict with the participants refining their responses if they were sent to them prior, (2) for transferability, the research maintained clarity of the research process and context to ensure that the research can be replicated should the need arise, even though this presented difficulties considering the structure of qualitative research.

Additionally, demographic information and conditions under which the research was conducted were made clear throughout in order to ensure replication is possible (Rindfleisch et al., 2008). (3) A clear research process was maintained, which can be verified through records of the data collected, and is kept in order to maintain trustworthiness and credibility. An audit trail was maintained throughout the study to document decisions, coding processes, and data management steps, therefore enabling external verification of the research process. As mentioned in the methodology, triangulation was used to assist in verifying across sources and to ensure quality and rigor in the data collected from the sampled interviewed population (Golafshani, 2003).

#### **4.7.9 Limitations (of Methodology)**

Qualitative research presents several inherent limitations over quantitative research. The method is subjective to the researchers bias as a human being. Interpretation is influenced by the researchers perspectives and experiences. Separating the epistemological assumptions as an interviewer during data collection was noted as a limitation in this type of research.

The choice of a cross-sectional time horizon also presented validity concerns with establishing causal inference (Rindfleisch et al., 2008). That is, with the lack of temporal sequence of events, it is not possible to determine if factors influencing behaviour and CAS adoption were affected by the regulation enforcing adoption or if that had a direct impact on TMM safety. Furthermore, the relatively small sample size limited the extent to which the findings could be generalised for the South African mining industry. Although the study provides contextual insights, the results should be interpreted within the scope of the sampled population found in the interviews and research setting. The participants were condensed in underground coal mines in the Mpumalanga region but included participants from open-cast mines in the Waterberg and Northern Cape region.

## **5 Chapter 5: Finding/Result**

### **5.1 Introduction**

This chapter presents the results as drawn from interviews conducted with mineworkers who are licensed to operate TMMs equipped with CAS. The study was guided by the research objectives which intended to unravel aspects of trust, compliance or resistance, and safety perceptions of mineworkers following mandated CAS installations on TMMs in the mining context. The findings are presented in two sections, which are made up of the demographic section and the thematic analysis results.

The study portrayed demographic particulars of the individuals who were engaged in the mining sector, including their job descriptions, working years in the mine, familiarity with CAS, and the TMMs in which they were licensed to operate. These details help in locating the analysis to support sense-making and transferability (Creswell & Poth, 2018, p.218). The thematic variables were developed in a defined manner, revolving coding and categorisation described in [Chapter 4](#). The analysis contemplates on five primary themes relating to the study objectives. The direct quotes of the participants were linked to all the themes and, were subject to interpretation on the basis of the reviewed literature in [Chapter 2](#), which add to the credibility and richness of the analysis.

### **5.2 Demographic Data**

Demographic information about the participants is provided in the following section. This will play an important role as a source of context in interpreting the results. Demographic information helps locate participants' viewpoints in terms of relevant positions, experiences, and exposure to CAS in the mining sector. These variables allow for transferability of the research and for the responses to be understood under the specific working conditions and career experiences at the time that the research was conducted.

#### **5.2.1 Roles of Participants**

The participation and distribution of interviewees regarding the functional and supervisory roles were around the need to be more diversified across the personnel who were directly required to utilise or ensure the effective use of CAS. Their roles

are familiar, making them understand the environment under which CAS is adopted, especially given that the sense of safety and user experience can vary among the operators, artisans and supervisors. These alternative work functions to the operators play an important role in triangulating viewpoints across safety, production, maintenance, and supervisors.

**Table 5-1: Roles of Participants**

| <b>MINEWORKER ROLE</b>           | <b>FREQUENCY</b> |
|----------------------------------|------------------|
| Mining: Operators/Learner Miners | 5                |
| Engineering: Artisans            | 4                |
| Engineering: Foreman/Supervisor  | 2                |
| Safety Officer (Not an operator) | 1                |

The number of participant roles indicate that a significant number of operators were present compared to other roles. This positioning ensured operator voices were represented in the data. Overall, all participants except one, used for triangulation purposes, had at least operated a TMM installed with CAS L9 within their operations. As a result, first-hand experiences of the system's response, hindrances, and compliance requirements dominate the data. However, having supervisors, engineering, mining, and safety officers is a desirable breadth, as they are the groups that manage compliance and whose participation in CAS maintenance and enforcement is directly linked.

Purposive sampling as Saunders and Lewis (2018) suggests for researcher judgment (p.145), was the appropriate choice in this situation since it contributed to the selection of only the participants who have direct contact with CAS. The data from the triangulated sources and narratives supported the representation of different occupations. Creswell and Poth (2018) state that having multiple stakeholders captured is a way of increasing the transferability and therefore leads to the richness of interpretation used in qualitative studies (p.224). These differences ultimately effect contextualisation of trust, safety perception, compliance and resistance across different realities of working places in the mines.

### **5.2.2 Years of Experience in Mining**

Experience in mining is one of the most important contexts that could shape one's perception of mining. The comparative experiences between the pre-CAS and post-

CAS implementation, as well as the experience of the new workers shaped by operations where CAS had already been implemented, are the norms of which both workers compare with. This divergence facilitates perception of historical and present perspectives of the role of the system in enhancing safety and shaping work practices.

**Table 5-2: Years of Experience in Mining**

| EXPERIENCE IN YEARS | FREQUENCY |
|---------------------|-----------|
| 0 – 5 years         | 3         |
| 5 – 10 years        | 5         |
| 10 – 20 years       | 2         |
| 20+ years           | 2         |

There is a balanced spread in terms of experience levels. The less experienced participants of one to five years, shared detailed accounts of working with CAS from the time it was installed, while the more experienced participants provided information about CAS compared to the practices prior to when it was installed.

This distribution makes the research more acceptable as it is associated with a comparative evaluation (Patton, 2015, p.428). According to Saunders and Lewis (2018), the diversity in the experience of the participants is vital to achieve the qualitative richness, this maximises variation of the sample (p.146), with the help of which the researcher can monitor the development of their unique views. The interviews of long-service mineworkers are of special value since they recount changes in safety culture associated with CAS implementation over the past decade since promulgation of the law.

### **5.2.3 Types of TMMs Licensed to Operate**

The degree of direct interaction with CAS is achieved through licensing to operate certain TMMs of significant risk installed with the system. CAS functions interact daily with operators of shuttle cars, roof bolters, continuous miners, face drills, haul trucks, and load-haul-dumps (LHDs) who made up the participants as shown in Table 5-3. Focusing participation on operators licensed for machines with CAS L9 installed avoided the tendency to overlook other equipment as less significant. This approach ensured that the analysis could adequately answer the question on which types of machines have integrated CAS more extensively than others, and how the operators have experienced the system in comparison across machine types.

**Table 5-3: Types of TMMs Licensed to Operate**

| <b>TMM TYPE LICENSED TO OPERATE</b> | <b>FREQUENCY OF LICENSES</b> |
|-------------------------------------|------------------------------|
| Shuttle Cars                        | 6                            |
| Roof Bolters                        | 4                            |
| Continuous Miners (CMs)             | 2                            |
| LHDs                                | 3                            |
| Haul Truck                          | 1                            |
| Face Drill                          | 2                            |

Participants possessed one or more licenses but the largest number of licenses, according to Table 5-3, is on the shuttle car, which is noteworthy, given that such vehicles pose a significant risk of collisions in confined areas such as the underground coal mines. They were noted as a fast moving equipment within the confined underground space. Roof bolters and continuous miners are also mentioned strongly with participants noting the benefits and exasperations relating to the installation of CAS into those machines during activities such as drilling functions.

In this regard licensing data generated one more important quality, relating the response of the participants to specific types of machinery and the details of its functionality with respect to even differentiating CAS functions across. This distribution provides more validity to the study, in the sense that the accounts that the mineworkers provided are based on lived experiences within operations. According to Saunders and Lewis (2018), relevance is ensured in purposive sampling as the participants are people with first-hand experience of the topic under research (p.98). In addition, it is beneficial to assign roles to participants in order to interpret thematic results (Braun & Clarke, 2006).

#### **5.2.4 Operating Years in CAS-Equipped Machines**

One of the high-impact items noted was trust and compliance, which is conditioned by the experience of working with TMMs installed with CAS. The length of time spent with the system, determines the exposure to the system's advantages or disadvantages. Less experienced workers in CAS tend to report issues related to reliability and workarounds, whereas experienced ones tend to focus on safety reassurance and adaptation over lived experiences through witnessed incidents.

**Table 5-4: Years in Operations with CAS-Equipped Machines**

| EXPERIENCE WITH CAS TMM(S) | FREQUENCY |
|----------------------------|-----------|
| 0 – 5 years                | 3         |
| 5 – 10 years               | 4         |
| 10 +                       | 4         |

Patton (2015) presents that such contrasts are vital in interpretive qualitative research, as they highlight differing adaptation trajectories. Importantly, this spread reflects the gradual rollout of CAS across South African mines post-2015, with many workers encountering the technology mid-career. This distinction allows the study to capture transitional experiences on how workers who previously operated without CAS adjust compared to those who only know mining with CAS implemented on TMMs. These differences are crucial in addressing the research objectives on compliance, resistance, and safety perceptions as a result of the change in regulation.

### **5.2.5 Work Experience before CAS Installation**

Additional to the years of experience, is the period post- and pre-CAS because regulatory enforcement required all mines to adopt a system to retard and stop TMMs, commonly referred to as CAS. However some open cast mines were late adopters to the system. Therefore, identifying whether participants worked before periods of installation provides insights into comparative experiences, without erroneously assuming from the year 2015 when it was mandated. Those with pre-CAS exposure reflected on safety conditions before, while post-CAS entrants perceived the technology as a normal feature of mining work, an inseparable part of operations.

**Table 5-5: Work Experience Before CAS Installation**

| ASPECT                     | FREQUENCY             |
|----------------------------|-----------------------|
| Pre-CAS experience         | 5 (+1 Safety Officer) |
| Post-CAS experience (only) | 6                     |

The uneven distribution between participants who worked before and after CAS became mandatory, was valuable for comparative analysis. Their narratives provide a baseline for evaluating CAS's perceived benefits. Comparing these generational cohorts enhances the credibility of the findings, as it captures shifts in organisational

practice over time and maximises variation (Patton, 2015, p.281). This dataset, therefore, enabled the study to assess both historical and current perceptions, creating a holistic picture of CAS adoption across different stages.

### **5.3 Thematic Analysis of the Study**

The thematic analysis generated five integrating themes, which were focused on the intentions of the research. Each theme corresponds to three sub themes. The quotes extracted from the respondents have been clustered with the view of being original, and the interpretation has been anchored against the reviewed literature in Chapter 2. This plan ensured golden thread of connecting the aim of the research.

The thematic analysis, as outlined by Braun and Clarke (2006), was employed to interpret the narratives of the mineworkers, whereby data regarding their experiences with CAS was collected using the semi-structured interviews. This analysis followed the six phase approach described in Chapter 4. This included familiarisation with the collected data, coding of each transcript, theme development from codes, review of the themes, definition of the final themes, and the reporting. The interview transcripts were coded in the software, ATLAS.ti using both inductive and deductive reasoning. Inductive reasoning was used to capture meanings emerging directly from a participants' accounts, while deductive reasoning was used to align insights with already established theoretical constructs evident in the interview guide, such as trust, compliance, resistance, and perceived safety (Fereday & Muir-Cochrane, 2006).

### **5.4 Presentation of Results**

The overall coding process was iterative and reflexive, whereby a total of 88 final codes were produced. These were then grouped into 17 categories and synthesised into six overarching themes. The final themes were, namely, (1) Trust in CAS for Safety, (2) Compliance, Symbolic Use and Resistance, (3) Perceived Safety Benefits, (4) Impact on Work Practices and Productivity, and, (5) Challenges and Frustrations or User Experience, the Regulation and Awareness themes was used for contextualisation. Themes were validated for conceptual alignment across grouped codes and, theme distinctiveness to avoid duplication through repeated review within ATLAS.ti and will be discussed in the following sub-sections.

Credibility and dependability were enhanced through audit trails, reflexive memos, and cross-verification of codes across participant groups. Participant groups added variation in terms of experience in mining years (Table 5-2), CAS familiarity post- or pre-CAS implementation (Table 5-5), and their respective roles in mining or engineering (Table 5-1). Furthermore, a comparison across codes and code groups using the co-occurrences in Atlas.ti was employed for variation, the full codes and co-occurrences found in Appendix D.

Quotes were extracted verbatim to substantiate the findings. This also maintained the transparency between raw data and interpretation to ensure no meaning is lost in translation. The analysis provided a structured and interpretive understanding of how mineworkers make meaning regarding the use of CAS, reflecting the link between mandated compliance, perceived reliability, and level of trust in safety technology. The entire process is summarised by the figure below.

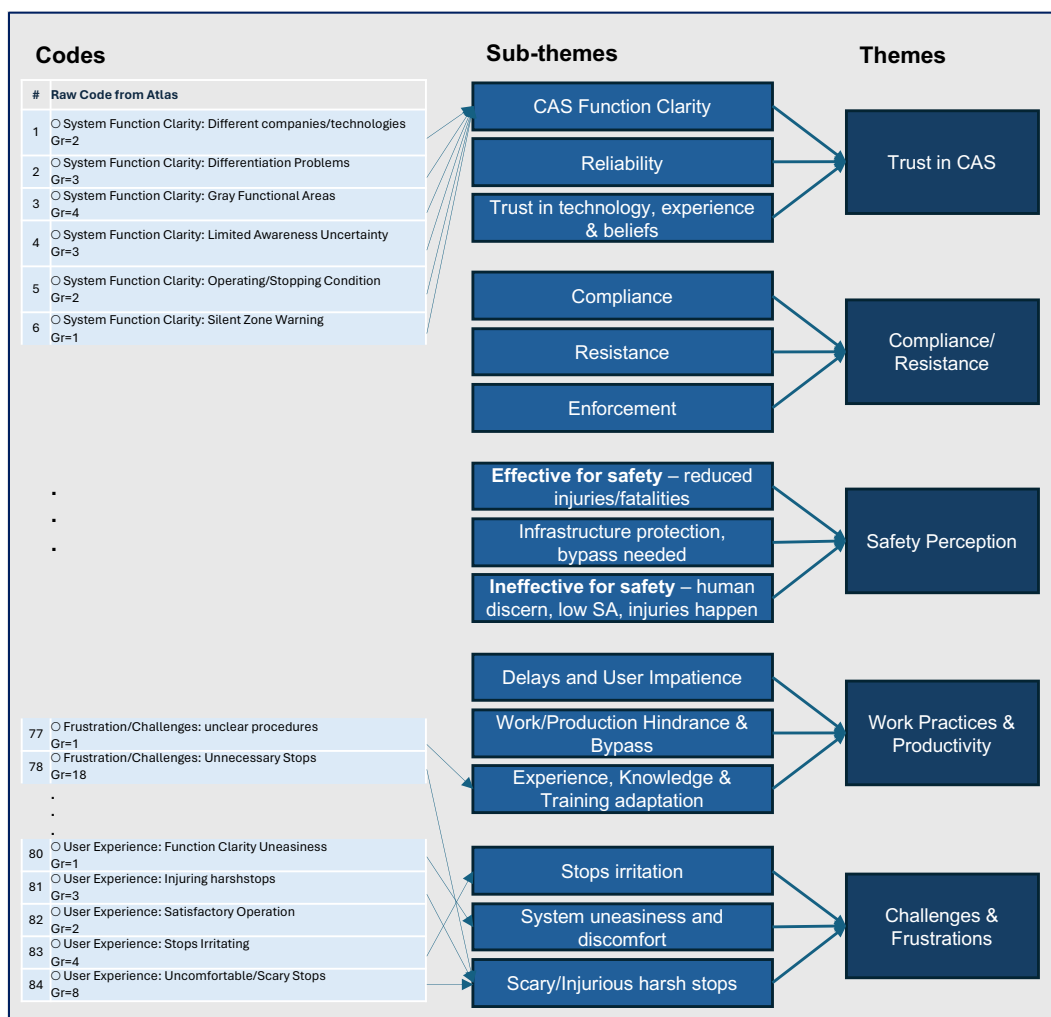


Figure 5-1: Thematic Map/Code Tree (full code list in Appendix C)

The themes were primarily driven by the emergent codes generated from the transcripts in Atlas.ti as shown in Figure 5-2, wherein the code groups directed the key sub-themes generated in **Error! Reference source not found.**, which were then grouped into the relevant themes appropriate for the study.



**Figure 5-2: The emergent dominant code groups and codes from Atlas.ti**

#### 5.4.1 Theme 1: Mineworkers' Trust in CAS for Safety

#### 5.4.1.1 Subtheme 1.1: Reliability of the system

The subject of reliability became dominant where most participants expressed the effectiveness of CAS for safety, while in the same breadth, most also expressed doubt. Trust in the safety of technology is strongly linked to its consistency and predictability, when the system behaves erratically, confidence erodes. Mineworkers reported mixed experiences in this regard, with some acknowledging the system's life-saving potential, while they also stressed its shortcomings under reliability and trust sentiments, such as the below:

*"You must not count on it. Sometimes, remember the system is man-made.... What if the relays are faulty inside?" – (Par. 77, Interview 1.docx)*

*“[don’t trust that it will do the right thing all the time] No... There was a time whereby something broke... and pinched my hand while I was operating the machine...” – (Par. 77, Interview 11.docx)*

*“if it's over that 10 kilometres an hour, most of the systems won't be able to do anything... if they do stop or turn... it causes more problems.” – (Par. 66, Interview 10.docx)*

Similarly, the safety officer noted the following, reinforcing the perception that the system's reliability cannot be guaranteed under all circumstances:

*“some machines stop at a certain distance... when we calculate the distance, the loader itself can hit the person before the machine completely stops” – (Par. 79, Safety Officer.docx)*

These quotations illustrated that trust is conditional on reliability to the mineworker. When CAS operates correctly, it is acknowledged as useful, however, malfunctions, partial coverage and past incidents, seem to undermine mineworker confidence in the system to protect them under all circumstances.

*“I don't fully trust it to protect me because some people bypass the system. So if it can be bypassed then one can never know.” – (Par. 66 Interview 6.docx)*

*“you cannot trust the system hundred percent because it can fail.... If someone breached the system before you start working? ...You use the system at the same time you're cautious..” – (Par. 79 Interview 5.docx)*

Regarding the overall reliability of the system, most participants with pre-CAS experience expressed more concerns over the reliability, expressing how the 'system can fail, and that it is man-made and may not always do what it is intended to do. These participants also expressed cautiousness. The results under reliability intersected with trust in technology, showing how mineworkers trust in the system shapes their behaviour towards CAS. The results demonstrated high co-occurrences towards exercising caution when compared across participant groups, highlighting this level of mistrust that CAS presents with reliability and experience.

|                                                  |    | Experience (1-5...<br>3 95 | Experience (5-10...<br>4 142 | Experience (10+...<br>4 120 | Post CAS<br>6 19 | Pre-CAS<br>5 19 | Roles (Eng...<br>6 214 | Roles (Min...<br>5 143 |
|--------------------------------------------------|----|----------------------------|------------------------------|-----------------------------|------------------|-----------------|------------------------|------------------------|
| Reliability: Interference Issues                 | 1  |                            | 1                            |                             | 1                |                 | 1                      |                        |
| Reliability: System can fail                     | 11 | 1                          | 4                            | 6                           | 2                | 9               | 5                      | 6                      |
| Trust in Technology: Exercise caution            | 9  | 1                          | 1                            | 7                           | 2                | 7               | 2                      | 7                      |
| Trust in Technology: Man-made systems unreliable | 4  |                            | 3                            | 1                           | 3                | 1               | 3                      | 1                      |
| Trust in Technology: Wont Always Stop            | 9  | 2                          | 5                            | 2                           | 5                | 4               | 5                      | 4                      |
| Totals                                           |    | 4                          | 14                           | 16                          | 13               | 21              | 16                     | 18                     |

**Figure 5-3: Reliability (Co-Occurrences across Participant Groups)**

The overall experiences of the mineworkers suggest that, trust in the technology is shaped by the reliability of the system. If the system is unreliable, mineworkers exercise a level of caution as the system could potentially fail, considering that it is a man-made and man-maintained system. The fact that participants could attribute a failure to their sentiments of why it is not trusted, demonstrates the conditional trust that reliability presents.

#### 5.4.1.2 Subtheme 1.2: Safety reassurance

Most participants emphasised the importance of CAS, reporting that the system enhanced their safety in the high-risk mining environment. The fact that the system could detect invisible danger and warn operators, was an aspect of the system that resulted in a sense of security. This assurance came in especially during poor mining conditions that are unfavourable such as the low-visibility, in which the human senses can be further restrained by a noisy environment. The affective component of trust tended to be commonly felt on a basis of perceived benefits of safety, with the technology serving as a psychological safety net amid the high-risk perception of the environment, however, this was not to say that the reliability was no longer an aspect that shaped trust.

*"I was happy because I saw that I am protected. I will not be injured like if there's a machine that is coming from behind that I cannot see or hear." – (Par. 34 Interview 7.docx)*

*"it does happen that maybe the operator cannot see.... So if you are at a distance, and you notice someone being in danger around the machine then you can trip the machine" – (Par. 56 Interview 6.docx)*

*"it's 100%. I see the PDS made a lot of changes to avoid the accidents. So it's very good" – (Par. 28 Interview 8.docx)*

The results and accounts emphasised that CAS provided psychological security for more than a few participants, complementing its functional role. For most of the newer workers, as demonstrated in Figure 5-4 below, these sentiments show that the presence of CAS reduced some of their concerns in challenging conditions by increasing their sense of alertness more than on the pre-CAS mineworkers.

There was more expressions on the latter from engineering mineworkers, and even more so with less than 10 years of experience. The results demonstrated how those

who primarily operate the machinery (mining) from those that only operate it for maintenance purposes (engineering) required more assistive devices. This also suggested that experience with the machineries technical aspects and proximity to risk while working around the live machines, prompted a desire for assistive devices during these complex engineering tasks.

|                                                     | Experience (1-5...<br>3 95 | Experience (5-10...<br>4 142 | Experience (10+...<br>4 120 | Post CAS<br>6 203 | Pre-CAS<br>5 154 | Roles (Engineerin...<br>6 214 | Roles (Mining)<br>5 143 |
|-----------------------------------------------------|----------------------------|------------------------------|-----------------------------|-------------------|------------------|-------------------------------|-------------------------|
| Safety Perception: Assist with alertness 10         | 4                          | 5                            | 1                           | 7                 | 3                | 9                             | 1                       |
| Safety Perception: Effective for safety 25          | 7                          | 4                            | 14                          | 11                | 14               | 9                             | 16                      |
| Safety Perception: Reduced collision/fataliti... 15 | 3                          | 2                            | 10                          | 5                 | 10               | 5                             | 10                      |
| Totals                                              | 14                         | 11                           | 25                          | 23                | 27               | 23                            | 27                      |

**Figure 5-4: Safety Perception – Effectiveness Assurance (Co-Occurrences across Participant Groups)**

#### 5.4.1.3 Subtheme 1.3: Persistent doubts and caution

Although the safety benefits of CAS has been acknowledged as the inherent feature of the system when installed on TMMs, where participants noted that TMMs are better off with CAS installed in the previous [Sub-Theme 1.2](#). There remained the overbearing feeling of constant uncertainty in most of the pre-CAS participants as highlighted by the cautious approach towards the system (Figure 5-4). Their expressions aimed at personal protection were often characterized by uncertainty in functionality or operation, and also the reliability of the system.

*“I still take all the necessary precautions for my own personal safety instead of just fully depending on the system to protect me..” – (Par. 20 Interview 3.docx)*

*“you can bump the machine with your head, because you are not aware. So you must always careful. It can happen. The machine can stop any time.” – (Par. 36 Interview 8.docx)*

*“I think I'll be more comfortable if most people can understand that the area that we working is dangerous. They should bring themselves first. They must be alert..” – (Par. 186 Interview 9.docx)*

These findings support the overarching theme that describe how mineworkers do not unconditionally trust CAS for their safety. They still favour personal vigilance even when they are registering its advantages on safety. The doubtfulness expressed by mineworkers often translates into ambiguous compliance, whereby adherence may be more symbolic than actually genuine.

External or visible compliance demonstrated as merely using the system but still applying caution suggests that CAS implementation aligns with regulatory requirements. However mineworkers' internal convictions on being cautious demonstrate reservations of their scepticism. As suggested by Figure 5-3, this cautious stance was more among mineworkers with over a decade of experience, which are more likely to reference from their experiences on operational failures vividly expressed in past-incidents stories, or any malfunctional cases.

#### **5.4.2 Theme 2: Compliance, Symbolic Use and Resistance to CAS**

The second primary theme is compliance with CAS. Compliance with CAS was achieved by regulating it and not by the natural progression of technology maturity. As an overall comment, mineworkers felt the necessity to operate through processes but on many occasions commented that compliance practices were repeated or conducted mechanically to satisfy organisational requirements, other than by strong individual conviction. Resistance, reflected as system bypassing and workarounds, also demonstrated acting-out compliance acts, especially when CAS was seen as a productivity or maintenance barrier.

##### **5.4.2.1 Subtheme 2.1: Symbolic compliance with rules**

Symbolic compliance is the situation whereby mineworkers shall only formally adhere to the use of CAS, whilst they do not consider it to be effective by internal conviction. Most participants often described compliance as influenced by external factors rather than an individual decision about personal safety. This aligns with legitimacy theory, which presumes that organisational practices may be maintained not because of their actual effectiveness but because they conform to institutional expectations or compliance to rules. The participants highlighted that although they followed procedures they did so highly because of the mechanisms of enforcement.

*"I don't believe anyone would risk their job by doing something that is not allowed..." – (Par. 60, Interview 7.docx)*

*"[on bypass removed] unfortunately that it's part of the things that our management decide on doing ...even if it takes long, unfortunately, we have to understand it and because if you don't understand it, then you are on your own. You might even get a warning or even dismissal." – (Par. 45, Interview 5.docx)*

*"I think they do practice it because if you don't they will question you that this lamp didn't test any machine." – (Par. 124, Interview 9.docx)*

The reports also indicate that conformity is mainly motivated by lip-service, where the above narratives demonstrate that some employees follow CAS procedures to avoid punishment or as it is beyond their decision, and not because of their own internal convictions. Enforced adoption encourages superficial compliance, the focus becomes demonstrating visible compliance, whereby procedures are acted out for organisational visibility and to avoid consequences as seen in more than a few expressions across the participant groups below.

Most of the participants expressed their sentiments to the restrictions regarding CAS as 'not allowed,' demonstrating enforcement and rule following. This was predominantly participants from post-CAS implementation and in engineering roles. The latter sentiments occurred highly across the need for the bypass function, but yet expressing the convictions that it is not allowed.

|                                                         |    | Experience (1-5...<br>3 95 | Experience (5-10...<br>4 142 | Experience (10+...<br>4 120 | Post CAS<br>6 9 | Pre-CAS<br>5 9 | Roles (En...<br>6 214 | Roles (Mini..<br>5 143 |
|---------------------------------------------------------|----|----------------------------|------------------------------|-----------------------------|-----------------|----------------|-----------------------|------------------------|
| > Compliance/Enforced Compliance: "not my decision"     | 3  | 1                          | 1                            | 1                           | 2               | 1              | 2                     | 1                      |
| > Compliance/Enforced Compliance: 'not allowed'         | 13 | 7                          | 4                            | 2                           | 11              | 2              | 11                    | 2                      |
| > Compliance/Enforced Compliance: Conditional tolerance | 1  | 1                          |                              |                             | 1               |                | 1                     |                        |
| > Resistance: By-pass needed                            | 12 | 6                          | 5                            | 1                           | 8               | 4              | 11                    | 1                      |
| <b>Totals</b>                                           |    | 15                         | 10                           | 4                           | 22              | 7              | 25                    | 4                      |

**Figure 5-5: Symbolic Compliance (Co-Occurrences across Participant Groups)**

This demonstrated institutional control mechanisms aimed at enforcing compliance, such as the authorisation prior to bypassing, however one participant mention the lack of such mechanisms where bypassing was a button likened to a 'light switch', whilst the rest of the participant had administrative authorisation mechanisms. Most mineworkers mentioned the removal of the bypass function, and how it is needed. This was due to a recent ban for misuse and function clarity issues, but this did not stop the mineworkers from expressing their dissatisfaction with management's decision, with comments such as *"unfortunately that it's part of the things that our management decide on doing"* emerging.

Perceived behavioural control was found to be high due to the strict rules over the mineworkers, more in engineering, needing the system but having to work without it while maintaining frustrations that, it is 'not allowed', this illustrated mineworkers'

intrinsic position towards compliance as uncertain. The mixed responses towards the removal of the bypass function and the sentiments towards the restrictions are also demonstrated in Figure 5-5.

#### 5.4.2.2 Subtheme 2.2: Bypassing and workarounds

Resistance to CAS was mostly demonstrated in bypass behaviour, especially when the system in the process delayed productivity or maintenance. Employees would discuss restoring overrides, doing away with the safety gear, or the staff discussing how they will devise ways of how to get something through. This is a realistic focus of resistance where the workers are taking the balance of both regards, which is on the regulatory factors as well as the realities of operations. The process of bypassing presents the conflict between operational needs and safety enforcement.

*“When we do maintenance. You always had to override the system... Because it makes life easier, and you finish the work on time...” – (Par. 67 Interview 5.docx)*

*“we’re under pressure to do certain work to engage and now this is becoming a hinderance when you thinking, okay, maybe if we just disable it for now...” – (Par. 42 Interview 2.docx)*

*“...going through the process of bypassing can be frustrating... people would rather take a risk, bypass and take off their lampie and try to get close to the machine to just see” – (Par. 28 Interview 3.docx)*

The co-occurrences shown in Figure 5-6 demonstrates that resistance and compliance around CAS are shaped by both experience and job role. Enforced compliance, particularly attributed to the code “not allowed,” are mostly concentrated among post-CAS participants in engineering or maintenance roles, demonstrating how rule enforcement emerged after CAS implementation.

Contrary to this, this participant group mostly expressed sentiments of undermining or working around such safety systems in order to continue with work. Expressions of where and how a ‘by-pass is needed’ and related frustration are also most frequent in the engineering participants, indicating that workers involved in maintenance activities often face delays that make bypassing operationally necessary. Similarly, user impatience or perceived delays follows the same pattern to the latter as seen

with the co-occurrences across participant groups in Figure 5-6. This demonstrates the conflict between operational demands and procedural compliance.

|                                                       |    | Experience (1-5...<br>3 95 | Experience (5-10...<br>4 142 | Experience (10+...<br>4 120 | Post CAS<br>6 | Pre-CAS<br>5 | Roles (En...<br>6 214 | Roles (Mini...<br>5 143 |
|-------------------------------------------------------|----|----------------------------|------------------------------|-----------------------------|---------------|--------------|-----------------------|-------------------------|
| Compliance/Enforced Compliance: "not my decision"     | 3  | 1                          | 1                            | 1                           | 2             | 1            | 2                     | 1                       |
| Compliance/Enforced Compliance: 'not allowed'         | 13 | 7                          | 4                            | 2                           | 11            | 2            | 11                    | 2                       |
| Compliance/Enforced Compliance: Conditional tolerance | 1  | 1                          |                              |                             | 1             |              | 1                     |                         |
| Resistance: By-pass needed                            | 12 | 6                          | 5                            | 1                           | 8             | 4            | 11                    | 1                       |
| Resistance: Undermining safety systems/rules          | 11 | 3                          | 7                            | 1                           | 10            | 1            | 9                     | 2                       |
| Resistance: User impatience/perceived delay           | 6  | 2                          | 2                            | 2                           | 3             | 3            | 4                     | 2                       |
| Resistance: work/bonus/production pressure            | 15 | 6                          | 1                            | 8                           | 6             | 9            | 6                     | 9                       |
| <b>Totals</b>                                         |    | <b>26</b>                  | <b>20</b>                    | <b>15</b>                   | <b>41</b>     | <b>20</b>    | <b>44</b>             | <b>17</b>               |

**Figure 5-6: Bypass and Workarounds(Co-Occurrences across Participant Groups)**

Most participants experienced 'production or bonus pressure across the roles and years of experience, with mining and more experienced workers expressing stronger sentiments. This suggests that experienced miners perceive more external pressures, which may influence their willingness to take such shortcuts. The data along the co-occurrences highlighted a dual dynamic, strict enforcement of rules coexists with practical frustrations and pressures that may lead to resistance, where such resistance is evidently shaped by role type and experience levels.

These findings place emphasis on how bypassing is a viable solution when CAS disrupts the working processes. These workers acknowledge that while bypassing is risky, it is sometimes seen as necessary to maintain productivity or troubleshoot technical faults. Safety rules are often balanced against production pressures, with workers exercising discretion to maintain workflow. However, other exercise this function out of these reasons, and merely to avoid nuisance alarms as noted by participant 10 below, demonstrating the undermining of a safety device:

*"there are some people who actually override the system continuously... It's basically like saying you are going back to not having the system" – (Par. 76 Interview 10.docx)*

Furthermore, bypassing is also encouraged from the managerial level, with engineers who are meant to uphold the system often pressured to allow it due to production pressure, these were points corroborated by the safety officer:

*"They disconnect, they bypass the system... the 3.1, the manager will give an instruction to the engineer that, 'do what you have to do,' and we all know what that means... It means that you must bypass, but when mining is under with*

*poor planning... put the pressure on the engineer, because only the engineer is allowed to do that, give that instruction” – (Par. 42-44, Safety Officer.docx)*

Overall, it can be said that, if CAS hinders operations, intention to comply is seen to weaken with workers displaying their frustrations and pressures, with participants demonstrating the intent to bypass with user impatience and the undermining of safety systems observed from mineworkers to leadership. The data therefore illustrates the challenges of CAS implementation, while it is designed to save lives, the very frustrations it causes sometimes encourages risky behaviours that reintroduce hazards.

#### **5.4.2.3 Subtheme 2.3: Compliance due to enforcement**

While symbolic compliance and bypassing were common as discussed, some participants noted that strict enforcement mechanisms ensured adherence. These views reflected that, supervisory oversight, mandatory reporting, and disciplinary measures created an environment where compliance was easier to sustain. Such compliance was not necessarily dependent upon trust but rather upon fear of repercussions.

*“if ever you experience that, you just stop the machine and call the technician. We will not run with that feature, it is not allowed.” – (Par. 115 Interview 1.docx)*

*“But it's not something that I can comment on or emphasize on because it's not something that is allowed.. the engineer, is the only person who can allow it to be done [bypass]” – (Par. 105 Interview 5.docx)*

*“you can't operate the [bypassed] machine without permission and that permission will come from certain PPOS and cluster observations forms that you have to fill in.” – (Par. 56 Interview 4.docx)*

Focusing on enforcement, regulatory frameworks project a demand for visible compliance, requiring workers to perform prescribed good conduct even when there is little internal conviction or belief in the system. Mineworkers are ready to act as such because disobedience has undesirable consequences. Most of the mineworkers referred to compliance to CAS use and its processes as mandatory under idea that ‘it is not allowed,’ or ‘we cannot do that’, a normative climate where disobedience is not condoned.

These views were also substantiated by the Safety Officer, who noted how the degree of enforcement at the mines often drives workarounds, whereby mineworkers will find ways around the system. Additional to that, a culture of acting out compliance was noted in sentiments toward risk appetite underground including from supervisors.

*“Operators are scared of being charged. Now they have to find an alternative route...” – (Par. 32, Safety Officer.docx)*

*“It’s a very small percentage that has genuine safety compliance... people will take chances... Supervisors only live standards in boardrooms, when they’re underground they say, ‘do what we have to do’... Everyone does it to comply, to be honest... I think if it wasn’t for that [regulations] we would still be on CAS Level 7” – (Par. 61-73, Safety Officer.docx)*

The safety officer also made an important remark on the latter quotation, how mines are installing the system just to comply, which was also shared amongst participants, that mines would not be opting for this route if it wasn’t for the regulations, in fact a few participants felt the mines were reluctant to adopt due to costs. This illustrated the enforcement at the regulatory level observed by mineworkers.

*“introducing these systems it costs the mines a lot... So if there was no law that the mines should have the PDS systems, I don’t think they would have installed them.... maybe just encouraged us to be cautious around machines.” – (Par. 118-120, Interview 6.docx)*

*“...every system that has to be installed underground is becoming more and more expensive. I think they avoided getting the system because they didn’t want to spend a lot so they tried to come up with their own ways of cutting costs by suggesting that maybe operators should not come too close to the machines instead of installing the system.– (Par. 96, Interview 4.docx)*

*“So you want to reduce liability.... But then at the end of the day, it reduces your cost” – (Par. 90, Interview 10.docx)*

Nonetheless, the increased dependence on enforcement presented sustainability issues. In the case of compliance being strictly coercive, there was a danger of collapse in case enforcement measures are relaxed or the mineworkers feeling that

they have a way out as seen with the undermining of safety systems in Figure 5-6 and with the safety officers views. A display of this was in mines like where participant 10 and the safety officer worked, they had no authorisation for the bypass, whilst most of the others did, they also had rules restricting its use.

However, mineworkers in participant 10's mine were mentioned in Section 5.3.1.1 to '*override the system continuously*' throughout the shift to avoid activating frequently, signalling relaxed enforcement over the process, an undesirable demonstration of how unsustainable it is to rely on reinforcement of rules if a need is persistent for the function. This enforcement did not end at the operational level, mineworkers expression of systems installations reasons, illustrated how the enforcement was received at the organisational level, as an expense, rather than a system they genuinely needed to combat safety concerns proactively.

### **5.4.3 Theme 3: Impact of CAS on Work Practices and Productivity**

The third theme focuses on how CAS reshapes everyday work practices and influences productivity in the mining environment. Although CAS received positive responses across participants for improved safety, instances of disappointments on inconveniences created by nuisance stoppages were reported especially in intense production environments.

The findings indicate that compliance with some of the requirements of CAS altered routines, required adaptation through training process, experience and also behaviour in the work environment altered. These results presented the effectiveness and the intrusive nature of CAS in everyday operations as a safety system and yet a hindrance to productivity. This is the point that contradicts operational priorities and systems that need to align with safety in the mining sector.

#### **5.4.3.1 Subtheme 3.1: Productivity disruptions and delays**

One of the most evident reactions noticed among the participants was that CAS caused hindrances to production by resulting in frequent and unwarranted stoppages. Most participants described CAS as a costly inconvenience under the "cause of delays," since it provided safety at the expense of productivity, whereby production is held as a priority due to noted incentives and management pressure. Tripping of the system was also reported by the employees, and it occurred at times with no clear reason, which irritated the operators and created the delays:

*“because with us we are cutting coal and also chasing bonuses so that experience of having machines trip all the time, it was frustrating for a lot of us.”*

– (Par. 42,, Interview 6..docx)

*“...most of the time it would disturb us on production because we sometimes had to stop operating”* – (Par. 30,, Interview 4..docx)

*“...but when it starts tripping on when the nuisance trip starts kicking and then you get really, really frustrated..”* – (Par. 73, Interview 2.docx)

These accounts emphasise the productivity in opposition to safety trade-offs inherent in CAS adoption. With the system reducing accidents, numerous stoppages are seen to introduce inefficiency that disrupts the flow of operations, and most participants expressed frustrations across participant groups over this. The constant mentioning of the word frustration in the extracts also shows how employees internally view CAS as a hindrance towards achieving production goals when it trips, rather than as a protective shield for safety in contrast to what they relayed on its safety benefits, demonstrating internal conflict.

The sentiments were mostly expressed among those with less than a decade of experience, in engineering roles and have entered mining post-CAS as shown in Figure 5-7, the results also highlight how although CAS delays were experienced across, work-haste was perceived predominantly amongst engineering roles and those with less than a decade of work experience, demonstrating the role of experience, which can be extended to age and work role, in rushing tasks.

|                                               |    | Experience (1-5...<br>3 95 | Experience (5-10...<br>4 142 | Experience (10+...<br>4 120 | Post CAS<br>6 | Pre-CAS<br>5 | Roles (En...<br>6 214 | Roles (Min...<br>5 141 |
|-----------------------------------------------|----|----------------------------|------------------------------|-----------------------------|---------------|--------------|-----------------------|------------------------|
| ◇ Frustration/Challenges: Unnecessary Stops   | 18 | 5                          | 3                            | 10                          | 8             | 10           | 6                     | 12                     |
| ◇ Resistance: User impatience/percieved delay | 6  | 2                          | 2                            | 2                           | 3             | 3            | 4                     | 2                      |
| ◇ Work Practices: Causes Delays               | 16 | 8                          | 2                            | 6                           | 9             | 7            | 8                     | 8                      |
| ◇ Work Practices: Requires patient operators  | 1  |                            | 1                            |                             | 1             |              | 1                     |                        |
| ◇ Work Practices: Work/Production Hindrance   | 10 | 3                          | 6                            | 1                           | 9             | 1            | 8                     | 2                      |
| <b>Tals</b>                                   |    | <b>18</b>                  | <b>14</b>                    | <b>19</b>                   | <b>30</b>     | <b>21</b>    | <b>27</b>             | <b>24</b>              |

**Figure 5-7: Work Practices – Productivity disruptions and delays (Co-Occurrences)**

#### 5.4.3.2 Subtheme 3.2: Adaptation through training and routines

Regardless of frustrations, most participants realized that with the help of training, experience with the system over time and change management process, they

managed to integrate CAS into their everyday lives. Most of the mineworkers overtime were accustomed to the system's behaviour and modified their individual practices to reduce unneeded stoppages. In a few instances, it was to avoid being injured due to the harsh stops, an unintended unsafe benefit of CAS adjusting the operator's behaviour towards safety.

This points out to the adaptability of frontline employees in high risk environments, in which early resistance is reduced over time by gaining experience and training. The following extracts highlight this:

*"...we are used to it and we understand how it operates. We adhere to every system requirement for it to operate properly." – (Par. 40 Interview 4.docx, 24 years of experience)*

*"...now we understand the system. We know how to get around the system and not bypassing it, but know how to control the system." (Par. 140 Interview 6.docx, 14 years of experience)*

*"most of the times, where we are working with the people, [you] must adjust machine slowly because we are working [around] the people.. So you must slow [down]. Work the machine on the first gear. It's simple..." – (Par. 30 Interview 8.docx, 30 years of experience)*

The results demonstrate that through familiarity and training, particularly seen with the more experienced workers of over a decade of experience in Figure 5-8. CAS shows that it can be a significant factor in moving the technology to an integrated aspect of mining practices rather than a disruptive one. The initial frustrations yielded to acceptance as operators realised how to predict system behaviour and modify their practices to suit, particularly amongst the pre-CAS mineworkers who displayed stronger sentiments on adapting behaviour (Figure 5-8), demonstrating time and experience's value in integration.

|                                                                 |    | Experience (1-5...) | Experience (5-10...) | Experience (10+...) | Post CAS | Pre-CAS | Roles (En...) | Roles (Mini...) |
|-----------------------------------------------------------------|----|---------------------|----------------------|---------------------|----------|---------|---------------|-----------------|
|                                                                 |    | 3 95                | 4 142                | 4 120               | 6        | 5       | 6 214         | 5 143           |
| Work Practices: Training required                               | 5  | 1                   | 2                    | 2                   | 2        | 3       | 3             | 2               |
| Work Practices: Training/Knowledge/Experience - User adaptation | 20 | 3                   | 5                    | 12                  | 6        | 14      | 7             | 13              |
| Totals                                                          |    | 4                   | 7                    | 14                  | 8        | 17      | 10            | 15              |

**Figure 5-8: Work Practices – User Adaptation**

#### 5.4.3.3 Subtheme 3.3: Changes in everyday work behaviour

CAS not only transformed the work practices but also transformed daily practices. In this sub-theme, a few participants described the way their behaviour, their relationships with the colleagues and work processes became altered. Such behavioural adaptations would for instance involve, waiting until individuals had carried out their work before conducting work, so as to respect the constrained work zone as dictated by CAS. These changes demonstrate how technology is integrated as small scale practices that strengthen existing safety norms and also reshape other practices in order to force integration of the system into the organisation.

*“Once you barricade that area, you and the operator know you bypassed the machine so no one must come in there.” – (Par. 51 Interview 1.docx)*

*“I don’t know what there is something there on the rescue bay to make that machine stop. So always I must go slowly, cannot go at a high gear or a high speed..” – (Par. 34, Interview 8.docx)*

*“I can even stop until those people pass or finish whatever that they are doing so that I can continue operating the machine.” – (Par. 60, Interview 9.docx)*

The descriptions above demonstrate the fact that CAS has reshaped everyday work behaviour, and reorganized the new principles of work coordination, machine operation and task controls. To explain further, using the scenario to demonstrate changes in responsibility, participant 9 describes awaiting completion of activities, this implies that certain activities that would have otherwise run parallel, would now be altered as a result of not wanting to interrupt the machine or bridge safety clearances, as indicated by participant 1 as well. Furthermore, this demonstrated how there is a duly responsibility for the prior mineworkers to clear the area for safety before the next workers.

Nevertheless, on the other hand, a few participants narratives also revealed that CAS restricted their freedom and at some instances introduced risks in operating the machinery. Mineworkers had to also adjust their own ways of working and also their behaviour in response to the actions of other employees. At times, this slowed down processes and in contrast frustrated other employees instead as indicated below, reflecting the dual nature of CAS to adjust behaviour towards both safety and resistance.

*“The frustrating part is because we are working with production and most we rely on it for bonuses so sometimes it delays that process of you getting bonus. Because now the CM operator is operating the CM and when I come with the shuttle car, the shuttle car will shift to lower gear and it becomes very slow. Unlike before.” – (Par. 82, Interview 9.docx)*

*“There are some equipments, when the collision detection system comes on, you only have to press the override button like once... others you have to press it constantly while you are in that proximity... You actually have to press an override button with one hand. So now you are operating a truck, 200 tons equipment, with one hand.” – (Par. 62, Interview 10.docx)*

*“...when you are done with changing the component you wanted to change, you cannot test it because you must stand far.” – (Par. 30, Interview 3.docx)*

While it encouraged a sense of awareness and individual accountability for one's safety, it also compromised the flexibility and efficiency of work, and to contrary, practical safety as well. Overall, the integration of CAS into daily operations marked a broader transition towards safety culture, whereby safety technology is integrated into everyday work behaviour, however with limitations.

#### **5.4.4 Theme 4: Perceived Safety Benefits of CAS in Mining**

One of the most prevailing themes in interviews was the recognition of the role played by CAS in enhancing safety in mining activities. The respondents noted fewer collisions, increased alertness, and safety security of workers and equipment. These benefits reinforced the view that despite disappointments, CAS remained highly invaluable where life was at risk. The findings substantiate the fact that despite concerns about CAS reliability as well, workers in the direct line of fire acknowledged its role in saving lives, avoiding delays, and improving health and safety outcomes in the mining environment.

##### **5.4.4.1 Subtheme 4.1: Reduction of accidents and collisions**

The most commonly cited benefit of CAS was that it was used to reduce collisions, particularly between TMMs. This was due to death rates being high, which most of the respondents recalled before the implementation of CAS and highlighted that the safety improvements were due to the system being installed. This recognition implied a direct contribution which is given by the system to the achievement of safety. It also

underscores how regulatory enforcement, while negatively received in some ways, produced measurable positive impacts on applying pressure to organisations, generating meaningful improvements in practice as a result.

*“It has played a big role in terms of safety especially with PDS and colliding with other machines and machines colliding with people. Because most of the machines before had killed so many people..” – (Par. 63, Interview 4.docx, 24 years of experience)*

*“if you look at the accidents or incidents that have been happening lately you are more likely to have a roof falling on someone than a machine colliding with someone. So it has reduced a lot of accidents” – (Par. 70, Interview 6.docx, 14 years of experience)*

*“Too much, too much, too much, too much... PDS make a lot of difference. That's why the accident of person to bump with the machine goes down. It says zero...” – (Par. 20, Interview 8.docx, 30 years of experience)*

The testimonies confirm that CAS has achieved one of its primary objectives of reducing accidents and collisions in mining. Most of the long-serving workers contrasted pre- and post-CAS implementation conditions, noting sharp declines in fatalities and serious injuries, some even describing incidents that still play in their mind vividly prior to CAS installations. Overall, most of the workers credit CAS for reducing accidents, injuries and fatalities in the mine, with stronger sentiments among mining roles and pre-CAS mineworkers as shown below.

|                                                                | Experience (1-5...<br>3 95 | Experience (5-10...<br>4 142 | Experience (10+...<br>4 120 | Post CAS<br>6 | Pre-CAS<br>5 | Roles (Eng...<br>6 214 | Roles (Min...<br>5 143 |
|----------------------------------------------------------------|----------------------------|------------------------------|-----------------------------|---------------|--------------|------------------------|------------------------|
| ○ Safety Perception: Effective for safety 25                   | 7                          | 4                            | 14                          | 11            | 14           | 9                      | 16                     |
| ○ Safety Perception: Reduced collision/fatalities/injuri... 15 | 3                          | 2                            | 10                          | 5             | 10           | 5                      | 10                     |
| Totals                                                         | 10                         | 6                            | 24                          | 16            | 24           | 14                     | 26                     |

**Figure 5-9: Perceived Safety Benefit – Safety Effectiveness**

#### 5.4.4.2 Subtheme 4.2: Extension of worker alertness

More than a few participants emphasised that CAS extended their alertness, particularly in noisy, dusty, or confined conditions where visibility and hearing were limited, and therefore their overall senses impaired. The system’s alarms and stop functions provided critical warnings that humans might otherwise miss. This reflects literature highlighting the value of assistive technologies in extending human

perception in hazardous settings. Extension of alertness was particularly important for protecting pedestrians underground, who were also vulnerable to collisions with machinery considering the visibility constraints.

*“it’s loud in the section. So I think it was a good thing that the machine stopped and then immediately when I turned, I could see something was wrong” – (Par. 41, Interview 11.docx)*

*“a shuttle car was coming nearby... and we couldn’t hear anything behind it. Only thing that alerted us was the... in that moment, you realise how vulnerable you are” – (Par. 30, Interview 2.docx)*

*“...like when they are working in dusty place or a confined place or a noisy space where visibility is a problem. The PDS does not only protect workers alone but also the equipment.” – (Par. 32, Interview 7.docx)*

The data shows that CAS extends alertness by compensating for human limitations in the harsh underground environments. Workers acknowledged that the system’s alarms and automated responses alerted them to hazards they could not detect on their own. CAS somewhat addressed the challenge of awareness in underground conditions through such an automated systems.

However, reliance on CAS for awareness introduces a paradox. A few participants described becoming more relaxed, depending too heavily on the system, coded under ‘situational awareness’. While an extension of alertness was reportedly said to be improved by most participants, but some descriptions of alertness were risky, and actually described reduction in situational awareness, where reliance was entirely on the system. As shown in Figure 5-10, these were fewer than what mineworkers described for alertness, which was often like a second pair of eyes considering the conditions, an assistive device. The sentiments were mostly from engineering roles and with less than a decade of experience.

|                                                                  | Experience (1-5...) | Experience (5-10...) | Experience (10+...) | Post CAS | Pre-CAS  | Roles (Eng...) | Roles (Min...) |
|------------------------------------------------------------------|---------------------|----------------------|---------------------|----------|----------|----------------|----------------|
|                                                                  | 3 95                | 4 142                | 4 120               | 6 203    | 5 154    | 6 214          | 5 143          |
| ◇ Safety Perception: Assist with alertness 10                    | 4                   | 5                    | 1                   | 7        | 3        | 9              | 1              |
| ◇ Safety Perception: Situational Awareness decreased with CAS 3  | 1                   |                      | 2                   | 1        | 2        |                | 3              |
| ◇ Safety Perception: Situational Awareness Increased w/out CAS 2 | 1                   |                      | 1                   | 1        | 1        | 1              | 1              |
| <b>Totals</b>                                                    | <b>6</b>            | <b>5</b>             | <b>4</b>            | <b>9</b> | <b>6</b> | <b>10</b>      | <b>5</b>       |

**Figure 5-10: : Perceived Safety Benefit - Alertness and Situational Awareness**

Overall findings highlight the enhanced safety risks of automated systems in conditions that would otherwise decrease your awareness to make informed decisions, paralleled with the risks of overreliance by less experienced personnel, requiring the use of such assistive devices to mitigate their visibility and suppressed-sense limitations.

#### 5.4.4.3 Subtheme 4.3: Protection of equipment and infrastructure

Beyond protecting workers, a few participants highlighted CAS's role in reducing damage to machinery and infrastructure. By automatically stopping vehicles before collisions, the technology prevented costly breakdowns and safeguarded the equipment. This benefit reinforced management's case for CAS, as it contributed not only to worker safety but also to operational efficiency by minimising downtime caused by machine damage. Thus, CAS was perceived to have dual functionality, that is for safety and an asset-protection mechanism.

*“even the machines were bumping one another, that was causing delays and production not going as planned. The production must [would] stop because of those incidents” – (Par. 44, Interview 7.docx)*

*“...it will step a bit forward to allow it to stop and not collide and save damages on the machines instead of causing breakdowns and cause other costs. – (Par. 34, Interview 4.docx)*

*“I feel these systems are only safeguard equipment to equipment.. Yes. They do not really save guard you as an operator from anything.” – (Par. 58 Interview 10.docx)*

The participants' reflections demonstrate that CAS's benefits extend beyond human safety to the protection of valuable mining assets. CAS serves the business and business interests by avoiding collisions, which minimize equipment downtime and cost of repairs.

Nevertheless, equipment protection is considered to have lower significance in comparison with the inconvenience of the technology such as, the frustrations against nuisance stoppages. The desire of workers to give credit to CAS with reasons as protecting machines proves that organisational and worker interests are partially harmonised, though there also are tensions, with participants who notably asserted

with scepticism that the system is to protect the assets of the organisation and does not protect operators from ‘anything.’

#### 5.4.5 Theme 5: Challenges and Frustrations with CAS

The participants regardless of them admitting the advantages of CAS, were defiant in the way they were complaining about its deficiencies and intolerable side effects. The hurdles included unnecessary stoppages, malfunctioning systems, hazardous operation and maintenance issues. The disappointments often led to withdrawals and declining sense of responsibility as considerations in flexibility of operation decreased. The findings indicate that though CAS increased safety there were emerging safety risks, like a sense of complacency, delays and resistance behaviours, as a result. These strains reflect more general differences in existence in relation to use of technology enforced, which may be subject to simultaneous uncertainty on the other hand.

##### 5.4.5.1 Subtheme 5.1: False alarms and unnecessary stoppages

Common frustrations regarding CAS comprised of repetitive false alarms and unnecessary stoppages. Most participants described how the machines could just stop before or even where there was not yet an evident threat. This type of malfunctions did not only disrupt the working process, but also created a sense of distrust in the system. False positives destroy reliability because they occur in such a manner that casts doubt on the system, as to whether it is acting on real threats or failure. Such experiences prove the capability of safety technologies to provoke frustrations due to reliability issues.

*“It would even just stop without giving you a warning... if you are not wearing your safety belt, you can hit other components there.” – (Par. 42, Interview 4.docx)*

*“I am driving the machine, and it is on working mode and there is no one. Suddenly the machine just stop. That is more irritating.” – (Par. 57, Interview 1.docx)*

*“...when it trips now, most of the time, it detects even a person who's not even near the machine. I don't know what makes that happen” – (Par. 49, Interview 11.docx)*

False alarms was one of the largest predicaments that tainted the credibility of CAS, more so from mining operators who had day to day experiences with running the machinery (Figure 5-11). Recounts of the machine just shutting down without any known cause co-occurred with user-experience accounts of hazardous stops, such as being thrown across the cabin as noted by a few participants, whilst another mentioned interrupting delicately sensitive processes such as underground support drilling on the roof bolter. Notably, the findings reveal the contradictions with CAS, whereby the solutions that are intended to enhance its safety also decrease its influence among mineworkers as the solutions are met without clarity on day to day operational function.

|                                                           | Experience (1-5...<br>3 95 | Experience (5-10...<br>4 142 | Experience (10+...<br>4 120 | Post CAS<br>6 9 | Pre-CAS<br>5 9 | Roles (Eng...<br>6 214 | Roles (Min...<br>5 143 |
|-----------------------------------------------------------|----------------------------|------------------------------|-----------------------------|-----------------|----------------|------------------------|------------------------|
| ○ Frustration/Challenges: Harsh braking 4                 |                            | 3                            | 1                           | 2               | 2              | 3                      | 1                      |
| ○ Frustration/Challenges: Machine Stopping Unexpectedly 1 |                            | 1                            |                             | 1               |                | 1                      |                        |
| ○ Frustration/Challenges: Unnecessary Stops 18            | 5                          | 3                            | 10                          | 8               | 10             | 6                      | 12                     |
| ○ User Experience: Injuring harshstops 3                  |                            |                              | 3                           |                 | 3              |                        | 3                      |
| ○ User Experience: Uncomfortable/Scary Stops 8            |                            | 6                            | 2                           | 2               | 6              | 6                      | 2                      |
| <b>Totals</b>                                             | <b>5</b>                   | <b>13</b>                    | <b>16</b>                   | <b>13</b>       | <b>21</b>      | <b>16</b>              | <b>18</b>              |

**Figure 5-11: Challenges and Frustrations – False Alarms and Unnecessary Stoppages**

#### 5.4.5.2 Subtheme 5.2: Technical limitations of the system

Most participants identified technical limitations in CAS, including inaccuracies in detection range, delayed responses, and inconsistencies across machine types. These limitations reinforced doubts about system reliability and created uncertainty during operations. The perception that CAS was not always accurate undermined trust, as workers felt they could not depend solely on the system to operate as intended. Technical shortcomings illustrate the challenges of implementing sophisticated technologies in complex underground environments.

*“OEM B, it slows down even though it is abrupt but it does it slowly. On the OEM A once there is a problem it immediately locks up... that immediate stop is scary, you even feel like you hit something.” – (Par. 30, Interview 10.docx)*

*“Hence sometimes it can feel like the system has been bypassed, you will see the cap lamp beeping but the machine not tripping... It doesn’t slow down at all.” – (Par. 76-78, Interview 6.docx)*

*“Different machines have different ranges in terms of operation.” – (Par. 35, Interview 5.docx)*

The narratives highlights persistent technical limitations in CAS, undermining perceptions of reliability. Workers described inconsistencies in detection range and timing, with some systems failing to respond in a timely manner. The usefulness of CAS is questioned with CAS seen as inconsistent, whereby participants also described these as ‘Gray areas.’ The workers outwardly expressed following procedures while privately doubting system effectiveness.

*“It’s like I don’t know if that system can have at least a warning because from a silent zone position there is no warning” – (Par. 65, Interview 1.docx)*

*“... I just wish there was understanding around the grey areas...” – (Par. 121, Interview 2.docx)*

*“there are certain equipments, We have to press button continuously. Others you press it once. You see, there’s already a big difference in those equipment... it can go and crash into another equipment.” – (Par. 102, Interview 10.docx)*

Sentiment of these limitations were strongly expressed by engineering mineworkers in the 5-10 years of experience range. Overall this demonstrated how technical know-how of the system brought forth recognition of the system’s gaps, and not necessarily an attribution of their own limitations interacting with it.

|                                                        | Experience (1-5...<br>3 95 | Experience (5-10...<br>4 142 | Experience (10+...<br>4 120 | Post CAS<br>6 9 | Pre-CAS<br>5 9 | Roles (Eng...<br>6 214 | Roles (Min...<br>5 143 |
|--------------------------------------------------------|----------------------------|------------------------------|-----------------------------|-----------------|----------------|------------------------|------------------------|
| System Function Clarity: Different companies/tech... 2 |                            | 2                            |                             | 1               | 1              | 2                      |                        |
| System Function Clarity: Differentiation Problems 3    | 1                          | 2                            |                             | 3               |                | 3                      |                        |
| System Function Clarity: Gray Functional Areas 4       |                            | 3                            | 1                           | 2               | 2              | 3                      | 1                      |
| <b>Tals</b>                                            | <b>1</b>                   | <b>7</b>                     | <b>1</b>                    | <b>6</b>        | <b>3</b>       | <b>8</b>               | <b>1</b>               |

**Figure 5-12: System Function Clarity - Technical Limitations**

#### 5.4.5.3 Subtheme 5.3: Engineering and maintenance difficulties

CAS had a particularly significant impact on maintenance and engineering work. A few participants cited that the system made routine checks more complex, bypass during testing was essential, and recovery time was prolonged, while others mentioned the lack of clarity why it removed or how it works there, yet expected to work on such machinery. These challenges frustrated the employees in charge of equipment integrity, where some to the extent of risking their lives, since CAS strained their capability to carry out necessary duties. These experiences demonstrate the accidental effects of safety technologies, with systems that exist to

ensure the safety of operators making it more difficult to service as they are vital to the continuity of operations.

*“Sometimes one is not able to get the bypass card. So it makes it hard to do your job in the authorized way. Because if you had a bypass card it was going to be easy to do the job as planned.” – (Par. 48, Interview 7.docx)*

*“I need to move the car track and visualize the scene. So this means you can’t identify the breakdown easier with the PDS and that cause people to bypass.” – (Par. 30, Interview 3.docx)*

*“...now what they do, they stay clear, then you operate and then you go, you switch off, you go close and switch. So, it’s a process, but that takes a lot of time.” – (Par. 43, Interview 5.docx)*

CAS complicated the process of engineering and maintenance work. A few workers reported having to stop functionality of the machine then switch on which extended the time to resolve a breakdown and posed risks to production. The records of workers reveal how CAS, even though advantageous to the operator, induces unwanted obstacles in maintenance mineworkers everyday tasks, and results in resentment and resistance behaviour. This resistance was noted in unfortunate events where a few participants recalled instances of undermining safety systems to get around work, whereby in some cases this resulted in the removal of the system in favour of human discernment with the unclarity it presented to maintenance workers:

*“there was incident.. before the PDS was installed on the crusher... After this incident it was recommended by the DMRE to install the PDS on the feeder and the crusher.” – (Par. 32, Interview 3.docx)*

*“They don’t know where the warning zone or danger zone is. That’s why they remove it so when you climb on the feeder breaker you know it is not on so you switch it off.” – (Par. 123, Interview 1.docx)*

*“I think in May, June they removed the PDS system from the from the feeder break. I don’t know why. But now it raises questions because feeder breaker is one machine that causes us a lot of injuries.” – (Par. 74, Interview 9.docx)*

These views were corroborated by the safety officer, who noted the undesirable technical and financial consequences of the systems design not fully integrated to the machines:

*“when it comes to the engineering side, the breakdowns, because the machines weren't built for CAS [L9]. They were built for level 7... but for level 9, those stop start, stop start it really affects the engines... mainly because it's very expensive and when they did the trial run with an engine, it ceases faster... this stop and start, it's not healthy for the TMMs to be honest” – (Par. 30-32, Safety Officer.docx)*

Overall, the above narratives collectively point to an integration problem between safety technology and maintenance realities such the tuning of the detection zones, presence of a safe maintenance lockout in the absence of clarity with CAS function, actual machine interlocks during intrusive work, CAS consistency across functions and machine manufacturers, and most importantly, communication as displayed by participant 9, who did not know why it was removed, whilst in other mines the DMRE recommended CAS for installation surrounding the same industry fatality on the same type of machinery.

Another aspect that was evident was the work as imagined and work as done pointed out by the safety officer from the below stated. It illuminated how CAS was imagined to be working (as desired) and how it is actually is designed (practically) for operations with respect to the latter mentioned challenges. This explained the findings on why some work processes were strained with the implementations of CAS.

*“...work as imagined and work as done the way it's done underground. Because when we do procedures, it's how we imagine work should be done. Sometimes it's not practical” – (Par. 65, Safety Officer.docx).*

## 5.5 Conclusion

This chapter presented mineworkers lived experiences with mandated CAS across mining operations in SA. The participants made up of, operators, artisans, supervisors, and a safety officer, provided rich accounts of how the system is perceived, trusted, and adapted in daily operations. Demographic and experiential

information was outlined to locate the perspectives and support the triangulation across participant groups and job role categories.

The thematic analysis revealed five themes from the data collected (1) trust in CAS for safety, (2) compliance and resistance, (3) impact on work practices and productivity, (4) perceived safety benefits, and (5) challenges and frustrations. Collectively, these themes provided evidence that acceptance of CAS is mostly conditional to reliability, usability, and the operational pressures to the individual. Although, the system was widely acknowledged to improve safety and reduce incidents, frustrations with false alarms, harsh braking, and operational slowdowns led to adaptive behaviours, occasional workarounds, and symbolic compliance.

A key insight that emerged across themes is the contrast between work as imagined, that is, management's expectation of compliance and work as done, that is, mineworkers' readjustment to CAS use in order to balance safety and productivity. When the system performed reliably, mineworkers integrated it into safe working habits, but when it conflicted with work or operations, it was selectively disengaged, encouraged to be disengaged or resisted. Overall, this chapter has consolidated the findings on understanding how mineworkers perceive and respond to CAS within mining operations, through the lived experiences of mineworkers themselves. The findings provide the foundation for Chapter 6, which will interpret these results theoretically.

## 6 Chapter 6 Discussion

The following chapter aims to present the participants' descriptions across the five themes established in Chapter 5, namely on trust, compliance, symbolic use and resistance, perceived safety benefits of CAS, work practice adaptations and challenges and frustrations. The evidence was offered as patterns of reported mineworkers experiences supported by verbatim quotations and co-occurrences across participant groups defined in Chapter 5 and a safety officers views, whereby relations across themes and codes were made using a reflexive approach to analyse the data.

The themes are discussed and then reflected upon to answer the research questions that guided their development. This chapter presents the deductive part of the analysis, in which the findings are discussed and related to the theory. This is done in order to establish how the Chapter 5 findings address the research questions posed in Chapter 3. This addresses the overarching research question of the study on how compliance and resistance behaviours shape acceptance under the mandatory adoption of CAS in mines by evaluating mineworkers' experiences.

### 6.1 Thematic Discussion of Findings

#### 6.1.1 Theme 1: Trust in CAS for Safety

##### *Reliability*

The conditional trust demonstrated in the findings exposed mandatory adoption's core failure that, regulatory enforcement cannot develop intrinsic acceptance necessary for genuine technology integration. The mineworker's scepticism in acknowledging the functionality of CAS to keep them safe while exercising caution revealed how reliability and performance of the system hinders trust formation. In the results, it was found that when CAS functions in unpredictable ways, workers rationally reject full reliance on the system, particularly those with longer experience and pre-CAS exposure.

This confirms trust in automation models, that integrity and ability of the system, can trigger adaptive distrust in the system, relative to the system's performance as suggested by Lee and See (2004) in the literature. However, this contradicts Davis (1989) TAM assumption on linking the perceived usefulness to behavioural intention

as discussed in [Section 2.3.1](#). In the findings, the mineworkers simultaneously recognised the safety value (that is, usefulness) yet withheld trust due to perceived performance of the system. Similarly, in the literature of [Section 2.3.4](#), trust is linked to consistent performance by Carter et al. (2024). This validates Heidenreich and Talke's (2020) identification of symbolic use rather than genuine acceptance, supporting the argument, as reviewed in the literature, that poor reliability risks trust.

In this context, the UTAUT performance expectancy construct is not validated as a strong predictor for behavioural intention and consequent use in the context of mandated technology, even though accidents are being prevented and the system assures safety, which, based on Venkatesh et al. (2003) in the literature, should validate behavioural intention. However, the system's unpredictability in the findings validates the opposite, there is use without intention.

#### *Safety Assurance*

In terms of the safety assurance, the findings indicated that psychological security operated independently of the reliability of the system. This revealed how sentimental trust dimensions can sustain partial acceptance despite cognitive (internal) doubt, as demonstrated by cautiousness intersecting with performance perceptions in the findings. Workers in the findings valued CAS primarily for the sensory compensation in visibility-impaired, high-noise environments where human perception can be deterred, supporting additional studies on technology reducing anxiety and mental workload during challenging transitions for inexperienced workers (Eimontaite et al., 2019) and, extending their capabilities in such conditions (Imam et al., 2023).

This emotional reassurance as discussed in [Section 2.3.2](#) with the Ajzen's (1991) TPB, when workers perceive positive behavioural beliefs such that, they believe that the system assists them in high-risk conditions or extends their senses and provides protection regardless of technical inconsistencies, the intention to comply should increase. This, however, in the context of mandatory technology adoption based on the findings, is moderated by mineworkers' experience and exposure pre-CAS, as discussions on the findings highlighted under reliability.

Lastly, mineworkers in the findings viewed CAS as integral protection to their hazardous environment, not because of its flawless behaviour, but because it provided a safety net in the psyche against unforeseen risks. This finding revealed

the nuanced elements of acceptance, that in reality, psychological security can still coexist with technical scepticism, and therefore develop fragile trust relationships where regulatory pressure and perceived safety protection overcome reliability concerns to generate functional but partial adoption, which is ultimately what Heidenreich and Talke (2020) define as symbolic compliance. The arguments posed in the literature review, that the technology's usefulness for one's safety under self-determination theory, as Hu et al. (2020) suggested, can translate into acceptance, are not supported by these findings.

#### *Persistent doubts and caution*

The cautiousness of mineworkers in the findings despite CAS safety, revealed the technology's inability to influence complete reliance on it. This exposed the misalignment between the technology's functions and what is operationally practiced. The imperfect reliability prevented mineworkers from progressing beyond operator-in-the-loop dependency, as suggested by Parasuraman and Riley (1997) in [Section 2.2](#) with the technology as an assistance meant to intervene under risk. The mineworkers in the findings as a result treat the CAS as a supplement and not a replacement for those functions meant to protect them. However, that is also its demise with access to override functions as noted in the findings, it risks being misused if it reacts unnecessarily.

Such a cautious approach shown in the findings, manifests what Heidenreich & Talke (2020) identify as superficial adoption under imposed conditions, in which external compliance aligns with regulations while internal convictions remain sceptical. It is important to note that this compliance, as posed in [Section 2.2](#) on use under enforcement, does not necessarily translate to acceptance. It validates the mere compliance for obedience (just using it) presented by Tyler (1997) in the literature. This therefore challenges the assumption that mandatory technology adoption alone is sustainable, as true acceptance requires internalized beliefs in the technology's perceived usefulness and reliability (Brown et al., 2002; Venkatesh et al., 2016; Venkatesh & Davis, 2000), which in this case has not been achieved intrinsically as demonstrated by the findings with mineworkers' cautiousness.

Once again as noted in TAM, this uncertainty in the findings affects behavioural intention even if usefulness is perceived as suggested by Davis (1989) in [Section 2.3.1](#). Legitimacy theory further develops this idea by requiring users to ensure that

the system functions to maintain credibility constantly. Otherwise, trust may diminish, and then mineworkers may likely misuse the system, as Lee and See suggested on trust with reliable performance, and supported by Suchman (1995) on maintaining legitimacy through the system. Sustainable integration of such a technology requires that workers internalize the perceived benefits, not merely go through the motions of just using the system to comply with rules as the literature suggests in [Section 2.3.3](#).

The contradiction with this is that, self-trust deemed as complacency enhances safety by avoiding over-trust associated with automation as Horowitz and Kahn (2024), and Parasuraman and Manzey (2010) suggest with automation bias risks in [Section 2.3.4](#). This also created a disconnect between what legislature desires and what actually occurs on the ground as observed in the findings. This cautious scepticism was a rational reaction to unreliable technology and that mineworkers embraced mandatory requirements but reserved the responsibility for safety in their own hands, especially those with experience.

### **6.1.2 Theme 2: Compliance, Symbolic Use and Resistance to CAS**

#### *Symbolic compliance with rules and Compliance due to Enforcement*

The key findings in these sub-themes were that compliance was driven by the fear of being punished, obedience was enforced as shown in evidence of limited autonomy, and there is evidence of superficial compliance, judging on mineworkers' internal convictions towards the rules. The latter collectively demonstrated symbolic compliance among mineworkers. Such behaviour was meant to satisfy management and thus serve institutional expectations.

Compliance driven by fear of consequences and low autonomy indicated performative compliance at both the institutional and individual level, validating the literature in [Section 2.2](#) on legitimacy as an instrument. At the institutional scale, this can be taken that mines have little regard about the practicality of the process as seen in the findings, with impractical rules observed through the aggrieved mineworkers needing the bypass function. It was also observed that, the organisations place it upon the mineworker to make it work while they merely comply due to the coercive pressures from the regulators. The latter is what was found to be institutional isomorphism defined by DiMaggio and Powell (1983). At the individual

level, this secures visible acted-out conformance while failing to transform internal perceptions that influence operational practices, resulting in symbolic compliance.

In terms of technology adoption, the mineworkers in the findings following procedures to avoid punishment rather than believing in the effectiveness of CAS, which validates Heidenreich and Talke (2020) on enforced adoption encouraging superficial compliance without authentic integration. This performative enactment of processes for organizational visibility demonstrates operational legitimacy maintenance, where appearances addresses management's expectations (Suchman, 1995).

The need for bypass cards paralleled with the mandatory reporting in the findings reveal institutional control mechanisms designed to enforce compliance. This demonstrates coercive isomorphism, where regulatory pressure or management enforcement drives conformance (Dimaggio & Powell, 1983). This is a nuance introduced by mandatory technology adoption. However, there are conflicting interests between management and mineworkers regarding rule enforcement on bypass restrictions based on the findings, especially in mines which had banned the function, and the practical need for it was there. This notably encouraged undesirable behaviours. The TPB's (Ajzen, 1991) perspective on this is that while enforcement may increase compliance due to the social pressure by management, it may reduce perceived behavioural control, therefore hindering genuine acceptance of CAS. [Section 2.3.2](#) on TBP therefore validates that compliance in the case of CAS, stems from supervisor expectations rather than intrinsic motivation or trust, this is also substantiated by UTAUT's social influence construct by Venkatesh et al. (2003) in [Section 2.3.3](#).

As a reflection on the findings and theory, this creates an unsustainable form of acceptance whereby rules maintain compliance. When such coercion-based compliance is utilised, sustainability becomes hard to reach as relaxation of enforcement or existing opportunities for bypassing, can be used to collapse the system. The gap between external visible conformance and internal belief undermines sustainable effectiveness, revealing once again how regulatory pressure alone cannot generate genuine technology acceptance.

*Bypassing and workarounds*

The findings in this sub-theme captured how mineworkers demonstrate resistance towards CAS through bypassing. It does not go without noting that there were different reasons for bypassing presented, but it was often as a response to production pressure, maintenance reasons or operational hindrances rather than outright defiance of safety rules. However, such resistance was made evident when it was also exercised to make things easier. The interview extracts revealed that workers override systems or remove the supporting safety gear when CAS interferes with task efficiency or even to merely avoid alarms out of irritation. Such internal convictions, with the ban on bypassing, can manifest in the undermining of safety systems through small deviating acts with increasing operational pressures or conflicting interests with management, these findings illustrate the theory of practical drift as employed by Lundestad and Hommels (2006). In this context, the option to resist becomes what is negotiated between safety requirements and performance targets, highlighting a persistent internal conflict of what is prioritised between compliance and productivity, a validation of the literature on the priority of safety systems over production presented in [Section 2.4](#).

From a technology acceptance perspective, such behaviour illustrates low perceived usefulness and effort expectancy as defined in TAM and UTAUT models by Davis (1989) and Venkatesh et al. (2003) in [Section 2.3](#). When CAS is perceived to obstruct efficiency or add unnecessary friction, mineworkers may override or disable it, particularly during maintenance where most of the frustrations were expressed. Also, poor system reliability and nuisance alarms as discussed in Theme 1 of the discussions, as found to undermine trust in automation (Lee & See, 2004), which reinforces what was found, that this technology is treated as a supplement rather than a substitution for human control, thus operators overriding at signs of inconvenience.

At an institutional level, bypassing confirms the legitimacy gap between the intent of DMRE regulations and practical acceptance in operations as presented in [Section 2.2](#) of the literature. Mandated CAS implementation achieves the performative compliance for legitimacy suggested by Suchman (1995) and Tyler (1997), but not internalised behavioural change, signalling symbolic compliance by Heidenreich and Talke (2020). This sub-theme therefore challenges the assumptions under

command-and-control stance of management that regulation alone can enforce safety adoption. Sustainable and true acceptance requires alignment across the organisation as suggested by Le Coze and Dupré (2022) in the literature, other than the dominance of top-down rule demonstrated in mining, as the findings suggest, to realise safety practices. These findings extend technology adoption, where the intersection between safety regulated technology and acceptance is challenged to understand the resulting behaviours using mandated CAS implementation in SA.

### **6.1.3 Theme 3: Impact of CAS on Work Practices and Productivity**

#### *Productivity disruptions and delays*

Organisations have often wrestled with safety over productivity as suggested in [Section 2.4](#) of the literature. The findings in this sub-theme were no different, delays and disruption to production due to CAS frustrated employees, coupled with an environment of enforcement as discussed in Theme 2, whereby the same enforcement may apply to managing production. One notable aspect of the results was that such frustrations were experienced predominantly amongst mineworkers with less than a decade in the sector.

This productivity versus safety opposition exposes the conflicting interests, identified as a fundamental tension in high-risk environments in [Section 2.4](#). The findings confirm how safety tends to compete with operational efficiency rather than complementing it. Mineworkers in the findings viewed CAS as an operational hindrance due to stoppages, despite the safety benefits, which contradicts TAM assumptions highlighted in [Section 2.3.1](#), that usefulness alone influences acceptance by Davis (1989). However, in the context of mandated technology, use depends on internalised beliefs about usefulness and ease of use. When CAS is experienced as intrusive, the literature in [Section 2.3.1](#) confirms that the intention to use is weakened despite its usefulness (Brown et al., 2002; Venkatesh & Davis, 2000).

The presence of nuisance trips causing frustration confirms [Section 2.3.3](#)'s UTAUT performance expectancy construct when efficiency is affected negatively by technology (Venkatesh et al., 2003). The expectation is that CAS will provide safety but frustrates the operator instead. Therefore, the negative outcome belief on productivity, weakens positive beliefs on safety.

The critical finding is that, mandated technology adoption focusing solely on accident reduction without addressing operational integration generates such resistance behaviours such as bypassing and workarounds in order to force integration. These behaviours reintroduce the very hazards CAS aims to eliminate, creating a vicious cycle of undermining the safety system and ultimately, undermining effective implementation of CAS.

*Adaptation through training and routines*

Mineworkers were found to modify their behaviours to accommodate the technology's limitations rather than systems being refined to support workflows. This confirms studies on single-loop learning (Argyris & Schön, 1989), whereby organizations adjust actions without questioning underlying assumptions. The findings revealed that mineworkers had to adapt to CAS limitations instead of the system design suiting operations.

The facilitating condition construct proposed by Venkatesh et al. (2016) on the UTAUT model in [Section 2.3.3](#) is affirmed in the sense that, in the findings, the knowledge provided to workers through training and support mechanisms allowed them to work within the constraints of CAS, making them subsequently more compliant with them, even though they were resistant at first. The experience factor also plays a role in adapting to the environment over time, as more experienced mineworkers fit this demographic in the findings.

The TPB's perceived behavioural control by Ajzen (1991) in [Section 2.3.2](#) confirms this variation in acceptance. Willingness went up in the findings when people believed that they could control their response while using the system, that is manoeuvring operation to suit CAS requirements, and went down when perceived control was impossible, that is when frustrations intrinsically arose with bypass being necessitated. Regardless, this describes how symbolic compliance develops, workers change or adapt behaviours because the system requires it, instead of trusting in the system to effectively work practically as suggested by Heidenreich and Talke (2020).

Employees develop informal adaptations or workarounds to make CAS usable in operation, illustrating the persistent gap between WAI and WAD, as noted by Hollnagel (2014), which validates Dekker's (2014) view that such adaptations are

rational. This also confirms the risk at the national level, due to the system not having a standardised approach for implementation to date, as discussed in the literature, makes it prone to such workarounds to make it work. This is evident in the findings where, some have a bypass as an easy-access switch, others receive it through authorisation mechanisms, and others have it banned completely. In other instances, the functionality of various types of machine manufacturers differs. The variation is too wide for a regulated system, it has been simply left to organisations that are not in the business of technology but rather miners, to make it work.

Organisation legitimacy issues are also evident in the findings, apparent compliance proves that there is agreement with the regulations, but negotiation with organisational flexibility to just implement and comply argues otherwise. This can be extended to individual legitimacy in [Section 2.2](#), to say, mineworkers adapt their behaviour using the system to cover defects of the technology, demonstrating the lack of true acceptance, and resorting to one's abilities. Cooper's (2000) safety culture framework warns that adaptation masking design problems creates fragile compliance vulnerable to collapse when enforcement weakens or workarounds become normalized, therefore validating literature that enforcement presents surface compliance that is, symbolic compliance by Heidenreich and Talke (2020).

#### *Changes in everyday work behaviour*

Work behavioural changes in the findings show that CAS has side effects operationally beyond its function for safety, it reshapes how mineworkers coordinate work and interact with each other. It was highlighted how they have to wait for others to finish before starting their tasks. Hollnagel's (2017) ETTO principle in [Section 2.4](#) is realised in this aspect, when mineworkers coordinate more carefully, processes may slow down but become safer; in turn, slower and safer work can make the operation more efficient overall, without overemphasising either production or safety.

However, the results also demonstrate CAS's unintended consequences, described in the findings by the poor ergonomics when stopping and overrides happen, frustrating slowed cycles and difficulties completing tasks. This ultimately limits the intended safety effects, and introduces in CAS, what is deemed as 'harmful safety' and rigid controls that limit adaptation as suggested by Dekker (2014) in [Section 2.4](#). These patterns confirm the introduction of risk compensation and the offset benefits

of adaptability in the literature under behavioural-adaptation theory by Naujoks and Totzke (2014).

This change in coordination also confirms the UTAUT model's notion of social influence (Venkatesh et al., 2003), in which people's actions are shaped by peer pressure and shared norms. People follow group norms because they feel social pressure to act in socially acceptable ways, not because of their own internal beliefs. In this context, legitimacy theory validates such symbolic compliance, with mineworkers in the findings following rules and adjusting their behaviour to meet social expectations, that is mandatory requirements.

However, Dekker (2014) argues that such strict safety systems can limit the freedom workers need to adapt safely in changing conditions. When systems like CAS create tight control, they reduce the flexibility of the mineworker's need to respond to unexpected events (Steen et al., 2024), therefore limiting their sense of awareness in this regard. Overall, the implementation of safety technology in mining sector demonstrated both progress and risk.

#### **6.1.4 Theme 4: Perceived Safety Benefits of CAS in Mining**

##### *Reduction of accidents and collisions*

Mineworkers acknowledged the life-saving benefits of CAS in the findings, with the more experienced contrasting pre-CAS conditions with current safety outcomes. This served as evidence of the effectiveness of CAS in reducing exposure to hazards in mining as desired by regulators ([Section 2.2](#)). However, in the previous themes, it was discussed how operational frustrations conflict with acceptance. This reduction of accidents and fatalities validates the regulatory mandates while simultaneously revealing the challenges of acceptance under enforcement in [Section 2.3](#).

When workers believe that using CAS is a safer option than relying on their risk perception, they are more likely to comply, even if the system frustrates them. This affirms the TPB (Ajzen, 1991) in [Section 2.3.2](#). Experienced operators in this regard, are more likely to comply as the findings suggested they value its collision prevention benefits, demonstrating the system's importance in preventing serious incidents. From a legitimacy theory perspective, as posed in [Section 2.2](#), when organisations in the mining sector present CAS as a tool that demonstrates care for workers' safety,

it validates that CAS builds both their moral legitimacy and organisational legitimacy as suggested by Suchman (1995) and Tyler (1997).

#### *Enhancing worker situational awareness*

The mineworkers in the findings expressed how CAS improved their alertness in high-risk areas, especially in noisy, dusty, or confined areas where visibility and hearing were poor. The system was said to provide functions that warn them of things they may have otherwise missed due to the constrained senses in such conditions. In such challenging environments, CAS plays an important sensory role by extending human perception, further assisting mineworker to adapt to the environment, particularly those with less experience as the results suggest.

Literature on situational awareness in [Section 2.3.4](#), however, flags those with less experience as a risk. The findings in the results suggest novices are more inclined to over-trust automation and automated technologies, thus subjecting themselves to poor perceptions of risk identification, especially when they lack understanding of the system's limitations. These findings suggest that these participants are more at risk based on Tong et al.'s (2024) fatigue-prone novices in automated driving. Additionally, as confirmed by the findings, such technologies were said to reduce anxiety by Sanbonmatsu et al. (2024) in new workers. These mineworkers were likely unfamiliar with the environment's risks and not yet confident in their abilities to detect them and therefore had more trust on the system.

However, as a reflection, automation overall becomes a problem when workers rely too heavily on CAS to an extent that they over-trust the system. Therefore, although automation improves detection, it can weaken active monitoring necessary to assess risk as noted in the literature by Parasuraman and Riley (1997) and, Horowitz and Kahn (2024) on situational awareness. Training must therefore balance human alertness with technological support. Grote (2015) recommends maintaining operator engagement while using automation to complement, not replace, human awareness. This would ensure that technology supports human performance.

#### *Protection of equipment and infrastructure*

In addition to protecting people, participants in the findings emphasised that CAS also helped prevent damage to machines and infrastructure. The system stopped

vehicles automatically before collisions, ultimately preventing equipment failures and downtime that would otherwise cost the organisation. These benefits demonstrate that CAS offers value beyond safety, its ability to prevent equipment damage is seen to strengthen management's business case for adoption and reinforces compliance with regulations. Venkatesh et al.'s (2016) performance expectancy construct of the UTAUT model in [Section 2.3.3](#) validates both direct and indirect usefulness in this case, positive in protecting both the mineworkers and assets. As a reflection, when employees see that CAS protects not only their safety but also the machines they operate, it aligns the individual and the organisation's interests. This confirms Suchman's (1995) observation that technologies serving multiple stakeholders tend to gain broader acceptance.

From a legitimacy theory perspective, management can justify CAS to regulators as evidence of safety compliance and to shareholders through reduced costs and fewer damages. This demonstrates organisational legitimacy based on the literature in [Section 2.2](#), as this shows utility to multiple stakeholders in order to secure resources. However, some mineworkers in the findings still view this as the organisations' façade, that the system is not there for them, but rather to serve the business' agenda, this creates intrinsic resistance, and is not supported by individual legitimacy (Tyler, 1997), over and above the nuisance of frequent stoppages as outweighing the equipment protection benefits, negative beliefs about operational disruptions reduce positive attitudes toward the system (Ajzen, 1991; Suchman, 1995; Tyler, 1997).

This situation validates Grote's (2012) concept of competing goals. In the findings, management is seen to prioritise asset preservation but expects workers to maintain uninterrupted productivity. Although both groups value safety, their differing priorities on cost reduction versus operational efficiency create a cultural misalignment. This divergence of the safety versus productivity trade-off discussed in Theme 3 weakens the foundation of a genuine safety culture based on the literature (Grote, 2015; Hollnagel, 2017).

#### **6.1.5 Theme 5: Challenges and Frustrations with CAS**

Although the participants accepted there is positives to CAS, they demonstrated internal resistances by complaining over its flaws, and side effects that caused 'uneasiness'. According to the results, despite the contribution that CAS had towards

improvement of safety, other issues emerged such as stoppages, technical challenges and maintenance hindrances, as a result inducing the following challenges and frustrations.

*False alarms and unnecessary stoppages*

The main frustrations in the findings involved with CAS were repetitive alarms and unnecessary stops. False alarm normalization tends to destruct the credibility of automation (Parasuraman & Riley, 1997), where repeated unreliable responses erode trust more than consistent failure. This creates a dangerous complacency where workers begin dismissing legitimate warnings alongside false ones, similarly to in the findings where a participant mentioned operators effectively keeping the machine on bypass to avoid such alarms, rendering the safety system ineffective.

TAM (Davis, 1989) proposes that PEOU tends to decrease as system designs create unnecessary work challenges such as these nuisance trips disturbing work processes. A reduction in acceptance may be imminent despite the apparent safety benefits of CAS. TPB (Ajzen, 1991) explains this attitude formation, that false alarms are related to negative outcome beliefs, which ultimately, as demonstrated in the results, override positive safety beliefs, and prevent genuine acceptance as seen with the workarounds indicated in the findings.

As a reflection, this contradiction raises alarms, as the very technology designed to improve the safety of TMMs, decreases worker trust and encourages workaround behaviours. The focus on compliance, including preventing bypasses, without addressing the root causes of worker frustrations, such as the causes of the false alarms, ends up treating symptoms and not core issues with the system. Once again, in the context of CAS, mineworkers are encouraged in this aspect to work around the unnecessary alarms and stoppages, not the system to work for them.

*Technical limitations of the system*

Most participants in the findings identified technical limitations in CAS that included inaccuracies in detection range, delayed responses, and design inconsistencies across machine types. Detection inconsistencies across range, timing, and machine types expose misalignment between CAS capabilities and the operational requirements. This undermined what Lee and See (2004) identified as appropriate

reliance in [Section 2.3.4](#), mineworkers cannot adjust their trust accordingly when the system's behaviour is unpredictable.

In terms of technology adoption literature in [Section 2.3](#), a system failing to deliver consistent performance, that is, a weak performance expectancy construct of UTAUT by Venkatesh et al. (2016), weakens acceptance regardless of regulation. TAM's perceived usefulness, as defined by Davis (1989), is similarly invalidated by CAS's unstable performance in the findings, preventing workers from forming consistent beliefs about its reliability. This creates legitimacy issues because when CAS is seen as unreliable, the driver of compliance is then regulation and not mineworkers beliefs or trust, this results in what Heidenreich and Talke (2020) deems symbolic acceptance instead, this extends the latter technology models. Overall, the results highlight the legitimacy gap between what organizations claim CAS achieves and what workers actually perceive with the system acting unpredictably. With this, CAS risks losing user trust, resulting in compliance driven by regulation at the expense of operational effectiveness.

#### *Engineering and maintenance difficulties*

CAS had a major impact on maintenance and engineering in the findings, causing renewed frustrations with the cancellation of the authorised bypass. Respondents reported that inspections became complex with the system installed, often requiring bypassing during testing and increasing delays. CAS is introduced to optimise the safety of operations, but is seen to complicate maintenance activities, this introduces conflicting safety goals as illustrated in the results, whereby the system that improves operator safety, inadvertently introduces new hazards for maintenance personnel. Another aspect is how the results show the poor integration of CAS, or rather management's misalignment with the prohibition of an authorised bypass. Leaving engineering workers to work around the system during emergency stop tests for the effectiveness of other safety devices, demonstrates the weak integration to maintenance tasks. This supports Hollnagel's (2014) argument in the literature that traditional safety systems fail to address the realities of work as done.

In terms of technology adoption literature in [Section 2.3](#), Ajzen's (1991) TBP validates how, when such systems restrict employee's ability to perform necessary tasks, with low perception on behavioural control, they may bypass procedures regardless of formal rules in order to achieve their tasks. Similarly based on the UTAUT model by

Venkatesh et al. (2016), this illustrates poor facilitating conditions, particularly in the form of maintenance support, which confirms undermined acceptance. What was a decision to improve safety by management ended up encouraging unsafe behaviours in the findings. Conversely, the inclination in the findings to implement the system, with all its risks and without a solution for its seamless integration across, can be challenged as management's or the organisation's strategic approach to managing cognitive legitimacy as posed in [Section 2.2](#), confirming how maintaining non-negotiable compliance can outweigh safe functionality of the system, albeit that the system has reduced certain risks.

## 6.2 Answering the Research Questions

### 6.2.1 Research Question 1

*RQ 1: What are mineworkers perceptions of CAS, particularly in terms of usefulness, usability and reliability?*

The findings and discussions asserted that mineworkers view CAS as useful for safety assurance, but as unreliable for everyday operation. The perceived usefulness for safety has shown that it does not guarantee intention to rely on it, as the system's reliability concerns leads to its cautious use, particularly for experienced operators, reinforcing the "operator in-the-loop" automation dynamic. The disruptions caused by false alarms, stoppages, and inconsistent detections are what undermines the system's credibility and erodes mineworkers perception of it being reliable.

The systems also tends to disrupts workflow and productivity with the latter reliability issues, therefore perceived ease of use is low when the system interferes with tasks. Furthermore, training and experience is appreciated among the more experienced, which affects how usability is perceived. For instance, the inadaptable mineworkers will negate this perception, but for the adaptable, they find it is part of the system to adjust accordingly for it to work. However, for the more experienced, while managing the system more effectively by adapting and managing risks, they remain the most cautious of the system. Despite all the frustrations it causes with reliability concerns, CAS is valued by mineworkers for preventing collisions and improving safety of TMMs.

The overall perception of the system to answer the research question is that, in terms of usefulness, there is a positive perception for its use for safety. However presents

moderated perceptions for usability which based on the findings is shaped by, its integration to operation, design functions, reliability and, the mineworker's experience that is supported by training and adaptation, whereby experience add caution. The following conceptual diagram explains the relationship using TAM (Venkatesh et al., 2003). CAS use challenges the behavioural intention (BI) or use intent under TAM, as it achieves behavioural use (BU) or actual use without intent, but primarily due to the fact that the system is mandatory. Such mandates bypass intent, and drive behavioural use, therefore reflecting symbolic compliance and not internal acceptance (Heidenreich & Talke, 2020).

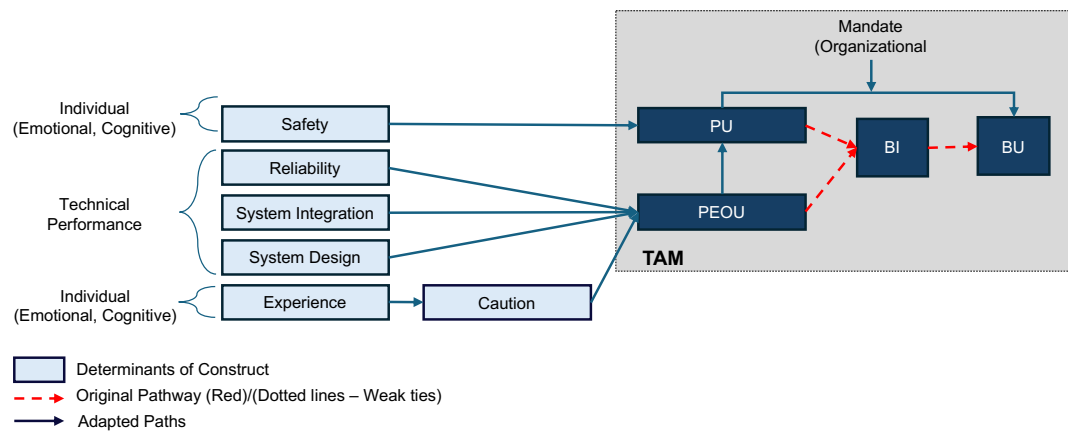


**Figure 6-1: Adapted TAM by the author moderated by study requirements, from Venkatesh et al. (2016)**

Using UTAUT (Venkatesh et al., 2016), a broader extension of TAM, the picture becomes even clearer, the conditions under which Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) develops can be expanded to UTAUTs four (4) constructs, Performance expectancy (PE) on addressing safety and technical reliability, Effort Expectancy (EE) based on PEOU aspects on design challenges presented to tasks when it is not reliable. Social influence was managed through mandatory enforcement.

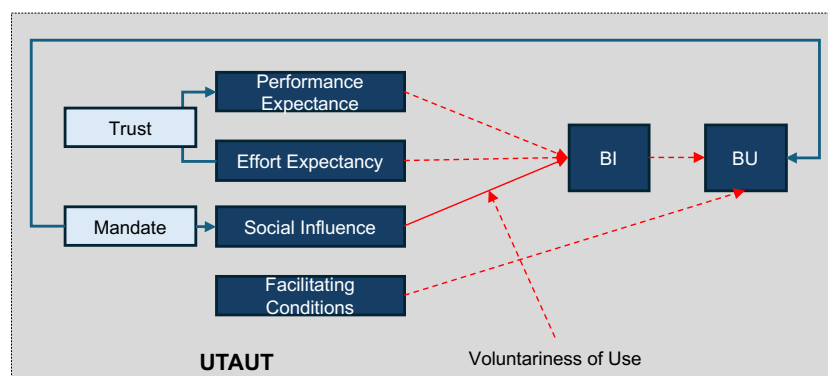


**Figure 6-2: UTAUT model adapted by the author from Venkatesh et al. (2016)**

All of these constructs present weak ties for BI, except for social influence, but the internal convictions of mineworkers' cautiousness present weak intentions. It could be argued that the facilitating conditions extends to use, however, it was found that CAS presented poor integration in the mines, resulting in mineworkers having to adapt their behaviours to work around some of the noted flaws, facilitating conditions thus presented weak ties for use to develop in those circumstances but it still was utilised. Therefore the UTAUT model underplays mandated contexts, where BU of CAS is compulsory and not due to the individual's intent in South African mines.

### 6.2.2 Research Question 2

*RQ 2: How have mineworkers experienced CAS in terms of trust or distrust?*

The findings and discussions asserted how mineworkers' experiences on trusting CAS for safety was conditional and as a result, formed a fragile sense of trust such that workers rely on CAS selectively based on how it performs as illustrated in Figure 6-2. In lesser experienced participants, it presented stronger trust ties in the provision for psychological reassurance. Claims that it extends their senses or sense of awareness demonstrates positive trust relations in placing the responsibility for senses required to assess risk and keep them safe, on this system. These workers display greater emotional trust but risk over-trust and complacency, which presents the dark sided risk of automated technologies discussed in [Theme 4](#) regarding situational awareness.

On the other hand, trust is threatened technically based on the reliability of the system, whereby experienced workers display adaptive distrust with their cautious approach, demonstrating the preference for self-reliance on their safety. This highlights the variable levels of trust that co-exist across mineworkers based on work experience and CAS experiences, thus illustrating the fragility of CAS trust.

However, the cautious use of CAS reflects a rational balance where mineworkers trust CAS for certain aspects but not for judgement. This is a safer approach to CAS, and avoid weakening of the operator's situational awareness, which introduces safety risks, but traditionally this could be misread as a sign of resistance because safety systems like CAS are meant to be used unquestionably Lee and See's (2004).

Lee and See's (2004) determinants of trust in automation (performance, process and purpose) explain the conditional trust observed. For CAS, the performance determinant was undermined by the inconsistent reliability. Process based trust, which depends on a predictable and transparent system, was also weakened by operators who felt they could not anticipate the systems operation. Purpose based trust was further diluted by the perceptions that CAS was primarily to protect the mines assets and for regulatory compliance rather than mineworker safety. With that regard, collectively these determinants under mandatory CAS use develop fragile and conditional trust based on how it behaves. Unstable trust risks over-trust which may lead to complacency, while distrust can drive self-reliance or misuse (Lee & See, 2004), both of which were evident among mineworkers under mandatory CAS use.

### 6.2.3 Research Question 3

*RQ 3: How does the regulatory requirement of CAS affect acceptance (effective-use or misuse behaviour)?*

The finding discussed show that the regulatory requirement for CAS adoption drives compliance-based adoption, where behaviour align with rules rather than intentional use which is more reliant on cognitive (intrinsic) beliefs. With this, mineworkers use the system primarily maintain mandatory and managerial expectations rather than out of their personal convictions or belief in its benefits. This illustrates symbolic acceptance, where use is acted out, but not necessarily internalised (Ashforth & Anand, 2003; Heidenreich & Talke, 2020). Mandatory CAS adoption therefore bypasses the BI stage of acceptance described in the TAM (Figure 6-1) and UTAUT (Figure 6-2) models, resulting in behavioural use BU even without intention achieved. While social influence from enforcement is strong, facilitating conditions such as maintenance support and integration are weak, forcing workers to adapt or override the system to keep operations running.

The aforementioned findings result in both behavioural outcomes, effective use and misuse behaviour. Whereby effective use results when CAS performs reliably and integrates well to operational activities. This still embraces caution but genuine reliance can be established here. Misuse or work-around behaviours result when the system is unreliable and disrupts work due to stoppages or poor integration to operational activities, this encourages mis-use or bypass behaviours. At an institutional level this highlight the legitimacy gap presented by CAS between the

intentions of the regulations and operational acceptance (Suchman, 1995; Tyler, 1997). The regulation secures formal legitimacy by enforcing and achieving adoption of CAS across mines in SA, but not pragmatic legitimacy among at the individual level among mineworkers, this produces compliance with fragile trust, symbolic use.

### 6.3 Conclusion: Overarching Research Question

The overarching research question that was asked was:

*“How do mineworkers experience and perceive Collision Avoidance Systems (CAS) in South African mines, and what explains their behaviour of use, trust, and acceptance under mandated adoption?”*

The study found that mineworkers generally perceive CAS as useful for safety purposes, however the technical performance, that is, the reliability and usability challenges tend to weaken reliance. This conflicting goals of CAS' function as a safety system and measured against its technological aspects resulted in what was observed as conditional or fragile trust. Inexperienced workers demonstrated emotional trust in the sense that CAS provided a sense of reassurance, whereas experienced operators displayed adaptive distrust in so that they maintained caution and self-reliance on machines. Such cautiousness emerged as a rational adjustment for trust and not particularly resistance to CAS. When examined through Lee and See's (2004) Trust in Automation to observe the cognitive aspect of acceptance, none of the determinants were strong enough to realise strong trust ties to the technology's acceptance being intrinsic. Consequently, trust in CAS was partial and conditional as indicated.

Further applying TAM and UTAUT (Davis, 1989; Venkatesh et al., 2016) models to answer the research questions revealed that PE for safety strengthened BI, but EE and facilitating conditions (FC) were weakened by poor operational integration and maintenance challenges. BU nonetheless remained high because CAS use is enforced and already on the machines. This detached BI from BU for use to happen, operators use CAS because they must, not because they trust or prefer it. Such enforced usage represents symbolic compliance, where the mandatory requirement of CAS bypasses the opportunity for internal acceptance.

Considering the latter synthesised findings, and to answer the research question, the integrated Lee and See's (2004) trust development framework and UTAUT model in

Figure 6-3. conceptualises the study. Trust in CAS which is shaped by system performance, transparency, and perceived purpose feeds into technology acceptance pathways, but under mandatory conditions, trust's influence can weaken. Legitimacy pressures brought forth by mandates directly drive BU and bypass BI. Therefore symbolic compliance bridges the trust and acceptance frameworks to explain how organisational and regulatory enforcement achieves use without genuine acceptance, this is supported by legitimacy theory and technology symbolic compliance studies (Heidenreich & Talke, 2020; Suchman, 1995; Tyler, 1997).

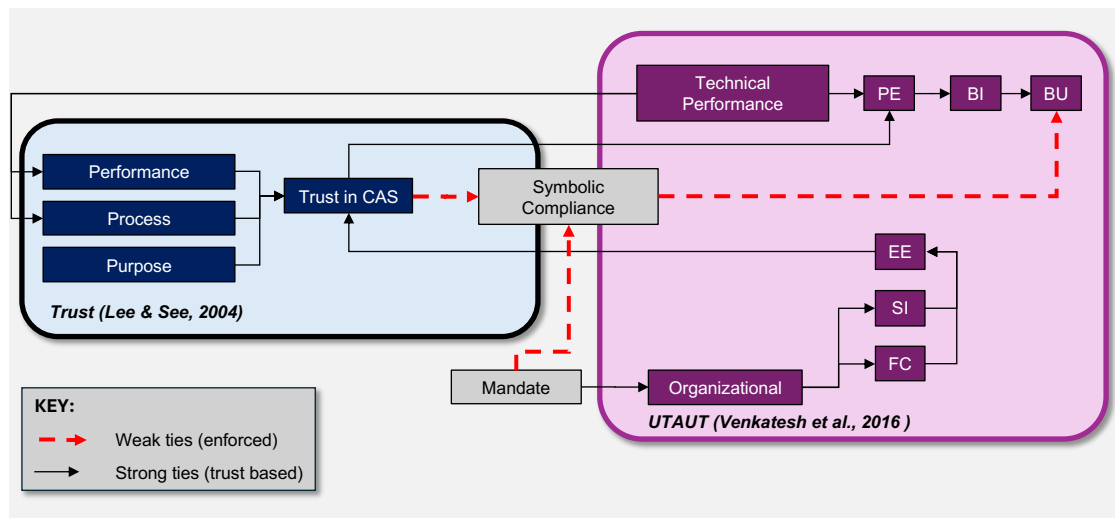


**Figure 6-3: Integrated Trust and UTAUT model adapted by author for the study (Lee & See, 2004; Venkatesh et al., 2016)**

In summary, the research demonstrates that acceptance of CAS by mineworkers is compliance-based and not attributed to the individual's beliefs. The system's usefulness for safety ensures basic acceptance, but reliability flaws, a lack of transparency, and the perceived organisational intentions limit trust.

Mandatory implementation secures BU but not psychological security, resulting in fragile, conditional trust and symbolic adoption of CAS. The abovementioned findings therefore extend UTAUT to high-risk environments with mandatory technology. Furthermore, this demonstrates how trust development through reliable systems, system transparency and operator feedback can be used to encourage true acceptance in such environments. Building on this, the following chapter offers recommendations to foster genuine acceptance of mandatory technology in high-risk environments.

## 7 Chapter 7: Conclusion and Recommendations

### 7.1 Principal Conclusions

The study aimed to explore how mineworkers experience and perceive CAS under mandatory adoption across South African mines. This study was conducted to address the adoption of CAS in mines amid persistent TMM fatalities, despite regulations requiring its installation on TMMs. These experiences and perceptions were with intention to understand how acceptance was formed in this latter context, as traditional technology models address adoption in voluntary contexts. Furthermore, compliance and resistance behaviours were not addressed in these models.

Building on these technology acceptance models, TAM and UTAUT (Davis, 1989; Venkatesh et al., 2016) and Lee and See's (2004) trust development framework, the study was consolidated into a model with intention to explain the findings on how cognitive aspects of trust influenced by the technology's performance and mandatory enforcement of technology shapes symbolic compliance (Heidenreich & Talke, 2020; Suchman, 1995).

The findings from [Chapter 5](#) and discussed in [Chapter 6](#) are presented in the following subsections in relation to the research questions posed in [Chapter 3](#). Overall, the findings revealed that while mineworkers broadly valued CAS for enhancing their safety, acceptance was compliance-based rather than belief-driven. It was also noted how CAS has created a fragile sense of trust, reinforcing symbolic compliance amongst mineworkers.

#### *RQ1: Usefulness, Usability and Reliability*

It was found that the usefulness of CAS is recognised, but the reliance is conditional. Mineworkers view CAS as beneficial for preventing collisions and improving situational awareness. However, this usefulness alone does not generate reliance due to the inconsistent technical performance. The usability and technical performance concerns of CAS dominated the perceptions of mineworkers, from technical performance issues such as, frequent false alarms, detection inconsistencies, and work disruptions, which was aspects that lowered perceived ease of use and ultimately eroded the confidence in the system. These operational

issues made operators cautious and selective in their engagement with CAS, reflecting what was deemed as symbolic compliance.

*RQ2: Trust and Mistrust*

Trust was found to be fragile and was differently expressed across mineworkers' experiences. Inexperienced mineworkers' interactions with CAS demonstrated emotional trust with the system for reassuring them psychologically, while experienced operators displayed adaptive distrust and relied on their own judgment than on the system. Trust was therefore concluded to develop conditionally, depending on how the system behaves and was shaped by mineworkers' experiences. A relevant theoretical basis for this was found in Lee and See's (2004) trust-in-automation studies, which were integrated into technology acceptance studies to understand how trust develops or erodes among mineworkers towards CAS. This also served as knowledge towards understanding how cognitive aspects affect the acceptance of CAS in the context of mandatory adoption of a safety technology.

*RQ3: Acceptance – Effective Use or Misuse Behaviours*

In terms of effective use, that is intentional use of CAS, it was found that regulatory enforcement of the system in mines secured use without intention to use, thus even without acceptance, the system is used. In terms of technology acceptance, the mandatory basis of CAS adoption leads to high BU but not BI. This resulted in symbolic compliance as per Heidenreich and Talke (2020), CAS was used to comply with the enforced rules rather than from internal convictions based on mineworkers' beliefs.

It was noted that the regulations achieved formal legitimacy in terms of compliance, where mineworkers even acknowledged how it enhanced the safety of TMMs. However, the regulations were found to have poor outcomes on producing pragmatic legitimacy at the individual level, that is at the mineworker level. This gap encouraged workaround behaviours as this limited individual buy-in that would have ultimately influenced better safety outcomes.

Overall CAS achieved its objectives in terms of compliance, the system has gained popularity across mines in SA, and is acknowledged for its safety benefits on TMMs

based on the findings. However, the system falls short of stronger psychological buy-in and operational integration in mining. The technology requires a shift from symbolic acceptance to genuine acceptance for it to maintain sustainable safety outcomes.

## **7.2 Academic and Practical Implications of the Study**

### **7.2.1 Academic Contribution**

#### *Extension of Technology Acceptance Models/Theory*

The study extends TAM (Davis, 1989) and UTAUT (Venkatesh et al., 2003, 2016) application to CAS in mining in south Africa by demonstrating that behavioural use without behavioural intention, can occur under regulatory enforcement. This introduces the concept of compliance-based adoption as a new pathway in technology acceptance frameworks, where symbolic compliance is tuned based on trust in the technology (Heidenreich & Talke, 2020; Lee & See, 2004; Suchman, 1995; Tyler, 1997).

#### *Integration of Trust and Legitimacy Theory*

The combination of technology adoption (Davis, 1989; Venkatesh et al., 2003, 2016), trust in automation (Lee & See, 2004) and legitimacy theory (Suchman, 1995; Tyler, 1997) developed as an outcome of the findings to demonstrate the fragility of trust and how this mediates acceptance in the context of high-risk mandated technology. This synthesised model can be used to build on future studies on mandatory safety technologies and how they adapt in similar high-risk industries. On a notable aspect, the study highlighted the socio-technical dynamics of forced adoption (regulatory legitimacy) of technologies that are not yet mature, it also illuminates how organisations are quick to portray legitimacy in the face of business sustainability risks, even with the risks of poor implementation.

### **7.2.2 Business and Practical Contributions**

The implications for the study are addressed below for two stakeholders, mining organisations and for regulators, as follows:

### *Mining Organisations*

Experience was highlighted as key to adaptation, therefore this can be extended through relevant training on how to respond and adapt to risks rather than just licensing workers to operate, but rather licensing them for operations. A participant highlighted the contrast in training for level 7 and level 9, which affected how CAS was socialised as a system that assists the operator, rather than how Level 7 was, with the first line of defence being the operator. This needs to be incorporated into level 9, to socialise it as no different from the latter, besides it intervening a stop. The operator must arguably be trained to remain vigilant despite the technology in place.

CAS has the potential to be reframed from a technology used to comply with the law to a collaborative safety partner. One of these aspects is the use of operational feedback to improve system design and use. This would ensure the system is effectively integrated into everyday work, and that CAS start working for operations, rather than operations working around the system to make it work. This aligns with the distinction between work-as-imagined (WAI) and work-as-designed (WAD) to address the gap between prescribed safety procedures and operational practices (Hollnagel, 2014, p.44).

Considering the costs of such technologies, effective implementation would assist small scale mines in having to not go through the financial hurdle of technology trials that would otherwise not be fit for purpose, such as considering reliability or design flaws that would be accounted for, affecting production over trials. Standardisation and the WAI and WAD approach (Hollnagel, 2014, p.44) can mitigate trial and error costs for mines that are already at risk with the high costs of implementing CAS.

Stage-gate training and feedback sessions to take mineworkers through the transition and change management journey should be employed. This will ensure that workers are aware of changes and limitations of the system.

### *Regulators*

Ensure industry alignment across all platforms such as, TMM OEMs, technology manufacturers, standardisation bodies and suppliers, in order to ensure industry adoption readiness, and if need be to enforce, force-readiness across technology

manufacturers and OEM designers to adhere to standardisation requirements to protect the small business from absorbing costs of being testing grounds for developing technology.

Prior to regulating technology, the technology maturity cycle needs to be considered in order to provide mandates or instructions to push adoption. For example, establish workgroups that will champion adoption, similarly to the MOSH adoption team. Whereby types of mines (underground or surface or quarry), work processes or ways of work (maintenance, shift cycles) are considered in order to influence design inputs and change management process on how to integrate the system under various conditions.

The adoption team can track mine readiness interventions in the forms of traffic management plans, work and process integration readiness, and mine design readiness for adoption. The team should provide an audit rating where the mine's progress is, and if they are ready to deploy the technology or if they have justifiably eliminated significant risk, thus implying the technology is not required according to the law. This may be frowned upon in mining considering the dangers and how technology has evidently reduced risks, however, in the South African mining context, social issues take precedence as livelihoods are also lost due to illegal mining exacerbated by issues such the closure of mines, unemployment, and other socio-economic factors. Currently, significant-risk is subjective, so providing clear guidelines on eliminating such risk, prevents running small operations out of business, and also provides clear technology mapping strategies for operations that can implement.

### **7.3 Limitations**

The following are the limitations acknowledged from the study.

#### *Limited Research on CAS in South Africa*

CAS technology has not yet reached maturity in South Africa, and with the country being the only known case to mandate the system across all TMMs of significant risk, the country is leading in this aspect. This has resulted in the acceleration of technological progress globally. However, there is limited South African research on the systems other than the technology progress in technical studies. This is also part

of the reason why variation exists in how certain features, such as the bypass design or how it is addressed in operations, there are no mature standards for the system's fail-safe considerations, even though this is part of the regulation, or to make a valid basis that the research could be anchored upon. Furthermore, the industry relies on guidelines set as an attempt to formalise what has been accelerated adoption before industry preparation. Therefore, the research could be observing the technology at a stage where it is not yet ready to make sustainable recommendations, as it goes through this transitional stage of establishment.

Another limitation of this study that was identified during the literature review, is the scarcity of studies on CAS in mining. Most available research focuses on automation and driver assistance technologies in road transport or general industrial settings. As a result, concepts such as trust in automation, and behavioural adaptation were drawn from the automation literature and interpreted for application to the mining and earth moving machinery context. This limitation justifies the relevance and highlights the originality of the study presented.

#### *Scope and Generalisability across Industry*

The research was focused on a limited number of mines within South Africa. Although it captured underground and surface mine participants, it did not capture participants from other commodities which would have expanded the studies in terms of perceptions across the sector. This could have the study to address the mining industry as a whole. Also, the qualitative approach yielded depth, but the findings cannot be statistically generalised across all mining operations in South Africa, or even at the global level, due to the number of participants which do not reflect a statistically significant sample of the mining population.

#### *Self-Reporting and Interpretivist Bias*

The data collected was based on participants reporting on their own experiences and perceptions. These may be influenced by social cognitive factors especially considering how the system is enforced in mining, the fear of repercussions for example when discussing bypass practices could have been reserved for more socially acceptable practices. The validity of the participants narrative could also be affected by the social desire to be admired and limited memory recall quality of their accounts.

*Cross-Sectional Timing*

The study captures perceptions at one point in time. As CAS technology evolves and organisational integration improves, perceptions will also shift with time as seen in the results with mineworkers who had more experience in mining. These experiences shaped the results differently.

*Technology Diversity*

The differences in CAS types and configurations, TMM manufacturers, and installation limitations across mines limited direct comparisons of the technology. The technology also offers different aspects of automated features across machine types which could cause different behaviours. Therefore, the findings represent a variety of systems and site practices across mines in SA.

**7.4 Future Research**

As noted in the limitations, future work can extend to cover longitudinal studies. This could track how mineworkers' experiences such as trust, use, and acceptance evolve over time as CAS technology matures and the operational integration of the technology improves. In addition, to generalise the studies as applicable to high-risk areas, consider other industries such as the aviation for similar mandatory technologies to test the applicability of research against.

The study was primarily focused on mineworkers who interacted with the system, the meso-level. However, nuanced elements of how the leadership and the regulator was perceived to view the system emerged. The study could be extended to study how organisations at the macro level perceive regulatory pressures on behavioural actions, and if regulations receive buy-in at that level or symbolic compliance to maintain business continuity.

Another critical aspect that emerged from the study is that behaviours often interpreted as resistance, such as caution or reluctance to rely on CAS, may in fact represent rational responses critical to personal safety. The findings suggest even though CAS is intended to enhance safety, over-reliance on it can introduce new risks when the system fails or behaves unpredictably. Future research should therefore interrogate this contradiction of trust in safety automation relating to how technologies designed for full integration into operational systems simultaneously

require a degree of scepticism for safe use, especially for such a safety device which is intended to operate as a last resort following personal safety. Investigating this balance between necessary caution and required effective use could contribute to the development of more nuanced models of trust, training, and human-technology interaction in high-risk environments to extend the proposed, or even challenge that symbolic compliance is necessary for CAS if it means being cautious.

Lastly, the model has been derived from what was reflected from the qualitative study. A quantitative validation of the model is recommended to test the constructs and their relationships for applicability and validity.

### **7.5 Concluding Remarks**

In closing, the study concludes that technology adoption in high-risk environment like the mining sector, cannot rely on mandatory enforcement alone. Sustainable safety improvements requires reliable technology, inclusive engagements across users, designers, industry, and regulators and, transparent processes. Through this, integration can be realised, and CAS can transition from being symbolically complied with to genuinely accepted. This will enable effective use and enhanced safety value in the South African mining sector.

## 8 References

- Abdul Rashid, S. F., Ramli, R., Palil, M. R., & Amir, A. M. (2022). The Influence of Power of Tax Administrator on Cognitive and Affective Tax Attitude in Malaysia. *Asian Journal of Accounting & Governance*, 17, 59-74. <https://doi.org/10.17576/AJAG-2022-17-05>
- Abiodun, N. (2024). Trust and distrust in safety leadership: Qualities of importance. *Safety Science*, 176, 106553. <https://doi.org/10.1016/J.SSCI.2024.106553>
- Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi-structured interviews. *JACCP Journal of the American College of Clinical Pharmacy*, 4(10), 1358–1367. <https://doi.org/10.1002/JAC5.1441>
- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Alqahtani, M., & Braun, R. (2022). Reviewing influence of UTAUT2 factors on cyber security compliance: A literature review. *IBIMA Business Review*, 2021, 2165–9923. <https://doi.org/10.5171/2021.666987>
- Argyris, C., & Schön, D. A. (1989). Participatory action research and action science compared: A commentary. *American Behavioral Scientist*, 32(5), 612–623. <https://www.proquest.com/scholarly-journals/participatory-action-research-science-compared/docview/1306752366/se-2>
- Ashforth, B. E., & Anand, V. (2003). The normalization of corruption in organizations. *Research in Organizational Behavior*, 25, 1–52. [https://doi.org/10.1016/S0191-3085\(03\)25001-2](https://doi.org/10.1016/S0191-3085(03)25001-2)
- Bellanca, J. L., Ryan, M. E., Orr, T. J., & Burgess-Limerick, R. J. (2021). Why Do Haul Truck Fatal Accidents Keep Occurring? *Mining, Metallurgy and Exploration*, 38(2), 1019–1029. <https://doi.org/10.1007/s42461-021-00410-1>
- Bellanca, J. L., Swanson, L. R., Helton, J., & Mcninch, M. (2019). Mineworkers' Perceptions of Mobile Proximity Detection Systems. *Mining, Metallurgy and Exploration*, 36, 647-655. <https://doi.org/10.1007/s42461-018-0045-3>
- Bester, V. (2023). Towards a sustainable artisanal gold mining sector in South Africa: Proposed developmental initiatives. *Journal of Rural Studies*, 97, 375–384. <https://doi.org/10.1016/J.JRURSTUD.2022.12.029>

- Bester, V., & Groenewald, L. (2021). Corporate social responsibility and artisanal mining: Towards a fresh South African perspective. *Resources Policy*, 72, 102124. <https://doi.org/10.1016/J.RESOURPOL.2021.102124>
- Blanc, F., Ottimofiore, G., & Myers, K. (2022). From OSH regulation to safety results: Using behavioral insights and a “supply chain” approach to improve outcomes – The experience of the health and safety Executive. *Safety Science*, 145, 1–49. <https://doi.org/10.1016/J.SSCI.2021.105491>
- Bowen, G. A. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*, 9(2), 27–40. <https://doi.org/10.3316/QRJ0902027>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706QP063OA>
- Brown, S. A., Massey, A. P., Montoya-Weiss, M. M., & Burkman, J. R. (2002). Do I really have to? User acceptance of mandated technology. *European Journal of Information Systems*, 11(4), 283–295. <https://doi.org/10.1057/PALGRAVE.EJIS.3000438>
- Bulled, N., & Singer, M. (2024). The occupational syndemics of miners in South Africa. *Discover Social Science and Health*, 4(36), 1–12. <https://doi.org/10.1007/s44155-024-00098-w>
- Burgess-Limerick, R. (2020). Human-Systems Integration for the Safe Implementation of Automation. *Mining, Metallurgy and Exploration*, 37, 1799–1806. <https://doi.org/10.1007/S42461-020-00248-Z>
- Carragher, D. J., Sturman, D., & Hancock, P. J. B. (2024). Trust in automation and the accuracy of human–algorithm teams performing one-to-one face matching tasks. *Cognitive Research: Principles and Implications*, 9(41), 1–17. <https://doi.org/10.1186/S41235-024-00564-8>
- Carter, O. B. J., Loft, S., & Visser, T. A. W. (2024). Meaningful Communication but not Superficial Anthropomorphism Facilitates Human-Automation Trust Calibration: The Human-Automation Trust Expectation Model (HATEM). *Human Factors*, 66(11), 2485–2502. <https://doi.org/10.1177/00187208231218156>
- Chang, M., Walimuni, A. C. S. M., Kim, M. cheol, & Lim, H. soon. (2022). Acceptance of tourism blockchain based on UTAUT and connectivism theory. *Technology in Society*, 71, 1–13. <https://doi.org/10.1016/J.TECHSOC.2022.102027>

- Chang, W. C., Borowiak, A., & Hasanzadeh, S. (2023). The importance of situational awareness in future construction work: Toward the effects of faulty robots, trust, and time pressure. In *Computing in Civil Engineering 2023* (pp. 821–828). <https://doi.org/10.1061/9780784485224.099>
- Chen, T., Hu, W., & Li, H. (2023). The effect of empowering leadership on miners' unsafe behavior: a cross-level chain mediation model. *International Journal of Occupational Safety and Ergonomics*, 29(4), 1345–1357. <https://doi.org/10.1080/10803548.2022.2127253>
- Cheng, L., Guo, H., & Lin, H. (2020). The influence of leadership behavior on miners' work safety behavior. *Safety Science*, 132, 104986. <https://doi.org/10.1016/J.SSCI.2020.104986>
- Cobley, A. (2020). Powering Apartheid: The Coalbrook Mine Disaster of 1960. *South African Historical Journal*, 72(1), 80–97. <https://doi.org/10.1080/02582473.2020.1728577>
- Cooper, J. M., Crabtree, K. W., McDonnell, A. S., May, D., Strayer, S. C., Tsogtbaatar, T., Cook, D. R., Alexander, P. A., Sanbonmatsu, D. M., & Strayer, D. L. (2023). Driver behavior while using Level 2 vehicle automation: a hybrid naturalistic study. *Cognitive Research: Principles and Implications*, 8(71), 1–19. <https://doi.org/10.1186/S41235-023-00527-5>
- Cooper, M. D. (2000). Towards a model of safety culture. *Safety Science*, 36(2), 111–136. [https://doi.org/10.1016/S0925-7535\(00\)00035-7](https://doi.org/10.1016/S0925-7535(00)00035-7)
- Coulson, N., & Christofides, N. (2021). How worker health and safety representatives are captured and outdone by production on South African mines. *Economic and Industrial Democracy*, 42(4), 1004–1028. <https://doi.org/10.1177/0143831X19830491>
- Coulson, N., & Stewart, P. F. (2024). Communication constraints in the safety system on South African mines and implications for the exercise of the Right to Refuse Dangerous Work. *Journal of the Southern African Institute of Mining and Metallurgy*, 124(4), 185–192. <https://doi.org/10.17159/2411-9717/2444/2024>
- Creswell, J. W., & Poth, C. N. (2018). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. (4th ed.). Sage Publication.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly: Management Information Systems*, 13(3), 319–339. <https://doi.org/10.2307/249008>

- Dekker, S. W. A. (2014). The bureaucratization of safety. *Safety Science*, 70, 348–357. <https://doi.org/10.1016/J.SSCI.2014.07.015>
- Demeulenaere, X. (2020). How challenges of human reliability will hinder the deployment of semi-autonomous vehicles. *Technological Forecasting and Social Change*, 157, 120093. <https://doi.org/10.1016/J.TECHFORE.2020.120093>
- Department of Mineral Resources and Energy. (2015). *Regulations relating to machinery and equipment, Mine Health and Safety Act, 1996 (Act No. 29 of 1996)*. Government Gazette No. 38493. [https://www.dmre.gov.za/Portals/0/Resource%20Center/Mine%20Health%20and%20Safety%20Act%20and%20its%20Regulations/MHS%20Regulations\\_Sub-regulation%208.10.1.2b%20and%208.10.2.1b\\_GG%2038493.pdf?ver=2018-04-01-152624-507](https://www.dmre.gov.za/Portals/0/Resource%20Center/Mine%20Health%20and%20Safety%20Act%20and%20its%20Regulations/MHS%20Regulations_Sub-regulation%208.10.1.2b%20and%208.10.2.1b_GG%2038493.pdf?ver=2018-04-01-152624-507)
- Department of Mineral Resources and Energy. (2022a). *Government Notice: Commencement of the Regulations Relating to Trackless Mobile Machinery*. Retrieved from: [https://www.gov.za/sites/default/files/gcis\\_document/202212/47790gon2908.pdf](https://www.gov.za/sites/default/files/gcis_document/202212/47790gon2908.pdf)
- Department of Mineral Resources and Energy. (2022b). *Mine Health and Safety Inspectorate: Annual Report 2021/22*. Retrieved from: <https://www.dmre.gov.za/Portals/0/Resource%20Center/Mine%20Health%20and%20Safety%20Inspectorate%20Annual%20Reports/2021-2022%20MHSI%20Annual%20Report.pdf?ver=2023-10-13-094803-650>
- Department of Mineral Resources and Energy. (2024). *Mine Health and Safety Inspectorate: Annual Report 2023/24*. Retrieved from: [https://static.pmg.org.za/2023-2024\\_MHSI\\_Annual\\_Report.pdf](https://static.pmg.org.za/2023-2024_MHSI_Annual_Report.pdf)
- DiMaggio, P. J., & Powell, W. W. (1983). The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review*, 48(2), 147–160. <https://doi.org/10.2307/2095101>
- Dowling, J., & Pfeffer, J. (1975). Organizational legitimacy: Social values and organizational behavior. *Sociological Perspectives*, 18(1), 122–136. <https://doi.org/10.2307/1388226>

- Earth Moving Equipment Safety Round Table. (n.d.). *Vehicle interaction control improvement – EMESRT*. Retrieved May 20, 2025, from <https://www.emesrt.org/vehicle-interaction-control-improvement/>
- Eimontaite, I., Gwilt, I., Cameron, D., Aitken, J. M., Rolph, J., Mokaram, S., & Law, J. (2019). Language-free graphical signage improves human performance and reduces anxiety when working collaboratively with robots. *International Journal of Advanced Manufacturing Technology*, 100, 55–73. <https://doi.org/10.1007/S00170-018-2625-2>
- Endsley, M. R. (2024). Understanding Automation Failure. *Journal of Cognitive Engineering and Decision Making*, 18(4), 386–393. <https://doi.org/10.1177/15553434231222059>
- Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, 5(1), 80–92. <https://doi.org/10.1177/160940690600500107>
- Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: an introduction to theory and research*. Addison-Wesley Pub. Co.
- Gao, Y., Fan, Y., & Wang, J. (2020). Assessing the safety regulatory process of compliance-based paradigm in China using a signalling game model. *Safety Science*, 126, 104678. <https://doi.org/10.1016/J.SSCI.2020.104678>
- Gefen, D., Karahanna, E., & Straub, D. W. (2003). Trust and tam in online shopping: AN integrated model. *MIS Quarterly: Management Information Systems*, 27(1), 51–90. <https://doi.org/10.2307/30036519>
- Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report*, 8, 597–607.
- Grote, G. (2012). Safety management in different high-risk domains – All the same? *Safety Science*, 50(10), 1983–1992. <https://doi.org/10.1016/J.SSCI.2011.07.017>
- Grote, G. (2015). Promoting safety by increasing uncertainty – Implications for risk management. *Safety Science*, 71(PB), 71–79. <https://doi.org/10.1016/J.SSCI.2014.02.010>
- Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. *Field Methods*, 18(1), 59–82. <https://doi.org/10.1177/1525822X05279903>

- Guest, G., Namey, E., & Chen, M. (2020). A simple method to assess and report thematic saturation in qualitative research. *PLOS ONE*, 15(5). <https://doi.org/10.1371/JOURNAL.PONE.0232076>
- Gülşen, M., & Arslan, S. (2025). The Effect of Alarm Fatigue on the Tendency to Make Medical Errors in Surgical Intensive Care Nurses: A Correlational Study Examining the Role of Moderating Factors. *Healthcare* 2025, 13(6). <https://doi.org/10.3390/HEALTHCARE13060631>
- Haas, E. J., & Yorio, P. L. (2021). Exploring the Differences in Safety Climate Among Mining Sectors. *Mining, Metallurgy and Exploration*, 38(1), 655–668. <https://doi.org/10.1007/S42461-020-00364-W>
- Hancke, T. (2020). Ironies of Automation 4.0. *IFAC-PapersOnLine*, 53(2), 17463–17468. <https://doi.org/10.1016/J.IFACOL.2020.12.2122>
- Harrison, R., Fischer, S., Walpol, R. L., Chauhan, A., Babalola, T., Mears, S., & Le-Dao, H. (2021). Where do models for change management, improvement and implementation meet? A systematic review of the applications of change management models in healthcare. *Journal of Healthcare Leadership*, 13, 85–108. <https://doi.org/10.2147/JHL.S289176>
- Hasija, A., & Esper, T. L. (2022). In artificial intelligence (AI) we trust: A qualitative investigation of AI technology acceptance. *Journal of Business Logistics*, 43(3), 388–412. <https://doi.org/10.1111/JBL.12301>
- Heidenreich, S., & Talke, K. (2020). Consequences of mandated usage of innovations in organizations: developing an innovation decision model of symbolic and forced adoption. *AMS Review*, 10, 279–298. <https://doi.org/10.1007/S13162-020-00164-X>
- Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, 292. <https://doi.org/10.1016/J.SOCSCIMED.2021.114523>
- Hoebbel, C. L., Bellanca, J. L., & Hrica, J. K. (2024). Lessons Learned From Near-Miss Events: Use of the Critical Decision Method to Identify Strategies to Improve Haul Truck Safety in Mining. *Centers for Disease Control and Prevention*. <https://stacks.cdc.gov/view/cdc/155322>
- Hoff, K. A., & Bashir, M. (2015). Trust in Automation. *Human Factors*, 57(3), 407–434. <https://doi.org/10.1177/0018720814547570>
- Hollnagel, E. (2014). *Safety-I and safety-II : the past and future of safety management*. Ashgate.

- Hollnagel, E. (2017). The ETTO Principle: Efficiency-Thoroughness Trade-Off : Why Things That Go Right Sometimes Go Wrong. The ETTO Principle: Efficiency-Thoroughness Trade-Off. <https://doi.org/10.1201/9781315616247>
- Hollnagel, E., Laursen, T., & Sørensen, R. (2022). A day when (Almost) nothing happened. *Safety Science*, 147. <https://doi.org/10.1016/J.SSCI.2021.105631>
- Hopkins, D., & Schwanen, T. (2021). Talking about automated vehicles: What do levels of automation do? *Technology in Society*, 64. <https://doi.org/10.1016/J.TECHSOC.2020.101488>
- Horowitz, M. C., & Kahn, L. (2024). Bending the Automation Bias Curve: A Study of Human and AI-Based Decision Making in National Security Contexts. *International Studies Quarterly*, 68(2), 20. <https://doi.org/10.1093/ISQ/SQAE020>
- Hrica, J. K., Bellanca, J. L., Benbourenane, I., Carr, J. L., Homer, J., & Stabryla, K. M. (2022). A Rapid Review of Collision Avoidance and Warning Technologies for Mining Haul Trucks. *Mining, Metallurgy and Exploration*, 39(4), 1357–1389. <https://doi.org/10.1007/S42461-022-00633-W>
- Hu, X., Yeo, G., & Griffin, M. (2020). More to safety compliance than meets the eye: Differentiating deep compliance from surface compliance. *Safety Science*, 130. <https://doi.org/10.1016/J.SSCI.2020.104852>
- Hulme, A., Stanton, N. A., Walker, G. H., Waterson, P., & Salmon, P. M. (2019). What do applications of systems thinking accident analysis methods tell us about accident causation? A systematic review of applications between 1990 and 2018. *Safety Science*, 117, 164-183. <https://doi.org/10.1016/j.ssci.2019.04.016>
- Hunt, D., & Naweed, A. (2023). The risk of risk assessments: Investigating dangerous workshop biases through a socio-technical systems model. *Safety Science*, 157, 105918. <https://doi.org/10.1016/J.SSCI.2022.105918>
- Hutchinson, B., Dekker, S., & Rae, A. (2024). Audit masquerade: How audits provide comfort rather than treatment for serious safety problems. *Safety Science*, 169. <https://doi.org/10.1016/J.SSCI.2023.106348>
- Imam, M., Baïna, K., Tabii, Y., Ressami, E. M., Adlaoui, Y., Benzakour, I., & Abdelwahed, E. hassan. (2023). The Future of Mine Safety: A Comprehensive Review of Anti-Collision Systems Based on Computer Vision in Underground Mines. *Sensors*, 23(9), 4294. <https://doi.org/10.3390/S23094294>

- International Organization for Standardization. (2022). *Earth-moving machinery — Collision warning and avoidance – Part 1: General Requirements*. (ISO 21815-1:2022) Geneva: ISO. Retrieved from <https://www.iso.org/standard/77302.html>
- Ismail, S. N., Ramli, A., & Aziz, H. A. (2021a). Influencing factors on safety culture in mining industry: A systematic literature review approach. *Resources Policy*, 74. <https://doi.org/10.1016/J.RESOURPOL.2021.102250>
- Ismail, S. N., Ramli, A., & Aziz, H. A. (2021b). Research trends in mining accidents study: A systematic literature review. *Safety Science*, 143. <https://doi.org/10.1016/J.SSCI.2021.105438>
- Jacob, S. A., & Furgerson, S. P. (2012). Writing Interview Protocols and Conducting Interviews: Tips for Students New to the Field of Qualitative Research. *The Qualitative Report*, 17(6), 1–10. <https://files.eric.ed.gov/fulltext/EJ990034.pdf>
- Joughin, W. C. (2024). Quest for zero harm in South African deep gold mines. *Journal of the Southern African Institute of Mining and Metallurgy*, 124(4). <https://www.scielo.org/za/pdf/jsaimm/v124n4/02.pdf>
- Kenesei, Z., Kökény, L., Ásványi, K., & Jászberényi, M. (2025). The central role of trust and perceived risk in the acceptance of autonomous vehicles in an integrated UTAUT model. *European Transport Research Review*, 17(1), 1–15. <https://doi.org/10.1186/S12544-024-00681-X>
- Kineber, A. F., Antwi-Afari, M. F., Elghaish, F., Zamil, A. M. A., Alhusban, M., & Qaralleh, T. J. O. (2023). Benefits of Implementing Occupational Health and Safety Management Systems for the Sustainable Construction Industry: A Systematic Literature Review. *Sustainability*, 15(17). <https://doi.org/10.3390/SU151712697>
- Kohn, S. C., de Visser, E. J., Wiese, E., Lee, Y. C., & Shaw, T. H. (2021). Measurement of Trust in Automation: A Narrative Review and Reference Guide. *Frontiers in Psychology*, 12. <https://doi.org/10.3389/FPSYG.2021.604977>
- Le Coze, J. C., & Dupré, M. (2022). Safety as a network, digital and global reality. *Safety Science*, 156. <https://doi.org/10.1016/J.SSCI.2022.105896>
- Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors*, 46(1), 50–80. [https://doi.org/10.1518/HFES.46.1.50\\_30392](https://doi.org/10.1518/HFES.46.1.50_30392)

- Leger, J. P. (1991). Trends and causes of fatalities in South African mines. *Safety Science*, 14(3–4), 169–185. [https://doi.org/10.1016/0925-7535\(91\)90019-I](https://doi.org/10.1016/0925-7535(91)90019-I)
- Leonida, C. (2023). COLLISION AVOIDANCE CAS Comes of Age. *Engineering and Mining Journal*, 224(8), 30–35. <https://www.proquest.com/scholarly-journals/cas-comes-age/docview/2852769828/se-2?accountid=14717>
- Leonida, C. (2025). Lessons for Success in Situational Awareness. *Engineering and Mining Journal*, 226(5), 32–35. <https://www.proquest.com/docview/3207820373?pq-origsite=gscholar&fromopenview=true&sourcetype=Scholarly%20Journals>
- Liang, N., Yang, J., Yu, D., Prakah-Asante, K. O., Curry, R., Blommer, M., Swaminathan, R., & Pitts, B. J. (2021). Using eye-tracking to investigate the effects of pre-takeover visual engagement on situation awareness during automated driving. *Accident Analysis & Prevention*, 157. <https://doi.org/10.1016/J.AAP.2021.106143>
- Likhi, C. (2024). Transportation and Mining, and General Types of Accidents. <https://mhsc.org.za/wp-content/uploads/2024/10/Breakaway-Feedback-Transportation-Mining-Machinery-18-October-2024.pdf>
- Lincoln, Y. S., & Guba, E. G. (2000). Paradigmatic controversies, contradictions, and emerging confluences. *The Sage handbook of qualitative research*, 4(2), 163-188. [https://www.academia.edu/download/47862926/gubaelincoln\\_novo.pdf](https://www.academia.edu/download/47862926/gubaelincoln_novo.pdf)
- Lino, A. F., Aquino, A. C. B. de, & Neves, F. R. (2022). Accountants' postures under compulsory digital transformation imposed by government oversight authorities. *Financial Accountability and Management*, 38(2), 202–222. <https://doi.org/10.1111/FAAM.12313>
- Lumadi, VW., & Nyasha, S. (2024). Technology and growth in the South African mining industry: An assessment of critical success factors and challenges. *Journal of the Southern African Institute of Mining and Metallurgy*, 124(4), 163–171. <https://doi.org/10.17159/2411-9717/2287/2024>
- Lundestad, C. V., & Hommels, A. (2006). Software vulnerability due to practical drift. *Ethics and Information Technology*, 9(2), 89–100. <https://doi.org/10.1007/S10676-006-9123-1>

- Macmillan, H. (2017). Plus ça change? Mining in South Africa in the last 30 years-an overview. *Review Of African Political Economy*, 44(152), 272–291. <https://doi.org/10.1080/03056244.2017.1313728>
- Manchon, J. B., Bueno, M., & Navarro, J. (2022). How the initial level of trust in automated driving impacts drivers' behaviour and early trust construction. *Transportation Research Part F: Traffic Psychology and Behaviour*, 86, 281–295. <https://doi.org/10.1016/J.TRF.2022.02.006>
- Maqutu, L. (2022). The Management of African Workers' Wages at South African Mines: Law and Policy Before 1948. *Potchefstroom Electronic Law Journal*, 25(1), 1–32. <https://doi.org/10.17159/1727-3781/2022/V25I0A8390>
- Marikyan, D., Papagiannidis, S., & Alamanos, E. (2023). Cognitive Dissonance in Technology Adoption: A Study of Smart Home Users. *Information Systems Frontiers*, 25(3), 1101–1123. <https://doi.org/10.1007/S10796-020-10042-3>
- Maseko, R. (2021). Being a Mineworker in Post-Apartheid South Africa: A Decolonial Perspective. In M. Steyn & W. Mpofu (Eds.), *Decolonising the human : Reflections from Africa on difference and oppression* (pp.109–129). Wits University Press. <https://www.jstor.org/stable/10.18772/22021036512>
- Masumbuko, C., & Phiri, J. (2024). Technology Adoption as a Factor for Financial Performance in the Banking Sector Using UTAUT Model. *African Journal of Commercial Studies*, 4(2), 121–130. <https://doi.org/10.59413/ajocs/v4.i2.5>
- Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An Integrative Model of Organizational Trust. *The Academy of Management Review*, 20(3), 709. <https://doi.org/10.2307/258792>
- Meesters, M., Wostyn, P., van Leeuwen, J., Behagel, J. H., & Turnhout, E. (2021). The Social Licence to Operate and the legitimacy of resource extraction. *Current Opinion in Environmental Sustainability*, 49, 7–11. <https://doi.org/10.1016/J.COSUST.2020.11.002>
- Mehdy, A. K. M. N., Ekstrand, M. D., Knijnenburg, B. P., & Mehrpouyan, H. (2021). Privacy as a planned behavior: Effects of situational factors on privacy perceptions and plans. *UMAP 2021 - Proceedings of the 29th ACM Conference on User Modeling, Adaptation and Personalization*, 169–178. <https://doi.org/10.1145/3450613.3456829>

- Minerals Council South Africa. (n.d.). *Traffic Management Mosh Leading Practice Adoption Guide*. <https://www.mosh.co.za/transport-and-machinery/leading-practices/tmlp-summary>
- Mooren, L., & Shuey, R. (2024). Systems Thinking in Road Safety Management. *Journal of Road Safety*, 35(2), 63-73. <https://doi.org/10.33492/JRS-D-24-2-2109985>
- Morgan, H. (2024). Using Triangulation and Crystallization to Make Qualitative Studies Trustworthy and Rigorous. *The Qualitative Report*, 29(7), 1844–1856. <https://doi.org/10.46743/2160-3715/2024.6071>
- Munir, A., Aved, A., & Blasch, E. (2022). Situational Awareness: Techniques, Challenges, and Prospects. *AI*, 3(1), 55–77. <https://doi.org/10.3390/AI3010005>
- Mushtaq, A., Haq, I. U., Nabi, W. U., Khan, A., & Shafiq, O. (2021). Traffic Flow Management of Autonomous Vehicles Using Platooning and Collision Avoidance Strategies. *Electronics*, 10(10). <https://doi.org/10.3390/ELECTRONICS10101221>
- Muthelo, L., Mothiba, T. M., Malema, N. R., Mbombi, M. O., & Mphekgwana, P. M. (2022). Exploring Occupational Health and Safety Standards Compliance in the South African Mining Industry, Limpopo Province, Using Principal Component Analysis. *International Journal of Environmental Research and Public Health*, 19(16), 1–16. <https://doi.org/10.3390/IJERPH191610241>
- Mutzenich, C., Durant, S., Helman, S., & Dalton, P. (2021). Updating our understanding of situation awareness in relation to remote operators of autonomous vehicles. *Cognitive Research: Principles and Implications*, 6(9), 1–17. <https://doi.org/10.1186/S41235-021-00271-8>
- Naiseh, M., Clark, J., Akarsu, T., Hanoch, Y., Brito, M., Wald, M., Webster, T., & Shukla, P. (2025). Trust, risk perception, and intention to use autonomous vehicles: an interdisciplinary bibliometric review. *AI and Society*, 40(2), 1091–1111. <https://doi.org/10.1007/S00146-024-01895-2>
- Naujoks, F., & Totzke, I. (2014). Behavioral adaptation caused by predictive warning systems – The case of congestion tail warnings. *Transportation Research Part F: Traffic Psychology and Behaviour*, 26(PART A), 49–61. <https://doi.org/10.1016/J.TRF.2014.06.010>
- Ochoa Pacheco, P., Cunha, M. P. e., & Abrantes, A. C. M. (2022). The impact of empowerment and technology on safety behavior: evidence from mining

- companies. *International Journal of Occupational Safety and Ergonomics*, 28(1), 581–589. <https://doi.org/10.1080/10803548.2020.1808343>
- Oesterreich, T. D., Anton, E., Hettler, F. M., & Teuteberg, F. (2024). What drives individuals' trusting intention in digital platforms? An exploratory meta-analysis. *Management Review Quarterly*, 1–53. <https://doi.org/10.1007/S11301-024-00477-2>
- Panchal, I., Metz, I. C., Ribeiro, M. J., & Armanini, S. F. (2022). Urban air traffic management for collision avoidance with non-cooperative airspace users. In *Proceedings of the 33rd Congress of the International Council of the Aeronautical Sciences (ICAS 2022)*. <https://research.tudelft.nl/en/publications/urban-air-traffic-management-for-collision-avoidance-with-non-coo>
- Parasuraman, R., & Manzey, D. H. (2010). Complacency and bias in human use of automation: An attentional integration. *Human Factors*, 52(3), 381–410. <https://doi.org/10.1177/0018720810376055>
- Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse - ProQuest. *Human Factors*, 39(2), 230–253. <https://www.proquest.com/docview/216444294/fulltextPDF/11B2661351EE410APQ/1?accountid=14717&sourcetype=Scholarly%20Journals>
- Patton, M. Q. (2015). *Qualitative research & evaluation methods : integrating theory and practice* (4th ed.). SAGE Publications, Inc.
- Pickering, B., Phillips, S. C., & Surridge, M. (2022). Tell me what that means to you: Small-story narratives in technology adoption. In M. Kurosu (Ed.), *Human-computer interaction: Theoretical approaches and design methods (HCII 2022)* (Lecture Notes in Computer Science, Vol. 13302). Springer. [https://doi.org/10.1007/978-3-031-05311-5\\_19](https://doi.org/10.1007/978-3-031-05311-5_19)
- Pienaar, H. (2024, March 26). *Mining employment down by less than feared in Q4 2023*. <https://www.mineralscouncil.org.za/all-categories?task=download.send&id=2238:mining-employment-down-by-less-than-feared-in-q4-2023&catid=113>
- Platt, J. (1985). Weber's Verstehen and the History of Qualitative Research: The Missing Link. *The British Journal of Sociology*, 36(3), 448-466. <https://doi.org/10.2307/590460>
- Prinsloo, H., & Hofmeyr, K. B. (2022). Organisational culture, frontline supervisory engagement and accountability, as drivers of safety behaviour in a platinum

- mining organisation. *SA Journal of Human Resource Management*, 20. <https://doi.org/10.4102/SAJHRM.V20I0.1705>
- Priolo, G., Vignoli, M., & Nielsen, K. (2025). Risk perception and safety behaviors in high-risk workers: A systematic literature review. *Safety Science*, 186, 1–12. <https://doi.org/10.1016/J.SSCI.2025.106811>
- Provan, D. J., Woods, D. D., Dekker, S. W. A., & Rae, A. J. (2020). Safety II professionals: How resilience engineering can transform safety practice. *Reliability Engineering & System Safety*, 195. <https://doi.org/10.1016/J.RESS.2019.106740>
- Rammohan, A., Chavhan, S., Chidambaram, R. K., Manisaran, N., & Kumar, K. V. P. (2022). Automotive Collision Avoidance System: A Review. *Studies in Systems, Decision and Control*, 412, 1–19. [https://doi.org/10.1007/978-3-030-94102-4\\_1](https://doi.org/10.1007/978-3-030-94102-4_1)
- Rindfleisch, A., Malter, A. J., Ganesan, S., & Moorman, C. (2008). Cross-sectional versus longitudinal survey research: Concepts, findings, and guidelines. *Journal of Marketing Research*, 45(3), 261–279. <https://doi.org/10.1509/JMKR.45.3.261>
- Rowland, J. (2025, March 21). Issues in collision avoidance - North American Mining Magazine. <https://northamericanmining.com/index.php/2025/03/21/issues-in-collision-avoidance/>
- Ruan, S., You, S., Li, S., & Qi, Y. (2024). Factors influencing recommendation intentions for autonomous vehicles: A path analysis in a pilot study. *Acta Psychologica*, 249. <https://doi.org/10.1016/J.ACTPSY.2024.104450>
- Rubin, H. J., & Rubin, I. S. (2005). *Qualitative Interviewing: The Art of Hearing Data* (2nd ed.). SAGE Publications, Inc. <https://doi.org/10.4135/9781452226651>
- Sackstein, S., Matthee, M., & Weilbach, L. (2023). Theories and Models Employed to Understand the Use of Technology in Education: A Hermeneutic Literature Review. *Education and Information Technologies*, 28(5), 5041–5081. <https://doi.org/10.1007/S10639-022-11345-5>
- Saldaña, J. (2021). *The Coding Manual for Qualitative Researchers*. SAGE Publications Ltd.
- Sanbonmatsu, D. M., Crabtree, K. W., McDonnell, A. S., Cooper, J. M., & Strayer, D. L. (2024). Automated driving experiences, attention, and intentions following extensive on-road usage of a level 2 automation vehicle. *Journal of Safety Research*, 90, 199–207. <https://doi.org/10.1016/J.JSR.2024.05.002>

- Saunders, M., & Lewis, P. (2018). *Doing research in business and management: An essential guide to planning your project* (2nd ed.). Pearson.
- Schnebelen, D., Charron, C., & Mars, F. (2020). Estimating the out-of-the-loop phenomenon from visual strategies during highly automated driving. *Accident Analysis & Prevention*, 148. <https://doi.org/10.1016/J.AAP.2020.105776>
- Shareef, M. A., Das, R., Ahmed, J. U., Mishra, A., Sultana, I., Rahman, M. Z., & Mukerji, B. (2024). Mandatory adoption of technology: Can UTAUT2 model capture managers behavioral intention? *Technological Forecasting and Social Change*, 200. <https://doi.org/10.1016/J.TECHFORE.2023.123087>
- Shariff, A., Bonnefon, J. F., & Rahwan, I. (2021). How safe is safe enough? Psychological mechanisms underlying extreme safety demands for self-driving cars. *Transportation Research Part C: Emerging Technologies*, 126. <https://doi.org/10.1016/J.TRC.2021.103069>
- Simons, H. J. (1960). Death in South African Mines. *Africa South*, 5(4), 41–55. <https://sahistory.org.za/sites/default/files/archive-files2/asjul61.8.pdf>
- Simonson, R. J., Keebler, J. R., Blickensderfer, E. L., & Besuijen, R. (2022). Impact of alarm management and automation on abnormal operations: A human-in-the-loop simulation study. *Applied Ergonomics*, 100. <https://doi.org/10.1016/J.APERGO.2021.103670>
- Soares, A. L. V., Mendes-Filho, L., & Gretzel, U. (2021). Technology adoption in hotels: applying institutional theory to tourism. *Tourism Review*, 76(3), 669–680. <https://doi.org/10.1108/TR-05-2019-0153>
- Society of Automotive Engineers. (2021). *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles* (SAE J3016-2021). [https://www.sae.org/standards/content/j3016\\_202104/](https://www.sae.org/standards/content/j3016_202104/)
- South African Government. (2025, January 23). *Minister Gwede Mantashe: Release of 2024 mine health and safety statistics*. <https://www.gov.za/news/speeches/minister-gwede-mantashe-release-2024-mine-health-and-safety-statistics-23-jan-2025>
- Steen, R., Norman, J. E., Bergström, J., & Damm, G. F. (2024). Dark knights: Exploring resilience and hidden workarounds in commercial aviation through mixed methods. *Safety Science*, 175. <https://doi.org/10.1016/J.SSCI.2024.106498>

- Suchman, M. C. (1995). Managing Legitimacy: Strategic and Institutional Approaches. *The Academy of Management Review*, 20(3), 571–610. <https://doi.org/10.5465/AMR.1995.9508080331>
- Swanson, L. T. R., Bellanca, J. L., & Helton, J. (2019). Automated Systems and Trust: Mineworkers' Trust in Proximity Detection Systems for Mobile Machines. *Safety and Health at Work*, 10(4), 461–469. <https://doi.org/10.1016/J.SHAW.2019.09.003>
- Thomas, D. R. (2006). A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation*, 27(2), 237–246. <https://doi.org/10.1177/1098214005283748>
- Thonon, F., Godon-Rensonnet, A. S., Perozziello, A., Garsi, J. P., Dab, W., & Emsalem, P. (2023). Return on investment of workplace-based prevention interventions: a systematic review. *European Journal of Public Health*, 33(4), 612–618. <https://doi.org/10.1093/EURPUB/CKAD092>
- Tian, Y., & Wang, X. (2022). A study on psychological determinants of users' autonomous vehicles adoption from anthropomorphism and UTAUT perspectives. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/FPSYG.2022.986800>
- Tong, Y., Jia, B., Bao, S., Wu, C., & Sethuraman, N. (2024). The difference in physical and mental fatigue development between novice young adult and experienced middle-aged adult drivers during simulated automated driving. *Journal of Safety Research*, 91, 165–174. <https://doi.org/10.1016/J.JSR.2024.08.011>
- Trading Economics. (2025). *South Africa Mining Production*. Trading Economics. Retrieved October 31, 2025, from <https://tradingeconomics.com/south-africa/mining-production>
- Trieu, V. H., Burton-Jones, A., Green, P., & Cockcroft, S. (2022). Applying And Extending the Theory of Effective Use in a Business Intelligence Context. *Management Information Systems Quarterly*, 46(1), 645–678. <https://doi.org/10.25300/MISQ/2022/14880>
- Tyler, T. R. (1997). The psychology of legitimacy: A relational perspective on voluntary deference to authorities. *Personality and Social Psychology Review*, 1(4), 323–345. [https://doi.org/10.1207/S15327957PSPR0104\\_4](https://doi.org/10.1207/S15327957PSPR0104_4)

- van Aswegen, J. C., Hamersma, H. A., & Els, P. S. (2024). Collision Prediction for a Mining Collision Avoidance System. *Lecture Notes in Mechanical Engineering*, 756–762. [https://doi.org/10.1007/978-3-031-70392-8\\_107](https://doi.org/10.1007/978-3-031-70392-8_107)
- van de Merwe, K., Mallam, S., Nazir, S., & Engelhardt, Ø. (2024). Supporting human supervision in autonomous collision avoidance through agent transparency. *Safety Science*, 169. <https://doi.org/10.1016/J.SSCI.2023.106329>
- Vasta, N., & Biondi, F. (2025). Effect of Partially Automated Driving on Mental Workload, Visual Behavior and Engagement in Nondriving-Related Tasks: A Meta-Analysis. *Human Factors*, 67(9), 962–991. <https://doi.org/10.1177/00187208251323132>
- Veiga, M. M., & Marshall, B. G. (2019). The Colombian artisanal mining sector: Formalization is a heavy burden. *The Extractive Industries and Society*, 6(1), 223–228. <https://doi.org/10.1016/J.EXIS.2018.11.001>
- Venkatesh, V., & Davis, F. D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Management Science*, 46(2), 186–204. <https://doi.org/10.1287/MNSC.46.2.186.11926>
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly: Management Information Systems*, 27(3), 425–478. <https://doi.org/10.2307/30036540>
- Venkatesh, V., Thong, J. Y. L., & Xu, X. (2016). Unified Theory of Acceptance and Use of Technology: A Synthesis and the Road Ahead. *Journal of the Association for Information Systems*, 17(5). <https://doi.org/10.17705/1jais.00428>
- Walker, F., Forster, Y., Hergeth, S., Kraus, J., Payre, W., Wintersberger, P., & Martens, M. (2024). Editorial: Trust in Automated Vehicles. *Frontiers in Psychology*, 15. <https://doi.org/10.3389/FPSYG.2024.1404200>
- Wang, L., Chai, W., Sun, N., & Tong, R. (2024). Unlocking the mechanism of work environment on miners' unsafe behaviors: A meta-analysis and system dynamics. *Resources Policy*, 96. <https://doi.org/10.1016/J.RESOURPOL.2024.105217>
- Washburn, C., Kueny, C., & Murray, S. (2023). Establishing links between safety culture, climate, behaviors, and outcomes of long-haul truck drivers. *Journal of Safety Research*, 85, 371–379. <https://doi.org/10.1016/J.JSR.2023.04.004>

- Weber, M. (1968). *Economy and society* (G. Roth & C. Wittich, Eds.; 1st ed., Vol. 1). University of California Press. <https://www.ucpress.edu/books/economy-and-society-2/paper>
- Wong, J. (2024). Role distance. An ethnographic study on how street-level managers cope. *Journal of Public Administration Research and Theory*, 34(3), 359–370. <https://doi.org/10.1093/JOPART/MUAD027>
- Xu, D., Liu, F., Ding, X., Ma, J., Suo, Y., Peng, Y. Y., Li, J., & Fu, X. (2025). Exploring ICU nurses' response to alarm management and strategies for alleviating alarm fatigue: a meta-synthesis and systematic review. *BMC Nursing*, 24(1), 1–13. <https://doi.org/10.1186/S12912-025-03084-Y>
- Zhang, S., Hua, X., Huang, G., Shi, X., & Li, D. (2022). What Influences Miners' Safety Risk Perception? *International Journal of Environmental Research and Public Health*, 19(7). <https://doi.org/10.3390/IJERPH19073817>

## Appendices

### Appendix A Semi-Structured Interview Guide

#### Semi-Structured Interview Guide (Draft)

| INTERVIEW GUIDE                                                                                  |
|--------------------------------------------------------------------------------------------------|
| <b>1. Demographics</b>                                                                           |
| 1.1 Can you tell me about your role in the mine?                                                 |
| 1.2 How long have you worked in mining?                                                          |
| 1.3 What type of TMM(s) are you licensed to operate?                                             |
| 1.4 How long have you operated machines with CAS installed?                                      |
| 1.5 Were you operating machines before 2015/before CAS was installed?                            |
| 1.6 What type of CAS are you familiar with?                                                      |
|                                                                                                  |
| <b>2. Perception</b>                                                                             |
| 2.1 Can you describe your first experience using the Collision Avoidance System (CAS)?           |
| 2.2 How has CAS affected the way you work?                                                       |
| 2.3 What advantages does CAS have, if any?                                                       |
| 2.4 Do you think it has resulted in a difference?                                                |
| 2.5 Are there any aspects of CAS you find frustrating or difficult to tolerate?                  |
| 2.6 Have you ever had to override the system? Can you tell me about that                         |
| <b>3. Trust</b>                                                                                  |
| 3.1 What do you think about CAS stopping the vehicle? Do you trust it to do so when it required? |
| 3.2 Please describe how you feel about safety when the system is installed?                      |
| 3.3 To what extent have you felt unsafe with the system intervening a stop?                      |
| 3.4 Describe how you feel when the system takes control?                                         |
| 3.5 Please describe how you feel if the system trips unnecessarily?                              |
|                                                                                                  |
| <b>4. Resistance/Compliance</b>                                                                  |
| 4.1 Where do you think the use of CAS comes from?                                                |

| INTERVIEW GUIDE                   |                                                                                                                                                 |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| 4.2                               | What extent do you personally support CAS or is it something require by someone else?                                                           |
| 4.3                               | To what extent do you think there is a way to work around the system?                                                                           |
| 4.4.                              | Do you think it is possible that other operators take shortcuts with the system? Why do you think that happens?                                 |
| 4.5                               | What are other people saying about CAS?                                                                                                         |
| 4.6                               | Please describe how you feel about the regulation? Do you think this improves safety? How stressful/comforting is it to have these regulations? |
|                                   |                                                                                                                                                 |
| <b>5. Further Recommendations</b> |                                                                                                                                                 |
| 5.1                               | What changes would you recommend for improvement? Or suggest for support to make you more comfortable/confident with the system?                |
| 5.2                               | Is there else anything you would like to share about your experience with CAS?                                                                  |

## Appendix B Survey Questionnaire

25/10/2025, 20:54

Demographics and Consent Form for CAS Research Interview (Preview)

### Demographics and Consent Form for CAS Research Interview

Thank you for participating in my research interview on Collision Avoidance Systems (CAS). Please complete this form to provide your demographic information and virtually confirm your consent to the use of the interview conducted purposes only reserved for my MBA research with the Gordon Institute of Business Science. All information will be kept confidential and used for research purposes only.

As mentioned, any concerns can be directed to my supervisor or me:

When you submit this form, it will not automatically collect your details like name and email address unless you provide it yourself

\* Required

1. Do you consent to participate in this research? \*

☒ Yes, I consent

☐ No, I do not consent

2. What is your age? \*

Enter your answer

3. What type of mining do you work in? \*

☐ Underground

☐ Surface

☐ Other

4. What is your role? \*

☐ Operator

☐ Artisan

☐ Miner

☐ Supervisor

☐ Other

5. What is your ethnicity? (Select all that apply) \*

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Figure C-1 Survey Questionnaire (Page 1 of 2)

25/10/2025, 20:54 Demographics and Consent Form for CAS Research Interview (Preview)

☐ Black/African

☐ Coloured

☐ Indian/Asian

☐ White

☐ Other (please specify)

6. What is your gender? (Select one) \*

☐ Male

☐ Female

☐ Non-binary

☐ Prefer not to say

☐ Other (please specify)

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Figure C-2 Survey Questionnaire (Page 2 of 2)

## Appendix C Theme Map

| Theme                                 | Sub-theme                        | #  | Raw Code from Atlas                                             |
|---------------------------------------|----------------------------------|----|-----------------------------------------------------------------|
| Trust in CAS for Safety               | System Function Clarity          | 1  | ◦ System Function Clarity: Different companies/technologiesGr=2 |
| Trust in CAS for Safety               | System Function Clarity          | 2  | ◦ System Function Clarity: Differentiation ProblemsGr=3         |
| Trust in CAS for Safety               | System Function Clarity          | 3  | ◦ System Function Clarity: Gray Functional AreasGr=4            |
| Trust in CAS for Safety               | System Function Clarity          | 4  | ◦ System Function Clarity: Limited Awareness UncertaintyGr=3    |
| Trust in CAS for Safety               | System Function Clarity          | 5  | ◦ System Function Clarity: Operating/Stopping ConditionGr=2     |
| Trust in CAS for Safety               | System Function Clarity          | 6  | ◦ System Function Clarity: Silent Zone WarningGr=1              |
| Trust in CAS for Safety               | Reliability                      | 7  | ◦ Reliability: Bypass not workingGr=1                           |
| Trust in CAS for Safety               | Reliability                      | 8  | ◦ Reliability: Conditional operationGr=6                        |
| Trust in CAS for Safety               | Reliability                      | 9  | ◦ Reliability: Effective systemGr=6                             |
| Trust in CAS for Safety               | Reliability                      | 10 | ◦ Reliability: Interference IssuesGr=1                          |
| Trust in CAS for Safety               | Reliability                      | 11 | ◦ Reliability: Maintenance errorsGr=1                           |
| Trust in CAS for Safety               | Reliability                      | 12 | ◦ Reliability: Nuisance/Unnecessary tripsGr=1                   |
| Trust in CAS for Safety               | Reliability                      | 13 | ◦ Reliability: Silent Zone IssuesGr=1                           |
| Trust in CAS for Safety               | Reliability                      | 14 | ◦ Reliability: System can failGr=8                              |
| Trust in CAS for Safety               | Pre-experience/ beliefs          | 15 | ◦ Pre-experience: Contrasted viewGr=3                           |
| Trust in CAS for Safety               | Pre-experience/ beliefs          | 16 | ◦ Pre-experience: Lack of System understandingGr=1              |
| Trust in CAS for Safety               | Trust in Technology              | 17 | ◦ Trust in Technology: dont trust machinesGr=5                  |
| Trust in CAS for Safety               | Trust in Technology              | 18 | ◦ Trust in Technology: Doubt in Compliance BehaviourGr=8        |
| Trust in CAS for Safety               | Trust in Technology              | 19 | ◦ Trust in Technology: Exercise cautionGr=9                     |
| Trust in CAS for Safety               | Trust in Technology              | 20 | ◦ Trust in Technology: Man-made systems unreliableGr=4          |
| Trust in CAS for Safety               | Trust in Technology              | 21 | ◦ Trust in Technology: Mechanical Lockout SaferGr=2             |
| Trust in CAS for Safety               | Trust in Technology              | 22 | ◦ <b>Trust in Technology: System could failGr=5</b>             |
| Trust in CAS for Safety               | Trust in Technology              | 23 | ◦ Trust in Technology: Tested for safetyGr=7                    |
| Trust in CAS for Safety               | Trust in Technology              | 24 | ◦ Trust in Technology: Uncertainty in FunctionalityGr=6         |
| Trust in CAS for Safety               | Trust in Technology              | 25 | ◦ Trust in Technology: Wont Always StopGr=9                     |
|                                       |                                  |    |                                                                 |
| Compliance, Symbolic Use & Resistance | Compliance & Enforced compliance | 26 | ◦ Compliance: Training/communication/awarenessGr=4              |
| Compliance, Symbolic Use & Resistance | Compliance & Enforced compliance | 27 | ◦ Enforced Compliance: "not my decision"Gr=3                    |
| Compliance, Symbolic Use & Resistance | Compliance & Enforced compliance | 28 | ◦ Enforced Compliance: 'not allowed'Gr=12                       |
| Compliance, Symbolic Use & Resistance | Compliance & Enforced compliance | 29 | ◦ Enforced Compliance: CAS for SpyingGr=1                       |
| Compliance, Symbolic Use & Resistance | Compliance & Enforced compliance | 30 | ◦ Enforced Compliance: Conditional toleranceGr=1                |
| Compliance, Symbolic Use & Resistance | Compliance & Enforced compliance | 31 | ◦ Enforced Compliance: Consequences to non-complianceGr=6       |
| Compliance, Symbolic Use & Resistance | Compliance & Enforced compliance | 32 | ◦ Enforced Compliance: organisational legitimacyGr=11           |
| Compliance, Symbolic Use & Resistance | Compliance & Enforced compliance | 33 | ◦ Enforced Compliance: regulatory legitimacyGr=10               |
| Compliance, Symbolic Use & Resistance | Resistance                       | 34 | ◦ Resistance: By-pass neededGr=12                               |
| Compliance, Symbolic Use & Resistance | Resistance                       | 35 | ◦ Resistance: fatigueGr=1                                       |
| Compliance, Symbolic Use & Resistance | Resistance                       | 36 | ◦ Resistance: Lamp overrideGr=4                                 |
| Compliance, Symbolic Use & Resistance | Resistance                       | 37 | ◦ Resistance: TrainingGr=1                                      |
| Compliance, Symbolic Use & Resistance | Resistance                       | 38 | ◦ Resistance: Undermining safety systems/rulesGr=11             |
| Compliance, Symbolic Use & Resistance | Resistance                       | 39 | ◦ Resistance: User impatience/percieved delayGr=6               |
| Compliance, Symbolic Use & Resistance | Resistance                       | 40 | ◦ Resistance: work/bonus/production pressureGr=15               |

Figure D-1 Code to Theme Map (1 of 2)

| Theme                                       | Sub-theme                 | #  | Raw Code from Atlas                                                    |
|---------------------------------------------|---------------------------|----|------------------------------------------------------------------------|
| Perceived Safety Benefits                   | Safety Perception         | 41 | o Safety Perception: Assist with alertnessGr=10                        |
| Perceived Safety Benefits                   | Safety Perception         | 42 | o Safety Perception: Bypass cards unsafeGr=5                           |
| Perceived Safety Benefits                   | Safety Perception         | 43 | o Safety Perception: Compliance means safetyGr=1                       |
| Perceived Safety Benefits                   | Safety Perception         | 44 | o Safety Perception: Does not remove riskGr=1                          |
| Perceived Safety Benefits                   | Safety Perception         | 45 | o Safety Perception: Effective for safetyGr=25                         |
| Perceived Safety Benefits                   | Safety Perception         | 46 | o Safety Perception: effective speed controlGr=2                       |
| Perceived Safety Benefits                   | Safety Perception         | 47 | o Safety Perception: Experience/Training/Change ManagementGr=5         |
| Perceived Safety Benefits                   | Safety Perception         | 48 | o Safety Perception: Human Disenchantment BetterGr=13                  |
| Perceived Safety Benefits                   | Safety Perception         | 49 | o Safety Perception: Infrastructure protectionGr=2                     |
| Perceived Safety Benefits                   | Safety Perception         | 50 | o Safety Perception: Injuries/Collisions still/can occurGr=5           |
| Perceived Safety Benefits                   | Safety Perception         | 51 | o Safety Perception: Low concentration unsafeGr=1                      |
| Perceived Safety Benefits                   | Safety Perception         | 52 | o Safety Perception: machine controlGr=4                               |
| Perceived Safety Benefits                   | Safety Perception         | 53 | o Safety Perception: Over-reliance unsafeGr=7                          |
| Perceived Safety Benefits                   | Safety Perception         | 54 | o Safety Perception: Prioritising productionGr=7                       |
| Perceived Safety Benefits                   | Safety Perception         | 55 | o Safety Perception: Reduced collision/fatalities/injuriesGr=15        |
| Perceived Safety Benefits                   | Safety Perception         | 56 | o Safety Perception: Reliable stopsGr=3                                |
| Perceived Safety Benefits                   | Safety Perception         | 57 | o Safety Perception: Situational Awareness decreased with CASGr=3      |
| Perceived Safety Benefits                   | Safety Perception         | 58 | o Safety Perception: Situational Awareness Increased w/out CASGr=2     |
| Impact on Work Practices & Productivity     | Work Practices            | 59 | o Work Practices: Causes DelaysGr=16                                   |
| Impact on Work Practices & Productivity     | Work Practices            | 60 | o Work Practices: Consistent bypassingGr=3                             |
| Impact on Work Practices & Productivity     | Work Practices            | 61 | o Work Practices: Experienced Operators PreferenceGr=1                 |
| Impact on Work Practices & Productivity     | Work Practices            | 62 | o Work Practices: Maintenance HindranceGr=4                            |
| Impact on Work Practices & Productivity     | Work Practices            | 63 | o Work Practices: Requires patient operatorsGr=1                       |
| Impact on Work Practices & Productivity     | Work Practices            | 64 | o Work Practices: Training requiredGr=5                                |
| Impact on Work Practices & Productivity     | Work Practices            | 65 | o Work Practices: Training/Knowledge adaptationGr=3                    |
| Impact on Work Practices & Productivity     | Work Practices            | 66 | o Work Practices: Training/Knowledge/Experience - User adaptationGr=12 |
| Impact on Work Practices & Productivity     | Work Practices            | 67 | o Work Practices: User adaptationGr=6                                  |
| Impact on Work Practices & Productivity     | Work Practices            | 68 | o Work Practices: Work HindranceGr=1                                   |
| Impact on Work Practices & Productivity     | Work Practices            | 69 | o Work Practices: Work/Production HindranceGr=5                        |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 70 | o Frustration/Challenges: Bypass function/process tediousGr=5          |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 71 | o Frustration/Challenges: Communication about system gapGr=3           |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 72 | o Frustration/Challenges: Harsh brakingGr=4                            |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 73 | o Frustration/Challenges: Human behaviour importantGr=8                |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 74 | o Frustration/Challenges: Machine availability lowerGr=2               |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 75 | o Frustration/Challenges: Machine Stopping UnexpectedlyGr=1            |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 76 | o Frustration/Challenges: System Maintenance LimitationsGr=5           |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 77 | o Frustration/Challenges: unclear proceduresGr=1                       |
| Challenges & Frustrations / User Experience | Frustrations & challenges | 78 | o Frustration/Challenges: Unnecessary StopsGr=18                       |
| Challenges & Frustrations / User Experience | User experience           | 79 | o User Experience: ConvenientGr=1                                      |
| Challenges & Frustrations / User Experience | User experience           | 80 | o User Experience: Function Clarity UneasinessGr=1                     |
| Challenges & Frustrations / User Experience | User experience           | 81 | o User Experience: Injuring harshstopsGr=3                             |
| Challenges & Frustrations / User Experience | User experience           | 82 | o User Experience: Satisfactory OperationGr=2                          |
| Challenges & Frustrations / User Experience | User experience           | 83 | o User Experience: Stops IrritatingGr=4                                |
| Challenges & Frustrations / User Experience | User experience           | 84 | o User Experience: Uncomfortable/Scary StopsGr=8                       |
| Regulation & Awareness (Context)            | Regulation Awareness      | 85 | o Regulation: AwarenessGr=4                                            |
| Regulation & Awareness (Context)            | Regulation Awareness      | 86 | o Regulation: CAS Financial impactGr=8                                 |
| Regulation & Awareness (Context)            | Regulation Awareness      | 87 | o Regulation: Procedures/Methods for safetyGr=1                        |
| Regulation & Awareness (Context)            | Regulation Awareness      | 88 | o Regulation: UnawarenessGr=5                                          |

Figure D-2 Code to Theme Map (1 of 2)

## Appendix D Codes and Co-Occurrences

Table E-1: Code Occurrences by Participant Groups

|    | CODES                                                                         | EXPE<br>R. (1-<br>5) | EXPE<br>R. (5-<br>10) | EXPE<br>R. (10+) | POS<br>T<br>CAS | PR<br>E<br>CA<br>S | ROL<br>ES<br>(ENG<br>.) | ROLE<br>S<br>(MININ<br>G) | TOT<br>AL |
|----|-------------------------------------------------------------------------------|----------------------|-----------------------|------------------|-----------------|--------------------|-------------------------|---------------------------|-----------|
| 1  | ○ Safety Perception:<br>Effective for safety<br>Gr=25                         | 7                    | 8                     | 14               | 15              | 14                 | 13                      | 16                        | 29        |
| 2  | ○ Work Practices:<br>Causes Delays<br>Gr=16                                   | 8                    | 10                    | 6                | 17              | 7                  | 16                      | 8                         | 24        |
| 3  | ○ Enforced<br>Compliance: 'not<br>allowed'<br>Gr=12                           | 7                    | 12                    | 2                | 19              | 2                  | 19                      | 2                         | 21        |
| 4  | ○ Resistance: By-pass<br>needed<br>Gr=12                                      | 6                    | 13                    | 1                | 16              | 4                  | 19                      | 1                         | 20        |
| 5  | ○ Enforced<br>Compliance:<br>organisational<br>legitimacy<br>Gr=11            | 4                    | 12                    | 3                | 15              | 4                  | 16                      | 3                         | 19        |
| 6  | ○ Safety Perception:<br>Human Disenment<br>Better<br>Gr=13                    | 3                    | 10                    | 6                | 10              | 9                  | 13                      | 6                         | 19        |
| 7  | ○ Enforced<br>Compliance:<br>regulatory legitimacy<br>Gr=10                   | 4                    | 10                    | 4                | 14              | 4                  | 14                      | 4                         | 18        |
| 8  | ○<br>Frustration/Challenges<br>: Unnecessary Stops<br>Gr=18                   | 5                    | 5                     | 10               | 10              | 10                 | 8                       | 12                        | 20        |
| 9  | ○ Resistance:<br>work/bonus/productio<br>n pressure<br>Gr=15                  | 6                    | 3                     | 8                | 8               | 9                  | 8                       | 9                         | 17        |
| 10 | ○ Safety Perception:<br>Reduced<br>collision/fatalities/injur<br>ies<br>Gr=15 | 3                    | 2                     | 10               | 5               | 10                 | 5                       | 10                        | 15        |
| 11 | ○ Trust in Technology:<br>Doubt in Compliance<br>Behaviour<br>Gr=8            | 4                    | 6                     | 2                | 10              | 2                  | 8                       | 4                         | 12        |
| 12 | ○ Resistance:<br>Undermining safety<br>systems/rules<br>Gr=11                 | 3                    | 7                     | 1                | 10              | 1                  | 9                       | 2                         | 11        |
| 13 | ○ Safety Perception:<br>Assist with alertness<br>Gr=10                        | 4                    | 7                     | 1                | 9               | 3                  | 11                      | 1                         | 12        |

|    | CODES                                                                      | EXPE<br>R. (1-<br>5) | EXPE<br>R. (5-<br>10) | EXPE<br>R. (10+) | POS<br>T<br>CAS | PR<br>E<br>CA<br>S | ROL<br>ES<br>(ENG<br>.) | ROLE<br>S<br>(MININ<br>G) | TOT<br>AL |
|----|----------------------------------------------------------------------------|----------------------|-----------------------|------------------|-----------------|--------------------|-------------------------|---------------------------|-----------|
| 14 | ○ Enforced Compliance: Consequences to non-compliance<br>Gr=6              | 4                    | 4                     | 2                | 8               | 2                  | 7                       | 3                         | 10        |
| 15 | ○ Resistance: User impatience/percieved delay<br>Gr=6                      | 2                    | 6                     | 2                | 7               | 3                  | 8                       | 2                         | 10        |
| 16 | ○ Safety Perception: Bypass cards unsafe<br>Gr=5                           | 2                    | 5                     | 2                | 7               | 2                  | 7                       | 2                         | 9         |
| 17 | ○ Trust in Technology: Exercise caution<br>Gr=9                            | 1                    | 3                     | 7                | 4               | 7                  | 4                       | 7                         | 11        |
| 18 | ○ Work Practices: Training/Knowledge/Experience - User adaptation<br>Gr=12 | 1                    | 2                     | 9                | 1               | 11                 | 2                       | 10                        | 12        |
| 19 | ○ Work Practices: User adaptation<br>Gr=6                                  | 2                    | 5                     | 3                | 7               | 3                  | 7                       | 3                         | 10        |
| 20 | ○ Frustration/Challenges : System Maintenance Limitations<br>Gr=5          | 3                    | 6                     | 0                | 9               | 0                  | 9                       | 0                         | 9         |
| 21 | ○ Safety Perception: Prioritising production<br>Gr=7                       | 1                    | 3                     | 5                | 4               | 5                  | 4                       | 5                         | 9         |
| 22 | ○ Trust in Technology: Tested for safety<br>Gr=7                           | 2                    | 2                     | 5                | 4               | 5                  | 4                       | 5                         | 9         |
| 23 | ○ Trust in Technology: Wont Always Stop<br>Gr=9                            | 2                    | 5                     | 2                | 5               | 4                  | 5                       | 4                         | 9         |
| 24 | ○ Reliability: Effective system<br>Gr=6                                    | 4                    | 4                     | 0                | 7               | 1                  | 5                       | 3                         | 8         |
| 25 | ○ User Experience: Stops Irritating<br>Gr=4                                | 1                    | 5                     | 0                | 6               | 0                  | 6                       | 0                         | 6         |
| 26 | ○ User Experience: Uncomfortable/Scary Stops<br>Gr=8                       | 0                    | 6                     | 2                | 2               | 6                  | 6                       | 2                         | 8         |
| 27 | ○ Frustration/Challenges : Human behaviour important<br>Gr=8               | 0                    | 4                     | 4                | 1               | 7                  | 4                       | 4                         | 8         |
| 28 | ○ Regulation: CAS Financial impact<br>Gr=8                                 | 0                    | 2                     | 6                | 1               | 7                  | 2                       | 6                         | 8         |

|    | CODES                                                              | EXPE<br>R. (1-<br>5) | EXPE<br>R. (5-<br>10) | EXPE<br>R. (10+) | POS<br>T<br>CAS | PR<br>E<br>CA<br>S | ROL<br>ES<br>(ENG<br>.) | ROLE<br>S<br>(MININ<br>G) | TOT<br>AL |
|----|--------------------------------------------------------------------|----------------------|-----------------------|------------------|-----------------|--------------------|-------------------------|---------------------------|-----------|
| 29 | ○ Reliability: System can fail<br>Gr=8                             | 0                    | 3                     | 5                | 0               | 8                  | 3                       | 5                         | 8         |
| 30 | ○ Safety Perception: Injuries/Collisions still/can occur<br>Gr=5   | 1                    | 5                     | 1                | 5               | 2                  | 6                       | 1                         | 7         |
| 31 | ○ Trust in Technology: System could fail<br>Gr=5                   | 1                    | 5                     | 1                | 4               | 3                  | 6                       | 1                         | 7         |
| 32 | ○ Work Practices: Training required<br>Gr=5                        | 1                    | 4                     | 2                | 4               | 3                  | 5                       | 2                         | 7         |
| 33 | ○ Enforced Compliance: "not my decision"<br>Gr=3                   | 1                    | 3                     | 1                | 4               | 1                  | 4                       | 1                         | 5         |
| 34 | ○ Regulation: Awareness<br>Gr=4                                    | 1                    | 4                     | 1                | 4               | 2                  | 5                       | 1                         | 6         |
| 35 | ○ Safety Perception: Over-reliance unsafe<br>Gr=7                  | 0                    | 2                     | 5                | 2               | 5                  | 2                       | 5                         | 7         |
| 36 | ○ Work Practices: Maintenance Hindrance<br>Gr=4                    | 1                    | 5                     | 0                | 6               | 0                  | 6                       | 0                         | 6         |
| 37 | ○ Pre-experience: Contrasted view<br>Gr=3                          | 2                    | 2                     | 1                | 4               | 1                  | 3                       | 2                         | 5         |
| 38 | ○ Regulation: Unawareness<br>Gr=5                                  | 2                    | 1                     | 2                | 3               | 2                  | 2                       | 3                         | 5         |
| 39 | ○ Reliability: Conditional operation<br>Gr=6                       | 1                    | 4                     | 1                | 2               | 4                  | 4                       | 2                         | 6         |
| 40 | ○ Trust in Technology: Uncertainty in Functionality<br>Gr=6        | 1                    | 3                     | 2                | 4               | 2                  | 3                       | 3                         | 6         |
| 41 | ○ Work Practices: Consistent bypassing<br>Gr=3                     | 1                    | 4                     | 0                | 3               | 2                  | 5                       | 0                         | 5         |
| 42 | ○ Frustration/Challenges : Bypass function/process tedious<br>Gr=5 | 1                    | 4                     | 0                | 4               | 1                  | 5                       | 0                         | 5         |
| 43 | ○ Resistance: Lamp override<br>Gr=4                                | 0                    | 4                     | 0                | 4               | 0                  | 4                       | 0                         | 4         |
| 44 | ○ Safety Perception: Experience/Training/C                         | 0                    | 4                     | 1                | 1               | 4                  | 4                       | 1                         | 5         |

|    | CODES                                                                        | EXPE<br>R. (1-<br>5) | EXPE<br>R. (5-<br>10) | EXPE<br>R.<br>(10+) | POS<br>T<br>CAS | PR<br>E<br>CA<br>S | ROL<br>ES<br>(ENG<br>.) | ROLE<br>S<br>(MININ<br>G) | TOT<br>AL |
|----|------------------------------------------------------------------------------|----------------------|-----------------------|---------------------|-----------------|--------------------|-------------------------|---------------------------|-----------|
|    | hange Management<br>Gr=5                                                     |                      |                       |                     |                 |                    |                         |                           |           |
| 45 | o Safety Perception:<br>Situational Awareness<br>Increased w/out CAS<br>Gr=2 | 1                    | 2                     | 1                   | 3               | 1                  | 3                       | 1                         | 4         |
| 46 | o System Function<br>Clarity: Differentiation<br>Problems<br>Gr=3            | 1                    | 2                     | 0                   | 3               | 0                  | 3                       | 0                         | 3         |
| 47 | o Trust in Technology:<br>dont trust machines<br>Gr=5                        | 0                    | 3                     | 2                   | 1               | 4                  | 3                       | 2                         | 5         |
| 48 | o Trust in Technology:<br>Man-made systems<br>unreliable<br>Gr=4             | 0                    | 3                     | 1                   | 3               | 1                  | 3                       | 1                         | 4         |
| 49 | o Work Practices:<br>Work/Production<br>Hindrane<br>Gr=5                     | 1                    | 3                     | 1                   | 4               | 1                  | 3                       | 2                         | 5         |
| 50 | o Compliance:<br>Training/communicatio<br>n/awareness<br>Gr=4                | 0                    | 0                     | 4                   | 0               | 4                  | 0                       | 4                         | 4         |
| 51 | o Enforced<br>Compliance:<br>Conditional tolerance<br>Gr=1                   | 1                    | 2                     | 0                   | 3               | 0                  | 3                       | 0                         | 3         |
| 52 | o Frustration/Challenges<br>: Harsh braking<br>Gr=4                          | 0                    | 3                     | 1                   | 2               | 2                  | 3                       | 1                         | 4         |
| 53 | o Resistance: fatigue<br>Gr=1                                                | 1                    | 2                     | 0                   | 3               | 0                  | 3                       | 0                         | 3         |
| 54 | o Resistance: Training<br>Gr=1                                               | 1                    | 2                     | 0                   | 3               | 0                  | 3                       | 0                         | 3         |
| 55 | o Safety Perception:<br>machine control<br>Gr=4                              | 0                    | 1                     | 3                   | 0               | 4                  | 1                       | 3                         | 4         |
| 56 | o System Function<br>Clarity: Gray<br>Functional Areas<br>Gr=4               | 0                    | 3                     | 1                   | 2               | 2                  | 3                       | 1                         | 4         |
| 57 | o System Function<br>Clarity: Limited<br>Awareness<br>Uncertainty<br>Gr=3    | 0                    | 1                     | 2                   | 1               | 2                  | 1                       | 2                         | 3         |
| 58 | o User Experience:<br>Satisfactory Operation<br>Gr=2                         | 0                    | 2                     | 0                   | 2               | 0                  | 2                       | 0                         | 2         |
| 59 | o Work Practices:<br>Work Hindrance<br>Gr=1                                  | 1                    | 2                     | 0                   | 3               | 0                  | 3                       | 0                         | 3         |

|    | CODES                                                                 | EXPE<br>R. (1-<br>5) | EXPE<br>R. (5-<br>10) | EXPE<br>R. (10+) | POS<br>T<br>CAS | PR<br>E<br>CA<br>S | ROL<br>ES<br>(ENG<br>.) | ROLE<br>S<br>(MININ<br>G) | TOT<br>AL |
|----|-----------------------------------------------------------------------|----------------------|-----------------------|------------------|-----------------|--------------------|-------------------------|---------------------------|-----------|
| 60 | ○ Frustration/Challenges : Communication about system gap<br>Gr=3     | 0                    | 1                     | 2                | 1               | 2                  | 1                       | 2                         | 3         |
| 61 | ○ Safety Perception: effective speed control<br>Gr=2                  | 0                    | 2                     | 0                | 2               | 0                  | 2                       | 0                         | 2         |
| 62 | ○ Safety Perception: Reliable stops<br>Gr=3                           | 2                    | 0                     | 1                | 2               | 1                  | 1                       | 2                         | 3         |
| 63 | ○ Safety Perception: Situational Awareness decreased with CAS<br>Gr=3 | 1                    | 0                     | 2                | 1               | 2                  | 0                       | 3                         | 3         |
| 64 | ○ System Function Clarity: Operating/Stopping Condition<br>Gr=2       | 0                    | 2                     | 0                | 2               | 0                  | 2                       | 0                         | 2         |
| 65 | ○ User Experience: Injuring harshstops<br>Gr=3                        | 0                    | 0                     | 3                | 0               | 3                  | 0                       | 3                         | 3         |
| 66 | ○ Work Practices: Training/Knowledge adaptation<br>Gr=3               | 0                    | 2                     | 1                | 2               | 1                  | 2                       | 1                         | 3         |
| 67 | ○ Frustration/Challenges : Machine availability lower<br>Gr=2         | 0                    | 1                     | 1                | 1               | 1                  | 1                       | 1                         | 2         |
| 68 | ○ Frustration/Challenges : Machine Stopping Unexpectedly<br>Gr=1      | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 69 | ○ Reliability: Bypass not working<br>Gr=1                             | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 70 | ○ Reliability: Silent Zone Issues<br>Gr=1                             | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 71 | ○ Safety Perception: Compliance means safety<br>Gr=1                  | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 72 | ○ Safety Perception: Infrastructure protection<br>Gr=2                | 0                    | 1                     | 1                | 0               | 2                  | 1                       | 1                         | 2         |
| 73 | ○ System Function Clarity: Different companies/technologi             | 0                    | 2                     | 0                | 1               | 1                  | 2                       | 0                         | 2         |

|    | CODES                                                            | EXPE<br>R. (1-<br>5) | EXPE<br>R. (5-<br>10) | EXPE<br>R. (10+) | POS<br>T<br>CAS | PR<br>E<br>CA<br>S | ROL<br>ES<br>(ENG<br>.) | ROLE<br>S<br>(MININ<br>G) | TOT<br>AL |
|----|------------------------------------------------------------------|----------------------|-----------------------|------------------|-----------------|--------------------|-------------------------|---------------------------|-----------|
|    | es<br>Gr=2                                                       |                      |                       |                  |                 |                    |                         |                           |           |
| 74 | ○ System Function<br>Clarity: Silent Zone<br>Warning<br>Gr=1     | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 75 | ○ Trust in Technology:<br>Mechanical Lockout<br>Safer<br>Gr=2    | 0                    | 2                     | 0                | 1               | 1                  | 2                       | 0                         | 2         |
| 76 | ○ User Experience:<br>Convenient<br>Gr=1                         | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 77 | ○ Enforced<br>Compliance: CAS for<br>Spying<br>Gr=1              | 0                    | 0                     | 1                | 0               | 1                  | 0                       | 1                         | 1         |
| 78 | ○ Frustration/Challenges<br>: unclear procedures<br>Gr=1         | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 79 | ○ Pre-experience: Lack<br>of System<br>understanding<br>Gr=1     | 0                    | 0                     | 1                | 0               | 1                  | 0                       | 1                         | 1         |
| 80 | ○ Regulation:<br>Procedures/Methods<br>for safety<br>Gr=1        | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 81 | ○ Reliability:<br>Interference Issues<br>Gr=1                    | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 82 | ○ Reliability:<br>Maintenance errors<br>Gr=1                     | 0                    | 0                     | 1                | 0               | 1                  | 0                       | 1                         | 1         |
| 83 | ○ Reliability:<br>Nuisance/Unneccesary<br>trips<br>Gr=1          | 0                    | 0                     | 1                | 0               | 1                  | 0                       | 1                         | 1         |
| 84 | ○ Safety Perception:<br>Does not remove risk<br>Gr=1             | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 85 | ○ Safety Perception:<br>Low concentration<br>unsafe<br>Gr=1      | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 86 | ○ User Experience:<br>Function Clarity<br>Uneasiness<br>Gr=1     | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |
| 87 | ○ Work Practices:<br>Experienced<br>Operators Preference<br>Gr=1 | 0                    | 1                     | 0                | 1               | 0                  | 1                       | 0                         | 1         |

|    | CODES                                                      | EXPE<br>R. (1-<br>5) | EXPE<br>R. (5-<br>10) | EXPE<br>R. (10+) |          | POS<br>T<br>CAS | PR<br>E<br>CA<br>S |          | ROL<br>ES<br>(ENG<br>.) | ROLE<br>S<br>(MININ<br>G) | TOT<br>AL |
|----|------------------------------------------------------------|----------------------|-----------------------|------------------|----------|-----------------|--------------------|----------|-------------------------|---------------------------|-----------|
| 88 | o Work Practices:<br>Requires patient<br>operators<br>Gr=1 | 0                    | 1                     | 0                |          | 1               | 0                  |          | 1                       | 0                         | 1         |
|    | Totals                                                     | 225                  | 565                   | 342              | 113<br>2 | 690             | 442                | 113<br>2 | 740                     | 392                       | 1132      |

Table E-2: Codes by Participant Groups – By Code Count (As Coded in Atlas.ti)

|                                                                                   | Experienc<br>e (1-5<br>Years)<br>Gr=95;<br>GS=3 | Experienc<br>e (5-10<br>Years)<br>Gr=143<br>; GS=4 | Experienc<br>e (10+<br>years)<br>Gr=120;<br>GS=4 | Post<br>CAS<br>Gr=203;<br>GS=6 | Pre-<br>CAS<br>Gr=155;<br>GS=5 | Roles<br>(Engineer<br>ing)<br>Gr=215;<br>GS=6 | Roles<br>(Mining)<br>Gr=143;<br>GS=5 |
|-----------------------------------------------------------------------------------|-------------------------------------------------|----------------------------------------------------|--------------------------------------------------|--------------------------------|--------------------------------|-----------------------------------------------|--------------------------------------|
| o Safety Perception: Effective<br>for safety<br>Gr=25                             | 7                                               | 4                                                  | 14                                               | 11                             | 14                             | 9                                             | 16                                   |
| o Frustration/Challenges:<br>Unnecessary Stops<br>Gr=18                           | 5                                               | 3                                                  | 10                                               | 8                              | 10                             | 6                                             | 12                                   |
| o Work Practices: Causes<br>Delays<br>Gr=16                                       | 8                                               | 2                                                  | 6                                                | 9                              | 7                              | 8                                             | 8                                    |
| o Resistance:<br>work/bonus/production<br>pressure<br>Gr=15                       | 6                                               | 1                                                  | 8                                                | 6                              | 9                              | 6                                             | 9                                    |
| o Safety Perception: Reduced<br>collision/fatalities/injuries<br>Gr=15            | 3                                               | 2                                                  | 10                                               | 5                              | 10                             | 5                                             | 10                                   |
| o Compliance/Enforced<br>Compliance: 'not allowed'<br>Gr=13                       | 7                                               | 4                                                  | 2                                                | 11                             | 2                              | 11                                            | 2                                    |
| o Safety Perception: Human<br>Disenchantment Better<br>Gr=13                      | 3                                               | 4                                                  | 6                                                | 4                              | 9                              | 7                                             | 6                                    |
| o System Function Clarity<br>Gr=13                                                | 1                                               | 10                                                 | 2                                                | 10                             | 3                              | 11                                            | 2                                    |
| o Resistance: By-pass needed<br>Gr=12                                             | 6                                               | 5                                                  | 1                                                | 8                              | 4                              | 11                                            | 1                                    |
| o Work Practices:<br>Training/Knowledge/Experien<br>ce - User adaptation<br>Gr=12 | 1                                               | 2                                                  | 9                                                | 1                              | 11                             | 2                                             | 10                                   |
| o Compliance/Enforced<br>Compliance: organisational<br>legitimacy<br>Gr=11        | 4                                               | 4                                                  | 3                                                | 7                              | 4                              | 8                                             | 3                                    |
| o Resistance: Undermining<br>safety systems/rules<br>Gr=11                        | 3                                               | 7                                                  | 1                                                | 10                             | 1                              | 9                                             | 2                                    |
| o Compliance/Enforced<br>Compliance: regulatory<br>legitimacy<br>Gr=10            | 4                                               | 2                                                  | 4                                                | 6                              | 4                              | 6                                             | 4                                    |

|                                                                          |   |   |   |   |   |   |   |
|--------------------------------------------------------------------------|---|---|---|---|---|---|---|
| ○ Safety Perception: Assist with alertness<br>Gr=10                      | 4 | 5 | 1 | 7 | 3 | 9 | 1 |
| ○ Trust in Technology: Exercise caution<br>Gr=9                          | 1 | 1 | 7 | 2 | 7 | 2 | 7 |
| ○ Trust in Technology: Wont Always Stop<br>Gr=9                          | 2 | 5 | 2 | 5 | 4 | 5 | 4 |
| ○ Frustration/Challenges: Human behaviour important<br>Gr=8              | 0 | 4 | 4 | 1 | 7 | 4 | 4 |
| ○ Regulation Awareness: CAS Financial impact<br>Gr=8                     | 0 | 2 | 6 | 1 | 7 | 2 | 6 |
| ○ Reliability: System can fail<br>Gr=8                                   | 0 | 3 | 5 | 0 | 8 | 3 | 5 |
| ○ Trust in Technology: Doubt in Compliance Behaviour<br>Gr=8             | 4 | 2 | 2 | 6 | 2 | 4 | 4 |
| ○ User Experience: Uncomfortable/Scary Stops<br>Gr=8                     | 0 | 6 | 2 | 2 | 6 | 6 | 2 |
| ○ Safety Perception: Over-reliance unsafe<br>Gr=7                        | 0 | 2 | 5 | 2 | 5 | 2 | 5 |
| ○ Safety Perception: Prioritising production<br>Gr=7                     | 1 | 1 | 5 | 2 | 5 | 2 | 5 |
| ○ Trust in Technology: Tested for safety<br>Gr=7                         | 2 | 0 | 5 | 2 | 5 | 2 | 5 |
| ○ Compliance/Enforced Compliance: Consequences to non-compliance<br>Gr=6 | 4 | 0 | 2 | 4 | 2 | 3 | 3 |
| ○ Demographics: CAS-Level 9 Experience<br>Gr=6                           | 3 | 3 | 0 | 6 | 0 | 5 | 1 |
| ○ Reliability: Conditional operation<br>Gr=6                             | 1 | 4 | 1 | 2 | 4 | 4 | 2 |
| ○ Reliability: Effective system<br>Gr=6                                  | 4 | 2 | 0 | 5 | 1 | 3 | 3 |
| ○ Resistance: User impatience/percieved delay<br>Gr=6                    | 2 | 2 | 2 | 3 | 3 | 4 | 2 |
| ○ Trust in Technology: Uncertainty in Functionality<br>Gr=6              | 1 | 3 | 2 | 4 | 2 | 3 | 3 |
| ○ Work Practices: User adaptation<br>Gr=6                                | 2 | 1 | 3 | 3 | 3 | 3 | 3 |
| ○ Demographics: Artisan<br>Gr=5                                          | 2 | 3 | 0 | 4 | 1 | 5 | 0 |
| ○ Demographics: Mixed CAS Experience<br>Gr=5                             | 0 | 1 | 4 | 0 | 5 | 1 | 4 |
| ○ Demographics: Operator/Lnr Miner<br>Gr=5                               | 1 | 0 | 4 | 1 | 4 | 0 | 5 |
| ○ Frustration/Challenges: Bypass function/process tedious<br>Gr=5        | 1 | 4 | 0 | 4 | 1 | 5 | 0 |

|                                                                                  |   |   |   |   |   |   |   |
|----------------------------------------------------------------------------------|---|---|---|---|---|---|---|
| ○ Frustration/Challenges:<br>System Maintenance<br>Limitations<br>Gr=5           | 3 | 2 | 0 | 5 | 0 | 5 | 0 |
| ○ Regulation Awareness:<br>Unawareness<br>Gr=5                                   | 2 | 1 | 2 | 3 | 2 | 2 | 3 |
| ○ Safety Perception: Bypass<br>cards unsafe<br>Gr=5                              | 2 | 1 | 2 | 3 | 2 | 3 | 2 |
| ○ Safety Perception:<br>Experience/Training/Change<br>Management<br>Gr=5         | 0 | 4 | 1 | 1 | 4 | 4 | 1 |
| ○ Safety Perception:<br>Injuries/Collisions still/can<br>occur<br>Gr=5           | 1 | 3 | 1 | 3 | 2 | 4 | 1 |
| ○ Trust in Technology: don't<br>trust machines<br>Gr=5                           | 0 | 3 | 2 | 1 | 4 | 3 | 2 |
| ○ Trust in Technology:<br>System could fail<br>Gr=5                              | 1 | 3 | 1 | 2 | 3 | 4 | 1 |
| ○ Work Practices: Training<br>required<br>Gr=5                                   | 1 | 2 | 2 | 2 | 3 | 3 | 2 |
| ○ Work Practices:<br>Work/Production Hindrance<br>Gr=5                           | 1 | 3 | 1 | 4 | 1 | 3 | 2 |
| ○ Compliance/Enforced<br>Compliance:<br>Training/communication/awareness<br>Gr=4 | 0 | 0 | 4 | 0 | 4 | 0 | 4 |
| ○ Frustration/Challenges:<br>Harsh braking<br>Gr=4                               | 0 | 3 | 1 | 2 | 2 | 3 | 1 |
| ○ Pre-experience<br>Gr=4                                                         | 2 | 0 | 2 | 2 | 2 | 1 | 3 |
| ○ Regulation Awareness:<br>Awareness<br>Gr=4                                     | 1 | 2 | 1 | 2 | 2 | 3 | 1 |
| ○ Resistance: Lamp override<br>Gr=4                                              | 0 | 4 | 0 | 4 | 0 | 4 | 0 |
| ○ Safety Perception: machine<br>control<br>Gr=4                                  | 0 | 1 | 3 | 0 | 4 | 1 | 3 |
| ○ System Function Clarity:<br>Gray Functional Areas<br>Gr=4                      | 0 | 3 | 1 | 2 | 2 | 3 | 1 |
| ○ Trust in Technology: Man-<br>made systems unreliable<br>Gr=4                   | 0 | 3 | 1 | 3 | 1 | 3 | 1 |
| ○ User Experience: Stops<br>Irritating<br>Gr=4                                   | 1 | 3 | 0 | 4 | 0 | 4 | 0 |
| ○ Work Practices:<br>Maintenance Hindrance<br>Gr=4                               | 1 | 3 | 0 | 4 | 0 | 4 | 0 |
| ○ Compliance/Enforced<br>Compliance: "not my<br>decision"<br>Gr=3                | 1 | 1 | 1 | 2 | 1 | 2 | 1 |

|                                                                        |   |   |   |   |   |   |   |
|------------------------------------------------------------------------|---|---|---|---|---|---|---|
| ○ Demographics: 6 Years Experience<br>Gr=3                             | 0 | 3 | 0 | 3 | 0 | 3 | 0 |
| ○ Demographics: Multiple Licensed/Maintenance<br>Gr=3                  | 1 | 2 | 0 | 3 | 0 | 3 | 0 |
| ○ Frustration/Challenges: Communication about system gap<br>Gr=3       | 0 | 1 | 2 | 1 | 2 | 1 | 2 |
| ○ Pre-experience: Contrasted view<br>Gr=3                              | 2 | 0 | 1 | 2 | 1 | 1 | 2 |
| ○ Safety Perception: Reliable stops<br>Gr=3                            | 2 | 0 | 1 | 2 | 1 | 1 | 2 |
| ○ Safety Perception: Situational Awareness decreased with CAS<br>Gr=3  | 1 | 0 | 2 | 1 | 2 | 0 | 3 |
| ○ System Function Clarity: Differentiation Problems<br>Gr=3            | 1 | 2 | 0 | 3 | 0 | 3 | 0 |
| ○ System Function Clarity: Limited Awareness Uncertainty<br>Gr=3       | 0 | 1 | 2 | 1 | 2 | 1 | 2 |
| ○ User Experience: Injuring harsh stops<br>Gr=3                        | 0 | 0 | 3 | 0 | 3 | 0 | 3 |
| ○ Work Practices: Consistent bypassing<br>Gr=3                         | 1 | 2 | 0 | 1 | 2 | 3 | 0 |
| ○ Work Practices: Training/Knowledge adaptation<br>Gr=3                | 0 | 2 | 1 | 2 | 1 | 2 | 1 |
| ○ Frustration/Challenges: Machine availability lower<br>Gr=2           | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| ○ Safety Perception: effective speed control<br>Gr=2                   | 0 | 2 | 0 | 2 | 0 | 2 | 0 |
| ○ Safety Perception: Infrastructure protection<br>Gr=2                 | 0 | 1 | 1 | 0 | 2 | 1 | 1 |
| ○ Safety Perception: Situational Awareness Increased w/out CAS<br>Gr=2 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| ○ System Function Clarity: Different companies/technologies<br>Gr=2    | 0 | 2 | 0 | 1 | 1 | 2 | 0 |
| ○ System Function Clarity: Operating/Stopping Condition<br>Gr=2        | 0 | 2 | 0 | 2 | 0 | 2 | 0 |
| ○ Trust in Technology: Mechanical Lockout Safer<br>Gr=2                | 0 | 2 | 0 | 1 | 1 | 2 | 0 |
| ○ User Experience: Satisfactory Operation<br>Gr=2                      | 0 | 2 | 0 | 2 | 0 | 2 | 0 |
| ○ Compliance/Enforced Compliance: CAS for Spying<br>Gr=1               | 0 | 0 | 1 | 0 | 1 | 0 | 1 |

|                                                                 |   |   |   |   |   |   |   |
|-----------------------------------------------------------------|---|---|---|---|---|---|---|
| ○ Compliance/Enforced Compliance: Conditional tolerance<br>Gr=1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ○ Demographics: 1 years experience<br>Gr=1                      | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ○ Demographics: 1.5 years experience<br>Gr=1                    | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ○ Demographics: 2 years experience<br>Gr=1                      | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| ○ Demographics: 7 years experience<br>Gr=1                      | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| ○ Demographics: 13 years experience<br>Gr=1                     | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Demographics: 14 years experience<br>Gr=1                     | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Demographics: 27 Years Experience<br>Gr=1                     | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Demographics: 30 years experience<br>Gr=1                     | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Demographics: FD/Maintenance<br>Gr=1                          | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ○ Demographics: Foreman<br>Gr=1                                 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Demographics: Haul Truck Licence<br>Gr=1                      | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| ○ Demographics: LHD Licence<br>Gr=1                             | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Demographics: Multiple Licensed/Production<br>Gr=1            | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Demographics: RB Licence<br>Gr=1                              | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| ○ Demographics: SC Licence<br>Gr=1                              | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Demographics: SC/Maintenance<br>Gr=1                          | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Frustration/Challenges: Machine Stopping Unexpectedly<br>Gr=1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Frustration/Challenges: unclear procedures<br>Gr=1            | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Pre-experience: Lack of System understanding<br>Gr=1          | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Regulation Awareness: Procedures/Methods for safety<br>Gr=1   | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Reliability: Bypass not working<br>Gr=1                       | 0 | 1 | 0 | 1 | 0 | 1 | 0 |

|                                                            |   |   |   |   |   |   |   |
|------------------------------------------------------------|---|---|---|---|---|---|---|
| ○ Reliability: Interference Issues<br>Gr=1                 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Reliability: Maintenance errors<br>Gr=1                  | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Reliability: Nuisance/Unnecessary trips<br>Gr=1          | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ○ Reliability: Silent Zone Issues<br>Gr=1                  | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Resistance: fatigue<br>Gr=1                              | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ○ Resistance: Training<br>Gr=1                             | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ○ Safety Perception: Compliance means safety<br>Gr=1       | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Safety Perception: Does not remove risk<br>Gr=1          | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Safety Perception: Low concentration unsafe<br>Gr=1      | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ System Function Clarity: Silent Zone Warning<br>Gr=1     | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ User Experience: Convenient<br>Gr=1                      | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ User Experience: Function Clarity Uneasiness<br>Gr=1     | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Work Practices: Experienced Operators Preference<br>Gr=1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Work Practices: Requires patient operators<br>Gr=1       | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ○ Work Practices: Work Hindrance<br>Gr=1                   | 1 | 0 | 0 | 1 | 0 | 1 | 0 |